STATE OF OHIO
Department of Transportation

Construction Administration
Manual of Procedures

Columbus, Ohio
2017

2017 Construction Administration Manual of Procedures

Ohio Department of Transportation
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The Construction Administration Manual of Procedures (MOP) is a companion document to the Construction and Material Specifications (C&MS). The C&MS is written to the Contractor and is a contract document included in each construction project the Department awards. The overall role of the MOP is to provide confidence that the quality of the workmanship incorporated into highway construction projects conforms to the requirements of the plans and specifications. More specifically, the MOP is used to:

- Describe how to inspect and document the contractor's work.
- Describe typical construction means and methods to improve inspection.
- Give guidance for directing the contractor's work when it is required.
- Give background technical information for specific items of work to aid understanding.
- Give guidance for resolving issues and problems when an item of work fails to perform.
- Ensure consistent construction project management across the state.

To fully take advantage of the information in the MOP, construction personnel must also be familiar with the C&MS, Standard Drawings, and other contract documents. The MOP and C&MS complement each other.

As the on-site representatives of the Department, the construction personnel are authorized to observe all work being performed to ensure compliance with the contract. The construction personnel record their observations and inspections to document that the work performed meets the contract requirements. This documentation is later used to verify that work paid for by the Department was actually performed and acceptable. The documentation may also be used to defend the Department in a dispute or claim. Written documents are valuable resources in a claim, to establish what was done and when, to demonstrate that the contractor was given proper instructions, and to demonstrate that Department testing was properly performed. The MOP gives guidance to the construction personnel as to what information is important to document based on the Department's experience as a whole. Proper documentation thereby helps ensure quality work and minimizes the Department's responsibility in a claim.

The C&MS does not dictate the contractor's means and method for performing the work. However, it helps if the construction personnel are familiar with typical means and methods of construction, so that they can recognize unusual construction methods and question the contractor about it. The MOP describes how items of work are typically performed and the type of equipment contractors typically use.

In many places, the C&MS directs the contractor to do work "as directed by the Engineer". The MOP provides guidance to the Engineer on how to direct the work for many different situations. The MOP also gives background technical information for specific items of work which helps the construction personnel understand the work in order to give proper direction.

The specifications dictate when items of work are acceptable or not. However, when an item of work fails to perform, the specifications generally say to repair or replace the item and do not give any details as to how to repair the item. It would be impractical to do this in the specification, because the necessary repair method will depend on the reason the item failed to perform, and the specifications cannot anticipate the multitude of things that can go wrong. The MOP gives guidance for resolving issues and problems, and it gives examples of typical things that can go wrong with an item of work and some of the possible solutions. It is important that the construction personnel help resolve these problems in a timely manner, because the Department shares with the contractor a duty to mitigate issues.

By studying the information in the MOP, the construction personnel can better:

- Understand the work the contractor performs and ensure contract compliance.
- Make appropriate decisions in the field and give proper direction.
- Properly document the work.
- Minimize the Department's responsibility in claims.
- Provide for consistency in construction project management throughout the state.

Construction Quality Process

It is the policy of the Ohio Department of Transportation to ensure that projects under its jurisdiction are constructed in conformance with the approved plans and specifications, i.e. the Contract. One purpose of this manual is to establish a statewide uniform process for creating an adequate project record that documents construction project engineering and inspection activities. It is the duty of construction personnel to become familiar with the contents of this manual in order to provide thorough and accurate inspections of the work.

Unless specifically referenced in the Contract, this manual is not a part of the contract. The information contained in the manual does not replace, supersede, or modify any contract documents.

This manual is for use by the Central Office Division of Construction Management, District Construction Offices, Local Public Agencies, and other offices or agencies that may be involved in the administration of ODOT construction projects.

Authority:

23 U.S.C. 114(b) as amended

Code of Federal Regulations, Title 23-Sections 635 and 637

Ohio Revised Code (ORC) Section 5501

References:

Construction and Material Specifications (C&MS), 2016 edition

Sampling and Testing Manual, 2016 edition

Referenced Forms are published at the following websites:

Office of Materials Management

Office of Construction Administration

The hierarchy of construction project oversight is as follows:

USDOT / FHWA: creates law and general requirements, approves State policies, and performs system reviews.

ODOT Central Office/Lab: creates policy, specifications, performs system quality checks (TPR’s/ IAS).

ODOT District Office: implements policy and administers projects, performs project final inspection reviews, reviews documentation for uniformity and content, monitors LPA inspection processes.

Project / Local Office: provides direct project oversight, coordinates project documentation, initiates change orders.

Field staff: inspects and oversees day to day project activities, creates and records primary documentation.

Background And Purpose:

The Ohio Department of Transportation is authorized to construct, reconstruct, widen, resurface, maintain, and repair the state system of highways and the bridges and culverts. Projects are designed and contract documents created that are fundamentally based on the concept that the project features will be constructed as designed and specified.

The Department provides project oversight in accordance with Federal and State requirements for project funding, as well as provide documentation of conformance with the contract and units of work completed for payment. The C&MS states: "The Department shall have the discretion to dictate the level of inspection for any item of work. The Contractor bears sole responsibility for the quality of work and compliance with the contract regardless of the Department's level of inspection." The C&MS also states: "Any action or inaction of the Inspector does not constitute a waiver of the Department's right to pursue any and all legal remedies for defective work or work performed by the Contractor in an un- workmanlike manner."

It is important to note that construction quality is considered separate from material quality. Material quality documentation is required regardless of the inspection priority or documentation frequency assigned. Typical inspection priorities and documentation frequencies are established to provide a consistent approach that project construction staff can use to identify critical attributes and establish frequencies for documentation of the quality of work in progress. The goal is to provide enough project oversight along with accurate and timely documentation while utilizing engineering and inspection staff in the most efficient manner.

Engineering and inspection staff will provide documentation for ***Quantity for Payment,*** as well as the ***Quality of Materials***, and the ***Quality of Construction*** according to this manual. Together with the Contractors Quality Control, these provide the Quality Assurance and Acceptance procedure for the ODOT Construction program.

Construction Inspection Process:

1. Quantity for Payment

a. The Contract documents denote the project pay items (proposal line numbers), as well as the units to be used for payment.
   i. Units that are denoted as discreet parts (CY, SF, FT, EA. Days, Mgal, etc.) are measured and paid accordingly.
   ii. Units that are denoted as Lump Sum are measured and paid as work progresses on the item, according to the contract documents.

b. Quantity for Payment will be determined and documented for every proposal line number.

c. Quantity for Payment will be determined and documented on standard forms as required:
   i. Length,
   ii. Area,
   iii. Volume,
   iv. Each, Day, Month, Lump Sum, Other,
   v. Some items may require special forms for quantity documentation, special forms will listed on the Division of Construction Management Forms website.

2. Quality of Materials

a. The Quality of Materials will be determined and documented as denoted in the Contract Documents, and the Sampling and Testing Manual.

b. The Contract documents (specifically Section 700 of the C&MS), denote the minimum requirements for sampling materials. These are Contract requirements, and generally describe material approval processes for the following:
   i. Qualified Products and other Approved products Lists
   ii. Sampling requirements
   iii. Sampling frequency
   iv. Field and Laboratory test requirements
   v. Notifications required

c. The Sampling and Testing Manual describes the acceptance sampling and testing procedures.
   i. Qualified Products List
   ii. Approved List
   iii. Dispute Resolution processes
   iv. Independent Assurance Program
   v. Forms to be used for sample and testing submissions
   vi. Sampling frequency, lot size representations.

d. The Quality of Materials will be documented on the appropriate testing forms listed on the Office of Materials Management website or SiteManager as denoted.

3. Quality of Construction

a. The Quality of Construction will be determined and documented according to the individual requirements outlined in this manual. These are intended to provide guidance to inspection staff in the following areas:
   i. Areas of construction activity that require higher levels of inspection,
   ii. specific construction details to witness and document,
   iii. measurements, or performance tests to be performed,
   iv. Contractor submissions, and other notifications that may be required,
   v. general contract administration guidance.

b. The Quality of Construction will be documented on Quality Checklists.

c. The Quality Checklists will describe the minimum construction attributes to be documented. ***Additional*** quality of construction information should be included on the checklists to denote pertinent findings.

d. Individual Quality Checklist requirements are denoted in the online Priority Table and will be completed based on the prioritization given in Section 4.

4. Prioritization of Inspection Activities

a. Quantity for Payment requirements will be documented for every project pay item in the Contract.

b. Quality of Material requirements will be documented for every project pay item in the contract according to the Sampling and Testing Manual and Contract requirements.

c. Quality of Construction requirements will be prioritized and documented according to the Inspection Priority Table listed on the Construction website:

www.dot.state.oh.us/Divisions/ConstructionMgt/

d. Inspection Priority is divided into the following groups:

Level 1 – Full time inspection. Inspection performed continuously while the item is actively under construction. This level of inspection is required for items where the consequence of failure could result in a catastrophic, life-threatening safety hazard.

Level 2 – Intermittent inspection. Inspection performed on an as needed basis, normally once per day, but focusing on initial setups and critical attributes when the item is actively under construction. This level of inspection is specified for items where the consequence of failure would directly affect environmental compliance, or where repair would delay the project or cause safety considerations. This priority level also includes items that require multi-activity construction processes. Inspection may occur as interim activities in the construction process are completed and before being covered or hidden by subsequent operations..

Level 3 – End product Inspection. Does not require inspection and construction quality documentation while the item is actively under construction, but inspection must be completed before the project is accepted. This level of inspection is specified for items where the consequence of failure is considered minimal in terms of Project performance. Generally, inspection may be completed by observation of the end product.

5. Documentation Requirements

a. Documentation of conformance with contract requirements will be made on the standard forms as listed on the Construction website:

www.dot.state.oh.us/Divisions/ConstructionMgt/

b. Documentation is part of the official project record and will be maintained as required by the FHWA in the following areas as appropriate:

i. On the Sharepoint project website,
ii. in the SiteManager database system,
iii. in an authorized e-document management system,
iv. in an organized paper, or other filing system as authorized by the Division of Construction.

c. Inspection Documentation Frequency is divided into the following groups:

Level 1 – Minimum once per day. Construction quality documentation frequency is typically required on a daily basis during active work specific to the item.

Level 2 – Minimum once per Item. Construction quality documentation frequency is required at major intervals in the construction process of the item (e.g. prior to being covered or hidden by subsequent work) and shall not occur less than once during the Project.

Level 3 – Minimum once per group of similar items. Construction quality documentation is required once per Project for all similar items (e.g., all shrubs, all traffic symbols…).

d. Documentation will be either entered directly into a computer system by the inspector who performed the inspection/test so that their digital signature is retained, or a completed form that includes the inspectors scanned signature is made part of the project record.

e. Construction Project records will be retained according to the official Document Retention Schedule on file with the Department of Administrative Services.

Project Record Requirements

The construction personnel will set up a records system to adequately record and permanently store project records. Project record keeping is required to be contemporaneous with the project activity. All project records with the exception of hard copies of weight tickets, concrete tickets, asphalt tickets, etc. shall be stored on the *ODOT Construction Website*.

Instructions for creating and updating the Construction Project Web Site are located online here:

http://construction.dot.state.oh.us

Records may be created by either scanning or photographing signed hand-written documents or creating properly signed electronic documents (XLS, PDF, DOC files, etc.)

Daily work reports, and other project information should be entered into the SiteManager system as required for project payments etc. Quality / Quantity documentation should NOT be entered on the SiteManager daily work report remarks section, but should be entered on the appropriate standard forms and properly filed by Item.

The project records will include the following, as applicable:

Folder Name	Sub-Folder Name	Contents
Change Orders		Sub folders of CO's by Number - as below
	###	CO Signed
		CO Documentation - Including any newly created references documentation
		Preliminary Approval Docs
		Correspondence
Contract Documents		Sub folders – as below
	Proposal	Proposal / Scope
	Addenda	Each Addenda
	Signed Contract	Contract
	Supp Specs	As listed on Title Sheet
	CA-D-10A/B/C	Contractor Signature forms
	CA-D-21 Waivers	Waiver of Liquidated damages forms
	Environmental	Permits, Asbestos, borrow / waste, NOI, SWPPP
	Schedules	Initial schedule and updates
	PE Submittals / Shop Drawings	Preliminary and Shop drawings
	DB Submittals	Submittals / Approvals
Correspondence		Sub folders – as below
	Outlook	All project correspondence
		CIN_YYMMDD_TITLE for correspondence IN

		COU_YYMMDD_TITLE for correspondence OUT
	RFI	Email, scanned letters
DWR IDR		YYMMDD – XXX (inspector initials)
EEO DBE		Sub folders – as below
	CUF	Commercial Useful Function documentation
	BBS	Bulletin board information
Estimates		Sub folders – as below
	###	Estimate Number
		Estimate
		Line Item adjustments
		Material Control Report
		CA-D-11, Contractor Progress Payment Certification
Finalization		Audit
		C85/Letter
		Final Acceptance
		Final Packet
		Final Quantities
		Material Certification
		Payroll Certification
		Affidavits
		Punch List
		CA-D-12, Contract Compliance Certification
Issues Claims		Sub folders – as below
	Crash Reports	OH-1 forms, photos, Emergency Reports
	C95 Documentation	Contractor Performance documentation
Proposal Line Items		Sub folders – as below
	####	Proposal Line Number
		Delivered material invoices
		Field calculations
		Material quality test reports
		Pictures (if applicable)
		Quantity Documentation form – Summary sheet
		Quality Documentation forms as required
		QPL sheets
Materials		Sub folders – as below
	Project QCP's	Aggregate – Nuclear gauge reports
		Asphalt – Core reports
		Asphalt – TE reports
		Concrete - TE reports
		Earthwork density / moisture reports
		Asphalt

	Test Lab Reports	Concrete
		Steel
Media		Sub folders – as below
	Pictures	Labeled and dated Photos
	Newspaper articles	Scanned or PDF
	PIO Information	Statements, video releases
	Haul roads video	Before and after construction drive through for each designated haul road
Meetings		Sub folders – as below
	Pre-construction	PRE_YYMMDD_TITLE
	Progress	PRG_YYMMDD_ TITLE
	Post-construction	POST_YYMMDD_ TITLE
Misc. /General		Sub folders – as needed
	VECP	All correspondence and approval docs
	Utility	Utility agreements / correspondence
	Right of way	ROW / Owner correspondence
	Other - to be titled accordingly	As needed

Guidelines for Documentation

Documentation consists of the properly recorded information necessary to verify the quantity and the quality of the work items. Documentation should be created at the same time as, and coordinated with, the construction progress.

To meet the requirements for payment on Federal-Aid and State projects, the following two conditions must be met:

- The final quantity has been determined in accordance with the specifications and the necessary weight tickets, measurements, calculations, etc. are validated properly.
- The Work has been completed in conformance with the Contract. This shall be documented in accordance with this manual and filed as part of the Project Record in the Project's Construction Web Site. It is required that documentation include the following three items:
    - Justification for the quantity of completed Work.
    - Documentation that the Work is constructed in accordance with the Contract.
    - Documentation that the Material incorporated is in accordance with the Contract.

Documentation shall be validated in every case on standard forms, that include the following identifiers:

- Date
- Project Number (or PID)
- Proposal Line Number
- Subject
- Location
- Signature or Initials of the inspector (or captured inspectors login credentials)

Standard Forms are generally divided into four groups:

- Administrative and daily activities
- Quantity for Payment
- Quality of Materials and Sampling
- Quality of Construction

The forms on the Departments website or via mobile entry are the most current version of standard forms and shall be used exclusively on all current projects.

www.dot.state.oh.us/Divisions/ConstructionMgt/

An automated Department wide forms system may be used, and the documentation stored in the project record as required.

101 Definitions and Terms

General

Definitions for most terms are found in the Construction and Material Specifications. Special terms used in this manual are defined in this section.

ACFA - Actual Cost of Force Account.

Blue Book - Rental Rate Blue Book for Construction Equipment.

Construction Monitor - The DCA appointed ODOT employee responsible for primary construction administration coordination with the LPA and its designated employees, engineers, and contractors on Local let projects.

Contract Limits - The amount a contract pay item may be increased or the cost of a new item of work that may be added to a project without competitive bidding or Controlling Board review. ORC 5525.14 sets these limits as:

Original Contract Price	Contract Limits
$500,000 or lower	$25,000
$500,001 to $2,000,000	5% of Total Contract Price
Over $2,000,000	$100,000

Conversion - The adaptation of one unit of measure to another unit of measure.

CPM Schedule - The type of progress schedule outlined in Proposal Note 107 that delineates a critical path of work from the start of the project to the end of the project.

Critical Path - The critical path is defined as the longest path of activities in the project that determines the project completion date. The activities that make-up the critical path of activities are the "Critical Activities."

DCA - District Construction Administrator.

DDD - District Deputy Director.

Density - The relation of weight to volume. The greater the weight to a given volume, the greater the density.

Documentation - Recording and filing evidence regarding the project materials or work as performed and witnessed by project personnel.

ECFA - Estimated Cost of Force Account.

Elevation - The height as measured from a predetermined point denoted in the plans.

Engineer's Punch List – The written list created by the Project Engineer or Project Supervisor of items not yet completed by the Contractor and those needing corrective work.

Estimate - The District authorization of monetary payment compensating the Contractor for work in place or stored materials following Contractor certification to the Engineer that the work for which the progress payment is being made was performed in accordance with the contract.

EWCO - Extra Work Change Order.

Final Estimate - The District authorization of monetary payment compensating the Contractor to the final value of the contract following the final inspection and acceptance of the project in accordance with current policies. The Final Estimate is signed by the District Construction Administrator.

Final Inspection Date - The date the Final Inspector physically inspects the project. This date is entered into SiteManager.

Final Inspection Punch List - Written list, by the Final Inspector, of deficiencies found during the Final Inspection.

Final Measurements - A legal term used in ORC 5525.14 which means an increase in an original bid item that was required to accomplish the originally planned work within the original work limits, but resulted in a payment on the bid item that exceeded the Contract Limits. Change orders for Final Measurements are not subject to Controlling Board approval, but must be reported quarterly to the Controlling Board. Final Measurements are not limited to pay quantities determined during finalization, but may occur any time during the project.

Final Package - Information submitted by the District to Central Office Capital Accounting that includes the transmittal IOC, Final Estimate, Final Report, and Summation of Extra Work Items.

Final Payment - The payment that is released when all the requirements of C&MS Section 109.12 have been fulfilled and the FHWA final voucher is issued.

Final Report - The document submitted by the District to Central Office Capital Accounting documenting the modifications to the original contract amount and certified by the District Construction Administrator and District Deputy Director.

Force Account - Payment for work directed by the Engineer based on the actual cost of labor, equipment, materials furnished, overhead, and profit in accordance with C&MS Section 109.05.

Inspection - Examination by observation, measurement, or testing to determine that materials and work are in conformance with the contract.

Inspector's Daily Report - A form used by an inspector to document the activities performed by a Contractor. The Inspector Daily Report is a standard Form.

Interim Completion Date - The date, as shown in the Contract Documents, on which a portion of the work contemplated, shall be completed.

Lane or Traffic Lane - A strip of pavement of specified width, usually 12 feet (3.6 m).

Lien - A Public Improvement Lien [ORC Section 1311.25]; the right to withhold payment from the Contractor as security for a debt to a material supplier, laborer, or subcontractor.

Local Public Agency (LPA) - Any other state agency, local political subdivision, board, commission, or other governmental entity identified under the Ohio Revised Code Section 5501.03, Paragraph C as being eligible for assuming the administrative responsibilities for Department improvement projects known as LPA or Local Let projects.

NHS - National Highway System. The system of roadways so designated by the National Highway Systems Act of 1995.

Pay Item - A specifically described unit of work for which a price is provided in the contract.

Physical Work Complete Date - Last day of work by the Contractor, including work to complete the Final Inspector's Punch List. If there were no Punch List items, then this date is the same as the Final Inspection Requested Date. This date is entered into SiteManager KETRK (Keycode 160).

Progress Samples - Samples taken by Laboratory or project personnel not engauged in job control sampling. Samples are obtained at random from materials delivered for incorporation in the work to provide an independent spot check on the reliability of the results obtained in job control sampling and testing.

Project - The specific section of the highway together with all appurtenances and construction to be performed thereon under the contract.

Project Engineer - Also called the Engineer. The person representing the Department who is charged with the overall responsibility at the project site for seeing that construction is in conformance with plans and specifications and that all checks for job control and validation of pay items are documented and filed properly.

PWC - Physical Work Completed.

RFI - Request for Information.

RWCO - Regular Work Change Order.

SiteManager - The Department-wide computer system for administration of construction projects.

Standard Drawings - The Standard Construction Drawings issued by the Department.

State Final Acceptance Date - The date of the Final Estimate Letter to the Contractor. This date represents that the requirements of ORC 5525.16, CFR 23 part 635, and C&MS 109.12 have been met. This date is entered into SiteManager KETRK (Keycode 370).

Time Extensions - Change in the contract provision that stipulates the date by which the work must be complete. (Previously known as Postponement of Contract Completion Dates).

Tolerance - The allowable limits of variation from a specified measurement.

Transition - The distance in which a change is made gradually from one pavement cross-section to another.

Verification - The steps necessary to determine that the work or materials described are in conformance with plans and specifications.

Workday - A calendar day that the Contractor normally works.

Flexible Pavement Terms

Aggregate - Mineral material, such as sand, gravel, crushed stone, slag, or combinations hereof.

Asphalt Concrete - A mixture of aggregate and asphalt binder. Types of asphalt concrete are 301, 302, 442, 446, and 448.

Batch Plant - A plant in which dry, hot aggregate and asphalt material are proportioned in fixed or batched quantities into a pugmill (mixer) for mixing. Then the resulting asphalt concrete is either batched directly into a haul truck or stored in a storage bin for later use.

Asphalt Concrete Base - A type of asphalt concrete which is used as a base course in the construction of a pavement. Two types of asphalt concrete base are 301 and 302.

Asphalt Binder- A thermoplastic binding material obtained as a residue in the distillation of petroleum, which may contain additives to enhance performance.

Bleeding - The rising of an excess of asphalt material to the surface of an asphalt concrete mixture.

Checking - Short transverse cracks, 1 to 4 inches (25 to 100 mm) in length and 1 to 3 inches (25 to 75 mm) apart, which develop in the surface of the asphalt concrete mat during the compaction process.

Choke - Aggregate used for the purpose of filling the surface voids of a coarse aggregate mixture.

CMS - Cationic medium setting emulsion. See the definition for emulsion.

Coarse Aggregate - Aggregate which is retained on the No. 4 (4.75 mm) sieve.

Compaction - A consolidation or compression of materials resulting in an increase in density of the materials.

Compression Rolls - The compaction load of a steel wheel roller, expressed in pounds per inch (kN/m), which is defined as the weight of the roller divided by the combined width of all the drums on the roller. The compression rolls requirements for rollers are specified in 401.13.

Course - A layer or layers of a given material or mixture placed as a part of the pavement structure.

Cross-Section - In the field, elevations taken along a line at right angles to the centerline. On a drawing, a profile of the existing ground at right angles to the centerline. The drawing of an earthwork cross-section also shows the shape of the finished excavation or embankment at the same point. A roadway cross-section shows the thickness and width of the pavement courses.

Cross-Slope - The transverse slope of the pavement, either crown or superelevation. See section 401.19 for details on checking the cross-slope of a pavement.

Crown - The height of the center of the roadway surface above a straight line drawn between its edges. See section 401.19 for details on checking the crown of a pavement.

Cut Back Asphalt - Asphalt binder which has been rendered fluid by fluxing it with a light volatile petroleum distillate. Upon exposure to atmospheric conditions, the volatile distillate evaporates, leaving only the asphalt cement which reverts to its original semi-solid condition. Cut back asphalts are classified as rapid curing (RC), medium curing (MC), or slow curing (SC).

Degradation - A reduction in aggregate particle size due to breakage and water.

Density - The ratio of the weight of a given material to its volume.

Drum Mix Plant - A continuous production plant in which cold aggregate is proportioned and dried in the first half of a drum and then mixed with bituminous material in the second half of the drum. Then the resulting asphalt concrete is stored in a storage bin for later use.

Emulsion (Asphalt) - A suspension of extremely small droplets of asphalt in water in the presence of an emulsifying agent, which usually is a type of soap. Upon exposure to atmospheric conditions, the water evaporates, leaving only the asphalt cement which has been modified by the emulsifying agent. Emulsions are classified as rapid setting (RS or CRS), medium setting (MS or CMS), or slow setting (SS or CSS). The letter “C” in front of an emulsion type (CRS, CMS, or CSS) denotes a cationic (positively charged) emulsion. If the emulsion type does not start with the letter “C” (RS, MS, or SS), the emulsion is anionic (negatively charged) or non-ionic (neutral charge). If the emulsion type is followed by an “h” (SS-1h, CMS-2h, etc.), the emulsion was made from a harder base asphalt cement.

Fat Spots - See the definition of bleeding.

Fine Aggregate - Aggregate which passes the No. 4 (4.75 mm) sieve.

Flushing - The drawing of asphalt material to the surface of an asphalt mixture due to the action of traffic.

Gradation - The classification of different sizes of aggregate within a given size of aggregate as determined by sieve tests.

Grade - The rate of change of the profile elevations. See section 401.19 for details on checking the grade of a pavement.

JMF - See the definition of job mix formula.

Job Control - Inspection and testing conducted to determine compliance of the materials and work with the contract requirements.

Job Mix Formula - The mix composition of an asphalt concrete approved by the Laboratory. The job mix formula (JMF) of a mix can be obtained from the “BCJMF” screen in the TAS portion of SiteManager. The JMF number of the mix needs to be known to use the “BCJMF” screen.

Keying - The interlocking of aggregate particles by compaction.

Laboratory - The Office of Materials Management of the Department’s Central Office in Columbus, which is also known as the Central Test Lab.

Marshall Mix Design - Volumetric mix design procedure used to establish the optimum asphalt binder content for an asphalt concrete. The procedures for designing a mix using

the Marshall mix design are contained in 441.02 and the Asphalt Institute Manual Series No. 2.

Mineral Filler - Limestone dust, Portland cement, or other inert mineral matter. The specifications for mineral filler are contained in 703.07.

NAPA - National Asphalt Pavement Association.

NCAT - National Center for Asphalt Technology.

Odometer - An instrument used for measuring traveled distance.

Oscillating Wheel - The vertical movement of pneumatic tire roller's wheels over irregularities in the surface on which the roller is operated, providing a kneading action.

PG (Asphalt) Binder - An asphalt binder which has been graded by the PG Binder system. An asphalt binder has to be modified with an additive to meet some of the PG Binder grades. An example of a PG Binder Grade is PG 64-28. An example of a modified PG Binder Grade is PG 70-22M (See Asphalt Binder).

Placement Rate - The placement of paving materials on the basis of a given weight and area covered. Placement rate is described in detail in section 401.21.

Plant - The plant where aggregate and asphalt material are mixed together or the plant which produces the aggregate or the asphalt material.

Pneumatic Tire Roller - A roller with three to five rubber tires mounted on two tandem axles. The wheels that the tires are mounted to oscillate, which means they are capable of moving up and down independently of each other. The pneumatic roller compacts a pavement using the combined force of weight and the kneading action of the oscillating wheels. The specifications for a pneumatic tire roller are contained in 401.13.

Prime Coat - An application of asphalt material made on the surface of a pavement layer for the purpose of binding the surface particles together. The specifications for a prime coat are contained in 408.

Profile - A line on a drawing which shows elevation of points along a selected route. A profile usually shows both ground elevations and grade-line elevations. See Section 401.19 for details on checking the profile of a pavement.

RAP - The abbreviation for reclaimed asphalt pavement, which comes from reclaimed asphalt concrete pavement. The specifications for the use of RAP is contained in 401.04 and 441.03.

Raveling - The loss of aggregate from the surface of an asphalt mixture due to a lack of adequate compaction, segregation of the mixture, moisture damage, high dust content, or a lack of PG binder for binding the aggregate particles together.

Screed - A rectangular trowel on an asphalt paver used to cut off the asphalt mixture at the desired thickness, to smooth the surface, and consolidate the material.

Screenings - This is No. 10 size gravel, stone, or air-cooled slag. The specifications for screenings are contained in 703.10.

Segregation - The separation of the coarse and fine particle sizes in an aggregate or asphalt mixture.

Shoving - The plastic deformation or displacement in an asphalt mixture in the direction of traffic movement.

Steel Wheel Roller - A roller which compacts asphalt concrete with static steel drums. Types of steel wheel rollers are the three-wheel roller, tandem roller, trench roller, and vibratory roller.

Strike Off - A blade used to cut off material at the desired elevation or thickness.

Superelevation - The difference in elevation between the inside and outside edges of a roadway on a horizontal curve. See section 401.19 for details on checking the superelevation of a pavement.

Superpave - Mix design procedure, which establishes material properties of an asphalt concrete mix by using a gyratory compactor and material requirements.

Surface Texture - A term used to describe the appearance of the surface of a pavement course such as sandy, coarse, open, dense, uniform, etc.

Surface Treatment - See the definitions for chip seal, prime coat, or tack coat.

Tachometer - An instrument for measuring the speed of rotation.

Tack Coat - An application of asphalt material made on a pavement surface for the purpose of bonding the existing course to the overlying course. The specifications for a tack coat are contained in 407. Tack coats are described in Section 6.

Tandem Roller - A steel wheel roller with two drums mounted on tandem axles, which compacts a pavement using the force of the roller's weight. The specifications for a tandem roller are contained in 401.13.

Three-Wheel Roller - A steel wheel roller with three drums, two drums mounted on the rear axle and a smaller drum mounted on the front tandem axle, which compacts a pavement using the force of the roller's weight. The configuration of the drums on a three-wheel roller allows it to compact longitudinal joints without interfering with traffic in the adjacent lane. The specifications for a three-wheel roller are contained in 401.13.

Vibratory Roller - A steel wheel roller with one (single drum) or two (double drum) drums, which compacts a pavement using the combined force of weight and the vibration of the drum or drums. The specifications for a vibratory roller are contained in 401.13.

Viscosity - Resistance to flow in a liquid. The higher the viscosity, the greater the resistance to flow.

Yield - The area of a surface covered by a given quantity of material measured in square yards (square meters).

Concrete Terms

Absorption - The soaking up of moisture (water) by aggregate.

Admixture - A substance other than cement, water, or aggregate added to a batch of fresh concrete to alter one of the normal properties of concrete.

Aggregate - Mineral material, such as sand, gravel crushed stone, slag, or the combinations thereof, with which cement or bituminous material is mixed to form a

mortar or concrete. "Fine Aggregate" may be considered as the material that will pass a 1/4-inch screen and "coarse aggregate" as the material that is retained thereon.

Aggregate Base - The layer of specified, compacted material placed on the subgrade to serve as a base for pavement.

Agitation - Slow stirring or turning over of freshly mixed concrete to keep it in workable condition until placed into forms.

Air Entrained Cement - Cement into which the air entrainment admixture has been incorporated at the cement plant when the cement was ground.

Batch - The combination of amounts of cement, aggregate, water, and admixture which will be mixed at one time in a mixer.

Batching Operation - Proportioning and assembling the materials which will comprise one batch.

Batching Plant - The plant either on or off the work site where the materials are assembled by batches for the mixer. Water and admixtures usually are added as the batch is introduced into the mixer.

Batch Weights -The individual weights of the cement, aggregate, and water used in each batch of concrete. Aggregate is adjusted for moisture content and specific gravity.

Bleeding - Flow of water to the surface of freshly placed concrete.

Bulkhead - A partition made of timber, concrete, or steel plate between stockpiles to prevent their intermingling.

A temporary form placed at the completion of a portion of concrete structure or pavement, or whenever production is interrupted for an extended period of time.

Cement - A mixture of clay, limestone, and other selected materials heated to high temperature to form clinker. The clinker is then ground into powder. When mixed with water, it forms a paste to surround and bind the aggregate into a solid and durable mass.

Charging - Filling. Charging a mixer is placing the ingredients for concrete into it.

Compacted - Made denser. When a material is compacted, the particles are forced together more tightly so that a given weight of material takes up less space.

Concrete Control Inspector - The Inspector at the job site who is responsible for the necessary inspections and tests to ensure concrete meeting specifications.

Counters - Meters on mixers which show the number of revolutions. Transit mixers may have two counters - one for mixing speeds and one for agitation speeds.

Cure - The treatment given concrete to ensure sufficient water and heat necessary for chemical action so that concrete attains the strength and durability for which it was designed.

Entrained Air - Millions of microscopic voids introduced into concrete through an admixture to permit the cured concrete to undergo freezing and thawing without damage.

Entrapped Air - Large air bubbles which enter concrete through mixing or handling. Being undesirable, they can be removed by vibrating, spading, or rodding.

Falsework - The bracing supporting concrete structural forms which are removed after the concrete has cured sufficiently to support its own weight.

Finishing - Shaping the surface of cement that is not shaped by forms. Also, it includes filling visible voids in the concrete after the forms are removed.

Footer - The concrete pad which spreads the load of a structure over an area of supporting earthwork.

Forms, Report - Printed sheets of paper which contain blank spaces for filling in desired information.

Forms, Structural - Molds of rigid material for receiving plastic concrete which will cast it to a specified shape and dimension.

Gradation - The classification of different sizes of aggregate within a given size of aggregate as determined by sieve tests.

High-Early-Strength Concrete - Concrete made with a special cement (Type III) that reaches design strength and hardness in considerably shorter time than concrete made with regular Portland cement.

Honeycombing - Large voids in the concrete which are due to inadequate spading or consolidating.

Intermingling - The unintentional dilution of one size of aggregate by aggregate of a different size as a result of improper storage or careless handling.

Job Control - Steps taken to keep quality and quantity of materials and work on a project within the specifications and plans.

Mixing - Combining the ingredients of a batch of concrete into a homogenous mass through raising and dropping action of a revolving drum. Specifications cover the rate and number of revolutions which are acceptable for proper mixing.

Moisture Content - The percentage by weight of water contained in aggregate as compared to the same aggregate in a completely dry condition.

Mortar - A mixture of water, sand, and cement. Mixed with coarse aggregate, this mortar completely envelopes each particle of coarse aggregate to form concrete.

Paved - An area covered with a hard surface to support traffic or material storage.

Plant Bins - Bins at the hatching plant for temporary storage of aggregate and cement for use in proportioning concrete batches.

Proportioning Concrete - Determination of the amount of each ingredient used in a class of concrete with adjustments as determined by tests called for in the specifications.

Retarder - An admixture placed in concrete which slows the setting of the concrete.

Rodding - Consolidation of a concrete mix sample by the repeated insertion of the prescribed steel tamping rod.

Saturation - Condition of aggregate when it is completely soaked and will not absorb additional water.

Scaling - Peeling away of small amounts of surface concrete.

Segregation - The unintentional separation of the larger pieces of aggregate from the smaller pieces within one size of aggregate or within a mixture of sizes in fresh concrete.

Set or set-up - A stage reached by freshly placed concrete as it hardens and can no longer be worked or shaped.

Sieve Analysis - Determination of the gradation of an aggregate sample by passing through a series of screens with specified openings and weighing the separated particle sizes.

Slump - A measure of the consistency and workability of plastic concrete.

Spading - Repeatedly inserting a flat steel blade edgewise into fresh poured concrete for consolidation and to drive out entrapped air, particularly where the concrete meets the forms or imbedded objects.

Spading Blade - A small steel blade about the size of a nail file used in making Chace air determinations.

Spading Tool - A tool resembling a garden hoe with the blade straightened out in line with the handle which is used for consolidating concrete.

Spalling - The breaking away of hardened parts of concrete from the main body at surface points.

Specific Gravity - The ratio of weight of any volume of a substance to the weight of an equal volume of water.

Stabilize - To make or hold steady and prevent fluctuations.

Stockpile - A large amount of aggregate placed in a pile for storage until ready for use.

Strike Off - Using a straightedge to scrape off excess concrete which may protrude above the mold or forms.

Subgrade - The portion of a roadbed upon which the pavement structure and shoulders are constructed.

Testing Equipment - That equipment furnished to the project for conducting field tests.

Test Weights - Ten 50-pound (22.7 kg) steel weights that must be readily available for checking weighing devices at concrete plants.

Ticket - A form record of quality, quantity, and other pertinent information which may accompany a shipment of construction materials to the project.

Validation - The signature or initials of an authorized individual on any form or ticket denoting that the information is as stated.

Verification - The steps necessary to determine that the work or materials described are in conformance with plans and specifications.

Water-Cement Ratio (W/C) - The proportion of an amount of water to the specified amount of cement used to produce concrete. Such amount of water is the sum of the calculated amount of water contained in the aggregates, plus all the water added both at the plant and at the site, less the calculated amount of water absorbed by the aggregates.

Yield - A check on the mix design made by dividing the total batch weight by the determined unit weight, weight per cubic yard (weight per cubic foot). The actual volume thus obtained is compared to the design volume.

Rigid Pavement Terms

Admixture - A substance other than cement, water, or aggregate added to a batch of fresh concrete to alter one of the normal properties of concrete.

Aggregate - Mineral material, such as sand, gravel, crushed stone, slag, or the combination thereof, with which cement is mixed to form a mortar or concrete. “Fine aggregate” may be considered as the material that will pass a 4.75 mm (No. 4) screen and “coarse aggregate” as the material that is retained thereon.

Batch - The combination of amounts of cement, aggregate, water, and admixture which will be mixed at one time in a mixer.

Batching Plant - The plant either on or off the work site where the materials are assembled by batches for the mixer. Water and admixtures usually are added as the batch is introduced into the mixer.

Beam, Test - A beam of specified size molded on the job and later broken in a testing machine to determine the flexural strength of the concrete.

Bleeding - Flow of water to the surface of freshly placed concrete.

Cap - A short tube, closed at one end, placed on the oiled end of a dowel in an expansion joint to provide space for movement of the dowel in hardened concrete. A stop in the tube prevents it from being pushed all the way onto the dowel before the concrete hardens.

Cement - A mixture of clay, limestone, and other selected materials heated to high temperature and ground into powder. When mixed with water, it forms a paste to surround and bind the aggregate into a solid and durable mass.

Contraction Joint - A joint which controls the location of a transverse crack and permits the slab to contract and expand with changes in temperature.

Construction Joint - A joint formed in concrete pavement at the end of the day’s production or any time production is interrupted for 30 minutes or longer.

Core - A cylinder of concrete cut from pavement with a hollow drill. Cores are 4 inches (200 mm) in diameter and are used to check the thickness and strength of the concrete.

Course - The depth of concrete pavement obtained in one pour.

Crown - The height of the center of the roadway surface above a straight line drawn between its edges.

Cure - The treatment given concrete to ensure sufficient water and heat necessary for chemical action so that concrete attains the strength and durability for which it was designed.

Curing Membrane - A compound sprayed over the exposed surface and edges of newly placed concrete to prevent the evaporation of water during curing.

Cylinder - A test sample of concrete molded into a cylinder 12 inches (600 mm) high and 6 inches (300 mm) in diameter, to be sent to the Laboratory for determination of strength and density.

Deformed Bar - A steel bar which has projections on its surface for increasing the bond between the concrete and the bar.

Density (Soil) - The density of soil is its weight-volume relationship, which usually is expressed in pounds of soil per cubic foot (kilograms of soil per cubic meter).

Dowel or Dowel Bar - A smooth steel bar extending across a concrete joint to transfer the applied load, prevent future misalignment of the slab, and permit movement at the joint.

Dowel Assembly - A cage or basket used to hold dowels in position during placement of concrete.

Edging - Rounding the edges of concrete pavement and hand-formed joints while the concrete still is workable, using an edging tool of specified radius.

Elevation or Grade - The height as measured from a predetermined point denoted in the plans.

Expansion Joint - A joint adjacent to a bridge or intersection to absorb expansion of concrete pavement and prevent expansive pressure on the bridge or intersecting pavement.

Fine Grading - Removing approximately 1 inch (25 mm) of the primary subbase and re-rolling to bring to exact grade upon which the concrete pavement is placed.

Finishing - Shaping the surface of concrete that is not shaped by forms. Also, it includes filling visible voids in the concrete after the forms are removed.

Finishing Machine - A machine, which screeds, and a float for performing the final grade and smoothness of the concrete pavement to meet the requirements.

Float - A straight piece of wood or metal used to smooth the surface of plastic concrete. Small hand-held floats are called paddle floats.

Forms, Pavement - Metal plates secured together and to the subbase for shaping the sides of the pavement and controlling alignment, grade, and thickness. Also, the forms serve as a track for paving equipment.

Grade (noun) - See Elevation.

Grade (verb) - To add or remove earth to obtain a desired level or slope.

Hand Finishing - Manually correcting irregularities left by the finishing machine, or performing those functions which cannot be accomplished by machine, such as edging or forming of joints.

Head - The roll of plastic concrete which forms ahead of a screed plate.

Honeycombing - Large voids in the concrete which are due to inadequate spading or consolidating.

Hook Bolt - A short steel bar with hooked ends joined by a threaded connection. Used to fasten a concrete slab to another, which is constructed beside it later.

Inspection - Examination by observation, measurement, or tests to determine that materials and work are in conformance with specifications.

Joint Lock - The device at each end of a section of paving form for attaching the sections together.

Job Control - Steps taken to keep quality and quantity of materials and work on a project within the specifications and plans.

Joint Sealer - A compound for preventing entrance of water and solid particles into a joint. The sealer may either be preformed or liquid.

Laitance - An accumulation of fine particles on the surface of freshly placed concrete occurring when there is an upward movement of water through the concrete due to the presence of too much mixing water or excessive vibration.

Lane or Traffic Lane - A strip of pavement of specified width, usually 12 feet (3.6 meters).

Longitudinal Joint - A joint which extends lengthwise on the roadway, parallel to the centerline.

Mesh - A fabric of steel wires welded together at their intersections for placement in concrete pavement as distributed reinforcement.

Mesh Installer - A machine for imbedding wire mesh into freshly placed concrete pavement.

Mortar - A mixture of water, sand, and cement. Mixed with coarse aggregate, this mortar completely envelopes each particle of coarse aggregate to form concrete. Also, mortar is used to fill honeycombing which becomes apparent upon removal of forms.

Oscillating - To swing back and forth, operating between fixed limits, such as the movement of a screed on a finishing machine.

Pin Template or Template - A device used to check the surface of the subbase.

Raveling - Slightly disturbing the surface of concrete pavement adjacent to sawing of a joint.

Random Cracks - Cracks which appear in concrete pavement due to contraction in the early stages of curing and follow no set pattern.

Rigid Pavement Inspector - An authorized representative of the Engineer to make detailed inspections and documentation of contract performance as it pertains directly to concrete paving operations.

Sawing - Using a circular saw to cut a groove in the surface of the pavement to control the location of transverse cracks.

Scaling - Peeling away of small amounts of the concrete surface.

Screed - A long metal plate moved across the surface of freshly placed concrete with a sawing motion to consolidate the concrete and rough finish it approximately to grade.

Segregation - The unintentional separation of the larger pieces of aggregate from the smaller pieces within one size of aggregate or within a mixture of sizes of fresh concrete.

Shim - A thin piece of stone, wood, or other material used to raise the object resting on it to the desired elevation. (Not permitted in adjusting forms to grade).

Slab - A continuous portion of concrete paving bounded by joints and/or the edge of the pavement.

Slip Form Paving - Concrete paving by use of a machine carrying its own forms between which low slump concrete is compacted sufficiently to retain its shape after the machine has progressed onward.

Slump - Measured in millimeters (inches) on a vertical axis. The amount that a sample of fresh poured concrete, which has filled a standard inverted cone, will sink down after the cone has been removed. A measure of the consistency and workability of concrete.

Spading - Repeatedly inserting a flat steel blade edgewise into fresh poured concrete for consolidation and to drive out entrapped air, particularly where the concrete meets the forms or imbedded objects.

Spalling - The breaking away of hardened parts of concrete from the main body at surface points.

Spreader - A machine which distributes fresh concrete generally over the area between the forms.

Station Marker - A numeral impressed into the surface of newly finished concrete pavement and located at specified longitudinal intervals near the edge of the roadway for purposes of future location references.

Straightedging - Placing a 10 foot (3.0 meter) straightedge on the finished pavement surface to determine if the surface is within tolerance.

Strike Off - Using a straightedge to scrape off excess concrete which may protrude above the mold or forms.

Subbase - The layer of specified, compacted material placed on the prepared subgrade to serve as a base for pavement.

Subgrade - The portion of a roadbed upon which the pavement structure and shoulders are constructed after it is prepared.

Surge - The rise in the surface of plastic concrete following the release of compaction after the screed has passed over it.

Texturing - Slight roughening of the finished surface of concrete pavement to provide greater safety through increased traction to the tires of vehicles which will pass over it.

Thin-Bonded Patching - Repairing concrete pavement only to the depth of unsound concrete rather than the full-depth of the pavement.

Tie Bar - A deformed dowel or hook-bolt placed across longitudinal joints of concrete pavement near middle-depth to tie the slabs together and hold the joint closed.

Tying - Wiring together overlapped mesh that is hand-tied by use of rings similar to hog rings.

Tolerance - The permitted variation from a specified condition.

Traction Speed - The rate of forward movement parallel to the centerline by the paving equipment.

Transverse - A theoretical line running perpendicular to the longitudinal or centerline of a roadway.

Validation - The signature or initials of an authorized individual on any form or ticket denoting that the information is as stated.

Vibrator - A device for pulsating fresh concrete so that entrapped air is released, and the concrete settles uniformly about reinforcement and to the forms.

Wearing Plate - A small plate which drags over the top of the pavement forms or adjacent paving to control the height of the screed plate.

Windrow - An accumulation of material as a result of rolling up or sliding off to the side. Applies here to loose material just inside of the forms left by the subgrader in the fine grading operation.

Yield - A check on the mix design made by dividing the total batch weight by the determined weight per unit volume. The actual volume thus obtained is compared to the design volume.

Earthwork

Aggregate Correction Method - A method of compaction testing that modifies the one point proctor method. It accounts for the material retained on the 3/4-inch sieve.

Atterberg Limits - The moisture content of a soil at certain stages of soil behavior.

Balanced Project - A project where the amount of embankment is required approximately equal to the amount of excavation.

Benching - The excavation of the existing embankment steps into a slope where new embankment is being placed on the slope. The benching connects the new embankment and the existing soil in the slope.

Blasting - The use of explosives to fracture rock or shale.

Borrow - Material obtained from approved sources that are required for the construction of the embankment.

Canvas Shroud - A canvas curtain used to control dust during the spreading operation.

Cement - A burned and pulverized chemical that that reacts with silty and granular soils.

Centrifugal Force - The roller force or load on a base course or material that adds the weight and the vibration energies.

Checking - The cracking of a base course or stabilized subgrade due to over rolling.

Clearing - Cutting down trees and brush.

Compaction - Increasing the density of soil by mechanical means, involving the expulsion of excess air.

Compaction Equipment - Equipment used to compact materials.

Consolidation - The removal of water from a soil over time to increase its strength.

Construction Underdrains - Sacrificial underdrains placed to drain the subgrade.

Contractor Designed Chemically Stabilized Subgrade - Tests performed by the Contractor to determine the optimum percentage of chemical (cement, lime, or lime kiln dust) that will stabilize the soil.

Curing - The act of ensuring that the lime or cement stabilized soil is wet for at least five days.

Deflections or Rutting - The vertical movement of the subgrade during proof rolling.

Density - The proportion of soil mass or weight to the volume of the soil. It is commonly expressed in pounds per cubic foot.

Depth Checks - The measuring of the thickness of the base course or embankment material.

Disking - The act of using a disk to break up a material so that it may dry.

Dozer - A machine that pushes and levels material.

Drainage - Constructing the embankment to drain the water away as fast as possible.

Drainage Blanket - A system of coarse aggregate, fabric and pipe that is designed to drain large areas of the slope.

Dry Density – The density of a soil that uses only the weight of the soil. The density of the soil when the soil is completely dry.

Drying - The act of lowering the moisture content of a material by disking, plowing, or other means.

Earth Moving Equipment - Equipment used to move earthen materials.

Earthwork Volumes - The calculation of a three dimensional earthwork quantities.

Electronic Grade Control - Controls on construction equipment that controls the grade.

Embankment - A structure consisting of suitable materials and constructed in lifts to a predetermined elevation and cross-section.

End Area - The cross-sectional area on the plans that represents a two dimensional plane.

End Dumping - The direct loading of the base or embankment material from the truck to the subgrade or foundation.

Excavation - The removal of materials to predetermined elevations and cross-sections.

Excavator - A machine that removes material with a bucket.

Fine Grading - The act for trimming the surface to meet the specification tolerances.

Finished Surface - The top of the base or subgrade materials that has been fine graded or trimmed.

Footed Rollers - Rollers that knit the materials together. Primarily used for clayey materials.

Foundation - The location at the base of an embankment.

Gradation - The level of coarseness or fineness of a soil, referring to soil sizes.

Grader - A machine used to level surfaces.

Grading - The act of leveling the embankment surface to drain.

Granular Material Types - Granular Materials in Item 203 that have specific gradations to perform certain engineering functions.

Grubbing - Clearing by digging up roots and stumps.

Hydrated Lime - A finer form of lime.

Ingots - Heavy concrete weights in the proof roller.

Iron Slags - Air-Cooled Blast Furnace slag (ACBF) and Granulated slag (GS).

Lift Thickness - The thickness of the material when placed on a horizontal surface.

Lime - A by-product of limestone that reacts with clayey soils.

Liquid Limit - Moisture content at which a soil passes from a plastic to a liquid state.

Moderately Soft Foundation - A foundation that is constructible with moderate changes to embankment construction techniques.

Moisture Content - The amount of water in a given soil expressed as a percent of the material's dry weight.

Moisture Density Curve - A plot of the moisture content verses the weight of a soil. This plot determines their relationship.

Natural Granular Materials - Broken or crushed rock, gravel, sand, durable siltstone, and durable sandstone placed in 8-inch (200 mm) loose lifts.

Natural Soils - All natural earth materials, organic, or inorganic resulting from natural processes, such as weathering, decay, and chemical action.

Nuclear Gauge - A device that uses nuclear radiation to determine the soils' density and moisture content.

Ohio Typical Density Curves - Curves that were developed in the 1930's and 40's that represent all the types of soils in the state. They are used with the one-point proctor method to pick the correct curve during compaction testing.

One Point Proctor Method - a method that determines the compaction of a soil. It requires making a proctor and using the Ohio Typical Density Curves to pick the correct curve.

Optimum Moisture - The water content at which the maximum dry density can be achieved by compacting an embankment material.

Partial Excavation Method - The act of removing only a portion of the soft material.

Plastic Limit - The moisture content at which the material breaks apart at a 1/8-inch diameter. Indicates how much clay is in the material. The moisture content at which a soil changes from a semi-solid to a plastic state.

Plasticity Index - The higher the PI, the more clay in the material. The numerical difference between the liquid limit and plastic limit.

Power Driven Mixer - A big roto-tiller used to mix the soil and the lime.

Prime Coat - An asphalt emulsion used to keep the lime soil moist for the cure period.

Proctor Hammer - A device that is used to compact a soil in a proctor mold. It weighs 5.5 pounds, compacts the soil 25 times for each soil lift in the proctor. The soil is placed in the proctor mold in three lifts.

Proctor Test – a procedure that uses a standard, compactive effort to determine or pick a soil moisture density curve.

Proof Rolling - The use of heavy rollers to test the subgrade stability.

Quick Lime - A coarser and more concentrated form of lime.

Random Material - Mixtures of suitable materials that can be placed in 8-inch (200 mm) loose lifts.

Rectangular Foot - A footed roller with rectangular feet.

Recycled Materials - Fly ash, bottom ash, foundry sand, recycled glass, tire shreds, RPCC, or RACP

Recycled Portland Cement Concrete (RPCC) - Recycled Portland cement concrete blended with natural soil or granular material.

Reclaimed Asphalt Concrete Pavement (RACP) - Recycled asphalt pavement blended with natural soil or granular material.

Rock - Sandstone, limestone, dolomite, glacial boulders, brick, and RPCC too large to be placed in an 8-inch (200 mm) loose lift.

Rock or Shale Subgrade Excavation - The 24 inches that is excavated below the pavement for drainage and uniform support.

Roller Pass - One pass over a given location.

Sand Blanket - The sand that is placed to drain the underlying soft material.

Saturated Embankment - Embankment that is full of water to the point of being unstable.

Scale – A weight measuring device used during compaction testing.

Scalping - Removal of remaining roots, sod, grass, agriculture crop, sawdust, and other vegetation so that the soil is completely exposed; however, topsoil should not be removed.

Scraper Plate - A device that is used to establish a location for the nuclear gauge.

Segregation - The separation of fine and coarse material in a base course.

Self-Propelled Spreading Machine - A piece of equipment that receives the base course from the truck and spreads it evenly on the subgrade.

Settlement - The compression of a soil into a more stable condition.

Severely Soft Foundation - Low lying areas with high or standing water that are not constructible with soil or standard construction techniques.

Shale - Laminated material with a finely stratified structure formed by the natural consolidation of a clay or silt. The material is sometimes cemented together.

Shale Compaction Testing – Compaction testing that uses a Bucket test to determine what compaction test to perform on a particular shale.

Sheepsfoot - An old footed roller that has 10 percent coverage per pass.

Side Drainage - Any ditches that drain the embankment away from the embankment construction.

Side Slopes - The embankment slopes that are perpendicular to the roadway (usually 2:1 slopes).

Slag Materials - Residual material from making iron or steel that must meet the requirements in 703.16.

Slide Repair - An area to be excavated for replacement.

Soil Classification - AASHTO classification of a soil determined from the gradation and characteristic of the different materials.

Spreading - Moving material in preparation for compaction.

Spring Drains - A system of coarse aggregate, fabric, and pipe that is designed to drain small areas of the slope.

Standard Count- a procedure performed on a nuclear gauge to ensure that the readings are accurate.

Steel Slags - Open Hearth (OH) slag, Basic Oxygen Furnace (BOF) slag, Electric Arc Furnace (EAF) slag, or Granulated slag.

Steel Wheeled Roller - Uses a drum with 100 percent coverage with one pass. Can be used with or without vibration. Used for granular and silty materials.

Stock Pile - A pile of material that has or will be approved by the Test Lab.

Straightedge - A piece of lumber with a level on it to check the grade.

Subgrade Compaction - The compaction of the top 12 inches of the subgrade.

Suitable Material - Natural soil, natural granular material, granular material types, slag material, brick, shale, rock, random material, or other materials that are appropriate for use in embankment construction.

Tamping Foot - A footed roller that has 40 percent coverage with one pass and is highly productive. Can be used for soil, rock, or shale.

Test Rolling - The use of a proof roller to test the stability of the subgrade prior to undercutting or stabilizing the subgrade. Used when spot locations are detailed in the plans.

Test Section Method - A compaction method that uses the relative density between two nuclear gauge readings to determine the materials potential maximum density.

Test Section Method A - A compaction method that uses the relative density between two nuclear gauge readings to determine the materials potential maximum density. It is used when the material has a definitive moisture density curve.

Test Section Method B - A compaction method that uses the relative density between two nuclear gauge readings to determine the materials potential maximum density. It is used when the material does 'not' have a definitive moisture density curve. A field test section moisture density curve is developed with this method.

Test Section Method C - A compaction method that uses the relative density between two nuclear gauge readings to determine the material's potential maximum density. It is used when the material is highly variable.

Total Excavation Method - Removing all of the soft material.

Waste - Excess material removed from the project limits.

Watering - The act of adding moisture to a material for proper compaction.

Weak Plane - An area in the embankment where the soil is weak and could slide apart.

Wet Density - the density of the soil that includes the weight of water and soil. It is also expressed as the total weight of the soil.

Zero Air Void Curve - A theoretical line that is used to ensure that the nuclear gauge readings are not dramatically incorrect. It plots the moisture density curve without the voids.

Landscape

Amendments - Mixed with the soil removed from the plant hole. To improve the soil texture or pH, add organic material. Sphagnum peat moss, shredded pine bark, yard waste compost, and sand are all accepted amendments.

Backfill - This soil and amendment mixture is placed back into the hole after the plant has been set (see C&MS 661.11).

Balled and Burlapped - This is one kind of method for digging field-grown plants with the ball of earth still intact in which they are growing. Can be supported by a wire basket and/or burlap and laced with bailing twine. Often denoted as B&B in plan notes.

Bare Root - Plants shipped by this method are done so without the soil from which they were grown. This type of plant can be seedlings, perennials, roses, fruit trees, etc. Roots should be white and unbroken.

Caliper - This is measured as the width of a single stem plant. See Page 6 for instructions on how to measure.

Competing Leaders - Found at the top most branch. This condition is where the main stem (leader) has been cut or broken and has continued to grow into two main stems. One stem should be removed to eliminate the potential for future problems.

Conifer - Cone-bearing plants, mostly evergreen, but not always.

Crown - The upper part of a tree, also called the canopy.

Deciduous - Term used to describe plants which lose their leaves at the end of a growing season. This typically occurs in the fall.

Fertilizer - A natural or synthetic material added to or spread on soil to increase its fertility. The three numbers indicate its percentage of ingredients. In order, these numbers are nitrogen, phosphorus, and potassium.

Foliage - This is the leaf structure of a plant, such as needles or deciduous leaves (can be composted).

Herbicide - A natural or synthetic product typically used to eradicate weeds. Product should be applied by a licensed applicator and as directed by the manufacturer's label.

Mulch - Placed on top of the plants rootball. Mulch keeps the ground cool, retains moisture, prevents heaving, and breaks down providing nutrients to the root system.

Multi-stem - Having two or more main stems; defined as clump or shrub form.

Root Crown - This is the union between the roots and the stem. Care should be taken not to bury this union with soil when planting.

Single Stem - Also called the central leader or trunk, tapers gradually from root crown to top.

Shrubs - Usually multi-stemmed with numerous side branches, can be evergreen or deciduous.

Tree Wrap - Placed around a deciduous tree trunk to protect it from frost cracking, sunscald, or insect damage.

DBE / /EEO / Prevailing Wage

Administering Agency - Any department, agency and establishment in the executive branch of government, including and wholly owned Government corporation, which administers a program involving federally and State assisted construction contracts.

Affirmative Action - The efforts exerted toward achieving equal opportunity through positive, aggressive, and continuous results oriented measures to correct past and present discriminatory practices and their efforts on the conditions and privileges of employment. These measures include but are not limited to recruitment, hiring, promotion, upgrading, demotion, transfer, termination, compensation, and training.

A good faith effort to eliminate past and present discrimination in all federally assisted programs, and to ensure future nondiscriminatory practices.

Apprentice - A person employed and individually registered in a bona fide apprenticeship program registered with the U.S. Department of Labor, Employment and Training Administration, Office of Apprenticeship Training, Employer and Labor Services, or with a State Apprenticeship Agency recognized by the Bureau, or (ii) A person in the first 90 days of probationary employment as an apprentice in such an apprenticeship program, who is not individually registered in the program, but who has been certified by the Office of Apprenticeship Training, Employer and Labor Services or a State Apprenticeship Agency (where appropriate) to be eligible for probationary employment as an apprentice.

Apprentice Permit - a permit issued by the Union to authorize a person desiring to achieve journey-person status to obtain skilled craft experience under supervision of a full journey-person.

Apprenticeship Program - A bona fide training program, registered with the Ohio State Apprenticeship Council, aimed at developing the skill level of a person until the person reaches full journey-person status (generally four years). The training includes both school and hands on study of the craft.

Area-wide Plans - An Affirmative Action plan to increase minority utilization of crafts in a specified geographical area pursuant to "Executive Order 11246" or taking the form of an "Imposed" Plan.

Area workforce - Employees at all Federal-Aid, Federal or non-Federal projects in a specific geographical area as determined under CFR 23; Part 230.409(b)(9).

Bid Conditions - Contract provisions, which have been issued by the Ohio Department of Transportation, Office of Contracts.

Commercially Useful Function - Responsible for execution of the work of the contract and is carrying out its responsibilities by actually performing, managing, and supervising the work involved. To perform a CUF the DBE must also be responsible, with respect to material and supplies used on the contract, for negotiating price, determining quality and quantity, ordering the materials and installing (where applicable) and paying for the material itself.

Conciliation Agreement - Agreement arrived by the Reviewing agency and the contractor, which outlines steps the contractor will take to bring his/her firm into compliance.

Construction Work - The construction, rehabilitation, alteration, conversion, extension, demolition, or repair of buildings, highways, or other changes or improvements to real property, including facilities providing utility services. The term also includes the supervision, inspection, and other onsite functions incidental to the actual construction.

Contractors' Workforce - All employees on the payroll of and who are directly supervised by the contractor.

Corrective Action Plan - A contractor's unequivocal written and signed commitment outlining actions taken or proposed within the time limits and goals, where appropriate to correct, compensate for, and remedy each violation of the equal opportunity requirements as specified in a list of deficiencies.

Disadvantaged Business Enterprise (DBE) - Small business as defined in "Appendix B" of Subpart D, Part 23, Title 49, Code of Federal Regulations, which is owned and controlled by persons who are citizens or lawful permanent residents of the United States, and who are members of a disadvantaged group including Black Americans, Hispanic Americans, Native Americans, Asian-Pacific Americans, and other individuals found on a case by case basis to be socially and economically disadvantaged.

Discrimination - A distinction in the treatment of a person based on race, color, religion, sex, national origin, age (40-70 years), or disability.

The act (or action) whether intentional or unintentional through which a person of the United States, solely because of race, color, religion, sex, or national origin, has been

otherwise subjected to unequal treatment under any program or activity receiving financial assistance from the Federal Highway Administration under Title 23 U.S.C.

District Equal Employment Opportunity Contract Coordinator (DEEOCC) - A Federal or State employee regularly employed and experienced in civil rights policies, practices, procedures, and equal opportunity compliance review and evaluation functions.

Equal Employment Opportunity - The absence of partiality or distinction in employment treatment, so that the right of all persons to work and advance on the basis of merit, ability and potential is maintained.

Equal Opportunity Clause - The contract provisions set forth in CFR Chapter 60-1.4(a) or (b), as appropriate.

Equal Opportunity Compliance Review - An evaluation and determination on non-exempt direct Federal, Federal-Aid or State contractor, or sub-contractor's compliance with equal opportunity requirements.

Equal Opportunity Requirements - A general term used throughout this document to mean all contract provisions relative to equal employment opportunity (EEO), sub-contracting and training.

Fringe Benefits - Includes medical or hospital care, pensions on retirement or death, compensation for injuries or illness resulting from occupational activity, or insurance to provide any of the foregoing: unemployment benefits, life insurance, disability insurance, sickness insurance, accident insurance, vacation or holiday pay. Also includes defraying costs of apprenticeship or other similar programs or other bona fide fringe benefits. Fringe benefits do not include benefits required by other federal, state, or local law.

Good Faith Effort Deficiency - A contractor may be found in noncompliance when compliance review findings indicate that good faith effort actions taken, or lack thereof, by the contractor have not resulted in the employment of minorities and females in the workplace.

Good Faith Effort - Affirmative action measures designed to implement the established objectives of an Affirmative Action Plan.

Home Office Workforce - Employees at the physical location of the corporation, company, or other ownership headquarters or regional managerial offices, including "white collar" personnel (managers, professional, technicians and clerical) and any maintenance of service personnel connected thereto.

Imposed Plan - An affirmative action requirement for a specified geographical area made mandatory by OFCCP, and in some areas by the courts.

Journeyman - A person who is capable of performing all the duties within a given job classification or craft.

Minority - A person who is a citizen or lawful permanent resident of the United States, and who is Black, Hispanic, Pacific Islander, Asian American, Native American or Alaskan Native.

New Hires - An individual who has a break in service (not on an employer's payroll) for a period of 12 months or longer and the person affected is not a salaried employee, but

belongs to a union craft. Individuals compensated for training or incidental work which does not cause a break in unemployment compensation, i.e., paid by voucher check or petty cash, are considered new hires if the individual's break in service is 12 months or longer. The time frame for a new hire shall be associated with the first project worked for that contractor regardless of whether it is public or private. When reporting new hires the contractor shall identify that employee as a new hire on that specific project only. Subsequent work, barring a break in service of 60 days or more, would not qualify the employee as a new hire for that contractor.

On-The-Job-Training - A program that includes the training and upgrading of minorities and females toward journey-person status.

Paper Deficiency - Any deficiency which can be corrected and verified by the reviewer within 10 days of the Exit Conference (i.e., EOE tagline, EEO/Sexual Harassment policy corrections).

Permit Person - A person signed with the Union who receives full benefits, but is in pre full member status, earning journeyman's wages working for a specific time period (generally 78 weeks) after which the permit person is sold full membership.

Persons/Protected Class - Where designation of persons by race, color, national origin is required, the following designations ordinarily may be used: "Black Americans," which includes persons having origins in any of the Black racial groups of Africa; "Hispanic Americans," which includes persons of Mexican, Puerto Rican, Cuban, Dominican, Central or South American, or other Spanish or Portuguese culture or origin, regardless of race; "Native Americans," which includes persons who are American Indians, Eskimos, Aleuts, or Native Hawaiians; "Asian-Pacific Americans," which includes persons whose origins are from Japan, China, Taiwan, Korea, Burma (Myanmar), Vietnam, Laos, Cambodia (Kampuchea), Thailand, Malaysia, Indonesia, the Philippines, Brunei, Samoa, Guam, the U.S. Trust Territories of the Pacific Islands (Republic of Palau), the Commonwealth of the Northern Marianas Islands, Macao, Fiji, Tonga, Kiribati, Tuvalu, Nauru, Federated States of Micronesia, or Hong Kong; "Subcontinent Asian Americans," which includes persons whose origins are from India, Pakistan, Bangladesh, Bhutan, the Maldives Islands, Nepal or Sri Lanka.

Prevailing Wages - Means the basic hourly rate of pay, any contribution irrevocably made by a contractor or subcontractor to a trustee or to a third person pursuant to a bona fide fringe benefit fund, plan, or program, and the rate of costs to the contractor or subcontractor which may be reasonably anticipated in providing bona fide fringe benefits to laborers and mechanics pursuant to an enforceable commitment to carry out a financially responsible plan program, which was communicated in writing to the laborers and mechanics affected. Prevailing Wage Exemptions: The following work types are exempt from the payment of prevailing wages: mowing, herbicidal spraying, trash pick-up in maintenance yards, center line survey, sign inventory, tree trimming and tree removal (with no construction to follow).

Project Workforce - Employees at the physical location of the construction activity.

Show-cause Notice - A written notification to a contractor, based on the determination of the reviewer (or in appropriate cases by a higher level authority), that the contractor is in noncompliance with the equal opportunity requirements. The notice informs the contractor of the specific basis for the determination and provides the opportunity with 30 days from the receipt to present an explanation as to why sanctions should not be imposed.

Site of Work - The physical place or places where the building or work called for in the contract will remain and any other site where a significant portion of the building or work is constructed, provided that such site is established specifically for the performance of the contract or project. Job headquarters, tool yards, batch plants, borrow pits, etc., are part of the site of the work, provided they are dedicated exclusively, or nearly so, to performance of the contract or project and provided they are adjacent or virtually adjacent to the site of the work.

Not included in the site of the work, are permanent home offices, branch plant establishments, fabrication plants, tool yards, etc., of a contractor or subcontractor whose location and continuance in operation are determined wholly without regard to a particular Federal or federally assisted contract or project. In addition, fabrication plants, batch plants, borrow pits, job headquarters, tool yards, etc., of a commercial or material supplier, which are established by a supplier of materials for the project before opening of bids are not on the site of the work. Such permanent, previously established facilities are not part of the site of the work, even where the operations for a period of time may be dedicated exclusively, or nearly so, to the performance of a contract.

Trainee - A person who receives on-the-job training, whether through an apprenticeship program, or other programs approved or accepted by the Federal Highway Administration, and/or the appropriate State agency.

Unified Certification Program (UCP) - The UCP is a unified directory including all certified DBE firms who are available for the entire State of Ohio. The main advantages for the DBE firms are: one certification will enable them to be eligible to fulfill DBE goals set on any project with any governmental agency receiving Federal Transportation funding in Ohio; and the DBE firms will also have more visibility due to the unified state-wide directory.

Virtually Adjacent - All work areas located within a 1-mile radius of the project site will be considered to be virtually adjacent.

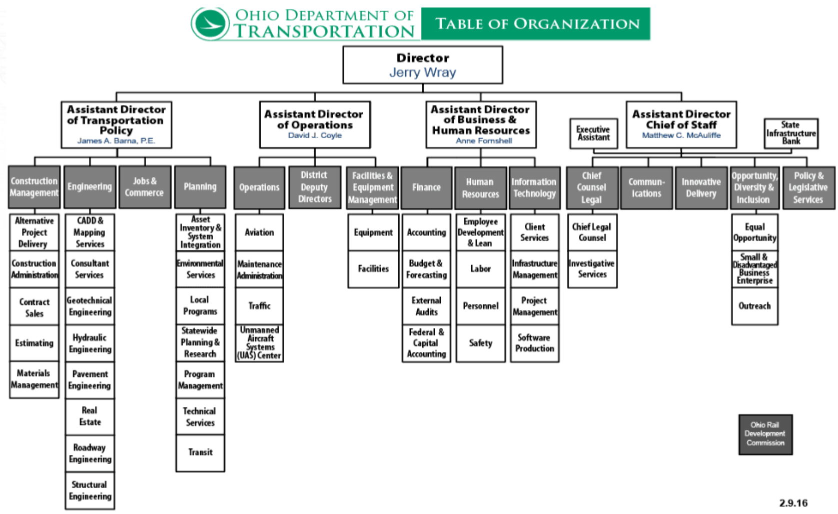
105 Control of the Work

Overview of Construction Contracts – General ODOT Organization

Central Office

District Construction needs to communicate with the Central Office on many issues. The primary contacts for construction related issues are within the Division of Construction. The Table of Organization for ODOT is shown below.

www.dot.state.oh.us/policy/Pages/ODOTTableofOrganization.aspx



The Central Office Division of Construction responsibilities include policy and standard procedure development, support services, and quality assurance. More specifically, its role is to:

- Work with other offices to develop specifications and policies that apply to the day-to-day operations at the project level.
- Act as a liaison with other offices, the various trade organizations, and FHWA on matters concerning ODOT's specifications, policies, and procedures.
- Act as a consultant to the Districts in matters concerning contract administration.
- Provide training to the Districts in contract administration.
- Review and report the effectiveness of various construction methods and materials and provide advice on their use.
- Conduct Quality Assurance Reviews (QAR) and Technical Process Reviews (TPR) to ensure that ODOT's policies, procedures, and specifications are being followed uniformly.

- Develop the performance measures by which the Districts are judged.
- Conduct the administrative closing of contracts.
- Provide support to the Districts, and other ODOT Divisions.

The responsibilities described above are of a general nature. The Division of Construction also has some specific approval functions that relate directly to the District. They are as follows:

- Answer legal questions and provide dispositions regarding claims.
- Answer pre-bid questions.
- Testify and report extra work to the State Controlling Board.
- Create and publish the Construction and Material Specifications along with the quarterly publication of all other specifications.
- Track and report on change orders and provide feedback to Production Offices.
- Test materials and maintain the Departments various materials lists
- Develop specifications, including research and new product review.
- Estimate analysis of trends, bid review, and provide change order support.

As mentioned above, the Division of Construction is responsible for the Office of Construction Administration, the Central Laboratory and the Office of Estimating. The Office of Construction Administration has experts in the areas of concrete, asphalt, traffic, bridges, contracts, and scheduling who can provide advice to the Districts and initiate specification or policy changes.

The Division of Construction Management Policies and Standard Procedures can be found online at the following website:

www.dot.state.oh.us/Divisions/ConstructionMgt/Pages/ConstructionPolicies.aspx

District

All District responsibilities begin with the District Deputy Director (DDD). The DDD, through the District Construction Administrator, is responsible for the administration of all contracts sold for the construction, reconstruction, and maintenance of the highway system within the District.

While Central Office's responsibilities are primarily program / systemic in nature, the District's responsibilities focus on direct project administration. The following is a summary of various District responsibilities required by state policies and procedures as they relate to contract administration:

- Ensure that all work done on each project is performed in accordance with the project's requirements (plans, proposal, specifications, supplemental specifications, special provisions, etc.)
- Approve all change orders that do not require approval by the Director as defined in Section 109 of this Manual.
- Approve all time extensions and waivers.
- Review the contractor/subcontractor certified payrolls for compliance with the contract requirements.
- Review the Contractor's performance and compliance with the contracts Equal Employment Opportunity requirements.
- Approve all estimates for work completed on the projects.

- Perform the final inspection and approve the final inspection report.
- Review the project records to ensure that all requirements have been met.
- Monitor Local Participating Agency (LPA) projects to ensure compliance with FHWA requirements.
- Prepare and approve the Final Package on the project.
- Issue the final acceptance letter and submit the finalized project to the Auditor.

In addition, the District is responsible for the following general project requirements and responsibilities:

- Provide a description of the work through the plans, proposal, specifications, supplemental specifications, and special provisions.
- Provide a method to pay for completed work.
- Provide a project site with full access for the Contractor to begin work. This includes right-of-way purchases and utility relocations.
- Furnish an adequate and trained inspection/engineering force at the project level.
- Secure good workmanship by the Contractor. This involves the monitoring, by the project staff, of all operations for compliance with the documents described above.
- Arrive at decisions in a thoughtful manner with due consideration of all facts involved.
- Make decisions in a timely manner to avoid undue delay.
- Promptly pay the Contractor for completed work.
- Monitor the Contractor's compliance with the legal aspects of the contract, such as prevailing wage and equal employment opportunity requirements.
- Review the Contractor's work zone traffic control to ensure the public can pass through the work zone with the least amount of interference.
- Respond to any complaints or questions in a timely manner.

Almost everything done at the project level affects another party. Because of this, the project personnel are constantly subject to pressures from outside sources. Always be mindful of the needs of these parties, the effects of the project on them, their relationship to the project and their effect on the project.

District Construction Administrator

The general responsibilities and requirements assigned to each District rest in the hands of the District Construction Office and specifically the District Construction Administrator (DCA). This person, with the approval of the District Deputy Director, is responsible for the administration of the contracts involving the construction, reconstruction, and maintenance of the District's highway system as well as local projects involving state and federal aid on the state's system. The DCA is responsible for assigning personnel to projects for contract administration. In addition, the DCA will work to resolve any issues that arise on these projects at the lowest possible level.

County Manager

Each county is under the supervision of a County Manager. The County Manager will be involved with all work within the county and will ultimately be the owner of the construction end product.

Other Agencies

Although the primary parties to any contract administered by ODOT are the Contractor and ODOT, other political subdivisions may also be involved either directly or indirectly. During the administration of each project, these relationships should be recognized and addressed.

Federal Highway Administration

The Federal Highway Administration (FHWA) is involved in many projects administered by ODOT. Federal funds are available for many programs and are utilized by both ODOT and local political subdivisions for improvement to their roadway systems. Their involvement varies with the type of project and its location on the National Highway System (NHS). FHWA's philosophy for review of federal aid projects has evolved over the years and now is as follows:

- Major projects on the National Highway System will continue to receive the most attention from FHWA. FHWA will be involved from preliminary design to finalization. This will include periodic reviews to monitor the project's progress and participation in the final inspection.
- FHWA, with the advent of MAP-21, has taken a step back in the tight oversight that had existed on all federal aid projects. On most federal aid projects, both with ODOT or local participation, FHWA has minor on-site participation. FHWA does not get involved with the project specifically, but expects ODOT to administer these projects in accordance with the plans and specifications and then certify that this has been done.
- FHWA will still participate in reviews of ODOT’s policies, procedures, and specifications. At the project level, this may involve a review of an individual process (paving, traffic control, etc.) that is also being studied statewide.

Local Participating Agency

Many contracts involve direct local participation. The Local Participating Agency (LPA) will provide funds for their portion of the contract and the remainder of the funds may be provided by either FHWA or ODOT or both. These projects may be administered by the Local or the Department. If the Local administers the project, the Department will monitor the project through the District Construction Monitor. See the Locally Administered Transportation Project Manual of Procedures for guidelines.

If ODOT administers the project, the LPA will still have to live with the project after completion. Therefore, with this in mind, ODOT should invite the LPA to the preconstruction meeting and all progress meetings. In addition, ODOT should keep the LPA informed about all changes to the contract. This is especially true when dealing with changes requiring large increases in the local participation.

The LPA must be involved in the final inspection. Additionally, the LPA must give their final approval and acceptance to the project.

Administration of Construction Contracts at the Project Level

In order to implement both the letter and spirit of any contract, it is necessary to have clearly defined lines of authority and communication between ODOT and the Contractor. This section will present a framework to establish these lines.

The purpose of this section is to give guidance to the project personnel on how to administer the physical work of the contract.

Authority / Responsibilities of the Engineer (105.01)

The Engineer is in charge of all details on the assigned project. The Engineer is the direct representative of the Department and has immediate charge of engineering details of each construction project. The Engineer is responsible for the administration and satisfactory completion of the project. The Engineer has the authority to reject defective work, suspend work being improperly performed, and order the replacement of defective material.

It is important to note that the Engineer's acceptance does not constitute a waiver of the Department's right to pursue any and all legal remedies for defective work or work performed by the Contractor in an unworkmanlike manner.

The Engineer is responsible for the following:

- Assignment of the inspection duties at the project level.
- Instruction of the inspection force in the requirements of the project and the items being constructed including:
    - Addenda, proposal and supplemental specifications, and equipment (e.g., concrete testing kit).
- Review of materials to be incorporated in the work. This may involve rejection of materials.
- Timely payment for work performed by performing the following activities:
    - Input daily diaries on SiteManager, review estimates, verify payrolls, and obtain approval of sampled materials.
- Determining the need for change orders within the scope of the contract.
- Monitoring the project and discussing progress schedule with Contractor's Superintendent.
- Maintaining project records:
    - Construction Daily Work Report, *CA-D-3* or *4*.
    - Work performed. Contractor's equipment, materials, and significant events of the day.
    - Job correspondence.
    - Letters from contractors, utility companies, and other public agencies, as well as any correspondence from District or internal agencies.
    - Minutes from project progress meetings, including who attended, items discussed, and resolutions to problems.

  - Other pertinent documents.
  - Shop drawings, working drawings, and erection procedures.
- Addressing and resolving job site problems in a timely manner.
- Providing the Contractor with specific information regarding the usage of contingency quantities or "as directed" items.
- Reporting to District Construction Administrator any major change in conditions, traffic accidents, or status of project.
- Determining final quantities, ensuring the Contractor completes the Punch List items, completing project files, and scheduling final inspection.

Authority/Responsibilities of the Inspector (105.09)

The Inspector is the front line ODOT representative at the project level. The Inspector has authority to inspect all work performed and materials used. The Inspector also has authority to reject non-conforming materials and to suspend operations until problem is resolved by Engineer. The Inspector can neither alter the contract nor issue orders contrary to the contract.

The Inspector is responsible for the following:

- Inspection of all work performed. This inspection will be done in accordance with ODOT policies and this manual and includes daily record keeping.
- Reporting quantities of work satisfactorily completed in the units established by the contract.
- Data entry into SiteManager, Inspector's Daily Work Report, completion of required Quantity and Quality forms, drawings of work performed.
- Inspecting and sampling the materials incorporated into the work.
- Rejecting unsuitable work and suspending the offending operation until the issue is resolved by the Engineer or DCA. Offending work will be monitored and corrective actions denoted on the Quality forms.
- Inspection of the material incorporated into the project.
- Being familiar with manuals and specifications of items of work being inspected.
- Communicating daily issues to the Engineer.
- Communicating with Contractor to ensure proper installation of work.

The Inspector cannot waive the Department’s right to pursue any and all legal remedies for defective work or work performed by the Contractor in an unworkmanlike manner.

Authority/Responsibilities of the Contractor

The Contractor's Superintendent is responsible for the work. He/she must be capable of reading and thoroughly understanding the plans and specifications and be experienced in the work. There will be only one superintendent who shall have full authority to execute instructions of the Engineer and shall be in charge of all construction operations regardless of who performs the work.

The Engineer should know if the Superintendent can agree to extra work, get the equipment needed to get the job done, and know if they can follow through with final quantities agreed on.

The Contractor must provide a superintendent on the project at all times. The Superintendent is responsible for all aspects of the work, irrespective of the amount of work subcontracted.

The Contractor bears sole responsibility for the quality of work and compliance with the contract regardless of the Department's level of inspection.

The Contractor is responsible for the following:

- In order to submit a bid that adequately reflects the conditions of the contract, the Contractor must research all aspects of the contract, such as visiting the project site, understanding the plan notes, and reviewing all plan requirements.
- The Contractor must notify ODOT of the project's starting date and keep ODOT informed of the proposed schedule of operations. This allows ODOT to anticipate engineering and inspection needs and therefore, efficiently manage staff.
- The Contractor must provide a list of material suppliers. ODOT will review the proposed list and obtain required samples. The list should be submitted early to avoid delays associated with sampling and testing.
- The Contractor must carry out the work on the project in a diligent manner utilizing adequate labor.
- In order to manage the project efficiently and to avoid project related problems, the Contractor must be aware of all federal, state, and local laws that apply. Many of the legal requirements of the contract are addressed in the proposal, but the Contractor must also be aware of other regulations, such as safety, which is not thoroughly detailed in ODOT's specifications, but is extremely important. ODOT requires the Contractor to protect and indemnify ODOT from all claims and liability resulting from negligence or willful violations.
- When open to traffic, the Contractor must maintain the project in order to permit the public to move safely through. This includes using clean, readable signs, traffic control devices, and maintaining the project free of debris.
- Once notified of problems, the Contractor must respond quickly to correct the problem. This is extremely important when public safety is involved.

105.04 Coordination of the Contract Documents

Contract documents are prepared to promote agreement between the various parts of the plans and specifications that control the work. In case of disagreement between the plans and specifications, the following will govern in descending order:

- Addenda
- Special provisions/proposal
- Plans
- Calculated Dimensions
- Scaled Dimensions
- Supplemental Specifications
- Standard Specifications

The Contractor shall take no advantage of any apparent error or emission in the plans or specifications. In the event the Contractor discovers such an error or emission, the Contractor shall immediately notify the Engineer.

Proposal

The proposal details numerous bidding, EEO, regulatory, special issues, and general requirements of the contract. The proposal may include details for incentives and schedule requirements. It also includes a list of bid items (Proposal Line Items) with associated quantities as well as wage rates that are in effect for the project. The proposal language overrules all plan and specification items.

Plans

The plans show details of structures, the line, grades, typical cross-sections of the roadway, and the location and design of structures. The Contractor shall, at all times, keep one set of project plans available at the project site. No changes shall be made to the plans except as approved by the Engineer.

Working Drawings

The plans shall be supplemented by working drawings when required to control the work adequately. Working drawings shall be furnished by the Contractor. Working drawings shall not be prepared until the applicable field and plan elevations, dimensions, and geometries have been verified by the Contractor. Specific items of work shall require working drawings. These requirements are stated in the specification section that is applicable to the item of work. See table below for typical examples of number of copies and where to submit the different types of working drawings.

Item	Drawing	Copies	Destination
501.05	Structural steel and other metal items, prestressed concrete members, precast concrete structural elements joint sealing devices and other similar items requiring either shop or field fabrication	3	Central Office
630	Overhead sign support	2*	District
630	Roadside sign support	2*	District
632	Signal poles	2*	District
632	Traffic signal heads	2*	District
*	Certified Working Drawings Section 625.06, 630.03		

Construction and Material Specifications

Sections 200 thru 600 of the Construction and Material Specifications are used to obtain the workmanship compliance required for each item. These specifications are typically arranged in the following manner:

- Description
- Materials
- Construction Requirements
- Method of Measurement
- Basis of Payment

Section 700 of the Construction and Material Specifications describes the material requirements.

Supplemental Specifications (SS) are stand-alone specifications that usually have their own pay items.

The SS800 is a specification called out on every project that provides corrections, revisions, and updates to the Construction and Material Specifications.

105.07 Cooperation with Utilities

Utilities will be encountered on most construction projects. The proposal will include a utility note that designates the utility names and times that they will be relocated. The plans should include the detailed locations of the utility changes. If the utility owners fail to relocate or adjust utilities as provided for in the contract documents and the Contractor sustains losses that could not have been avoided by the judicious handling of forces, equipment, and plant, or by reasonable revisions to the schedule of operations, then the Engineer will adjust the contract by change orders. Change orders associated with utilities should properly denote one of the following reasons codes:

14, Utility Relocation Delay.

15, Improperly Located Utility.

16, Unknown Utility.

17, Delay Caused For Reasons Other Than Utilities.

105.13 Haul Roads

Prior to hauling equipment or materials, the Contractor will provide written notification to the Engineer of the specific roads or streets on the haul route. The following procedure should be followed:

- The Contractor requests, through ODOT, that certain local roadways be used for hauling material and equipment to and from the project.
- ODOT reviews the request and contacts the LPA.
- If there is no objection by ODOT or the LPA, the roadway is designated as a haul road.
- The roadway's condition is reviewed prior to hauling.
- If, during the course of the project, the roadway becomes dangerous, ODOT will have the Contractor repair it.
- Once the project is completed, the condition is reviewed again.

- The roadway will be restored to its original condition either through the contract or by other means.

105.16 Borrow and Waste Areas

The purpose of this section is to establish uniform practices for administering borrow and waste areas on or off the right-of–way. It is the Department’s policy to approve requests to locate borrow and waste areas providing that:

- The location would not adversely affect the highway.
- The material is disposed of legally.
- The disposal minimizes the Department’s future liability.
- All environmental laws are observed.
- The offsite locations are serving the public and land owners best interest.
- The areas are restored according to the contract.

Material from outside the right-of-way used in embankment construction is considered to be borrow even though it is not paid for as borrow. Therefore, this section applies to all borrow and waste areas, including areas from which material is furnished and paid for under “203 Embankment,” as well as areas from which material is furnished and paid for under “203 Borrow.”

Requests from the Contractor to locate borrow and waste areas shall be directed to the Engineer, who shall either approve or disapprove the request. Action on each request shall be based on the information contained in the plan submitted by the Contractor, approvals from other ODOT Offices, certifications from environmental consultants, and other supplemental information available to the Engineer.

See Section 107.10 for criteria for evaluating borrow and waste environmental and other significant issues.

General Approval

Specific considerations, which are made a part of the general conditions for approval include, but are not limited to the following:

1. All of the general information listed in A through G of 105.16 is addressed in the Contractor’s submittal.
2. For borrow and waste areas which will not become ponds when the work is completed:
    a. The area shall be graded to ensure positive drainage.
    b. Restoration of all borrow and waste areas shall include cleanup, shaping replacement of topsoil, and establishment of vegetative cover by seeding, and mulching according to *659*.
3. For pits which will become ponds when the work is completed:
    a. In general, ponds are not considered objectionable, and often are considered highly desirable by property owners and persons engaged in conservation of natural resources and wildlife. The creation of additional ponds from borrow pits can provide enhanced

environmental benefits providing that they are constructed properly to avoid shallow stagnant water and are left in a condition to present an aesthetically pleasing appearance. If the pond is on the right-of-way, then approval should be sought from the County Manager and District Production since the District may not want to take the long-term responsibility for the pond.

4. Borrow Pit Final Grading:
   a. The tops of the pit slope shall be at least 25 feet (8m) from the highway right-of-way. This distance may be increased if there are slope stability or erosion problems. Twenty-five feet (8m) has worked well in the past.
   b. Borrow pit slopes adjacent to the highway shall not be steeper than 3 to 1, and all other borrow pit slopes shall not be steeper than 2 to 1.
   c. The borrow pit must be left in a condition satisfactory to the Engineer to blend with adjacent topography when the work is completed.

Stability and Settlement Concerns

Slope stability problems resulting from borrow and waste area construction is the sole responsibility of the Contractor. The Department is keenly interested in the Contractor's filling and cutting operations. The Department must assess the potential for settlement and future slides. The proper design and construction of the borrow and waste areas are provided in *105.16* and references in the Location and Design Manual.

Most of the stability and settlement issues can be evaluated by using the following general guidance:

1. If the material is placed according to C&MS, use a maximum slope of 2:1. Use a 3:1 slope if the embankment is higher than 30 feet (9 m).
2. Only end dump in nonstructural locations. Use a 4:1 slope if the material is end dumped. These areas may need to be re-graded at some future time. Large settlements should be anticipated if the material is end dumped in lifts greater than 3 feet (1 m).
3. Areas with soft foundations should be closely evaluated when the fill height is greater than 20 feet (6.1 m).
4. If the off-site location exceeds the above criteria, or when constructing a non-structural fill, then the property owner should be explicitly told in the agreement with the Contractor. The borrow or waste agreement must explicitly state that the property owners know that these location may settle and potentially slide. If this is not explicitly stated, then the public may be misled in believing that the final fill will be stable. The Department has a stake in making sure that the property owner is not misled.
5. For proposed locations in the right-of-way that exceeds the above criteria or looks suspicious, contact the District Geotechnical Engineer or the Office of Geotechnical Engineering.

105.17 Construction and Demolition Debris

The EPA regulates materials that come from structure removal, pipe removal, clearing or grubbing, and tree and brush removal operations. The EPA encourages the reuse of construction materials.

The OAC *3745-37, OAC-3745-400*, and *ORC Chapter 3714* regulate the use and disposal of this material. The law is governed by the OEPA or the Local Boards of Health, whichever has jurisdiction. The law governs the debris from construction sites that are not covered under solid or hazardous waste or other regulations. Use the following links:

http://codes.ohio.gov/orc/3714

http://codes.ohio.gov/oac/3745-27-01

By the EPA definition, construction and demolition debris is the material resulting from the alteration, construction, destruction, rehabilitation, or repair of any manmade physical structure. Those materials are those structural and functional materials comprising the structure and surrounding site improvements (e.g., fences, sidewalks). The definition identifies structures that are included and materials that comprise the structure, which are considered debris. Any materials that are removed prior to demolition or are not part of the structure and surrounding site will not be considered debris.

The contract documents may require TCLP (Toxicity Characteristic Leaching Procedure) testing of the debris prior to transport and disposal.

Debris does not include materials identified or listed as solid wastes, infectious wastes, or hazardous waste.

The rule identifies other process materials (e.g., mining operations, non-toxic fly ash, etc.) that are not debris.

The legal removal and disposal of all of the following materials are the responsibility of the Contractor. The specifications have been radically changed to address these issues. All parties to the project should monitor the Contractor's work to minimize the Department's future liability.

Clean Hard Fill

Clean hard fill material (asphalt millings) or Portland cement concrete material (or mixtures of these materials with soil, aggregate etc.) coming from pavement or structural removal operations. Clean hard fill may be used as:

- Fill, recycled, or taken to an approved Construction and Demolition Debris Site.
- Fill on or off the project provided the material is acceptable under Item 203. If the material is being used as fill off the site, the OEPA or local board of health in the area of the filling operations needs written notification seven days prior to the filling operation. See the definition of "on-site."
- These materials cannot be indiscriminately piled up and left. These materials must be placed in fill areas not in disposal piles.

- May be taken to a recycling operation for recycling and storage. Storage must be less than two years.

Construction Debris

Construction Debris such as wood, plaster, etc. in whole or mixed with clean hard fill.

These materials are:

- Usually associated with building debris.
- Do not meet the 203 embankment specifications and cannot be used in fill operations.
- Must be taken to an approved construction demolition debris site or licensed solid waste disposal facility.

Landscape Wastes

This law also regulates the disposal of landscape waste that result from roadway clearing and grubbing operations. Landscape wastes include brush, trees, stumps, tree trimmings, branches, weeds, leaves, grass, shrubbery, yard trimmings, crop residue, and other plant matter, excluding soil and garbage. The Department of Agriculture and the local authorities regulate the transportation of this waste to prevent the spread of the Emerald Ash Borer and the Asian Longhorned Beetle.

These wastes may be re-used by:

- Constructing a wildlife habitat according to published guidelines from the Ohio Division of Wildlife, U.S. Fish and Wildlife Services, or Natural Resources Conservation Services. This is subject to local board of health or local OEPA approval.
- Chipping waste into mulch and using or donating it for use on- or off-site.
- Selling or donating the waste for non-burial beneficial purposes.
- Using the waste for any beneficial use or re-use approved by the local OEPA Offices or the local board of health.
- Using the waste as fill material on-site from which the waste was generated. Item 203, Embankment, does not allow these wastes in embankments or structural areas. On-site placement is permitted in non-structural areas. OEPA guidance for on-site means any location on the right-of-way. This can be outside the construction limits or even on other state owned properties. If large amounts of these wastes are to be generated, then the Designer may provide specific right-of way locations to dispose of these wastes. Refer to 105.16, Borrow and Waste, in this manual.

All landscape wastes associated with ODOT projects are required to be disposed of at an appropriate landfill.

These wastes may be disposed of by:

- Open burning (requires special permitting of OEPA, local authorities, special equipment, and site management).
- Composting at an OEPA registered composting facility.
- Sending material less than 4 inches (10.6 cm) in size to a sanitary landfill and materials greater than 4 inches (10.6 cm) in size to a construction and

demolition debris landfill. Leaves cannot be taken to a construction and demolition debris landfill.

Portland Cement Concrete Waste

In recent years, we have increased the amount of Portland cement concrete waste that is wasted on and off the right-of-way.

Large accumulation of Portland cement concrete waste can cause high pH runoff in the range of 11 to 12. Runoff with a pH of 12.5 is considered a hazardous waste. Uncontrolled disposal of Portland cement concrete waste can cause significant environmental degradation in the ground water and surrounding water bodies.

The potential for environmental problems are a function of the availability of water, geometry of the flow net, permeability of the material, and the distance to a water body or ground water.

To minimize these potential future environmental problems, in 105.17, the following is required (see Figure 105.17.A):

- Mixing of the inner core of the Portland cement concrete waste with at least 30 percent soil.
- Covering the mixed Portland cement concrete waste with 3 feet (1 m) of soil on the top and 8 feet (2.4 m) on the sides.
- Placing and compacting the Portland cement concrete waste according to 203.06.D.

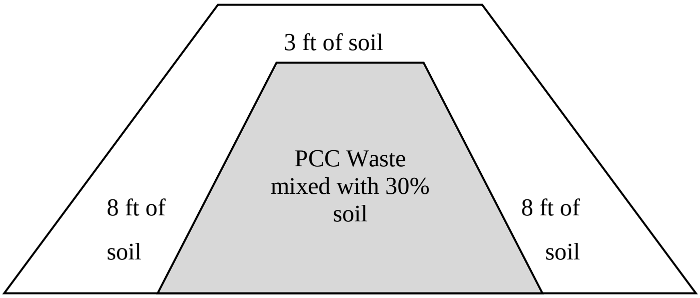


Figure 105.17.A - Typical drawing of the wasting of portland cement concrete waste

106 Control of Materials

Control of Material (Quality of Materials) provides that all materials are to be inspected, tested, and in compliance with the specifications prior to incorporation into the work. Minimum requirements for sampling materials are given in C&MS section 700, Material Details, and outlined in the Sampling and Testing Manual. Project personnel must ensure that all materials received are properly identified with the Project number and Proposal Line number. Samples of materials taken to meet these requirements are called Acceptance samples or Job Control samples (JCTL). Job control samples also include samples taken as judged necessary to determine continued compliance of materials previously approved. These samples always represent a defined quantity of material.

Advance notice by the Contractor of the intended source of supply for specified materials is required to permit sampling and testing of the materials. Systematic record keeping is necessary to furnish documentation that this has been accomplished. The minimum requirements for the necessary records are stated under the individual items of work covered in this manual, and in the Sample and Testing Manual.

The following examples identify the various methods of testing and / or accepting materials on the project.

- Physical sampling and testing of project-made materials.
  - Asphalt, Concrete.
- Electronic TE-24, material comes from pretested stock or from a Certified Supplier (Certified List) .
  - Concrete pipe, Guardrail, High strength bolts.
- Approved List for pre-qualified materials:
  - Trackless tack, Work zone items, Noise barriers.
- Materials from manufacturers certified test data: H Piles, Casing Pipe.
- Qualified Product List (QPL) materials / manufacturers have met preapproval requirements.
  - Curing compound, Fire hydrants, Bridge paint, Asphalt primer.

Material Approval Process

The District Construction Administrator will determine the extent of application of responsibilities for material compliance based on project staffing level and/or expertise. It may be applied on either a wholesale or project-by-project basis.

The Engineer may approve certain materials as listed below and may modify the project bill of materials. Materials that may be approved include:

- Any materials that are on Approved or Qualified Products lists.
- Materials provided by a certified supplier.
- Temporary applications.
- Any materials accepted as "small quantities" per C&MS section 106.03.

District Testing will perform the following functions:

- Sample, test, review, and authorize samples for which the Engineer does not have the authority to approve.
- Provide advice to Engineer concerning material requirements.
- Perform independent reviews of material certifications by Engineer using current guidelines for documentation of final quantities.
- Perform quality assurance reviews on active construction projects to ensure compliance with material approval requirements.

Material Documentation Process

Documentation of the Departments approval of all material incorporated into the work is required. Payments to the Contractor via estimates may only be made when the SiteManager Material Control report is compared to the estimate, and material deficiencies are corrected.

Document Material Quality in SiteManager or on appropriate forms in the following areas as per the Sampling and Testing Manual:

- Materials approved by Engineer.
  - Project personnel will complete appropriate documentation (SiteManager or TE 30, etc.) create sample IDs and assign materials to the proposal line numbers.
  - The Engineer must review and authorize/approve all samples.
- Materials approved by District Testing or the Office of Materials Management.
  - Project personnel will complete appropriate documentation (TE 31 physical sample), create sample ID's, and assign approved material to appropriate proposal line numbers.
  - The Engineer must review all documentation for completeness, and approve as necessary.
  - The District Testing Engineer or the Office Materials Management, as appropriate, will review the documentation, conduct testing on samples, and authorize materials.
- Material finalization and certification:
  - As final quantities are determined, the Engineer, using the C&MS, will ensure that the material requirements are met.
  - The District Testing Engineer, in conjunction with the Documentation Team, will perform a review of the material requirements using the same guidelines as required for final quantities.
  - Confirm that the Disposition of Not Approved Materials, Form TE-206 has been completed as necessary
  - Confirm that the Certification of Temporary Materials, from the Sampling and Testing Manual, 106.03 Appendix A, has been completed as necessary.
  - After all final quantities and material issues are resolved, a Final Certification of Materials Letter is prepared. A sample form can be found in Supplement 1102 Appendix D.
  - The Material Certification Letter is signed by the Engineer, District Engineer of Tests and the District Construction Administrator. This letter

will be directed to the Division Administrator of the Federal Highway Administrator for Non-Certification Acceptance Projects (CAP) or to the project file for all other projects.

Independent Assurance Sampling

The Sampling and Testing manual describes IAS in a systematic approach as follows:

- Yearly QARs or Technical Process Reviews (TPRs) of District laboratories to evaluate equipment calibrations and ODOT laboratory technician processes
- Yearly round robin testing for aggregate, asphalt and concrete. This round robin process includes District laboratories as well as private laboratories performing aggregate, asphalt and concrete laboratory tests (whether quality control or acceptance) for the Department
- Yearly validation of each technician used by the Department whether they are internal technicians, private test lab technicians, a supplier's technicians or contractor's technicians
  - The initial target is to establish procedures that would cover 100% of the operating technicians for the year.
  - For IAS testing of technicians, the year is January 1 thru December 31.
- In addition, ODOT employs a Project Approach through District notification for IA random sampling for specific material types that exceed a Central Laboratory determined quantity on a per project basis.

106.03 Small Quantities

Before accepting a material as a small quantity, the Engineer will evaluate:

- whether the item meets the requirements of Item 106.03,
- does not exceed 10% of the total quantity required for the specific construction item, and
- is not a critical structural or highway safety item.

Materials meeting all three of the above criteria may be accepted as small quantities. The maximum small quantity percent may be increased to 20% with the approval of the District Construction Administrator. For a construction item with a minimal quantity, the 10% limit will not apply if the other requirements are met.

Small quantities will be documented in SM. Project records should include at least type, source, quantity, and any delivery tickets or documentation provided to the Engineer used as evidence for acceptance.

106.03 Temporary Materials

This section establishes general requirements for control, acceptance and documentation of temporary construction items and any associated materials to assure safety, quality and durability.

The Engineer will evaluate temporary construction and material items according to 106.03 as follows:

- The Engineer will document temporary items by including in the project file:
  - Type
  - Source
  - Quantity
  - Any delivery tickets or documentation provided to the Engineer used as evidence for acceptance.
  - Certification showing compliance with NCHRP 350 or permitted usage of inventory items.
- Treat the following temporary construction and material items as permanent items and follow standard acceptance procedures using SiteManager to document acceptance of these items.
  - Temporary concrete pavement items
  - Temporary asphalt pavement items
  - Temporary structure items
  - Any other temporary item that will be permanently incorporated into the completed project.

- The Engineer may document inspection and acceptance of temporary items by entry into the Daily Diary. Any accompanying documentation or required certifications will be maintained in a file for the applicable pay item.

- If the Engineer has accepted temporary items by the above procedures without issuing a TE-30 to the District Lab, then at the conclusion of the project, the Engineer will complete and submit to the District Testing Engineer the form “Certification of Temporary Materials”. The “Certification of Temporary Materials” form is included in Appendix A of Item 106.03 in the Sampling and Testing Manual.

106.07 Unacceptable Material

The District Construction Administrator will determine if any unacceptable material may remain in place. In the event that unacceptable materials are incorporated into the work, these materials must be monitored to determine if they will function properly in the judgment of the Engineer. If so, the Engineer must follow the process to modify the contract to allow these materials to remain in place. See Non-Specification Material Supplement 1102.

Delivered Material

Materials must be approved prior to any payment being made. Materials being delivered are subject to inspection or testing at any time, and should at a minimum be inspected for general conformance prior to payment, preparation or use. Any material which has been tested and accepted at the source of supply may be subjected to a check test after delivery or a minimal visual inspection.

107 Legal Relations and Responsibility to Public

107.01 Laws to be Observed

Prevailing Wage on Federal Contracts

The ***Davis-Bacon Act***, 40 U.S.C. 3142 *et seq.*, as amended, requires that each contract over $2,000 to which the United States or the District of Columbia is a party for the construction, alteration, or repair of public buildings or public works shall contain a clause setting forth the minimum wages to be paid to various classes of laborers and mechanics employed under the contract. Under the provisions of the Act, contractors or their subcontractors are to pay workers employed directly upon the site of the work no less than the locally prevailing wages and fringe benefits paid on projects of a similar character. The Davis-Bacon Act directs the Secretary of Labor to determine such local prevailing wage rates.

In addition to the Davis-Bacon Act itself, Congress has added prevailing wage provisions to approximately 60 statutes which assist construction projects through grants, loans, loan guarantees, and insurance. These "related Acts" involve construction in such areas as transportation, housing, air and water pollution reduction, and health. If a construction project is funded or assisted under more than one Federal statute, the Davis-Bacon prevailing wage provisions may apply to the project if any of the applicable statutes requires payment of Davis-Bacon wage rates.

The geographic scope of the Davis-Bacon Act is limited to the 50 States and the District of Columbia. The scope of each of the related Acts, however, is determined by the terms of the particular statute under which the Federal assistance is provided. For example, Davis-Bacon prevailing wage provisions would apply to a construction contract located in Guam or the Virgin Islands funded under the Housing and Community Development Act of 1974, even though the Davis-Bacon Act itself does not apply to Federal construction contracts to be performed outside the 50 States and the District of Columbia.

Prevailing Wage on State Contracts

Ohio Revised Code Chapter 4115 requires prevailing wages be paid on state funded public improvement projects that reach the threshold level for the project. Thresholds are adjusted biennially by the Director of the Ohio Department of Commerce and can be found on the ODOT’s prevailing wage webpage.

Non-Discrimination Requirements

The following federal laws are in effect:

- Civil Rights Act of 1964, Title VI –Discrimination by Government Agencies
- Civil Rights Act of 1964, Title VII - Discrimination by Employers
- Americans with Disabilities Act of 1990 – Discrimination based on Disabilities

EEO / DBE Requirements

The Division of Opportunity, Diversity, & Inclusion shall ensure uniform administration of applicable Equal Employment Opportunity (EEO) policies for ODOT's statewide EEO contract compliance program and Disadvantaged Business Enterprise (DBE) Program as it applies to ODOT highway construction projects in accordance with Code of Federal Regulations (CFR) 23, Part 230, Subparts A-D and CFR 49, Part 26, Subparts A-F.

Specific requirements and training are available at the Division of Opportunity, Diversity, & Inclusion website here:

www.dot.state.oh.us/Divisions/ODI/Pages/default.aspx

107.10 Protection and Restoration of Property

All properties to be utilized by the Contractor outside the project right-of-way must be cleared for all environmental resource impacts prior to the start of work. The project right-of-way consists of the right-of-way the project is being constructed upon. Environmental resource features pertinent to the construction activity should be shown in the contract documents. The Contractor is responsible for evaluating all impacts on environmental resources outside the project right-of-way.

Environmental resources include, but may not be limited to:

1. Cultural resources.
    a. Buildings, structures, objects, and sites eligible for or listed on the National Register of Historic Places.
    b. Historic or prehistoric human remains, cemeteries, and/or burial sites (pursuant with ORC 2909.05 and 2927.11).
2. Ecological resources.
    a. Wetlands.
    b. Streams.
    c. Wooded areas with trees to be removed in excess of 8 inches diameter at breast height.
3. Public lands.
    a. Lands meeting the criteria of 49 U.S.C. 303, 23 CFR 771.I35: 4(f).
    b. Lands meeting the criteria of 16 U.S.C. 4601-4, 36 CFR59.1: 6(f).
4. FEMA mapped 100 year floodplains.
5. Hazardous waste areas.

All areas proposed to be utilized by the Contractor outside the project construction limits shall be reviewed by environmental contractor(s) that are prequalified by the Department for each environmental resource. Have the consultant(s) certify that the proposed site to be utilized for the Contractor will not impact:

- Cultural resources.
- Ecological resources.
- Public lands.

- FEMA mapped 100 year floodplains.
- Hazardous waste areas.

Provide all documentation and the consultant certification to the Department's Office of Environmental Services.

107.11 Contractor's Use of the Project Right-of-Way or Other Department Property

General

This section compiles the requirements for sections 104.03 Rights in and Use of Materials Found on the Work, 105.16 Waste and Borrow Areas, and 105.17 Construction and Demolition Debris.

All of the environmental requirements in 105.16 Waste and Borrow Areas and 105.17 Construction and Demolition Debris apply to on-site locations. The exceptions to these requirements are detailed in 105.16 Waste and Borrow Areas of this manual.

Borrowing and/or Wasting on the Right-of-Way (107.11.A)

Under 104.03, Rights in and Use of Materials Found on the Work, the Contractor has the right to all materials found in the contract work. However, the Contractor does not have the right to materials outside the plan work. For example, the Contractor does not have the right to rock found outside the cross-section work. On the other hand, if the Contractor finds rock within the cross-section, they can use the rock for other items of work.

In order for the Contractor to have the "fee free" right to the material, the Designer needs to detail borrow and/or waste areas in the plans prior to bid. If the locations are not shown and the Contractor receives approval to borrow and/or waste on ODOT property, then a charge of $ 0.50 per cubic yard will be assessed. When borrow and/or waste areas are shown on the plans, there is not a charge for the material.

This requirement was put into the specifications to even the bidding for all contractors.

Approval for Borrowing and/or Wasting on the Right of Way

All borrow and waste location requests on the right-of-way need the District Office of Planning and Engineering approval. The guidance document for the approval can be found at the following link:

www.dot.state.oh.us/Divisions/Engineering/Roadway/DesignStandards/roadway/Pages/locationanddesignmanuals.aspx

The District Office of Planning and Engineering will look at the following during the approval process:

- Safety grading and clear zone.
- Sight distances.
- Future expansion.
- Environmental regulations (404, 401, NPDES, etc.), (See Environmental Approval in 105.16, Waste and Borrow Areas, of this manual).
- Public commitment.
- Effects on utilities.
- Stability (See Stability and Settlement in 105.16, Waste and Borrow Areas, of this manual).

As this process evolves, there may be changes to this criterion.

Portable Plants within the Project Limits (107.11.B &107.11.C)

The use of ODOT property for portable plants is restricted under this section of the specifications. Production may detail potential locations on the plans. If the locations are detailed on the plans, then the location is fee free. If the location was not shown in the plans and the site is approved by the District for use, then the Department will consider this change a Value Engineering Change Proposal.

There are four requirements detailed in C&MS 107.11.C that must be met by the Contractor.

- The Contractor's efforts to comply with the noise ordinances (107.11.C.1) need approved by the District Environmental Coordinator.

- The EPA permits (107.11.C.2) need approved by the District Environmental Coordinator.

- The written certification that the plant will supply material only for the project (107.11.C.3) must be submitted to the Engineer.

- The traffic plan (107.11.C.4) needs approved by District Planning and Engineering.

Equipment Storage and Staging (107.11.D)

The "fee free" use of project right-of-way for staging, equipment storage, and/or office site is granted in this section.

The only restrictions are that these locations do not interfere with the work and are not otherwise restricted in the contract documents.

Checklist for Waste and Borrow Sites (105.16, 105.17 and 107.11)

The project personnel must review and document submissions made by the Contractor. References to the appropriate laws, specifications, and proposals and plan notes or details

for all the submissions are required. Specifications or other requirements waived by the Engineer shall be recorded.

Regulated waste work may be inspected and documented by the District Environmental Coordinator (DEC), District Hazardous Waste Coordinator (DHWC), or Regulated Waste Project Engineer (RWPE). Inspection required by these individuals is denoted below.

In addition, clearances or reviews that need to be performed by other offices or individuals in the Department will be denoted. This includes the District Office of Production (DOP) and the Office of Geotechnical Engineering (OGE).

1. Contractors Waste and Borrow operational plan approval.
2. Stability and settlement (OGE).
3. NPDES permit and erosion control (DOP).
4. 404 and 401 permit or evaluation (DEC).
5. Floodplain clearance (DEC).
6. Cultural resource clearance (DEC).
7. Open burning permit (DEC).
8. Any disposal requiring manifesting (DEC, DHWC, or RWPE).
9. Construction and demolition debris.
    a. Determination if clean, hard fill or construction debris.
    b. Quantities and locations of material leaving and filling on the site.
    c. Seven day notice to the local board of health or OEPA.
    d. Record quantities going to the C & D landfills.
        i. Manifest properly (DEC, DHWC, or RWPE)
10. Landscape Wastes.
    a. Record quantities and locations of materials leaving and buried on-site.
    b. Record what happened to the rest of the material.
    c. Recycled.
    d. Reused.
        i. Manifest Properly (DEC, DHWC, or RWPE).
11. Open Burning.
    a. Obtain a copy of the permit.
    b. Is the smoke causing a hazard?
    c. Is the burning at the correct time?
    d. Is an air curtain used?
    e. Are there any fire hazards?
12. Proper disposal of concrete waste.
    a. Three-foot cover on-top.
    b. Eight-foot cover on the sides.
    c. Core mixed with 30 percent soil.
    d. Is the fill stable?
13. Contractor use of the right-of-way.
    a. Approval (DOP).
    b. All clearances. See No. 3 through 7 above.
    c. Fifty cents a cubic yard or free.
    d. Portable plant approval (DOP).
14. Cross-section the site if required for payment.
    a. Wasting.
    b. Borrowing.

15. Owner's permission statement.
    a. Material not the Departments.
    b. ODOT not a part of the agreement.
    c. ODOT held harmless.
16. Restoration.
    a. Temporary BMP removal.
    b. Site clean-up.
    c. Final acceptance.

108 Prosecution and Progress

The purpose of this section is to discuss tools available to the Department for use in tracking the Contractor's progress and timely completion of the project.

Following the signing of a contract for a construction project, the District will contact the Contractor and schedule a Preconstruction Meeting. On or about the time, a Preconstruction Meeting is scheduled, an Engineer will be chosen by the Department for that project.

Once the Engineer is chosen, it is the responsibility of that individual or team to review all of the project documents and terms of the contract prior to the Preconstruction Meeting. Special attention must be paid to the following items:

- Plan Notes.
- Completion date.
- Interim completion dates.
- Special uses of "As per Plan" reference items.
- Proposal notes and supplemental specifications.
- Phasing requirements.
- Special provisions.
- Addenda.

A check of the status of utility relocation (must be performed immediately as to avoid delays to the start of the project).

108.03 Partnering

The purpose of Partnering is to develop a proactive effort and spirit of trust, respect, and cooperation among all stakeholders in a project. Project personnel are to adopt the Partnering concepts on each project. Self-facilitated Partnering is the standard on all Projects and is to be performed by the Engineer and Contractor. Once the contract is awarded, the DCA, or designee will initiate Partnering activities by discussing with the Contractor how Partnering will be implemented on the Project. At this stage, the DCA, the Engineer, and Contractor will identify and define major issues and project concerns and share relevant information to help determine the scope of the partnering efforts and to establish the agenda for the Preconstruction Meeting. Partnering will be an important part of the Preconstruction Meeting and shall have its own agenda with specific time set aside to develop the necessary partnering protocols.

108.02.A Preconstruction Meeting

The Contractor will contact the District to schedule a preconstruction meeting following the signing of a contract and before beginning work. The purpose of the Preconstruction Meeting is to review the various items of work as set forth in the detailed construction plans, bid proposal, specifications, and the Contractor's work schedule and to establish the Partnering relationship among project personnel. Those items to be discussed are the necessary utility adjustments, availability of right-of-way, maintenance of traffic, and the Department's responsibility for the interrelated activities so that all concerned might have

a better understanding of the problems involved and thus be able to coordinate the project.

The rationale of employing a thorough Preconstruction Meeting is pervasive as regards claim avoidance in that it seeks to uncover problems at a time when there is the greatest flexibility available for their solution and with the least disruption to the project. It is designed to create, for all parties, an overview of the conduct of the work and flush out any misconceptions or erroneous assumptions. By including Partnering as an important piece of the Preconstruction Meeting, the environment of open communication, trust, and cooperation necessary for effective and efficient contract performance is established.

Understandings reached at meetings of this nature have resulted in improved relations and coordination of interrelated activities by all concerned.

The Preconstruction Meeting really is the place to establish communication, voice and discuss intentions, discuss concerns, and lay out the road map and rules for the conduct of the project.

A preliminary study of the project shall be made in advance of the meeting in order that the pertinent problems involved are known. Also, prior to the meeting, the DCA shall coordinate with the Contractor to determine whether the Initial Partnering Session will be a component of the Preconstruction Meeting or held as a separate session.

After the Contractor has contacted the District Construction Administrator about setting up the Preconstruction Meeting, both parties shall invite all important stakeholders to the Preconstruction Meeting, including but not limited to:

- Subcontractors.
- Key suppliers.
- State personnel, including the Engineer and staff, Utilities Coordinator, EEO Coordinator, Design Engineer, Traffic Engineer, Test Engineer, Public Information Office, County Manager, District Environmental Coordinator, and all parties involved with the preparation of the plans.
- Utility companies with facilities located within the right-of-way, including all railroads and local park boards.
- Maintaining agency.
- Regional Transit Authority.
- Parties funding project including FHWA/County/Local.

At the Preconstruction Meeting, the Project Engineer must obtain a list of contacts for all parties involved with the project. This list will be useful in the future for timely resolution of problems which surface during the project construction. These contacts should also be invited to attend the progress meetings held on-site once the project begins.

Ensure that required items listed in C&MS 108.02, which the contractor needs for the Preconstruction Meetings, are obtained and reviewed in addition to the items below:

- List of haul roads.
- Executed contractor signature authorization form (CA-D-10).

An agenda should be used at every Preconstruction Meeting. It is recommended that the standard Preconstruction Meeting Agenda/Minutes form be utilized and formatted as needed for each project. The checklist below represents the more common items that should be included in the agenda.

Review of planned project work:

- Right-of-way issues.
- Utility relocations.
- Railroad coordination, including any agreements between the Contractor and a railroad.
- Any pending change orders or contemplated extra work.

Information from the Contractor:

- State, in general, work procedures, type of equipment to be used, and the number of working shifts to be used.
- State the haul roads (C&MS Section l05.l3) and waste and borrow areas (C&MS Section l05.16) to be used.
- Submit documentation itemizing the payroll taxes that the project will incur under C&MS l09.04.A and 109.05.C.2 if extra work is added to the project.
- Submit documentation stating the method of paying fringe benefits to workers required by prevailing wage law.
- Requests for clarification of any questionable aspects of the contract or project site conditions.

Documentation of the Preconstruction Meeting:

- A list of meeting attendees and their affiliation.
- Written minutes using Preconstruction Meeting Agenda/Minutes.
- A tape recording of the conference can be used as a back-up.
- Record the date of the Preconstruction Meeting in SiteManager Key Dates/Critical Dates screen.

Preconstruction Meeting EEO /DBE /Prevailing Wage Requirements

The District Contractor Compliance Officer (CCO) or a designee is expected to attend all pre-construction meetings regarding the status of the project. The District CCO or a designee should obtain a copy of the sign-in sheet from each meeting for documentation of attendance.

Pre-Construction Meetings are the first contact ODOT has with the contractor with respect to a specific project. They are held prior to the beginning of a construction project, and are attended by a representative of the prime contractor, representatives of ODOT (usually an engineer), CCO for DBE/Prevailing Wage, Right-of-Way, Project Personnel, any interested landowners, utility companies, and subcontractors. During this meeting all expectations of the contractor are discussed along with any special issues concerning the project.

It is important during this meeting to direct the contractor to the wage rate link in the proposal, all the requirements of payroll submittal and the bulletin board on the project, as well as informing the contractor that Prevailing Wage and Commercially Useful Function interviews will be taking place at the project site. Also, it must be documented that this information was given to the contractor in the form of a packet in the meeting minutes.

The following items must be included in the preconstruction packet:

- Statement of Compliance Form

- All applicable posters
- Prevailing Wage Guidelines
- Blank Federal/State Payrolls
- Blank C-92 (optional)
- The posters and wages from the proposal. The contractor is responsible for inserting the company EEO Policy and name and phone number of the EEO officer.
- A summary of the DBE requirements as outlined in the contract.
- Contractor's guideline for participation in the ODOT OJT Program.

CCOs will advise the prime contractor at the Pre-Construction Meeting to maintain and make available to ODOT, when so requested, records substantiating the performance of a CUF by a DBE contractor and supplier as part of the contractor's compliance. Contractor records, which may be reviewed to substantiate CUF, include, but are not limited to:

- Contracts, subcontracts, or rental agreements
- Delivery tickets
- Invoices
- Bills of Lading
- Lease agreements
- Hauling tickets
- Contractor's daily trucking records
- Canceled checks
- Bank records
- Equipment titles of ownership
- Material/supply agreements
- Payroll records

The District Contractor Compliance Officers (CCOs) must monitor the progress of the project for Prevailing Wage Compliance and DBE participation. Use of the CRL system will assist in identifying the DBEs affirmed for each project. The monitoring effort is accomplished in conjunction with the Project Field Engineers, Project Managers, and Highway Technicians, who have daily contact with the contractor and subcontractors, monitoring monthly payments, completing one CUF Form per DBE subcontractor and Prevailing Wage (PW) Interview Forms - (if necessary) on the prime and subcontractor employees, and observations by the Project personnel, recorded on Daily Work Reports. The CCOs will be able to determine if the prime is utilizing an identified DBE and if the DBE subcontractor is providing a CUF as required by 49 CFR, Subtitle A, Part 26.55, while comparing the forms to the Certified Payroll and Daily Work Reports. If red flag problems are identified, the Construction Project Personnel shall notify the Contractor Compliance Officer for further disposition and review.

Bulletin Board

ODOT is required to ensure that the Project Bulletin Boards are placed on the project site and are in a location easily accessible to both the contractor employees and the general public. For mobile operations (i.e. guardrail, line striping, crack sealing), the bulletin board information may be kept on the outside of the foreman's vehicle, not inside the cab, and/or the staging area provided that the general public and all employees have safe, easy access to the material.

The following resources are available on the Division of Opportunity, Diversity and Inclusion website here:

www.dot.state.oh.us/divisions/odi/

- Commercially Useful Function Form
- Prevailing Wage Interview Form
- State Contractor Compliance Summary Requirements
- State Poster Checklist
- State Preconstruction Checklist
- Federal Poster
- Federal Preconstruction Checklist

108.02.B Initial Partnering Session

The DCA or designee, the Engineer, and the Contractor will jointly conduct the Partnering meeting. The meeting will cover administrative requirements. Document the meeting minutes on the Initial Partnering Session Agenda/Minutes form. The Engineer and the Contractor should review the list of stakeholders and send an invitation to all stakeholders involved in the project. At this session, all parties should:

- Discuss and obtain agreement on the meaning of any ambiguities identified in the contract documents include the proposal, any special provisions, and any general plan notes.
- Establishment of an RFI process, specifically to whom an RFI must be addressed, acceptable format (letter, e-mail), and standard response time.
- Empower the district staff to quickly resolve issues in steps l or 2 of the Dispute Resolution and Administrative Claims Process.
- Review the chains of commands of the Department and Contractor.
- Obtain understanding and agreement that ignoring an issue or making no decision is not acceptable.
- Individuals are not expected to make a decision with which they are uncomfortable, but should escalate upward in the dispute resolution process.
- Both parties should agree to finalize-as-you-go.
- Obtain contact information for all stakeholders.

Distribute the meeting minutes to all stakeholders for review and commitment to the plans developed.

PN 111 Facilitated Partnering

Proposal Note 111 sets forth the requirements and compensation for Facilitated Partnering. Facilitated Partnering is used on select projects that are typically over $5 million, complex in nature, project duration over a year, a high diversity of stakeholders, pubic involvement, coordination issues, and a high extent of utility and railroad involvement.

With input from the Engineer, select a partnering facilitator from the ODOT prequalified list located on the Division of Construction Management’s Partnering website. Ensure the Facilitator teaches all partnering sessions according to the Department’s Partnering Facilitator Standards and Expectations manual.

Payment

- A Special Item, Lump Sum, will be furnished in the Proposal to pay for the services of the facilitator.
- Submission for Compensation. The facilitator shall submit to the Contractor actual invoice costs.
- Facilitator Compensation. After a review and verification by the Contractor and Department of the facilitator's submission for compensation, the Contractor shall pay the facilitator the fees earned.
- Contractor Reimbursement. The Department and the Contractor shall bear the costs and expenses of the facilitator and venue equally.
- The facilitator chosen by the Department and the Contractor shall be compensated at a maximum rate of $3,500 for the Initial Partnering Session.
- The facilitator shall be compensated at a rate maximum rate of $1,500 for the Partnering Update Sessions.
- If the Department's costs of the Facilitated Partnering item exceed the fixed amount, the Department will continue to pay its share of the actual invoice costs of the item by processing a change order.

Specific attention should be paid to coordinating the Partnering Specifications in C&MS 108.02, Dispute Review Board (PN 108), and/or the Dispute Review Advisor (PN 109) processes in order to maximize the effectiveness of the Partnering efforts.

108.02.C Progress Meeting

Progress meetings are very productive tools for enhancing communication, discussing issues, and solving problems, thus, furthering progress on the project. The Engineer must invite the appropriate personnel to attend the progress meetings. The status of the project must be discussed with the Contractor. Before the progress meetings, the Engineer should prepare an agenda. An agenda should cover all items pertinent to the success of the project and be similar in format to the standard Progress Meeting Agenda/Minutes form. Agenda items to be considered include:

- The Partnering relationship on the project.
- The progress towards the goals established in the Preconstruction Meeting.
- Report any issues that have been discovered on the project and how resolution has been approached, including timing with respect to the raising and consideration of the claims at all levels.
- Report the implementation plans for risk mitigation and opportunity enhancement.
- Identify additional risks and opportunities.
- Develop any additional, necessary strategies to improve project performance.

Report all findings in the project minutes with copies sent to the senior personnel team for the review.

108.02.D Post-Milestone Meeting

Contemplate holding a Post-milestone Meeting as a separate meeting on any multi-year, multi-phase project or projects with critical items of work or milestone dates. Review

the schedule with the Contractor and determine whether or not a Post-Milestone Meeting should be held separately from a regularly scheduled Progress Meeting. In cases where Post-Milestone Meetings are held, coordinate with the Contractor to develop an agenda and consider reviewing the goals set forth at the Initial Partnering Session. Review the stakeholders list for the project to and consider inviting all parties.

108.02.E Partnering Monitoring

Consistently monitor the progress of the Partnering Relationship based on the goals decided during the Initial Partnering Session. Determine whether to use the standard survey available online through the Division of Construction Management's Partnering website or to develop a different measure. The standard survey title, "Partnering Monitoring Survey," can be found at the following link:

http://www.surveymonkey.com/s/ODOT_Partnering_Monitoring_Survey

When project personnel choose to utilize the standard survey, the Engineer should coordinate with the Central Office Partnering Coordinator to ensure the results are distributed for review at the Progress Meetings.

108.02.F Mitigation and Notice

As issues arise throughout the course of the work, all parties have the shared contractual and legal requirement to mitigate the issue, whether caused by the Department, Contractor, third-party, or intervening event.

Most construction contracts, including ODOT's, include a requirement for the Contractor to provide prompt notice of circumstances that may require a revision to the contract documents. This notice of the existence of a potential change to the contract is required before the Contractor begins any changed or extra work. Failure to give prompt notice could defeat an otherwise properly documented claim.

The purpose of requiring early notice is so the owner has the option of proceeding with the work, redesigning the work, and/or otherwise reducing the effect of a claimed event. Early notice allows the owner the opportunity to begin keeping careful and specific records of the Contractor's activities, manpower, equipment, and materials which are related to the claim.

108.02.G Dispute Resolution and Administrative Claims Process

General

ODOT, by the nature, volume, and complexity of the work which it does, is subject to claims by Contractors who perform the work. Documents that make up the contract consist of the proposal, specifications, and the plans, which together are referred to as the stated terms. There are certain terms which are not stated in the contract documents. These are known as implied terms. For instance, there is an implied warranty that the plans and specifications are free from defects, and unless otherwise stated, there will be

safe and continuous access to all areas within the project's boundaries. Claims arise from both stated and implied terms.

Issues, Disputes, and Claims

The words issue, dispute, and claim are often used interchangeably, but the words, as used in ODOT contract language, do have different meanings. An issue is defined as a vital or unsettled matter, which arises during the course of the work and can be caused by the Department, Contractor, third-party entity, or some other intervening circumstance. A reasonable attempt must be made to resolve all issues according to all legal and contractual requirements. An issue rises to the level of a dispute when all efforts to mitigate have led to each party having a difference of opinion on the matter.

A dispute is a disagreement and/or a difference of opinion between ODOT personnel and the Contractor. A dispute matures into a claim when an issue in dispute cannot be resolved at the Project or District level. A dispute officially becomes a claim when the Contractor files a Notice of Intent to File a Claim or a Notice of Intent to Appeal to the Dispute Review Board. At this time, the Contractor will be asked to certify the claim. The Contractor must certify under oath, by signing in front of a notary, that the claim is made in good faith, is accurate and complete, and represents the actual costs incurred both in time and money.

On Federal Oversight projects, once the dispute becomes a claim, ODOT is responsible for providing all subsequent documentation involving that claim to the Federal Highway Administration. The Department’s Claims Coordinator is responsible for these submittals.

Who Can File a Claim?

The only entity that can assert a claim against the Department is the Prime Contractor. If the project is being performed by a joint venture, then only the joint venture can assert a claim. Do not discuss a dispute with a subcontractor without having the Contractor’s responsible representative present.

Elements of a Claim

Every claim has two distinct elements:

- **Entitlement** is the theory under which the Contractor asserts the claim. Examples include differing site conditions, conflict between plans and specifications, delays, etc.
- **Damages** are the monetary and/or time impacts incurred by the Contractor, which are a direct result of the claim event.

Types of Claims

Certain types of disputes by their nature are those which are most likely to result in a claim. The most common claims deal with:

- Interpretation of contract documents (102.05, 102.07, 104.01, 105.01, 105.04).
- Differing site conditions (102.05, 102.07, 104.02.B).
- Extra work (104.02.F, 109.05).
- Repair of defective work/material (105.01, 105.03, 105.10, 105.11, 106.07, 107.15).

- Suspension of work/failure to continue work (104.02.C, 104.02.G.3, 108.05, 108.08).
- Acceleration (109.06).
- Significant changes in the character of the work (104.02.D, 104.02.E).
- Interference by/cooperation with third-party (105.07, 105.08, 107, 108.04).
- Inspection (over/under) (105.01, 105.03, 105.09, 105.10, 105.11, 106.03, 106.07, 109.12).
- Inefficiencies (109.07).
- Quantity variations (102.04, 109.01, 109.04).
- Delays (108.06, 109.05.D).

Proof of Claim

The Contractor has the burden of proving both entitlement and damages. If the Contractor cannot prove entitlement, the claim must be denied. Likewise, if the Contractor proves entitlement, but cannot prove that it incurred any cost and/or time impacts, the claim must be denied.

Claim Cost Approaches

Contractors utilize various approaches to present the damages associated with a claim. Below are the most common:

- Total Cost: In this method the Contractor submits the total cost to perform the work. This method presupposes that there are no contractor inefficiencies or unanticipated contractor costs. ODOT rarely accepts this approach.
- Modified Total Cost: In this method the Contractor submits his total cost to perform the work and then deducts an agreed upon contractor inefficiency. A little better than the total cost method, but still not ODOT friendly.
- Force Account (Time and Materials) (109.05 C): Based on actual records and actual contractor costs. Cumbersome to assemble and check, but has a certain essential fairness built in. Mark-ups and determination of costs defined in the specifications.
- Measure Mile: Force Account records are kept for a specified length of time and the cost is calculated. This production rate and cost is then assumed constant throughout the rest of the work. Applicable only when a large quantity of similar extra work is to be done for an extended period of time.
- Agreed Unit Price/Agreed Lump Sum (109.04 B): Uses unit prices agreed upon by the Contractor and ODOT. Good for ODOT since ODOT has large amounts of data concerning unit prices. The Office of Estimating is available to provide expertise on work items not available in database.

Analyzing a Claim

The following step-by-step process should be used to analyze a claim.

- Did the Contractor give the required Early Written Notice (108.02.F)?

<u>ENTITLEMENT:</u>

- What is the Contractor's theory of entitlement?
- What do the contract documents say?
- Determine the actual sequence of events giving rise to the claim.
- Identify each specific claim issue.

- What is the position of both sides on each issue?
- If delay related:
  - Did the claim circumstance delay work on the critical path (108.06.A)?
  - Is it an excusable or non-excusable delay (108.06.B through 108.06E)?
  - Is it a compensable or non-compensable delay (108.06.B through 108.06.E)?
  - Were any of the delays concurrent (108.06.F)?

<u>DAMAGES:</u>

- Has the Contractor proven the damages directly relate to the issue being claimed?
- Do ODOT records agree with the Contractor's submitted documentation?
- Does the Contractor's cost submittal meet the guidelines for extra work (109.05)?
- Are the damages reasonably in line with industry standard costs for the same work? If not, is there a reason why?
- Did the Contractor mitigate the monetary and time damages?

Importance of Project Documentation

It is impossible to overemphasize the need for consistent, complete, and accurate project documentation. Contemporaneous records, documents written at the time of the event, normally carry more weight in claims decision-making than records written up at the time the claim is submitted for analysis. Project documentation must be clear and legible, written in real time, be a regular practice, and be sufficiently detailed to describe the writer's thoughts. Examples of project documentation that are routinely used to support a claim position include pre-bid, pre-construction, and progress meeting minutes; daily diaries; force account records; idle equipment records; correspondence, including e-mails; RFI's; transmittals/submittals; project schedule and changes; phone conversations; and photos and videos.

Claim Avoidance

Claim avoidance, at its most basic level, is accomplished by removing or lessening the factors which contribute to claims. Discussed below are some of the methods used by the Department:

- Prequalification and post project assessment of contractors:
  - Qualified, capable contractors with the resources (i.e., qualified superintendents, capacity to maintain schedule, quality work) to undertake a project can lessen the factors which lead to claims.
- Constructability Review: The Department has instituted Constructability Reviews which occur at the District level. The review team is generally designated by the DCA. The review team will:
  - Review general notes and special provisions.
  - Review plans.
  - Personnel should walk the project paying particular attention to:
    - Right of way encroachment or obstructions.
    - Utilities.
    - Drainage.

        - Pavement or bridge condition (i.e., heaving, cracking, deterioration).
        - Sediment and erosion problems and other geological features.
        - Stream and stream diversions.
        - Railings and signs.
        - Joint conditions.
        - Impact on signals.
        - Quantities.
    - Listen to operations personnel. They know existing problems.
    - Look for the obvious discrepancies in location, missing information, obstructions, conditions, or quantities.
- Change Order Review: At the time a change order is written, its creator is required to choose a reason code for each reference item included on that change order. If the chosen reason code is (Plan) Error or Omission, the change order is targeted for review by the Department's Change Order Review Team. This team reviews these change orders for recurring problems, recommends steps for correction, and provides this information to the District Planning and Engineering Office. This team also identifies changes caused by plan errors or omissions on which ODOT may pursue compensation for the cost of the required change from the designer of the plan.
- Claims Tracking: Disputes and claims are studied by ODOT, enabling clarification and/or correction of the contract documents in order to avoid future disputes and claims.

Claims Management

The Department takes a proactive approach which seeks to avoid disputes and claims. In the event disputes or claims do arise, orderly procedures are in place to assist with managing the claims.

ODOT's Dispute Resolution and Administrative Claims Process is a step-by-step sequence of events which occur following the Contractor's Early Notice submittal described in C&MS 108.02.F. This notice is required when the Contractor discovers a circumstance that may require a revision to the contract documents or may result in a dispute.

C&MS 108.02.G sets forth the details of each of the three steps of the Dispute Resolution and Administrative Claims Process. These three steps include On-Site Determination, District Dispute Resolution Committee, and Director's Claims Board. C&MS 108.02.G also sets forth specific submittal timeframes at each step which must be met by both the Contractor and ODOT personnel to move a dispute toward resolution. These timeframes are included as recognition that: (1) the Contractor deserves timely responses and (2) it is easier to resolve a dispute when the events are clear in everyone's mind rather than allowing an issue to remain until the finalization stages of a project.

The Dispute Resolution and Administrative Claims Process (C&MS 108.02.G) is the default process and is included on all projects except those that use the Dispute Review Board Process (PN108) or utilize a Dispute Review Advisor (PN 109). The applicable process must be followed by the Contractor in order to seek additional compensation or contract time.

Dispute Resolution Board Process (PN 108)

The Dispute Resolution Board (DRB) Process is used on select projects that are typically over $20 million and/or of a highly technical nature. Proposal Note 108 (PN 108) provides that a Dispute Resolution Board (DRB) be established prior to the start of construction of a project and exists through the life of that project. A DRB is comprised of three members, each with a minimum of 10 years' experience in construction, contract administration, and dispute resolution techniques. One member is chosen by the Contractor, one member is chosen by ODOT, and those two members choose the Chair of the Board. members.

The DRB conducts quarterly meetings and is provided monthly progress meeting minutes, project schedule updates, and any other information it requests to keep up-to-date on the progress of the project. The DRB may also conduct a hearing at the third step in the Dispute Resolution Board Process and provide recommendations to the Director of ODOT as to the disposition of that claim.

PN 108 sets forth the details of each of the three steps of the Dispute Resolution Board Process. These three steps include On-Site Determination, District Dispute Resolution Committee, and the Dispute Resolution Board. PN 108 sets forth specific submittal timeframes at each step which must be met by both the Contractor and ODOT personnel to move a dispute toward resolution.

The DRB may also be asked by mutual agreement of both parties to render an Advisory Opinion. An Advisory Opinion may be used to provide the parties with a preliminary assessment of the merits of each party's position in a dispute based upon the information presented. The process is meant to be expedient, primarily oral, and will not prejudice a future formal DRB hearing of the dispute.

The expectations and responsibilities of the Contractor, ODOT and the DRB as well as the compensation of the DRB members are included in the Dispute Resolution Board Three Party Agreement. This contract is signed by ODOT, the Contractor, and all three DRB members prior to the first DRB quarterly meeting.

Payment

- A Special Item, Lump Sum, and Dispute Resolution Board will be furnished in the Proposal to pay for the services of the DRB members.
- Monthly, the Chair shall submit to the Contractor the billable time and travel expenses for each board member.
- The Contractor will pay the DRB members' invoices. The Contractor will then submit the paid invoices to the ODOT Project Engineer for reimbursement payment under the above referenced pay item.
- Under the Special Item described above, the Contractor will be reimbursed 100 percent of the costs associated with the quarterly meetings. The Contractor and the Department will bear 50 percent of the costs associated with the development and issuance of Step 3 proceedings or advisory opinions.
- The ODOT Project Engineer will review each paid invoice. All billable time is to be at the rates agreed to in the Third Party Agreement and travel expenses, if applicable, are to be in accordance with Ohio Office of Budget and Management's Travel Policy. Any adjustments necessary should be made on the subsequent invoice.

Dispute Resolution Advisor (PN 109)

A Dispute Resolution Advisor (DRA) is used on select projects whose contract value is between $5 million and $20 million. Proposal Note 109 (PN 109) provides that a Dispute Resolution Advisor (DRA) be established prior to the start of construction of a project and exists through the life of that project. A DRA is an individual with a minimum of 10 years' experience in construction, contract administration, and dispute resolution techniques. The DRA is chosen based on the guidelines set forth in PN 109.

The DRA conducts quarterly meetings and is provided monthly progress meeting minutes, project schedule updates, and any other information it requests to keep up-to-date on the progress of the project. The DRA may also conduct a hearing at the third step in the Dispute Resolution Advisor Process and provide recommendations to the Director of ODOT as to the disposition of that claim.

PN 109 sets forth the details of each of the three steps of the Dispute Resolution Advisor Process. These three steps include: On-Site Determination, District Dispute Resolution Committee and the Dispute Resolution Advisor. PN 109 sets forth specific submittal timeframes at each step which must be met by both the Contractor and ODOT personnel to move a dispute toward resolution.

The DRA may also be asked by mutual agreement of both parties to render an Advisory Opinion. An Advisory Opinion may be used to provide the parties with a preliminary assessment of the merits of each party's position in a dispute based upon the information presented. The process is meant to be expedient, primarily oral, and will not prejudice a future formal DRA hearing of the dispute.

The expectations and responsibilities of the Contractor, ODOT, and the DRA as well as the compensation of the DRA are included in the Dispute Resolution Advisor Three Party Agreement. This contract is signed by ODOT, the Contractor, and the DRA prior to the first DRA quarterly meeting.

Payment

- A Special Item, Lump Sum, and Dispute Resolution Advisor will be furnished in the Proposal to pay for the services of the DRA.
- Monthly, the Chair shall submit to the Contractor the billable time and travel expenses for each board member.
- The Contractor will pay the DRA's invoices. The Contractor will then submit the paid invoices to the ODOT Project Engineer for reimbursement payment under the above referenced pay item.
- Under the Special Item described above, the Contractor will be reimbursed 100 percent of the costs associated with the quarterly meetings. The Contractor and the Department will bear 50 percent of the costs associated with the development and issuance of Step 3 proceedings or advisory opinions.
- The ODOT Project Engineer will review each paid invoices. All billable time is to be at the rates agreed to in the Third Party Agreement and travel expenses, if applicable, are to be in accordance with Ohio Office of Budget and Management's Travel Policy. Any adjustments necessary should be made on the subsequent invoice.

108.02.H Post Construction Meeting

Hold a Post-Construction Meeting prior to project finalization. Invite the design agency or any stakeholders necessary for the success of the meeting. Partnering shall be included as an agenda item. Use the standard Post Construction Meeting Agenda/Minutes form (CA-G-4) to document the meeting.

108.05.I Partnering Close-Out Survey

At least one representative each from the Contractor and ODOT should complete a Partnering Close-Out Survey at the conclusion of the project. Use the standard survey available online through the Division of Construction Management's Partnering website. The standard survey title, "Partnering Close-Out Survey," can be found at the following link:

http://www.surveymonkey.com/s/ODOT_Partnering_CloseOut_Survey

108.03.A Progress Schedule

The Contractor must submit a progress schedule, pursuant to C&MS 108.03. This schedule must show the Contractor's plan to carry out the work, the dates which the Contractor and subcontractor will start the critical work, including the procurement of materials and equipment, ordering special manufactured articles, working drawings, and the planned dates of critical project milestones.

A bar chart schedule is the default schedule required for all projects. More complex project may require the Contractor to use the Critical Path Method (CPM) progress schedule as specified by Proposal Note 107.

The progress schedule must be reviewed and accepted by the District Construction Administrator. The Project Engineer will review the schedule and forward his comments to the District Construction Administrator. The following items are to be used in determining an acceptable schedule:

- All major items of work must be included in the schedule.
- Completion of the entire project must follow contract requirements.
- Duration of activities must be reasonable.
- Sequence of operations must be logical.
- Schedule must be arranged per plan phases if required.
- Schedule must include special provisions in the contract, including completion dates.
- Special material requirements of the plans must be included.

The progress schedule is the responsibility of the Contractor. If the schedule does not make sense or is illogical, the District must ask for clarification. A revision of the details in question is required prior to acceptance.

Checklist for Reviewing and Accepting the Contractor's Schedule

- Is the project identified?
- Does the schedule graphically depict the work?
- Is there sufficient detail to truly describe the work?
- Are the sequences and activity durations reasonable?
- Are critical deliveries shown?
- Is there consideration for winter months?
- Are special ODOT requirements from plan notes or special provisions accounted for?
- Does the schedule fit within the duration allowed by contract?
- Are there clear relationships shown between activities?

The progress schedule is the main tool with which the owner can monitor the progress of the contract and determine at an instant the status of work. It is, therefore, very important that the Project Engineer accurately review the schedule before acceptance. Monitoring the progress schedule is very important in determining "fault" or responsibility for project delays. C&MS 108.06 allows the director to grant requests for an extension of time if the work was delayed. Guidelines for the review and acceptance of the bar chart schedule are specified in C&MS 108.03. Guidelines for the review and acceptance of Critical Path Method Progress Schedules are specified in Proposal Note 107.

Schedule Updates

There are several tools for monitoring the status of a project. The main tool, as stated above, is the monitoring of the progress schedule. The progress schedule must be reviewed at regular intervals with the Contractor at the project level by the Engineer and at the following times:

- The start of the project to detect if the Contractor began as scheduled.
- Every two weeks on larger more complex projects, monthly on smaller less complex projects.
- Following the completion of a major item of work.
- Following the completion of a phase or sub-phase of work.
  Before, during, and after any type of delay to determine whether or not the delay was owner caused, contractor caused, or concurrent.

Results of this review must be included in the Daily Work Report. The diary entry must list the reasons the Contractor cannot proceed with certain portions of the work. Accuracy and details in the Daily Work Report concerning delays will protect the Department against the successful prosecution of many claims.

108.06 Determination of a Time Extension

The Department may grant a time extension for excusable delays. The Contractor must make a written request giving details which will justify the granting of the request for

this extra time. Methods to analyze requests for time extensions are explained in detail in C&MS 108.06 and Standard Procedure listed below.

It is more important than ever that the Contractor submit the request for a time extension in the following time frame:

- Requests for an extension of time due to weather or seasonal conditions shall be submitted in writing to the Engineer at the end of each month.
- Requests for extensions other than for weather and seasonal conditions shall be submitted in writing to the Engineer within 30 days following the termination of the delay and prior to the expiration of the extended contract date.

Extensions of time are processed as change orders by the District.

Procedure to Analyze a Request for Time Extension

The following procedures are to be used in the preparation and approval of a time extension:

Evaluation of a Contractor's Request for Time Extension

The District shall evaluate and process all requests for postponement of an interim completion date or a contract completion date within 30 days of receipt of the Contractor's written request. Perform the evaluation consistent with contract progress schedule requirements for the project using appropriate analysis principles and techniques. If the request is approved, immediately process a change order in accordance with this procedure and the Standard Procedure for Processing Change Orders. If the request is denied, immediately notify the Contractor in accordance with Section III of this procedure.

Processing of an Approved Contractor's Request for Time Extension

Prepare a Regular Work Change Order to postpone an interim completion date or a contract completion date. The "Explanation of Necessity" shall include one of the following statements:

1. *The Contractor experienced an excusable, non-compensable delay due to weather as determined in accordance with C&MS 108.06.C. The revised (interim/contract) completion date is ______________.*

2. *The Contractor experienced an excusable, non-compensable delay due to (insert reason) as determined in accordance with C&MS 108.06.B. The revised (interim/contract) completion date is ______________.*

3. *The Contractor experienced an excusable, compensable delay due to (insert reason) as determined in accordance with C&MS 108.06.D. The revised (interim/contract) completion date is ______________. The allowable delay costs will be calculated in accordance with C&MS 109.05.D and processed on a subsequent change order.*

4. *The Contractor submitted and the Department has accepted an Early Completion Schedules in accordance with C&MS 108.02.B. The revised contract completion date is _______________.*

Attach to the change order copies of analysis and progress schedules with support documentation or other justification substantiating the duration of the revision to the interim/contract completion date.

Once the change order amending the interim/contract completion date has been approved, the District Construction Office shall enter the amendment into SiteManager.

Processing of a Denied Contractor's Request for Time Extension

The following procedure shall be followed when a requested time extension is not granted:

The District will notify the Contractor in writing, stating reasons for denial. In the event a recovery schedule is warranted, the District will request that the Contractor submit a detailed plan to finish that will show completion by the current contract completion date. If the Contractor disagrees with the denial of its request for time extension, the Contractor may pursue a remedy through the Department's Dispute Resolution and Administrative Claim Process.

Behind Schedule

In the event that a request for an extension of time is not justified by the District and/or the Contractor falls behind schedule due to their fault or lack of responsibility, the Contractor may need to submit a recovery schedule.

When the progress differs appreciably from the original schedule (more than 14 calendar days), a revised schedule must be requested by the Department. A letter from the District Construction Administrator to the Contractor must be written to request a revised schedule and reasons for the delays. Once a new schedule is submitted and the reasons for delay are given by the Contractor, the Engineer must review the Daily Work Report to determine the accuracy of these delays. If delays are due to poor or inexperienced workmen, C&MS 108.05 allows for removal of unskilled workmen from the project. If the delays claimed are caused by the Contractor, the revised schedule must show finishing by the original completion date and the method for recovery must be included.

The methods of monitoring a progress schedule are as follows:

- Percentage of completion by dollars paid to the Contractor.
- Examination of actual start and finish dates of line items.

Judgment must be used when reviewing the progress schedule. It may be possible that the dollars paid to the Contractor do not truly reflect the progress on the project. These issues must be discussed with the Contractor. A good time to do this is usually during the progress meetings when all parties involved with the project are present.

108.06 Delays

Delays may be associated with some of the claims listed above and may require careful analysis to determine who is responsible for the delay. It is important to keep the following principles in mind when evaluating a delay claim:

The Contractor must demonstrate that the delay was critical. It must be shown that the delay in question affected the overall project schedule and was a controlling operation with respect to project completion.

> Excusable Delays (108.06.B) are those delays, which are unforeseeable, beyond the control of the Contractor. Excusable Delays may be either compensable or non-compensable.
>
> > Excusable/Compensable (108.06.D) these are delays caused by the owner. Examples include lack of site access, late shop drawing approval, redesign, etc.
> >
> > Excusable/Non Compensable (108.06.B) these are delays caused by third parties outside the Contractors' control. Examples include area wide labor disputes, floods, transportation industry delays, fire, vandalism, etc.
>
> Non-Excusable (108.06.E) Non-Excusable delays are always non-compensable. These delays are caused by the Contractor or under his control. Examples are subcontractor delays, late mobilization, production takes longer than scheduled, equipment breakdowns etc.

Very often delays can occur from various sources at the same time. These are called Concurrent Delays (108.06.F). An ODOT caused compensable delay occurring at the same time as an excusable delay, which is non-compensable, should result in a time extension, but no recovery of costs. An ODOT caused delay occurring at the same time as a contractor caused delay should result in a time extension, but no recovery of costs. Both cases relieve the Contractor from liquidated damages for the time in question.

The Contractor is entitled to plan and pursue the work in order to finish ahead of the contract completion date (108.02.B.2). If ODOT delays the Contractor, the Contractor may be entitled to impact costs.

108.06.A Duty to Mitigate Delays

The Contractor and the Department must make a reasonable effort to mitigate damages resulting from a claim event, whether caused by the Department, Contractor, third party, or intervening event. Mitigation might include re-sequencing work activities, acceleration, continuing work through a planned shutdown period, etc. The Contractor may be entitled to recover the costs of mitigation. Prior to implementing a change of any kind, the Contractor and the Department must have agreed on the method of compensation and time responsibilities in writing.

108.07 Waiver of Liquidated Damages

If the Contractor fails to complete the work by the contract completion date (original or revised), he must request permission of the Engineer to remain in control of the work. The Contractor must make this request in writing and may be required to provide a written plan for completion of the work. This requirement is described in Section 108.07 of the C&MS, which includes a table of liquidated damages.

Certain plan notes may require interim dates for phase completion and include special liquidated damages. Different methods of bidding may include special liquidated damages.

Since the advent of SiteManager, the computer now deducts liquidated damages automatically from the estimates until dates for completion are entered or the time extension/waiver is processed and entered into the system.

Procedure to Waive Liquidated Damages

This standard procedure allows a waiver of all or portions of liquidated damages that accrued after the work is substantially complete and the conditions in C&MS 108.07 apply.

1. The District shall evaluate and process all requests for waiver of liquidated damages within 30 days of receipt of the Contractor’s written request.
2. Prepare a Form CA-D-21 for a waiver of liquidated damages. The remarks section shall include the conditions in C&MS 108.07 that apply.
3. The District Construction Office shall enter the waiver into SiteManager.
4. Provide the Contractor with a copy of the completed Form CA-D-21.

108.08 Termination by Default

Termination by default is explained in Section 108.08 of the C&MS. The Director has the right to terminate the project for the following reasons:

- Contractor abandons, fails, or refuses to complete work.
- Improperly performing the work.
- Has not commenced work in a reasonable time or does not make reasonable progress.
- Contractor goes out of business or files bankruptcy.

Termination by default or cause is not an immediate event. This type of default requires a series of events to occur over a period of time, all of which must be documented by the Department. Progressive documentation must occur and extensive records must be kept to avoid any legal action against the Department.

108.09 Termination for Convenience

Termination by convenience is explained in Section 108.09 of the C&MS and allows the Department to terminate a contract at any time. Several projects involving huge plan errors have been terminated. This is done to give the Department time to revise the plans and to allow the project to be bid competitively, rather than perform all work on change orders on the existing project.

109 Method of Measurement and Payment

This section is presented to provide information and guidelines for the proper method of measurement of completed items of work and the proper payment to the Contractor.

In the administration of construction projects, it is the policy of the Department to provide the Contractor with prompt payment for all completed and accepted work. After an item of work is completed, but before payment is made, a determination must be made based on the quantities of the various items of work performed. This will be the basis for final settlement between the Contractor and the Department. It is the responsibility of the Engineer to ensure this determination of quantities is performed. Likewise, the Project Inspector is responsible for making the detailed inspections necessary to measure, document, and turn in for payment the determined quantities.

As promptly as everyone expects their paycheck, the Contractor is entitled to prompt and accurate payment for all completed and accepted items of work. As outlined in the Ohio Revised Code Sections 126.30 and 5525.19 and this manual, the Department has the obligation to pay for completed items of work promptly. This payment must be made to the Contractor within 30 days of the first estimate date after the completion of the work, except for additional quantities found during the finalization process. Failure to meet the progressive payment time will result in interest being paid to the Contractor from monies deducted from the District's budget. To ensure prompt payment, the measurement of quantities and the recording for payment must be performed on a daily basis as the items of work are completed.

Project personnel are responsible for preparing documentation to support payment for work performed by the Contractor by measurement of completed and accepted quantities of work. This documentation serves two important purposes:

- It provides validation that the quantity for payment has been determined in accordance with contract requirements (contract proposal, plans, specifications) with the necessary measurements, calculations, weight, etc. This is further detailed under the next section entitled, “Method of Measurement.”
- It also verifies that the work was done in close conformity (as defined in Section 101.03 of the C&MS) to the plans and specifications.

109.05 Changes and Extra Work

The purpose of this section is show how modifications are made to ODOT construction contracts by change order. We will discuss reasons for change orders, pricing, preparation and processing, and record keeping.

ODOT contracts are unit price contracts using estimated quantities of work. Simply by the nature of this type of contract, change orders will occur if for no other reason than to adjust estimated quantities to the quantities of work actually performed. Change orders amend the contract by adding or deleting work, making reimbursement for additional costs incurred, making material substitutions, changing specifications, etc.

The Director is empowered by Section 5525.14 of the Ohio Revised Code to amend contracts for highway improvements by change order. This authority has the following statutory limitations:

- Any original bid item can be increased to the lesser of 5 percent of the total original contract amount or $100,000.00.
- A new item of work can be added to a contract to a value of the lesser of 5 percent of the original contract value or $100,000.00.

Additions beyond these limitations must be approved by the State Controlling Board. However, the director can exceed these limits if there are circumstances that warrant the declaration of an emergency. These circumstances could include a threat to public safety, idled equipment costs, delay costs, etc.

Guidelines for preparation of change orders are given in:

- C&MS Section 104.02, 109.03, and 109.04.

State law, ORC 5517.02, and Federal-aid regulations require the Department to contract for work with the lowest competent and responsible bidder after advertisement of the project letting.

ORC 5525.14 authorizes the Director to add Extra Work to a project without competitive bidding and to adjust contract quantities as necessary to complete the project as intended. This authority is subject to competitive bidding and Controlling Board requirements.

Building construction change orders will continue to be controlled by the Office of the State Architect (part of DAS), the Ohio Board of Building Standards, and good practice in the building construction industry.

Authority for Allowing Changes and Extra Work

Ohio Revised Code 126.30, 127.16, 5517.02, 5525.11, 5525.14, and 5525.99.

Code of Federal Regulations 635.

Procedure for Processing Change Orders

General

Work added or modifications to the contract documents made by change order must be

<u>only</u> those which are <u>necessary</u> and <u>integral</u> to the completion of the project as intended by the original plan. Work that is not necessary to complete a project as originally intended shall not be added to a project by change order and shall be contracted through the Department's competitive bidding process or the Director's emergency contracting authority. Convenience or lower costs are not valid reasons to avoid the competitive bidding requirements of State law.

Added work must be within the existing right-of-way, covered by the approved environmental document and waterway and miscellaneous permits, and within the project limits stated in the plans. If necessary, the District Deputy Director shall acquire additional right-of-way and/or reevaluate and update the approved environmental document and permits. If necessary, project limits shall be modified utilizing the forms contained in this procedure.

Each District shall develop and implement a collaborative process whereby the Production, Planning, and Highway Management Departments and the Construction Office reach consensus on the need for a change order before it is recommended in SiteManager.

The District Construction Offices shall determine the terms and conditions (e.g., scope of work, compensation, deduction, etc.) of change orders in accordance with this procedure, the C&MS, and the MOP.

All change orders shall be processed expeditiously to ensure prompt payment in accordance with ORC 126.30.

The District Construction Offices shall develop all documentation, with the exception of formal Controlling Board requests, required for the processing of change orders.

Each District Construction Office must subscribe to the Blue Book by: Printed book, CD-ROM, or Internet access and verify all equipment rates submitted by the Contractor.

All change orders shall be entered in SiteManager.

1. The terms, conditions, and justification for such change orders shall be fully documented in the "Explanation of Necessity" section of the change order.
2. One applicable reason code(s) must be assigned to each change order.
3. If multiple line items require different reason codes then separate change orders must be processed for each reason code and associated line item(s).
4. The OCA will maintain a list of change order reason code descriptions on its website.

The Deputy Director of the Division of Construction Management may instruct that a change order be prepared and approve such change order after consultation with the District and the Director.

Regular Work Change Order (RWCO)

A RWCO shall only be used for the following:

1. Contract quantity adjustments:
    a. Increases and decreases of contract quantities to meet field conditions and design modifications as provided in C&MS Section 109.04 within the

Contract Limits.

b. Decreases in Extra Work quantities.

2. Adjustments for contract specified payments or deductions:

    a. Adjustment of a contract price when the item is reduced by more than 25 percent as provided in C&MS Table 104.02-2.

    b. Price adjustments as specified in the Proposal.

    c. Price adjustments as specified in an individual pay item's specifications, such as, but not limited to, price adjustments specified in C&MS Sections 401, 446, 448, and 451 or the Proposal.

    d. Compensation for eliminated items as provided in C&MS Section 104.02.E and 109.04.

3. Changes in the contract documents or specifications.

4. Changes in materials requirements as follows:

    a. Allow a substitute material because of an area-wide material shortage or the specified material is not available.

    b. Acceptance of a superior material at no additional cost to the project.

    c. Acceptance of undocumented material incorporated into the work and performing satisfactorily.

    d. Department ordered change in materials.

    e. Accept with a cost savings, non-specification material incorporated into the work that is performing satisfactorily according to the Acceptance of Non-Specification Material Supplement.

5. Revise an interim completion date or a contract completion date.

    a. The change order shall be for zero dollars.

    b. For change orders postponing the interim/contract completion date the "Explanation of Necessity" shall include one of the following statements:

        i. The Department accepts the Contractor's early completion schedule in accordance with C&MS 108.02.B.2. The amended completion date is ______________. (Reason Code 32)

        ii. The Contractor experienced an excusable, non-compensable delay due to <u>(insert reason)</u> as determined in accordance with C&MS 108.06.B. The revised (interim/contract) completion date is _______________. (Reason Code 33)

        iii. The Contractor experienced an excusable, non-compensable delay due to weather as determined in accordance with C&MS 108.06.C. The revised (interim/contract) completion date is _______________. (Reason Code 34)

        iv. The Contractor experienced an excusable, compensable delay due to <u>(insert reason)</u> as determined in accordance with C&MS 108.06.D.

The revised (interim/contract) completion date is ______________. The allowable delay costs will be calculated in accordance with C&MS 109.05.D and processed on a subsequent change order. (Reason Code 35)

c. Attach to the change order copies of analysis and progress schedules with support documentation or other justification substantiating the duration of the revision to the interim/contract completion date.

6. Implement non-performances that result from the acceptance of a Value Engineering Change Proposal (VECP).

7. Other reasons as authorized by Administrative Rulings issued by the Division of Construction Management.

Extra Work Change Order (EWCO)

1. An EWCO shall only be used for the following:

   a. Increase of contract quantities to meet field conditions and design modifications as provided in C&MS Section 109.04 and are only those quantities that are beyond the Contract Limits.

   b. The addition of new items of work.

   c. Increase of quantities previously established by an EWCO.

   d. Project termination costs in accordance with C&MS Section 109.04 when the contract is terminated for convenience of the Department under C&MS Section 108.09.

   e. Force Account (commonly referred to as Time and Materials [T&M]) in accordance with C&MS Section 109.05.C and the Force Account Section of this procedure.

   f. Implement an accepted VECP according to the procedure on Value Engineering and payment of the Contractor’s share of the VECP savings.

   g. Payments that differ from fixed amounts established in the Proposal by the Department for specified items.

   h. Final payment for an item that differs from the lump sum amount bid by the Contractor.

   i. Payment for allowable delay costs.

   j. The payment of interest on delays in processing payments. Interest will be calculated according to ORC 126.30. In all cases, interest shall be a separately itemized payment utilizing the item code and description for interest that can be found on the Item Master. Interest shall not be included as part of a negotiated price.

   k. Compensate the Contractor for damages associated with claims in accordance with recommendations issued by the Dispute Review Board in accordance with the Dispute Review Board Process, decisions issued by the Director’s Claims Board in accordance with the Dispute Resolution and Administrative Claims Process, and decisions rendered by the Ohio

Court of Claims.

2. The EWCO shall include a "Description of Work," and when necessary, a "Supplemental Description."

   a. If the EWCO is for an increase in a contract quantity, use the existing "Description of Work" for that item.

   b. If the EWCO is for the addition of a new item of work, use a "Description of Work" contained in the Item Master. Use a "Supplemental Description" that clearly identifies the work for which the EWCO is being processed.

3. The EWCO "Explanation of Necessity" section shall include, at a minimum, the following information, if applicable:

   a. A thorough discussion of all the agreed upon or imposed terms and conditions.

   b. Basis of compensation (e.g., negotiated prices [109.05.B] or force account [109.05.C]).

   c. For change orders that are for an increase in quantity for an original bid item include a reference to the RWCO that increased quantities to the Contract Limits.

   d. A statement indicating that the FHWA Transportation Engineer has been consulted.

   e. A statement regarding federal participation eligibility and the effect on federal project funding.

   f. Whether the work will require additional time. Use one of the following statements:

      i. The additional work will not delay work on the critical path and will not delay the project.

      ii. The additional work will delay work on the critical path and will delay the project ____ days. A change order postponing the contract completion date will be processed.

      iii. The additional work will delay work on the critical path, but will not delay the project.

      iv. At this time, it is unknown how the additional work will affect the work on the critical path and time to complete the project. The contractor will perform and submit a schedule analysis within 30 days of the completion of the work authorized by this change order. A subsequent change order revising contract time will be processed, if warranted.

   g. If the EWCO includes any work that is subject to price adjustments as specified in the Proposal.

   h. If any additional cost of maintaining traffic is included in the agreed prices.

i. If any additional cost to revise or provide a Storm Water Pollution Prevention Plan is included in the agreed prices.

j. The details of a contractor's reservation of rights in accordance with the Execution and Distribution Section.

k. If the change order is compensating the Contractor for damages associated with a claim, the description of the change order shall include a disclaimer stating: "The execution of this document constitutes full settlement of Dispute or Claim Number (   ) and all rights for any additional compensation based on this cause are waived."

4. All supporting documentation, including the complete cost analysis, shall be attached to the copy of the EWCO on file in the District.

Force Account

1. An EWCO for the Estimated Cost of Force Account (ECFA) shall be processed if the amount of the force account work is likely to be greater than $100,000 and is expected to take more than two weeks to complete. When the amount of the force account work is likely to be less than $100,000 and is expected to take less than two weeks to complete, an EWCO for the Actual Cost of Force Account (ACFA) can be processed without processing an associated ECFA.

2. Estimated Cost of Force Account (ECFA)

   a. All ECFA's shall be paid by an EWCO.

   b. The ECFA shall state the estimated costs as determined by a cost analysis or estimate based on similar bid items according to the C&MS and MOP.

   c. An original affidavit by the Contractor shall be attached to the change order stating:
   "Labor rates shown are the actual rates paid for labor, unit prices for materials and rates for owned and rented equipment have been estimated on the basis they are not in excess of those charged in the area in which the work will be performed."

   d. The District will process estimates on ECFA every two weeks as the force account work is performed.

   e. Approval of an ECFA change order allows payments as the work is performed up to the estimated change order amount.

3. Actual Cost of Force Account (ACFA)

   a. After the work covered by an ECFA is complete or if an ECFA is not necessary as described the above Section of this procedure, the District shall prepare an ACFA reflecting the actual total cost in accordance with the C&MS and MOP and substantiated by a summary of the actual cost of performing the force account work.

   b. The difference between the actual cost and the original estimated cost of the force account work shall be entered as a plus (positive), minus (negative), or zero, as the case may be, and labeled "Difference Between Actual Cost and Estimated Cost of Force Account Work, Authorized by

Change Order Number xx."

i. If the difference is positive, another EWCO must be used to authorize payment beyond the ECFA.

ii. If the difference is negative, an RWCO shall be used to non-perform the unused balance of the ECFA.

iii. If the difference is zero, an RWCO shall be used to document that the actual costs equaled those shown on the ECFA.

c. The "Explanation of Necessity" shall include the reasons for the difference in cost and any conditions encountered that differ from those originally anticipated in order to substantiate final payment.

d. An original affidavit by the Contractor shall be attached to the change order stating:
"The name, classification, total hours worked and rates paid each person listed on the Summary of Actual Cost are substantiated by actual records of persons employed on the force account work. All unit prices for materials and rates for owned and rented equipment listed on the Summary of Actual Costs are substantiated by actual records of materials and equipment actually used in performance of the force account work and the price of any owned equipment not previously agreed upon does not exceed prices charged for similar equipment in the area in which the work was performed."

Federal Highway Administration (FHWA) Consultation and Concurrence

1. On all Federal oversight projects [per 23CFR635.120(a)(b) &(c)]:

   a. Following authorization to proceed with a project, all major changes in the plans and contract provisions and all major extra work shall have formal approval by FHWA in advance of their effective dates (23 CFR635.120 [a]).

   b. For non-major changes and for non-major work, formal FHWA approval is necessary, but such approval may be given retroactively (23CFR635.120[b]).

   c. All change orders amending contract time shall be submitted for approval by FHWA. When possible, change orders for contract time resulting from contract changes or extra work should be submitted at the same time as the change order for said contract change or extra work for approval by FHWA (23CFR635.120[c]).

2. The District shall consult with the appropriate FHWA Transportation Engineer when a major change is first contemplated on a full Federal oversight project.

   a. This consultation may be by e-mail or by telephone with a follow up e-mail. The results of this consultation shall be documented in the project file and in the change order, "Explanation of Necessity," as indicated in Extra Work Change Order Section of this procedure.

   b. The e-mail shall have the Project Number, PID, and the County-Route-

Section in the subject line and include adequate information to determine the nature and extent of the proposed change.

c. The purpose of the consultation is to determine the eligibility of the change for Federal participation, the effect on Federal project funding, and to obtain approval to execute the change order under the terms and conditions agreed upon in this consultation.

3. FHWA considers a change order to be a major change if it:

   a. Results in a project cost increase exceeding the lesser of $250,000 or five percent of the award amount.

   b. Alters the planned access controls, highway operations (highway operational characteristics), or work limits.

   c. Results in new environmental impacts.

4. FHWA does not participate in maintenance items or the purchase of surplus material.

5. FHWA does not participate in the repair of completed permanent items of work damaged by traffic and compensated under C&MS Section 107.15 with the following exceptions:

   a. FHWA participation is allowed on federally funded projects off the NHS as determined by State law and policy.

   b. FHWA participation is allowed on federally funded projects on the NHS when the proximate cause of damage was the result of traffic being diverted from its normal path by construction activity.

6. Copies or electronic versions presented through an ftp website or document management system of <u>all</u> change orders, including support documentation, shall be submitted to FHWA for approval on full federal oversight projects only. (Final approval of all major and minor change orders by FHWA based on the change order documentation review is permitted following execution of the change order by ODOT subject to the provisions of this Section of the procedure.)

7. ODOT approves change orders on behalf of FHWA for state administered federally funded projects. Change order documents are retained by ODOT only on state administered federally funded projects.

8. The Division of Construction Management will coordinate the review and advance approval of all claims on full Federal oversight projects with FHWA.

   a. The Division of Construction Management will provide notification to FHWA upon receipt of Notice of Intent to File a Claim.

   b. The Division of Construction Management will provide a copy of all claims decisions for review and advance approval prior to final execution of any change order that may result from the decision.

9. Federal oversight project criteria are provided in the ODOT/FHWA Stewardship & Oversight agreement which can be found at: www.fhwa.dot.gov/ohdiv/soa.htm.

10. Any questions regarding the status of federal oversight projects can be directed to the FHWA Transportation Engineer assigned to your District. The current FHWA Transportation Engineer map can be found at:

www.fhwa.dot.gov/ohdiv/

Program Manager Consultation and Concurrence

1. District Program Manager.
   a. Change orders on district funded projects must be approved by the appropriate district program manager in accordance with processes established by the DDD.
2. Central Office Program Manager.
   a. Change orders on projects funded by a Central Office program must be approved by the Program Manager (PM) if the change order amount exceeds the specified threshold for the program. Districts shall consult the appropriate PM when they first anticipate a change order over the threshold. The OCA will maintain a list of Program Managers and thresholds for each program on its website.
   b. The Deputy Director of the Division of Construction Management may require Districts on specific projects to consult with a PM on change orders below the normal program threshold.

Cooperation with Local Participating Agency (LPA) and Notice (ORC 5521.041)

Prior to approving any change order for an item containing local funding the District shall:

1. Discuss with an agent of the LPA the circumstance giving rise to the change order.
2. Provide written notice to the LPA detailing the proposed change order.
3. Obtain written acknowledgement of the LPA's receipt of notice of proposed change order.

Attach the written notice and written acknowledgement to the change order. Except for Contract quantity adjustments less than Contract Limits, ensure that the change order is approved prior to performing the authorized work.

Controlling Board (ORC 127.16 and 5525.14)

An EWCO with a pay item in excess of the Contract Limits, regardless of the funding source, and not covered by the second paragraph below, must be submitted to the Controlling Board for <u>approval prior to performance and payment</u> of an EWCO.

1. An EWCO shall NOT be divided into inappropriate pay items or participation codes for the purpose of avoiding Controlling Board review.
2. Processing of Controlling Board Requests:

a. The District shall recommend the EWCO, obtain the Program Manager's signature, and obtain the Contractor's signature in accordance with Execution and Distribution Section of this procedure.

b. The District shall forward to the Division of Construction Management the signed copy of the EWCO and a draft explanation appropriate for the Controlling Board request. This draft explanation shall be free of technical jargon and shall give a person unfamiliar with the project a basic understanding of the project and the request.

c. The Division of Construction Management will process the information submitted by the District and will officially request Controlling Board approval.

d. The Division of Construction Management will notify the District by telephone or e-mail of the Controlling Board's action by the next business day following the Controlling Board meeting. The District shall then approve the EWCO in accordance with the Execution and Distribution Section of this procedure4. DO NOT APPROVE THE EWCO UNTIL IT HAS BEEN APPROVED BY THE CONTROLLING BOARD.

e. The District will then inform the Contractor of the Controlling Board approval.

f. The Division of Construction Management will send to the District the executed Controlling Board approval of the EWCO. This approval shall be attached to the EWCO on file.

An EWCO with a pay item in excess of Contract Limits, regardless of the funding source, must be reported to the Controlling Board quarterly in accordance with ORC 5525.14(B), but does not have to be approved by the Controlling Board as follows:

1. An increase of a plan quantity that is determined during the final measurement of an item of work and which is coded as Final Measurements in SiteManager. .

2. Added work necessitated by federally mandated requirements that did not exist at the time of the original contract award.

3. Added work for which the Director has granted emergency permission to proceed with work in accordance with the Emergency Permission Section of this procedure.

The Division of Construction Management will prepare and submit a Report to the Controlling Board.

Approval Authority

All change orders for the extension of an existing contract item of work or for the addition of a new item of work beyond the Contract Limits shall be approved by the Director.

All change orders for additional work (new work beyond the scope or elective work), which consists of multiple related items (existing or new), the sum of which exceeds the lesser of $100,000.00 or 25 percent of the original contract value, shall be approved by the Director.

The District shall have authority to approve all change orders that do not require approval by the Director as set forth above.

For change orders requiring approval by the Director, the procedures are as follows:

1. Change orders based upon an emergency declaration.

    a. The District Construction Office shall obtain declaration of emergency as set forth in the Emergency Permission Section of this procedure.

    b. The District Construction Office shall then prepare the change order and execute as set forth in Execution and Distribution Section of this procedure.

2. Change orders based upon Final Measurement.

    a. The District Construction Office shall prepare and submit “REQUEST FOR ESTIMATED FINAL MEASUREMENT APPROVAL” or “REQUEST FOR ACTUAL FINAL MEASUREMENT APPROVAL” form to the Division of Construction Management for approval by the Director.

    b. The Division of Construction Management will obtain the Director’s approval and signature, promptly notify the District Construction Office of the Director’s action by e-mail, and return to them the fully executed document.

3. Change orders not based upon an emergency declaration and not Final Measurement.

    a. The District Construction Office shall prepare and submit “REQUEST FOR PRELIMINARY CHANGE ORDER APPROVAL” form to the Division of Construction Management for approval by the Director.

    b. The Division of Construction Management will obtain the Director’s approval and signature on “REQUEST FOR PRELIMINARY CHANGE ORDER APPROVAL” form, promptly notify the District Construction Office of the Director’s action by e-mail and return to them the fully executed document.

    c. The District Construction Office shall then prepare the change order and execute as set forth in the Execution and Distribution Section of this procedure.

4. The DCA shall have authority to recommend change orders requiring approval by the Director.

For change orders approved by the District, the procedures are as follows:

1. The District shall establish a change order approval process whereby two different signatures are required.

2. The people selected to sign change orders shall be knowledgeable with this procedure and familiar with the project involved and the circumstances of the proposed change. One signature on the change order shall be from a person within the Construction Department while the other signature shall be from a person not within the Construction Department.

3. A person will be granted authority to recommend the change order.

4. A person who is a Professional Engineer registered with the Ohio State Board of Registration for Professional Engineers and Surveyors will be granted approval authority.

5. Several people may be authorized for each of the two signature levels on a project.

   a. The District shall inform the Contractor, at the preconstruction conference, of the people with change order approval authority for the project.

   b. The Deputy Director of the Division of Construction Management has approval authority of change orders prepared in accordance with the General Section of this procedure.

Execution and Distribution

In all cases, the District Construction Offices shall coordinate and obtain all necessary approvals (e.g., FHWA, Director, Program Managers, Controlling Board, Local Participating Agency) prior to execution. Change orders shall be signed (electronically, digitally or physically) and posted as follows:

1. A person with recommended authority signs and dates on the “Recommended by” line indicating their title as appropriate. This person shall enter this action into SiteManager .

2. The District shall indicate any required Program Manager approval on the change order. If approval is required, the District must indicate the date concurrence was obtained and provide documentation verifying concurrence.

3. The Contractor signs and dates on the “By Contractor” line indicating their title as appropriate. At the discretion of the District, contractor signature can occur before or after signature by the person recommending the change order.

   a. In the event a Contractor attempts to “reserve its rights” either on a separate document (e.g., cover letter) or on the face of the change order:

      i. The District shall not execute change orders which contain any sort of reservation of rights language included by the Contractor except as set forth below.

      ii. Under limited circumstances, there may be a few instances where it is not feasible for the Contractor and Department to reach full agreement on all the costs and/or time damages arising from a specific circumstance. However, these instances should be rare. In such cases, it is expected that the Contractor notify the Engineer of its specific need and justification for such need to reserve its rights to claim specific time or costs at a later date. The Engineer may, only with the approval of the Division of Construction Management, permit a Contractor to reserve its rights. In all cases, when a reservation of rights is permitted, the details of the reservation of rights shall be documented in the “Explanation of Necessity” section of the change order.

iii. Any additional time required to process the change order as a result of this decision will not be justification for interest.

4. For change orders approved by the Director:

   a. The District Construction Office shall then submit the change order to the District Deputy Director

   b. The District Deputy Director will obtain the Director’s signature providing the approved preliminary amount of the change does not increase in value and the scope of the change remains consistent with the approved preliminary request. In the event that an increase in the approved preliminary amount of the change order or a change in scope occurs, the District Construction Office shall submit a revised preliminary approval document to the Division of Construction Management for Director approval as set forth in the Approval Authority and Authority to Proceed Sections with work.

   c. The District Construction Office shall notify the Division of Construction Management of this approval action by e-mail with an attached copy of the fully executed document.

   d. A person assigned approval authority for District level change orders for the project shall enter this action into SiteManager.

5. For change orders approved by the District:

   a. A person with approval authority signs their own name as a Professional Engineer with the initials P.E. next to their signature on the “Approved by” line and enters the date. This person shall enter this action into SiteManager.

   b. Do not approve a RWCO that is for the increase in the quantity of an original bid item to the Contract Limits that is in companion with an EWCO for the further addition of quantities to that same original bid item until the Declaration of Emergency or other preliminary authorization for the EWCO has been granted by the Director.

6. RWCO’s:

   a. District posts the original signed document of all RWCO’s, including attached documents to the Project document management and storage system.

   b. Notification of the signed RWCO’s. shall be sent to the Contractor and Project Engineer on all projects.

   c. Notification of all executed RWCO’s shall be provided to the FHWA on federal oversight projects.

7. EWCO’s:

   a. District posts the original signed document of all EWCO’s, including attached documents to the Project document management and storage system.

   b. Notification of the signed EWCO’s shall be sent to the Contractor and

Project Engineer on all projects.

c. Notification of all executed EWCO’s shall be provided to the FHWA on federal oversight projects.

d. Notification of signed EWCO’s, for additions due to Final Measurements and work added due to Federal mandates, shall be sent to the Division of Construction Management upon request for inclusion on the quarterly report to the Controlling Board.

Emergency Permission

Authority to proceed with work prior to processing a change order may be granted to the Contractor by the following people under the specified conditions and procedures. The Director may grant emergency permission under ORC Section 5525.14 to proceed with added work that exceeds the Contract Limits prior to processing a change order.

1. This permission shall be in writing and granted to add work that is necessary to eliminate emergency circumstances that would:

   a. Create a life, safety, or health threatening situation.

   b. Unduly delay the completion of a project and increase its costs.

2. Added work in these circumstances may include the following:

   a. Construction needed to complete a project.

   b. Adjustments needed to meet changed conditions.

   c. Alterations in original plans.

   d. Unforeseen contingencies.

   e. Payments necessitated by contract terminations or suspensions.

3. The declaration of emergency and permission to proceed with work shall be fully documented using only the “DECLARATION OF EMERGENCY AND PERMISSION TO PROCEED WITH WORK” form.

4. The District Construction Office shall complete the “DECLARATION OF EMERGENCY AND PERMISSION TO PROCEED WITH WORK” form, including all supporting documentation, obtain signature of the DDD, and submit to the Division of Construction Management for approval by the Director.

5. The Division of Construction Management will obtain the Director’s approval and signature on “DECLARATION OF EMERGENCY AND PERMISSION TO PROCEED WITH WORK” form, promptly notify the District Construction Office of the Director’s action by e-mail, and return to them the fully executed document.

6. The original signed “DECLARATION OF EMERGENCY AND PERMISSION TO PROCEED WITH WORK” form with supporting documentation shall be kept in the District project file.

7. Copies of the signed “DECLARATION OF EMERGENCY AND PERMISSION TO PROCEED WITH WORK” form shall be sent to:

a. The Contractor, as the Department's written commitment to pay for the work. The Contractor may proceed with the proposed work; however, it is not legally required to perform the proposed work until the change order is approved,

b. The Project Engineer.

8. Attach a copy of the emergency permission to the subsequent EWCO.

9. The EWCO shall be designated "Emergency" in SiteManager.

10. When the amount of an emergency change order exceeds the authorized amount, the Director may authorize the excess amount by an amended emergency declaration using only the "AMENDED EMERGENCY AND PERMISSION TO PROCEED WITH WORK" form. Copies of the "AMENDED EMERGENCY AND PERMISSION TO PROCEED WITH WORK" form shall be distributed in the same manner as the original Emergency Declaration.

11. When a District discovers that added work beyond the Contract Limits was performed without emergency permission, and the added work did not qualify as Final Measurements, the Director may declare an emergency provided the added work did qualify for emergency status. This action must be documented on the "DECLARATION OF EMERGENCY AND PERMISSION TO PROCEED WITH WORK" form.

The DCA, under authority given to the Director by ORC Section 5525.14, may grant permission to proceed with new items of work, if the total payment for each pay item is less than the Contract Limits and Director authorization, if required, has been obtained.

1. The written permission shall define the extent of the work and the agreed price for the work negotiated with the Contractor or the estimated cost of the force account.

2. The District shall consult with the FHWA under the conditions stated in the FHWA Section of this procedure prior to granting permission to proceed.

3. The District shall consult with the Program Manager under the conditions stated in Program Manager Consultation and Concurrence Section of this procedure prior to granting permission to proceed.

4. The permission shall be kept in the project file with a copy to the Contractor.

Change Orders for Payment of Claims

When such payments exceed the Contract Limits, a Controlling Board request and approval are required before payment is made. Payments for damages associated with claims do not qualify as an emergency.

Change Orders on Projects under Litigation

Change orders on projects under litigation shall be coordinated with the Office of Chief Legal Counsel prior to submitting to the Contractor for signature. Monthly, the Office of Chief Legal Counsel will supply each District with a list of projects that have pending litigation. For each listed project, the District shall inform the Office of Chief Legal

Counsel, Court of Claims Section, of the following:

1. Pending disputes on each listed project that could result in a change order.
2. Change orders currently in process on each listed project.
3. All change orders approved on each listed project.

Extension of Project Limits

The DDD may extend Project Limits on a project under contract for the purpose of adding work outside of the original project only to accomplish the following:

1. Complete the project as intended by the original plan.
2. Eliminate circumstances arising from the project that would create a life, safety, or health threatening situation.

The procedures are as follows:

1. The extension of project limits shall be fully documented on the "EXTENSION OF PROJECT LIMITS" form.
2. The original signed "EXTENSION OF PROJECT LIMITS" form with supporting documentation shall be kept in the District project file.
3. A copy of the signed "EXTENSION OF PROJECT LIMITS" form shall be sent to the Project Engineer.

Monitoring of Compliance

The Division of Construction Management will conduct routine Technical Process Reviews (TPR) to ensure District compliance with this policy and procedure.

Districts found in non-compliance may have their change order approval authority revoked until conformity is ensured.

Project File Requirements – Change Orders

1. Request for preliminary change order approval and permission to proceed with work.
2. Declaration of emergency and permission to proceed with work.
3. Request for estimated Final Measurement approval.
4. Request for actual Final Measurement approval.
5. Amended request for preliminary change order approval and permission to proceed with work.
6. Amended declaration of emergency and permission to proceed with work.
7. Extension of Project Limits.

Reasons for Change

The necessity for a change orders to an ODOT construction contract may arise for many reasons. The most common causes for change orders are discussed below. A complete list of ODOT's reason codes for change orders is included at:

www.dot.state.oh.us/Divisions/ConstructionMgt/Admin/Change%20Orders/CO_REASON_CODES.htm

Changes in Quantities of Work

The quantities of work actually performed differ from the quantities originally estimated and established in the contract for the following reasons:

- Final Measurements/calculations.
- Quantity changes to meet field conditions.
- Plan errors.

Differing Site Conditions

Existing field conditions differ from the plan to the extent that performance of additional or non-bid work is required for the following reasons:

- Differing subsurface conditions.
- Presence of any conditions not shown in the plan.

Changes in the Scope of Work

Changes to the project that are so far reaching that they can be considered outside the original intent of the work can be caused by:

- Significant changes in the quantities of work.
- Significant alteration of the work due to:
    - Sequence of construction.
    - Method of construction.
    - Materials.

Changes for the Convenience of the Owner

Changes in the work ordered by the owner to meet the needs of the owner. The following changes are typically not required for the proper construction of the project:

- Addition of new work or deletion of work.
- Acceleration.
- Change in materials.
- Suspension of work.

Actions by Others

Restriction, regulation, or delay imposed on the Contractor beyond the terms of the contract by an entity who is not a party to the contract can be caused by:

- Utility companies.

- Railroads.
- Regulatory agencies.
- Local governments.

Common Change Order Elements

Practically every change order will contain the following elements:

Face

- Project identification: project number, county, route, section, federal number, federal acceptance type.
- Change order identification: change order number, type of change order.
- Work item information: reference number, participation code, item code, item description, units of measure.
- Cost information: unit price/lump sum amount, reference total, addition/non-performance, change order total addition/non-performance.

Body

- Reference number identification: reference number, extra work number participation code.
- Reason code: mandatory field in SiteManager for each reference. SiteManager contains a list of reason codes to choose from.
- Explanation of necessity.

Signatures

- For request and approval by the Department.
- For agreement by the Contractor.
- For agreement by the local (when applicable).

Preliminary Approvals and Attachments (when applicable)

- Emergency declaration, preliminary approval or Final Measurement request as approved by the Director.
- Support documentation: additional information describing need for the change order.
- Cost documentation: cost analyses, comparative pricing information, etc.
- Forms and detailed instructions are available on the Division of Construction Management webpage.

Change Order Pricing

Once the need to perform extra work on a project has been identified a basis of payment for this work must be established. Pricing for extra work is usually established using one of the following methods.

Agreed Unit Price (109.05.B)

This method of pricing is used when the extra work can be broken down into measurable units. The number of units necessary to perform the work is estimated and a unit price is determined and agreed upon as described below. Final payment is based upon the final measurement of the number of units of work actually performed:

- Unit prices already established in contract.
- Comparative pricing. Contract unit prices for similar work on other projects (SiteManager database).
- Use force account type analysis (Appendix V).

Agreed Lump Sum (109.05.B)

This method of pricing is a negotiated amount and can be used when the extra work can be identified as something that is usually paid as a "lump sum." The "Agreed Lump Sum" can also be used as an alternate to the force account method:

- Prepare lump sum using force accounts style analysis.
- Maintain force account record of the work for a period of time and use to develop lump sum.
- Third party billing.
- Lump sum adjustment.

Force Account (109.05.C)

A force account method is used when the work cannot be broken into measurable units or when a unit price cannot be agreed upon. This method reimburses the Contractor the actual costs of labor, equipment, and materials incurred in the performance of the work, including allowable overhead and markup. This method requires a significant amount of record keeping and is described in Section 109.05 of the C&MS.

This method usually requires the preparation of two change orders both of which use the same format. The first change order is known as an "Estimated Cost Force Account" and is established so that money can be encumbered and payments can be made to the Contractor as the work is performed. The second change order is known as an "Actual Cost Force Account" and represents the final accounting of the cost of the performance of the work and is used to reconcile the "Estimated Cost Force Account" change order.

Additional Contract Time for Extra Work

The performance of extra work or additional quantities of work may warrant an extension of contract time. Extensions of contract time may involve additional direct project overhead costs.

Record Keeping

Record keeping is an integral part of contract administration and is especially important when considering change orders. Adequate records must be maintained to document the need for changes and to establish pricing for extra work.

Quantity Measurements

Measurements of the quantities of work in the units prescribed by the plan actually performed by the Contractor must be recorded by the project personnel. Change orders must be prepared to make adjustments for any differences between contract quantities and the quantities actually performed.

Issues of efficiency or other similar factors may arise that may impact unit costs when the quantities actually performed differ significantly from those shown in the plan. For these occasions the quantity records must be thorough enough to determine actual production rates and other such items.

Force Account Work and Extra Work Using Force Account Style Analysis

The records required for force account pricing of extra work must accurately depict all labor, equipment, and materials used by the Contractor to perform the work. The items that are necessary to record are as shown below:

- Description of work.
- Contractor's work force
    - Employee name
    - Classification
    - Hours worked, regular and overtime
- Contractor equipment
    - Type
    - Model
    - Age
    - Capacity
    - Hours worked
    - Hours idle
- Materials
    - Description
    - Quantity
    - Invoices

109.09 Estimates

General

The Department is required to pay for completed contract work promptly in accordance with ORC Section 5525.19, OAC Section 126.30, and C&MS 109.09. Interest penalty payments resulting from the tardy processing of progress estimates will be deducted from the appropriate District budget. Currently, it is the Department's goal to pay the final estimate on the project within six months of the physical work complete date.

SiteManager will be used to generate progress estimates on the assigned estimate dates and to generate the final estimate when project finalization is complete.

It is the District Construction Administrator's responsibility to establish the first estimate date for a project. This first estimate date, in general, should be two weeks after the first day of work or as otherwise agreed to by the Contractor at the preconstruction meeting. Once the first estimate date is established, a second estimate date is established 15 days later. Estimates will continue to be generated on the same two dates per month as long as the project is under construction.

Authority for Payment of Estimates

Ohio Revised Code (ORC) Sections 1311.25 - 1311.32, 5525.16, 5525.18, and 5525.19

Ohio Administrative Code (OAC) Section 126.30

Payments Under The Prompt Payment Act 2770.2A August 2, 1991

Daily Work Report

The project personnel document project facts and work completed on a Daily Work Report. The daily work report may be captured digitally (via Field Manager etc.) or on a form that is then entered into SiteManager in the Daily Work Report, these forms will become the Daily Work Report. The Daily Work Report has five tabs: DWR Info, Contractors, Contractor Equipment, Daily Staff, Work Items, and Force Account.

All information contained on the written forms is transferred by the project personnel to one of these tabs. For purposes of payment of completed items of work, pay items listed on the daily work report forms are entered on the SiteManager Work Items tab.

Once all information is entered on the various screens of the Daily Work Report, the Engineer, or alternate who has update authority, reviews the report, and if found acceptable, approves it as the Daily Work Report. This approval is performed on the SiteManager Diary screen.

Once approval of the Daily Work Report takes place, the SiteManager system automatically transfers any quantities turned in for payment to the Estimates screen. This SiteManager screen lists details about individual reference number quantities completed for payment. Any amount shown on this screen as being completed, but not previously paid, will now be picked up for payment when the next estimate is generated.

Procedure for Payment of Estimates

This manual establishes uniform processes and criteria for the prompt payment of completed contract work on ODOT administered projects.

Estimates for Progress Payments

The District shall establish procedures for approving estimates and payments as required by C&MS Section 109.09. These procedures shall include the following minimum requirements:

1. Establish the first estimate date at the Preconstruction Conference. The first estimate date should be two weeks after the first day of work or as otherwise agreed to by the Contractor.
2. Obtain from the Contractor an executed Contractor Signature Authorization CA-D-10 Form at the Preconstruction Conference.
3. Assign SiteManager approval authorities.
4. Confirm the accuracy of the pay quantities and delivered material quantities entered into SiteManager.
    a. Project inspectors may be granted update authority to enter these quantities.
    b. Delivered materials will be paid in accordance with C&MS 109.10 and ORC 5525.19. Delivered material invoices shall be kept in the project file.
5. Verify that all pay items have associated materials approved at the time of the estimate approval.
6. Establish a process for the daily review of SiteManager to determine estimates requiring approval.
7. Establish a process to override deficiencies on a SiteManager estimate. Deficiencies are limited to the following:
    a. An estimate held for deficient payrolls when the District verifies that all required payrolls were submitted, reviewed, and are acceptable.
    b. An estimate held for the lack of material approval when the Engineer establishes that the material used is approved and the hold is caused by the approval not being processed in time for the estimates.
8. Record the date the estimate was transmitted to Contractor for certification.
9. Obtain from the Contractor an executed Contractor Progress Payment Certification CA-D-11 form. Do not approve an estimate until it has been reviewed by the Contractor and the required certification received. Every estimate must have a signed Contractor Progress Payment Certification CA-D-11 Form attached to the estimate and retained in the project records.

Issue payment for contract bonds any time following the execution of the contract, but

no later than two weeks after the start of work.

Payments withheld to satisfy liens against contract funds in accordance with ORC Sections 1311.25 - 1311.32 will be withheld by the Office of Accounting.

Final Estimates and Processing Estimates after Physical Work Completed (PWC)

Following completion of physical work, agreements are reached with the Contractor as to final quantities. These agreed upon quantities are generated with the Final Quantities report from the SiteManager Portal.

Calculate and enter final price adjustments as required by the Contract, such as bituminous price, fuel, steel, Portland cement concrete pavement or base thickness, smoothness, etc.

The District generates and approves the final change order. The District generates and approves the final estimate. The final estimate shall be from zero dollars ($0.00) to no more than five-hundred dollars ($500.00).

The District Construction Administrator shall certify the correctness of the Final Estimate by signing it. Final quantities shall agree with the Contract quantities as adjusted by the approved change orders on the final report.

The District shall inform the Contractor by letter that the Final Estimate has been signed. Use the Final Estimate Letter standard form. Distribute copies to the Surety and others as indicated on the sample letter.

The District shall enter dates for appropriate finalization milestones on the Key Dates/Critical Dates screens in SiteManager.

Copies of the signed Final Estimate and signed Final Report with Summation of Extra Work Items shall be submitted to Central Office Capital Accounting as the Final Package. Distribute copies of the Final Package as follows:

1. Non-Federal Projects - Submit one signed copy each of the Capital Final Estimate and one signed copy of the Contractor Final Estimate with the final report attached.
2. Federal Projects - Submit one signed copy each of the Capital Final Estimate and two signed copies of the Contractor Final Estimate with the final report attached.

The Final Payment shall be generated by Central Office Capital Accounting when all the requirements of C&MS 109.12 have been fulfilled and the FHWA final voucher is issued.

Administrative Closing

In the event the District cannot obtain all the required documentation and judges that the Contractor cannot supply these documents, the District will refer the project to the Division of Construction Management for an Administrative Closing.

The Administrative Closing referral will consist of:

1. The signed final estimate copies, if available.

2. The finalization documents that were received.

3. Written explanation of why the Contractor cannot provide the required documents.

4. Written explanation and documentation of the efforts the District has made to obtain these documents.

The Division of Construction Management will perform Technical Process Reviews (TPR's) of the District project files to assure proper finalization of projects.

Project File Requirements – Estimates

- CA-D-10: Contractor Signature Authorization.
- CA-D-11: Contractor Progress Payment Certification.
- CA-D-12: Contract Compliance Certification.
- Final Estimate Letter.

Project Approval of Estimates

The Engineer is responsible for the electronic approval of their project's estimate on each estimate day. Before this approval takes place at the project level, the Engineer must ensure that:

- The pay quantities and delivered material quantities entered into SiteManager are correct.
- Any liquidated damages due to failure to meet an interim completion date are entered into SiteManager.
- Any pay item deficient in material approval and not eligible for override is deleted from the estimate.
- An executed Contractor Progress Payment Certification CA-D-11 form is obtained from the Contractor.

With respect to delivered materials, payment is allowed in accordance with Section 109.07 of the C&MS and ORC Section 5525.19. Payment is limited to approved, durable items that have a significant value in comparison to the total price of the contract and shall not be in excess of what is required to do the contract work. The unit costs allowed are the invoiced material costs and any reasonable delivery charges less any contractor's discounts. The allowed unit cost shall not exceed the applicable contract unit price. Delivered material invoices shall be kept in the project file. Costs for stockpile materials may be established by documents other than invoices.

Payment for approved materials outside the vicinity of the project may be made if it is determined that it is not practicable to deliver the material to the project site. This should apply to only bulky material that represents approximately $5,000 or more for related items of work. For small projects, payment for materials less than $5,000 may be made at the discretion of the District Construction Administrator. These materials are intended to include, but not be limited to guardrail, fence, aggregates, structural steel, precast concrete, light/strain poles, etc. Materials that have established shelf life or are temperature susceptible shall be protected in accordance with the manufacturer's recommendations. Small warehouse items shall not be included. Certain additional

requirements must also be met before payment of delivered material off the project takes place.

- The storage site of the material must be approved and documented in writing. This can be performed by the project personnel or other ODOT individuals (in cases where it is more practical for other Districts or Central Office Plant Inspectors to perform the inspection and provide the documentation).
- The material must meet the same level of approval at the storage site as that required of material at the project.
- The existence of the stored material must be verified and documented provided that it is designated or reserved for the particular project. This can also be performed by personnel from another District or Central Office when warranted by the location of the material.
- Payment for off-site storage of material must also be supported by invoices kept on file in the project records.

Liquidated damages due to the failure of the Contractor to meet the project completion date are automatically accounted for by SiteManager. The Engineer must, however, enter into SiteManager any liquidated damages as a result of failure to meet an interim completion date, such as a road closure limitation required by the plan notes. This is performed by entering the dates subject to liquidated damage and the amount per day into the Contractor Adjustments tab in SiteManager. Both automatic and manual Liquidated Damages are then saved for inclusion into the estimate total. SiteManager automatically checks to see if enough materials have been reported, approved, and entered into SiteManager to cover the amount paid at the time the estimate was generated. If a deficiency occurs, the project shall make every effort necessary to resolve the deficiency issues as soon as possible. SiteManager automatically checks to see if prime contractor payrolls have been submitted in a timely manner. When deficiencies occur the project will check with the District Prevailing Wage Coordinator and resolve any deficiencies as soon as possible. Consult the SiteManager Construction Administration Business Rules for resolving the material or payroll deficiencies. Once the Engineer has determined all the above has been accomplished, electronic approval of the estimate at the project level can take place. This is accomplished in the Contractor Payments tab and Estimates tab in SiteManager. The estimate is now ready for the District Level Approval.

District Office Approval of Estimates

District Level Approval is the responsibility of the DCA or back-up person. Before this level of approval takes place, all deficiencies should be resolved. .

The DCA or back-up person can now approve the estimate. This is accomplished in the Contractor Payments tab and Estimates tab in SiteManager. The estimate is now automatically forwarded to the Office of Accounting in Central Office for further processing and payment to the prime contractor.

Method of Measurement

In determining the proper method of measurement for a particular item of work encountered on a project, several sources of information exist. C&MS 109.01 provides general information for the determination of various units of measurement. These include items measured by weight, those measured by cubic meter (cubic yard), and those

measured by the liter (gallon). In addition, specific information can be found for every listed pay item with few exceptions. Every item number in the C&MS contains a unique section entitled, "Method of Measurement," which provides this specific information. For example:

> ***605.08 Method of Measurement****. The Department will measure Unclassified Pipe Underdrains, Shallow Pipe Underdrains, Deep Pipe Underdrains, Base Pipe Underdrains Construction Underdrains, Rock Cut Underdrains, and Prefabricated Edge Underdrains by the number of feet (meters) completed and accepted in place, measured from end to end of each run.*
>
> *The Department will measure Aggregate Drains by the number of feet (meters) completed and accepted in place, measured along the bottom of the trench.*

The few exceptions includes Items 402, 403, 404, 412, 446, and 448. These are all asphalt concrete items with the method of measurement for all these items described under Section 401.21. Likewise, Section 641.12 provides the method of measurement for all the pavement stripping items (642, 643, 644, and 645). No specific section exists for Items 441, 499, 501, 502, 505, 506, 508, 510, and 623. These are all general specifications, items involving lump sum payment, or items not paid separately, but included in other items for payment.

For items of work not covered in the C&MS, other sources can be utilized to determine the proper method of measurement. Supplemental Specifications are individual documents which describe the construction and material specifications for items whose requirements are changing from year to year, are still in the development or experimental stage, or are used only occasionally. These can be identified by their 800 series number. Just like the C&MS, these Supplemental Specifications contain a unique section entitled, "Method of Measurement," which provides the specific information for measurement purposes.

Items listed as "Special," which have no item number, have specific information with respect to proper measurement. This is included in a section entitled, "Method of Measurement," and is incorporated in either the plan notes or listed in the specific proposal for the project.

Another possible source of information with respect to method of measurement is items listed "as per plan." Reference items with an "as per plan" designation have been modified in some way from what would normally be required by the Specifications, Proposal, Standard Drawings, etc. This modification will be found in a plan note within the contract plans. The project personnel must investigate these "as per plan" modifications to determine what has been changed with the item.

For those projects designed in metric units, specific information with respect to measurement can be found. C&MS 109.02 provides information with respect to metrification, along with a list of conversion factors for converting English to metric.

Basis of Payment

As per C&MS 109.03, payment to the Contractor for an item of work performed by the Contractor shall be full payment for furnishing all materials and performing all work under the contract in a complete and acceptable manner. The "Basis of Payment" for any item of work details that the unit bid price is full compensation for certain work and/or

materials essential to that item. As such, this work and/or material will not be measured or paid for under any other pay item which may appear elsewhere in the plans or Specifications. Like "Method of Measurement" (with few exceptions), every item number in the C&MS contains a unique section entitled, "Basis of Payment," which provides specific information as to what is covered by the pay item. The following example is provided:

> ***613.10 Basis of Payment.*** *The Department will pay for accepted quantities at the contract prices as follows:*

Item	***Unit***	***Description***
613	*Cubic Yard (Cubic Meter)*	*Low Strength Mortar Backfill*
613	*Cubic Yard (Cubic Meter)*	*Low Strength Mortar Backfill (Type ___)*

The few exceptions include Items 441, 499, and 501. These are all general specifications dealing with asphalt concrete, concrete, and structures.

For items of work not covered in the C&MS, the same type sources exist. As with "Method of Measurement," item numbers in the 800 series are covered under Supplemental Specification.

Items listed as "Special" also have a unique section entitled, "Basis of Payment." These are found either in plan notes or the proposal.

"As per plan" modifications need to be investigated by the project personnel. These modifications could change the basis of payment of the particular item of work.

109.11 and 109.12 Partial and Final Acceptance

The purpose of this section is to explain the process by which ODOT construction contracts are closed out. We will discuss final inspections, the completion of contract requirements, the determination of the final contract value, and the issuance of the final payment and release.

Following the completion of the physical work of a project, a process to "closeout" the contract begins. This process ultimately leads to the final payment and release of the Contractor from further responsibility for the project. This process includes gaining acceptance of the project from all participating agencies, determining the final value of the contract, the completion of all remaining contract requirements, and the issuance of a final change order. It is the Department's goal that this process be completed within six months of the completion of the physical work for at least 90 percent of our projects.

Completion of Contract Requirements

Once the physical work is completed for a project there are a number of administrative contract requirements that must be completed before final payment can be issued. These requirements may differ from contract to contract and typically include the processing of various documents or the Contractor supplying certain information:

- Payroll requirements completed.
- Affidavit of Compliance.
- Final Wage Affidavit (state projects only).
- Profilometer Report.
- Concrete Core Report.

The dates on which each of these contract requirements has been satisfied are entered and recorded in SiteManager.

109.12.A Final Inspection

ODOT will perform a Final Inspection of all completed construction projects. The Final Inspection is typically conducted by a team that is headed by the District Deputy Director's Appointee for Final Inspection. This team shall include representatives of all local participating agencies and FHWA, when applicable, ODOT maintenance personnel, the Engineer, and the Contractor. The team will determine the need for any corrective or additional work and prepare a "Punch List" for the project. In the case of any disagreements among the team, the District Deputy Director's Appointee is empowered with final authority. The Punch List is provided to the Contractor in writing along with a specified time frame or a specified date for completion of the prescribed work. Final inspection must follow the standard procedure below and generally must include the following items:

- Resolution of Punch List: It is the responsibility of the Engineer to perform any necessary follow-up to ensure that the Contractor completes the Punch List work in a timely manner.

- Obtain acceptance of project by all local agencies: Upon completion of all physical work, including Punch List work, the District Construction Office must obtain a letter of acceptance of the project from all local participating agencies.
- Issuance of Report on Final Inspection: Following the completion of Punch List work, if any, the District Deputy Director's Appointee for Final Inspection issues the Report on Final Inspection, form *C-85*. This report represents an informal acceptance of the project.

Each District Deputy Director will designate a person as the Final Inspector for their District. The person designated as the Final Inspector will be a Professional Engineer, registered by the State of Ohio, in order to comply with ORC 4733.17. The Final Inspector will not be the Project Engineer for the project under inspection or any other person who had daily responsibility for inspection of the work. Each District Deputy Director will designate a person meeting the same criteria as the Final Inspector, as the Back-up to the Final Inspector.

Acceptance of a project or portion of a project by the Final Inspector or Back-up and their signature on the required form C-85 will constitute acceptance by the Director.

The Division of Construction Management will foster consistent standards of Final Inspection among the various Districts by sponsoring periodic meetings of all Final Inspectors and Back-ups. The Districts shall comply with the standard procedures for final inspection of construction projects established in standard procedure below.

For ODOT administered construction contracts, the Final Inspection is a contract event to start Warranty Maintenance Periods, to relieve the Contractor of maintenance responsibilities, and to transfer maintenance responsibilities to the appropriate ODOT District or Local Public Agency (LPA). The Final Inspection of ODOT projects acknowledges receipt of the Contractor certifications of compliance with Contract conditions and work performed in a reasonably close conformity with the contract documents and consistent standards of inspection and project administration among the various Districts.

The Final Inspector and Back-up will do Partial Inspections to accept a completed significant portion of the work when such acceptance serves the mutual interests of the Contractor and Department or to start a warranty period according to the relevant warranty specification.

The Ohio Department of Transportation will perform a Final Inspection of Local Let, LPA projects to ensure general conformity with the approved plans and scope of the project in compliance with federal aid requirements.

Authority for Performing Final Inspection

Ohio Revised Code 4733.17

Federal Aid Policy Guide 635.105

Procedure for Final Inspection

The District Deputy Director (DDD) is responsible for appointing personnel to perform the Final Inspections on Department and LPA projects. This inspection is performed by the Final Inspector as the authorized agent of the Director.

1. Each DDD shall appoint a Final Inspector and a Back-up Final Inspector to perform Final and Partial Inspections of construction projects in their District.
    a. Each Final Inspector and Back-up Final Inspector shall be a Professional Engineer, registered in the State of Ohio according to 4733 ORC.
    b. The Final Inspector and Back-up Final Inspector must have construction experience commensurate with the work being inspected.
    c. The Final Inspector and Back-up Final Inspector must have an independent and objective view of the work. Accordingly, the Engineer shall not perform the Final Inspection.
2. The names of each Final Inspector and Back-up Final Inspector shall be submitted to the Central Office, Division of Construction Management, who will maintain a list of Final Inspectors and will verify their qualifications.

Near the completion of the work, the Engineer shall create an Engineer's Punch List, in writing, of items not yet completed or requiring correction. The Engineer's Punch List must be provided to the Contractor and all items on the list must be complete before the Final Inspection.

The Engineer shall inform the Final Inspector of the end of work and the completion of the items on the Engineer's Punch List. The Final Inspection will be performed within 10 business days of the Final Inspection Requested Date in accordance with C&MS 109.12. The date the final inspection is requested is entered into SiteManager as the Final Inspection Requested Date when applicable.

1. Final Inspection, as defined in C&MS 109.12:
    a. The P.E./P.S. is responsible for coordinating attendance for the Final Inspection. In addition to the Final Inspector, the following people should be given an opportunity to attend the Final Inspection:
        i. Contractor.
        ii. District Highway Management Administrator or County Manager, in accordance with the District's organization preferences.
        iii. Any local government representative, in accordance with part VII of this procedure, if the project is LPA.
        iv. FHWA, in accordance with part VI of this procedure, if the project is subject to federal oversight.
        v. Other relevant personnel.
    b. The Final Inspector shall review the pertinent contract documents and shall physically inspect the project.
        i. District wide projects (e.g., pavement marking, guardrail, etc.) may be checked by randomly selecting sections rather than inspecting all

affected routes.

ii. Particular attention must be made to the following critical items:

(1) Rideability - If the project involves new pavement, resurfacing, bridge replacement, or a bridge overlay, it must be checked to see if it meets the applicable contract surface tolerance requirements. If the surface tolerances do not meet the contract requirements, the project must not be accepted.

(2) Drainage - The pavements, a random selection of underdrains, ditches, conduits, catch basins, and other items must have positive drainage and be free of obstructions.

(3) Structures - Bridges must be checked for all items which constitute the completed structure, both above and below the deck.

(4) Erosion Control - Roadside items must be checked to see that all erosion control items have been placed or established. The project's post construction Best Management Practices must be checked to ensure they are installed and working properly.

(5) Safety - Guardrail, end treatments, impact attenuators, lighting, pavement markings, signing, traffic signals, and other safety items must be in place, properly installed, and functioning.

(6) Clean-up - The project is not acceptable if clean-up in accordance with 104.04 is not complete. All borrow and waste areas must be restored in accordance with 105.16.

iii. The Final Inspector shall also pay particular attention to items that are, by experience, known to be problematic.

c. Report of Final Inspection (Form C-85-Final).

i. The Final Inspector shall complete Form C-85-Final to document the condition of the work inspected during the Final Inspection.

(1) The Final Inspection date on the C-85-Final shall be the date the Final Inspector performs the Final Inspection. This date is entered into SiteManager when applicable.

(2) If there are no Punch List items, the Final Inspector will fill in the date that the physical work was completed on the C-85-Final. This date is entered into SiteManager when applicable.

(3) The Remarks section of the C-85 shall list Final Inspection Punch List items found during the Final Inspection.

(4) The Form C-85-Partial or Form C-85-Final shall list the dates of the beginning of the warranty periods by item and location in the Remarks section.

d. The Final Inspection Punch List.

i. The Final Inspection Punch List is a list written by the Final

Inspector denoting deficiencies found during the Final Inspection.

ii. There shall be only one Final Inspection Punch List on a project. Punch Lists created by local authorities or other Department personnel will have no standing unless they are included on the Final Inspection Punch List by the Final Inspector.

iii. At the Final Inspection, the Final Inspector and Contractor shall agree to a duration or date for the completion of the Final Inspection Punch List. The Final Inspection Punch List shall state:

(1) The detailed list of items and locations found deficient during the Final Inspection.

(2) The duration or date established for completion of the Final Inspection Punch List (this is the "stipulated time" denoted in 109.12.B).

(3) The statement: Failure of the Contractor to complete the Punch List items by the stipulated time will result in the assessment of fifty percent of liquidated damages in accordance with 108.07 for every day beyond the stipulated time the Punch List work remains incomplete and beyond the revised completion date.

iv. The Engineer shall notify the Final Inspector, in writing, of the satisfactory completion of the Final Inspection Punch List.

e. Report of Punch List completion.

i. When the Contractor completes the Final Inspection Punch List to the satisfaction of the Engineer, the Final Inspector will complete the Report of Punch List completion.

(1) The date of Punch List completion shall be entered in SiteManager as the date of physical work completed date when applicable.

(2) Copies of the signed Form C-85 and report of Punch List completion shall be sent to the Contractor and the maintaining agency.

ii. Liquidated damages can be waived as per the requirements of 108.07 and 109.12.B. if the Contractor completes the Punch List work in the stipulated time.

f. End of Contractor maintenance responsibility.

i. When the Final Inspector completes the Final Inspection and finds the work substantially complete or substantially complete with Punch List items, the Contractor's maintenance responsibilities end on the day of the Final Inspection for the project, except for:

(1) Maintenance related to unfinished Punch List items.

(2) Defects in work that becomes known before the final estimate is paid.

(3) Specific items on projects that specify a guarantee, support, establishment period, or warranty period in accordance with the applicable specification.

ii. The District shall immediately inform the appropriate maintaining agency of the end of the Contractor's maintenance responsibility for the project. This is particularly important when guardrail, stop signs, traffic signals, or other safety devices are part of the project.

iii. The Final Inspection does not waive any available rights of the Department nor divest the Contractor of any responsibility for compliance with the contract.

iv. If there is a project guarantee, operational support, or continued maintenance that specifies a period of establishment (e.g., traffic control equipment, grass, trees, shrubs, or vines), the Final Inspector will note this period on the C-85, but shall accept the project without regard to completion of the establishment period. The Project Engineer is responsible for the inspection at the end of specified establishment period.

2. Partial Inspection, as defined by C&MS 109.11. A Partial Inspection will only be performed following a request by the Contractor.

a. Report of Partial Inspection (Form C-85-Partial).

i. If the Final Inspector determines that the work for which Partial Inspection was made was acceptable, the Final Inspector shall complete a Form C-85-Partial to document the Partial Inspection.

(1) The Partial Inspection date on the C-85-Partial shall be the date the Final Inspector performs the Partial Inspection.

(2) The Final Inspector will fill in the work completed date for the work for which Partial Inspection was made on the C-85-Partial. This date is entered into SiteManager when applicable.

(3) The Remarks section of the C-85-Partial shall state if there were any warranty items accepted during the Partial Inspection and list the specific location and item.

ii. If the Final Inspector determines that the work for which Partial Inspection was made was unacceptable, the Contractor's request for partial acceptance is denied and a subsequent partial inspection will not be granted.

b. End of Contractor Maintenance Responsibility.

i. When the Final Inspector completes the Partial Inspection, the Contractor is relieved of maintenance responsibilities for the items of work identified on the C-85-Partial, except for:

(1) Defective work or damage caused by the Contractor as defined by 109.11.

(2) Specific items on projects that specify a guarantee, operational support, establishment period, or warranty period in accordance

with the applicable specification.

ii. The Partial Inspection does not waive any available rights of the Department nor divest the Contractor of any responsibility for compliance with the contract.

c. The District shall immediately inform the appropriate maintaining agency of the end of the Contractor's maintenance responsibility for the items of work identified on the C-85-Partial. This is particularly important when guardrail, stop signs, traffic signals, or other safety devices are part of the Partial Inspection.

3. FHWA Notification.

   a. If a project is designated as a federal oversight project, the FHWA representative shall be notified of the date of the Partial or Final Inspection and invited to participate.

   b. If the project is exempt from federal oversight, FHWA shall be notified when the project has been accepted.

4. For ODOT administered projects, the Final Inspector shall sign (electronically, digitally or physically) and post the completed C-85-Partial and C-85-Final forms to the Project document management and storage system. Notification of signed C-85 Partial and C-85 Final will then be sent to:

   a. Office of Accounting.

   b. County Manager.

   c. Maintaining Agency.

   d. District Warranty Coordinator (if warranty items).

   e. FHWA (if federal oversight project).

   f. Contractor.

   g. District LPA Coordinator (for traditional LPA projects).

   h. Local Participating Agency (for traditional LPA projects).

5. For non-traditional LPA projects, the LPA will notify the Construction Monitor of the established time and date for the Final Inspection once the project is finished and corrective work items identified by the LPA are complete. The Construction Monitor will coordinate with the DCA/Designee or other ODOT/FHWA representatives, as appropriate, for attendance at the Final Inspection "walk-through" with the LPA and complete a District Construction Inspection Report marked "Final Inspection." Final Inspection Punch List items identified shall be noted in the "Remarks/Exceptions" section of the District Construction Inspection Report and assurance of completion is the responsibility of the LPA. The LPA will supply the remaining closeout documentation to the District who will then closeout the encumbrance.

Project File Requirements – Final Inspection

1. Form C-85 Report of Final Inspection.

2. Form C-85 Report of Partial Inspection.
3. Report of Punch List Completion.
4. Sample Final Estimate Letter.

109.12.C Determination of Final Contract Value

A key element of the project closeout process is the determination of the final dollar value of the construction project. This is accomplished by determining the final number of units to be paid for each item of the contract and by processing all necessary change orders, including a final change order.

In order to ensure timely closeout, it is strongly recommended that some of the activities, which will be discussed, be performed as work is completed on the project.

Prepare and Audit Final Contract Quantities

The Engineer is responsible for determining and preparing support documentation for the final quantity (final number of units) to be paid for every item of work contained in the construction contract. Ideally, this is accomplished progressively as the items are completed during the course of construction of the project. Once the physical work has been completed for the project, the Engineer submits all project records to the District Office for an audit. This audit is performed by the District Level Reviewer for the purpose of verifying the final quantities and ensuring that adequate documentation exists to support payment of those quantities. It is currently the Department's policy to audit a minimum of 25 percent of all projects awarded each calendar year. The District can audit additional projects at its discretion. Again, it is preferred for larger projects that the audit be performed progressively as items of work are completed and documented. The audit must be performed before a list of approved final quantities is prepared and is forwarded to the Contractor for concurrence. Once agreement with final quantities has been obtained, a change order is prepared to make any necessary adjustments between the final and original contract quantities. Any necessary pay estimates resulting from these change orders are initiated by the District Construction Office.

Material Certification

As discussed in earlier sections, all materials incorporated into construction projects must be approved for use. Once the work is completed for the project, an audit must be performed to ensure that sufficient quantities of material have been approved for each reported final quantity. As the final quantity audit is being performed and final quantities are approved, the quantities are reported to the District Engineer of Tests for the material audit. The District Engineer of Tests and staff review the project testing and acceptance records to ensure that sufficient materials are approved for the final quantity for every contract item. Material deficiencies are reported to the Engineer who is responsible for resolution of the deficiency. Once all material deficiencies are resolved, the District Engineer of Test generates the Letter of Certification of Materials for the project. This letter is signed by the District Engineer of Tests and the District Highway Management Administrator and is included in the final estimate package.

The project closeout process is modified as follows for projects constructed under the material acceptance process described above.

Under this policy, the Engineer prepares a material certification for the project and submits it along with the final contract quantities to the District for an audit. The final quantity documentation is audited by the District Level Review Team as described earlier. The District Engineer of Tests now only audits the Engineer's material certification using project audit guidelines similar to those used by the District Level Review Team. Deficiencies identified by the District Engineer of Test's audit are reported to the Engineer who is responsible for their timely resolution.

The Highway Management Administrator approves the material certification, which is included in the final estimate package.

Issuance of Final Change Order

A final change order is required for every construction project. Change orders for all quantity adjustments, extra work, additional costs, price adjustment, or contract amendments must be processed prior to the issuance of the final change order. Approval of the final change order signifies that all necessary changes have been made to adjust the contract from the original bid condition to the final "as built" condition.

109.12.D Final Payment

Following the approval of the final change order, the final estimate is prepared and processed, and the Contractor is released from any further responsibility for the project in accordance with C&MS 109.12.

Preparation of Final Estimate Package

A final estimate package is prepared for the project and includes the following items:

- Final estimate (reconciles payment to final quantities).
- Letter of Certification of Materials.
- Certification of Payroll Affidavit (100 percent State projects only).
- Letter of Acceptance from Participating Agency.
- Affidavit as to Non-Specified Materials (when applicable).
- Receiving ticket for Salvaged Materials (when applicable).
- Signed Contractor Certification Form CA-D-12.

The final report is signed (electronically, digitally or physically) by the District Construction Administrator and the District Deputy Director. The final estimate is approved by the District Deputy Director.

The District will post the final estimate package to the Project document management and storage system and then send a notification to the Office of Accounting.

109.12.E Release Contractor from Further Responsibility

Once submitted, the final estimate package is audited and approved for payment. Following this approval, the District Construction Office generates a letter to the Contractor advising of the final value of the contract and of their release. This letter also serves as the Department's formal acceptance of the project.

200 Earthwork

201 Clearing and Grubbing

General

The purpose of this section is to establish uniform practices for clearing, grubbing, scalping, and removing trees and stumps within the areas designated in the plans.

The following terms are defined for clarity:

- "Clearing" is cutting down all of the trees and brush.
- "Grubbing" is clearing by digging up roots and stumps.
- "Scalping" is removing the remaining roots, sod, grass, agriculture crop, sawdust, and other vegetation so that the soil is completely exposed. This does not include removing topsoil.

Varying interpretations as to the extent of removal are possible where these removals are set up on a lump sum basis. It is necessary to exercise judgment in the administration of this item to accomplish the desired results.

It is Department practice to remove only those trees that must be removed for the construction and maintenance of the highway and for the safety of the traveling public. In certain circumstances, it is desirable to leave healthy trees in place.

Ohio Administrative Code regulates the movement of trees and wood in order to retard and prevent the spread of some destructive insects and plant diseases. The handling and transportation restrictions are listed on the website for the Ohio Department of Agriculture, Plant Health Division (www.agri.ohio.gov).

Disposal of Materials

All material disposals in the 200-series of C&MS refer to Sections 105.16 and 105.17. The following statement is in 201.01 and is repeated throughout the 200s:

> *"Use removed or excavated materials in the work when the material conforms to the specifications; if not then recycle, burn, or dispose of the material according to 105.16 and 105.17."*

This statement is meant to encourage the Contractor to reuse, in the work, any material that can be reused. In the clearing and grubbing work, this is typically soil and topsoil. Any material that can't be reused needs to be disposed of properly. The use, reuse, and/or disposal of these materials may be regulated. (See Section 105.16, Borrow and Waste, of this manual).

Plan Notes

There are three plan notes that may be used by the Department to determine the extent of the clearing and grubbing work on the project. These notes are described below and

in the Location & Design Manual, Volume 3, Appendix B. In every case, the plan will denote the limits of the clearing and grubbing.

Plan Note G108A

When Plan Note G108A is used, no trees will be specifically called out for removal. Everything is removed within the areas denoted in the plan. In this case, the Contractor has the maximum risk if his field count is not accurate. This note is often used on small projects.

Plan Note G108B

When Plan Note G108B is used, trees and stumps are marked for removal on the plan. This note is used where the designer can reasonably count all of the trees within the work limits. This count should be accurate at the time of the count.

The count is not necessarily correct at the time of construction. The Contractors are responsible to visit the site prior to the bid. This allows the Contractor to take tree growth into account. Typical increase in growth is approximately 25 percent. This depends on the time between the count and construction.

The Contractor should bring large discrepancies between the plan count and the actual conditions to the Department's attention prior to the bid.

Plan Note G108C

When Plan Note G108C is used, everything in the plan limits is removed except for the trees denoted as "Do Not Disturb."

The plan denotes some trees and stumps, where feasible. In other locations, the plan denotes heavy wooded areas. An estimated count is given in the heavy wooded section. This estimate is based on representative counts in the heavy wooded areas.

There are inherent inaccuracies in this count. The Contractor will be able to make an informed decision in his bid by the knowledge of how the count is made. By denoting the type and accuracy of the tree counting, it minimizes the claims and change orders from this item of work.

Markings for trees to remain in place should be temporary and not result in an undesirable appearance beyond the life of the Contract.

Trees Located within the Plan Limits Allowed to Remain

Trees that are located within the plan clearing and grubbing limits technically must be removed. There are circumstances, however, where the Engineer may consider leaving trees in place or making other changes to the Contract.

It may be desirable to leave some trees because they are aesthetically pleasing and can provide structural value to an embankment or slope. Leaving flowering trees and shrubs such as dogwood, redbud, hawthorn, and other attractive growth should be given serious consideration. Special consideration should be given to rest areas or other specific nature locations.

The Project Engineer will contact the District Environmental Coordinator for recommendations on the attractiveness of trees to remain in place.

Where trees are allowed to remain in place, the area surrounding the trees should be cleared of undesirable undergrowth to provide an attractive appearance and to simplify maintenance.

Trees located within the plan work limits but outside the clear zone may not require removal. It is required to remove trees within the clear zone or a minimum distance of about 30 to 40 feet (9 to 12 meters) from the edge of the travel lanes. The actual clear zone distance depends on the roadway type. The Project Engineer needs to contact the District Office of Planning and Engineering to give approval recommendations on the clear zone.

It is not necessary to remove trees beyond areas required for construction if the grading section is in a cut with a 3:1 back slope, or is in fill with a depth requiring a guardrail.

All trees considered for remaining in place must be in good condition. A tree should be removed if it is dead, fallen, or unhealthy.

It may be necessary to remove some trees for fence or noise wall construction. This type of removal must be within the right-of-way limits and should not be greater than 10 feet (3 meters) in width in dense growth. Where trees are scattered, the removal should be confined to trees that are in line with the fence or noise wall.

The appearance of a mechanical cutting swath should be avoided when trees are left. This can be accomplished by having a curved or irregular tree line defining the area rather than a straight-line effect.

Scalping (201.04)

It is essential that the project enforce scalping work when it is required.

Scalping is not required under an embankment where the embankment height is greater than 9 feet (3 m) to the subgrade elevation and when the existing slope is 8:1 or flatter. Both conditions must be true for the location not to be scalped. See Figure 201.A for an illustration.

This requirement is in the specifications to ensure good friction between the existing foundation and the new embankment. This construction technique minimizes future potential sliding.

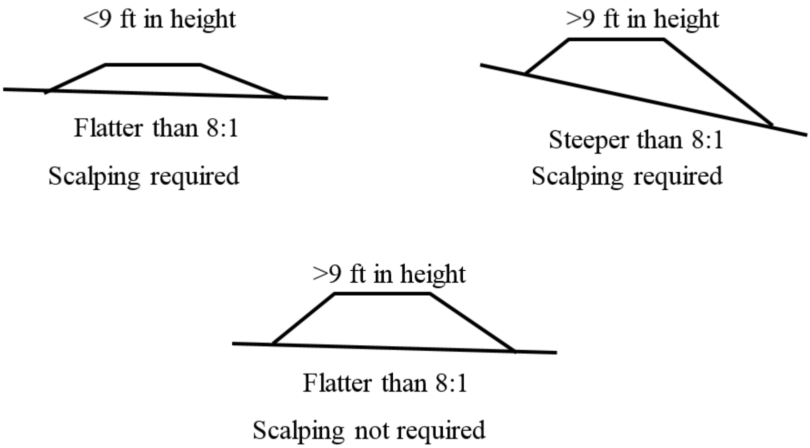


Figure 201.A – Scalping requirements

202 Removal of Structures and Obstructions

Structures Removed (202.03)

The plans will include a note regarding the bridge removal. The note will usually include the phasing of the demolition procedure, the requirement of the demolition plan, the specification of the equipment to be used, and the necessary protection for water ways and traffic.

Before the demolition starts, the Contractor should obtain an approval of the demolition plan, and notify the owners of all existing utility conduits using the structure. The Contractor should disconnect all utilities according to local requirements. If the Contractor is going to blast, then refer to 107.09 for the requirements associated with blasting.

Remove the substructures of existing structures, including piling, down to the proposed stream bottom. For those parts outside the stream, and for bridges that do not span over streams, remove substructures to a minimum of 1 foot (0.3 m) below proposed ground surface.

Where the plans call for the removal of portions of the structure, remove those portions with sufficient care. Avoid damage to the remaining portion of the structure. In case of damage to the existing structure, repair or replace the damaged portions of the structure at no expense to the Department.

The contractor should remove asphalt wearing courses from the bridge before demolishing the bridge or portion of the bridge. To this end, the Department pays for removing an asphalt wearing course separately from the structure removal. This is to ensure that no asphalt ends up in a stream. Even for bridges not over streams, the concrete deck may sometimes be broken up and used for erosion protection. Therefore, the Department removes the asphalt from all bridge decks before demolition.

Backfill the cavity created by the removal item according to 503.08, except when the cavity lies within the limits of subsequent excavation or other work.

Asbestos on Bridges

The plans will include a note regarding asbestos on bridges. Contact the District Environmental Coordinator to check for changes in the current law regarding asbestos removal. For a typical plan note, see the section, Typical Regulated Waste Plan Notes, Asbestos Abatement. This note is similar but not the same as 202 Asbestos Pipe Removal specification requirements in Item 202.

The Contractor should adhere to plan notes and specification while conducting the removal.

If the existing conduit attached to the structure is not specifically denoted in the Contract Documents as Item 202 Asbestos Pipe Removed, perform the work according to 109.05 (Extra Work).

Pipe Removal (202.04)

When a pipe is removed from beneath existing pavement, there should be a separate pay item for removing the pavement. If the pavement will be replaced, there should also be a separate pay item for the new pavement. The pay item for pipe removal does not include the pavement, but it does include the excavation and backfill.

Asbestos Pipes

If removing an existing concrete water line pipe that was constructed before 1980, it may be an asbestos pipe. Test the pipe by using a Department prequalified environmental consultant to determine if it is an asbestos pipe. If it is determined that the pipe is asbestos, then a certified Asbestos Contractor must perform the removal. Dispose of all asbestos pipes at a solid waste facility that is licensed by the Local Health Department and permitted by the OEPA. Contact the District Environmental Coordinator to check changes in the current law regarding Asbestos removal.

If the existing conduit attached to the structure is not specifically denoted in the contract documents as Item 202 Asbestos Pipe Removed, perform the work according to 109.05 (Extra Work).

Asbestos is not a hazardous waste or a solid waste; it is a special waste. This pipe is regulated and must be removed and disposed of properly.

When evaluating the potential for asbestos in the pipe, the project should look at the "Markings" on the pipe. Concrete underdrain, waterline, and sanitary sewer pipe with the following “Markings” are known to contain asbestos:

- ASTM C-663
- AASHTO M-217
- AWWA-C-400-64-T
- ASTM-C-296-65-T

Individual utility companies and Local Planning Associations (LPA's) may have used asbestos pipe under their own specifications.

Asbestos Cement Perforated Underdrain Pipe was allowed in 706.15 in the 1970's. In addition, Asbestos Bonded Bituminous Corrugated Steel Pipe and Pipe Arches were allowed in the 1980’s in 707.09.

Testing for Asbestos

Test the pipe for asbestos if there is any doubt about the pipe’s composition or identity.

Asbestos inspectors in Ohio are required to have a certificate of training from an EPA accredited company for Asbestos Building Inspector and Asbestos Management Planner. The certificates are sent to the Ohio Department of Health (ODH) to obtain the required Asbestos Hazard Evaluation license. Both the EPA accredited certificate and the ODH license are required to perform inspections.

Asbestos Contractor Qualifications

There are a multitude of rules, laws, and regulations that govern asbestos operations. One of the best websites is:

www.ehso.com/Asbestos/asbestreg.php

In addition, more information can be found under the Ohio Revised Code or the Ohio Administrative Code OAC-3701-34 and OAC-3745-20 at the following websites:

http://codes.ohio.gov/orc

http://codes.ohio.gov/oac/3701-34

http://codes.ohio.gov/oac/3745-20

Asbestos Removal Contractors must obtain the Asbestos Hazard Abatement Specialist license or Asbestos Worker license from Ohio Department of Health (ODH). Each asbestos removal company needs to have an Abatement Contractor license through ODH as well.

The training requirements are under CFR 1926.1101(9) (i-viii) requirements for the truck drivers to haul the asbestos. The only training required for the truckers to haul the asbestos is two hour OSHA Awareness training.

Asbestos Pipe Removal

It is highly recommended that the Project hire a third party Certified Asbestos Inspector to provide oversight during the removal.

Concrete pipe is non-friable asbestos. The pipe becomes friable if it is chipped, crumbles, or crushed during the removal. Therefore, the same requirements are required for friable and non-friable asbestos pipe. Cutting and crushing the asbestos pipe is strictly forbidden. Follow the instructions of the Asbestos Inspector or Contractor.

The project may need to notify the local air quality authority and follow strict OSHA demolition and removal requirements.

The material must be taken to a solid waste facility that is licensed by the Local Health Department.

Manifesting for disposal is required. The Regulated Waste Project Engineer or the District Environmental Coordinator is required to sign the Manifest for the Department. See the following Regulated Waste Requirements, “Manifesting” subsection for more information.

Pavement, Walks, Curbs, Steps, Gutters, or Traffic Dividers Removed (202.05)

The plans will designate the items for removal using a balloon with (R for Removal) attached to a line pointing out the removal item. As designated, remove and dispose of the existing Item. If removing only a portion of an existing item, saw cut a neat joint at the removal limit.

If the removed pavement will be replaced with embankment material, such as when an existing embankment is being raised, the Department pays for the embankment material separately. The embankment material is not incidental to the pavement removed.

Buildings Demolished (202.06)

The Contractor should disconnect all utilities according to local requirements, and notify the owners of water, electric, or gas meters when the meters are ready for removal.

The Contractor should not disturb buildings until the Engineer provides a Notice of Possession and Approval to Proceed. The demolition should be performed under the Engineer's direction in order to accommodate utility rearrangements and clearance of structures.

The Contractor may use buildings for storage or other purposes. The Engineer should secure a documented agreement to allow such use during the period of the Contract and save the Department harmless from any claims whatsoever by reason of such use.

Raze the building (including all items) to a minimum of 1 foot (0.3 m) below the grade of the surrounding area.

If the building contains any hazardous materials that require remedy before the start of the demolition, perform the necessary work under other items in the Contract or according to 109.05.

Asbestos in Buildings

All structures torn down by the Department are required to have an Asbestos Inspection. Ensure that the Office of Real Estate performed these asbestos inspections. An Ohio EPA form, Notification for Asbestos Demolition and Renovation, must be filled out by the Department or the Contractor ten days prior to the Demolition.

This form details the type and quantity of asbestos removed and small amount of asbestos left in the building. Generally, the Asbestos Abatement Contractor performs all of the asbestos removal. In rare cases, the asbestos abatement is performed under the highway contract.

The instructions and more details can be found at the following link:

www.epa.ohio.gov/dapc/atu/asbestos.aspx

Normally, friable asbestos cannot be left in the building during demolition. In rare cases, the Asbestos Abatement Contractor may leave a small amount of asbestos in the structure. Of course, large amounts of asbestos cannot be crushed or rendered friable. If the amount of asbestos is small and the Notification for Asbestos Demolition and Renovation allows the building to be demolished, then this material can be hauled away to a Construction and Demolition Land Fill if allowed by the local Board of Health.

If asbestos is left in the building, the building cannot be burned, even if the Notification for Asbestos Demolition and Renovation allows the building to be burnt.

The Notice will specifically mark on the form that the building can be burnt. In addition, an Open Burning Permit would be required if the structure is burned.

Burning or disposing of the building is allowed in 105.16 and 105.17. The Contract will specifically state whether burning is restricted due to the asbestos left in the building. This restriction will be based on the asbestos remaining in the building, and not on the Ohio Administrative Code (OAC) 3745 in 105.17.

Contact the Office of Real Estate, Regulated Waste Project Engineer or District Environmental Coordinator for a clear recommendation on the disposal.

Septic Tanks and Privy Vaults Removed (202.07)

Prior to the start of the demolition work, empty all septic tanks and privy vaults. Dispose of the removed contents in a manner that conforms to the requirements of the State and Local Boards of Health or other authorities having jurisdiction..

Completely remove and dispose of septic tanks and privy vaults located above the subgrade or finished ground surface. For septic tanks and privy vaults located below the subgrade or finished ground surface, remove tops and walls to a minimum depth of 3 feet (1 m) below subgrade or 1 foot (0.3 m) below finished ground surface. Break up floors and seal remaining drains with masonry or with precast clay or concrete stoppers.

Underground Storage Tanks Removed (202.08)

The Department evaluates all project sites during the planning process to determine if Underground Storage Tanks (UST) are present on the project. Typically the plans identify the tank location and requirements for removing or avoiding the UST in the work. UST’s that were not identified in the planning process will be handled in the same manner as described below.

If an unidentified UST is encountered, take precautions to prevent a release of the tank contents to the environment. The Project Engineer should notify the Regulated Waste Project Engineer, District Environmental Coordinator, or District Construction Administrator. In the event of a tank release or safety related issue, contact the local fire authority immediately.

Prior to initiation of the underground storage tank removal, empty the tanks and dispose of the contents in conformance with all applicable regulations (OEPA and/or BUSTR).

Obtain the required permit prior to the start of the UST removal. Provide a State Certified BUSTR inspector employed by BUSTR, Delegated Authority (local fire department), or independent Certified Underground Storage Tank Inspector (CUSTI) contractor to perform the BUSTR required inspections. Remove and dispose of the tank and its contents according to the Bureau of Underground Storage Tank Regulations of the Division of Fire Marshal (BUSTR), Ohio EPA, and all applicable federal, state, and local regulations. Provide a Certified Tank Installer to supervise the removal. For tanks containing hazardous substances other than petroleum, use and comply with the Ohio EPA regulations in addition to State Fire Marshal regulations.

Testing is required for any excavated material and related water prior to disposal. Perform the work under other items in the Contract or according to 109.05. In addition to the required disposal sampling, conduct the closure testing in accordance with all applicable BUSTR regulations and prepare the BUSTR Closure Report.

BUSTR Requirements

The State Fire Marshal and OEPA generally follow BUSTR regulations. The State Fire Marshal’s Office, Bureau of Underground Storage Tank Regulations (BUSTR), controls

the vast majority of the installations, uses, and removals of underground storage tanks in Ohio.

Valuable information can be found at the BUSTR website:

www.com.ohio.gov/fire/default.aspx

Project personnel must review the website and this section of the manual to become familiar with UST removal.

The types of tanks regulated by BUSTR are detailed on the frequently asked questions page:

www.com.ohio.gov/fire/FAQ.aspx#BUSTR

Specification and BUSTR Requirements

1. A Certified Installer is required for any removal of a UST regulated by BUSTR. The Certified Installers are required to have photo identification. The project engineer should check for this identification. There is a list of the Certified Tank Installers on the BUSTR website.
2. A Certified Inspector is required to inspect the work. This inspector may be a State Certified BUSTR inspector employed by BUSTR, Delegated Authority (local fire department), or independent Certified Underground Storage Tank Inspector (CUSTI) contractor. The Contractor must supply this person as part of the bid work. There is a list of these inspectors on the BUSTR website.
3. A tank removal permit must be applied for 30 days prior to the work. The Project Engineer should obtain a copy for project records. The delegated authority (local fire department) or BUSTR may issue the permit. See the Fact Sheet entitled, "The BUSTR Permit Process." A copy of a permit application is on the BUSTR website.
4. Even though the permit may be issued by the local fire department, BUSTR must receive a copy of the permit application 30 days prior to the removal.
5. Tank registration may be required if the tank is not registered. See the Fact Sheet entitled, "Underground Storage Tank Registration." In many cases the Department is the owner; the District Environmental Coordinator will handle tank registrations. The registration form is on the BUSTR website.
    a. For unidentified tanks, the owners are typically unknown. Make certain that the registration and tank removal permit forms accurately identify the owner as "UNKNOWN." **Never identify ODOT as the owner**.
    b. If a tank was last used prior to 11/8/84 then ownership is the last person who used the tank, which may not be known. In this case, make certain that the registration and tank removal permit forms accurately identify the owner as "UNKNOWN." **Never identify ODOT as the owner.**
6. The actual removal is summarized in the BUSTR Technical Guidance Manual. The Certified Inspector must sign the permit and should keep a copy for a permanent record.
7. The BUSTR Closure Report is required after the UST removal has been completed. The Contractor is required to submit the completed report to the Project Engineer within 30 days of the tank removal. The Regulated Waste Project Engineer should sign and submit the Closure Report to BUSTR within

45 days of the tank removal. The Regulated Waste Project Engineer may elect to have this closure report reviewed by an environmental consultant.

8. The District is required to retain the Closure Report record in perpetuity. The report should be given to the Regulated Waste Project Engineer and/or District Environmental Coordinator. The Regulated Waste Project Engineer must ensure that these records are given to the District Environmental Coordinator for final record keeping.
9. Depending on the result of the closure assessment, further investigation, risk assessment, and remedial action may be necessary. The District will determine if an Environmental Consultant will be needed to perform the assessment work. A task order contract may be used to perform this work.
10. The specification requirements in 202.08 do not cover risk assessment, remedial action, environmental cleanup, or the cleanup of the contamination plume beyond a "few feet" outside the UST footprint. If the assessment work is not described in the Plan Note, this work should be considered extra work.

Other Governing Agencies

The following personnel must be contacted when the UST is removed, and 25 gallons or more of petroleum are released, or if the product reaches a body of water or travels off the project site. Project Personnel should use the following website during a release:

www.epa.state.oh.us/derr/ersis/er/er.aspx

1. Immediate Notification:
    a. Regulated Waste Project Engineer.
    b. District Environmental Coordinator.
    c. Local Fire Department.
    d. The OEPA Emergency Response Unit at 800-282-9378.
2. BUSTR Corrective Action Hotline at 800-686-2878 within 24 hours.
3. Contact all of the following if a hazardous chemical in excess of its reportable quantity is released:
    a. Regulated Waste Project Engineer.
    b. District Environmental Coordinator.
    c. Local Fire Department.
    d. The Ohio EPA at 800-282-9378.

Reportable chemical quantities may be between 1 and 500 pounds depending on the chemical. The website refers to Code of Regulation (CFR) that gives the reportable quantities limits. In addition, it gives explicit instructions about what action should be taken by the project personnel.

The Contractor and the Regulated Waste Project Engineer should know the reportable quantities prior to the UST removal.

The District will determine if an environmental consultant will be retained to assist the District in regulatory compliance.

Guardrail and Fence Removed (202.09)

When guardrail or fence is designated for reuse or storage by the Department, Carefully dismantle and store existing guardrail including anchor assemblies, terminal assemblies,

attached posts, signs, delineators and fence. Otherwise, dispose all removed material according to 202.02. Wood posts are not considered salvageable.

If guardrail is next to a lane maintaining traffic, do not remove the guardrail until the replacement material is on the site and ready for installation. Do not leave hazards unprotected adjacent to a lane maintaining traffic, except for the actual time required to remove the existing guardrail and install the proposed guardrail in a continuous operation. The Engineer should suspend work for failure to comply with this requirement.

When fence is designated for replacement, do not remove the existing fence until the replacement material is on site. Begin the new installation within 7 workdays of beginning the removal process.

Manhole, Catch Basin, and Inlet Removed (202.10)

Remove existing drainage structures of the types designated for removal and take ownership of castings unless otherwise noted on the plans.

Manhole, Catch Basin, and Inlet Abandoned (202.11)

Remove existing drainage structures of the types designated to be abandoned to a minimum of 1 foot (0.3 m) below the finished subgrade or ground surface.

Do not damage pipes that are to remain.

Connect existing pipes with new pipe through the structures. Seal the existing inlet and outlet pipes with precast vitrified or concrete stoppers or with masonry of a type and thickness to fill the inlet or outlet pipe. Carefully hand tamp backfill under and around the pipe according to 202.02.

Regulated Waste Requirements

Importance

The Department has experienced contract administration problems during the disposal of regulated wastes, underground storage tanks and asbestos pipe, and administrating borrow and waste areas. The main cause of these problems is the confusion regarding current regulations and new regulations, which govern construction debris, as well as the infrequency that some of these items are included in the contract. The improper disposal or management of regulated materials can create substantial construction delay problems and a potential liability to the Department in the future.

Regulated waste, for the purposes of this manual, is defined as a hazardous waste, solid waste, construction and demolition debris, petroleum contaminated soil, or any other regulated material denoted for removal under the contract. For further explanation regarding hazardous waste classifications, types, and characteristics, see the Hazardous Waste Management Program Manual or other Hazardous Waste Training Manuals.

This section is to be used in conjunction with the Hazardous Waste Management Program Manual (HWMPM) and the handouts and manuals received in the 24- or 40-hour Hazardous Waste Operations and Emergency Response (HAZWOPER) training or the 8-hour HAZWOPER refresher courses.

Additional references can be found by reviewing the 8-hour Construction Safety or Construction HAZWOPER Manual.

This section does not expand on the technical, environmental details explained in other manuals. This manual should be used as a reference to other manuals when technical details are needed beyond the scope of this manual.

Responsibility

Project Engineer and Regulated Waste Project Engineer (RWPE)

The person in charge of work on a construction project is called the Project Engineer. A supervisor or an inspector may run the project on a daily basis depending on the District level of staffing for the project. The Project Engineer will randomly check in on the project and make any engineering decisions.

The Regulated Waste Project Engineer (RWPE) is in charge of all removal operations of regulated waste on the projects. The RWPE signs all manifests from the projects and ensures that all environmental documents from the project are transferred to the DEC for permanent storage. Each District will have at least two engineers working at this function.

In some Districts, the District Environmental Coordinator (DEC) or District Hazardous Waste Coordinator (DHWC) may substitute for the RWPE if the RWPE is not available.

Administering the Contract

The RWPE has the responsibility to effectively administer all aspects of regulated waste on the construction project. They must familiarize themselves with the specifications, the Contract, and this section of the manual to perform their duties. The RWPE makes interpretations of the regulated waste contract documents and this manual to the Project Engineer, Supervisors, or Project Inspectors. In addition, the RWPE insures that trained inspectors are inspecting the work.

The RWPE's main contacts for environmental advice are the District Environmental Coordinators (DEC). The DEC coordinates with the District Hazardous Waste Coordinator, District Safety Representatives, Emergency Coordinators, and the Environmental Site Assessment Section in the Central Office of Environmental Services to make environmental decisions.

The following is a link to their names and numbers:

www.dot.state.oh.us/Divisions/Planning/Environment/staff/Documents/DEC_List.pdf

Reporting of Significant Changes

The Project Engineer is responsible for reporting any significant deviations in the Contract documents to the District Construction Administrator and/or the County Manager. The Project Engineer has the authority to order the Contractor's personnel and

the Environmental Consultant to perform, "as directed work," in all situations within the contract limits. This authority is tempered with a great deal of responsibility for their actions. If the Project Engineer orders work contrary to the recommendations of the RWPE, Environmental Specialist, or the Environmental Contractor, then the Project Engineer becomes personally liable for their actions. Before making any final decisions, the Project Engineer must ensure that their instructions do not contradict any laws or regulations that govern the work.

Health and Safety Responsibilities

The RWPE, who has 24-hours Of HAZWOPER training, is responsible for the health and safety of the Department Inspection Forces.

Additional health and safety responsibilities are listed below:

1. Ensures that project inspections are performed with adequate personnel, equipment, and resources to complete the inspections safely.
2. Ensures that telephone communications between the Department Inspectors and emergency response personnel is maintained.
3. Ensures that all inspectors are adequately trained and qualified to work at the site.
4. Reviews the Site Specific Health and Safety Plan (SSHSP) and ensures that the SSHSP is adapted by the Department to include ODOT inspection forces. For this review, the Environmental Consultant can be hired by third party billing through the Contractor or by the District Task Order Contract.
5. Reviews the Contractor's Site Specific Health and Safety Plan. Do not accept the SSHSP for liability reasons.
6. Provides oversight of the Contractor's operations as it pertains to the Contractor's SSHSP.
7. Reviews the SSHSP with the Inspectors.
8. Serves as the primary contact to review ODOT health and safety matters that may arise on the project.
9. Informs the Inspectors of revised or new safety protocols for the field operations.
10. Informs the Inspectors of revisions to the SSHSP.
11. Reviews accident reports and the results of the inspections.

Project Inspector

The Project Inspector is responsible for the detailed inspection of the work and to follow the directions given by the RWPE, Project Engineer, and the SSHSP.

Contractor's Responsibilities

The Contractor is responsible for prosecuting the work according to the plans and specifications. The C&MS Section 107.01 explicitly states that the Contractor shall comply with the construction safety rules and regulations. Employers are always responsible for the safety of their employees.

District Environmental Coordinator (DEC)

The DEC is responsible for giving technical advice to the RWPE, reviewing or hiring an environmental consultant to review the Health and Safety Plan for ODOT workers, and

coordinating matters of safety and hazardous waste with the District Hazardous Waste Coordinator and District Safety Representative.

Training

General

Where the disposal of regulated wastes is necessary during construction, the District Construction staff must have knowledge beyond the plan note requirements in order to make appropriate and legally correct decisions when facing actual field mandated changes to the contract.

An understanding of the requirements of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), and Occupational Safety and Health Administration (OSHA) requirements is essential during the construction phase.

Training is available through the Office of Environmental Services in Central Office, Environmental Site Assessment Section (614-466-7942); Bureau of Workman Compensation, Division of Safety and Hygiene (800-644-6292); or through a variety of private training sources. The private training may be charged against the project on third party billing through the Contractor.

The following is a link to the Bureau of Workman Compensation, Division of Safety and Hygiene for free training courses:

www.ohiobwc.com/employer/programs/safety/SandHCourses.asp

Nothing in this manual requires ODOT project personnel to enter a hazardous waste site without the consent of the employee. All regulated waste removal work is performed by the Contractor and no ODOT personnel should actively participate in this work.

The majority of the regulated waste removal operations on highway construction projects consist of the removal of solid waste or petroleum-contaminated soil. The minimum training requirements listed below should be observed for all regulated waste or underground storage tank removal projects.

Project Engineers

All Project Engineers are required to attend the 8-hour Construction Safety Awareness Class and the 8-hour Construction HAZWOPER Awareness Class. This training will be given every three years. This training will enable workers to recognize hazards or conditions that require further investigation by other more specialized personnel.

Regulated Waste Project Engineer (RWPE)

The District will designate at least two Project Engineers with 24-hour Construction HAZWOPER training. The RWPE will deal with all regulated waste issues that arise on the projects. An 8-hour annual refresher course is required.

Project Inspector

All Project Inspectors are required to have the 8-hour Construction Safety and 8-hour HAZWOPER Awareness Training. Students who complete this training will be able to recognize hazards or conditions that require specialized training.

Consideration should be given to having a project inspector oversee the removal of underground storage tanks. Certified Underground Storage Tank Inspector training can be obtained from BUSTR. See Section 202 Removal of Structures and Obstructions.

Specialized Inspection

Additional environmental consultant inspectors may be hired through the Districts or Central Office Environmental Site Assessment Task Order Contract to provide specialized inspection. The RWPE should contact the District Environmental Coordinator to obtain these services. The procedure is further explained in the section, Obtaining Technical Advice or Inspection.

Medical Monitoring

Medical monitoring is required for employees working on hazardous waste projects who are:

1. Exposed to contaminants above the permissible exposure limits (PEL) for more than 30 days per year.
2. Wear a respirator for 30 days or more per year.
3. Injured or become ill due to exposure to hazardous substances.

OSHA 29 CFR 1910.120 covers this requirement. The SSHSP, the District Safety Coordinator, and the District Environmental Coordinator should be consulted to determine the need for medical monitoring of an employee. Medical monitoring is rarely needed due to the type of contaminates, solid wastes, or petroleum contaminated soil normally encountered on highway construction projects.

Changes to the Training Requirements

The SSHSP may alter the above requirements because of the particular contaminants on the project. Review Site Specific Health and Safety Plan Requirements and the project SSHSP.

Training and Medical Records

All training and medical records shall be kept according to sections 1105 and 1106 in the Hazardous Waste Program Manual (HWMPM).

Construction Safety Training

Confined space, trenching, excavation safety, and other construction related issues are covered by the 8-hour Construction Safety Awareness class. The 8-hour Construction Safety Awareness Training will be offered to all construction personnel every 3 years.

Additional training is provided at no cost through the Bureau of Workman Compensation at 800-644-6292. Any personnel who want extended training should take the following courses:

- Trenching and Excavation, Course SAF112

- Confined Space Assessment and Work, Course IHY214

These courses are offered at various times throughout the state. Construction personnel can sign up for the courses at the following website:

www.ohiobwc.com/employer/programs/safety/SandHCourses.asp

Site Specific Health and Safety Plan Requirements

The Contractor is required by OSHA and the contract documents to have a Site Specific Health and Safety Plan (SSHSP) when working within the exclusion or contamination zones of a construction project. Depending on the material contents of an underground storage tank, these exclusion zones may include the areas around the removal of underground storage tanks.

The Contractor is responsible for the health and safety of their personnel. The Contractor is required to have the SSHSP available at the project site for inspection. In no case will the Department accept or approve a Contractor's SSHSP.

Under C&MS 105.10, the Contractor must provide access to Department personnel to perform work inspections. The Contractor cannot restrict the inspection of the work when the inspection forces meet the minimum training requirements of the SSHSP.

The RWPE is responsible the health and safety of the inspection personnel. See "Health and Safety Responsibilities" in the Responsibility section of this manual. The RWPE may forward the Contractor's SSHSP to the District Environmental Coordinator (DEC) for review. The DEC will note how the SSHSP affects the qualifications of the inspection forces. The RWPE, in consultation with the DEC, will determine whether department forces or consultant forces should inspect the work. If consultant inspectors are used, the consultant will be responsible for the health and safety of its employees.

Minimum Contents of the SSHSP

The SSHSP will contain the following information:

1. Safety and Health Risk or Hazard Analysis.
2. Employee Training Assignments.
3. Personal Protective Equipment Requirements.
4. Medical Surveillance Requirements.
5. Frequency and Types of Air Monitoring.
6. Site Control Measures.
7. Decontamination Procedures.
8. An Emergency Response Plan.
9. Confine Space Entry Procedures (if necessary).
10. Spill Containment Program.

Further information about the SSHSP is detailed in the 24-hour training for the Regulated Waste Project Engineer.

Obeying the SSHSP Requirements

All construction personnel, including ODOT project personnel, will work under, and obey the requirements of the SSHSP during the inspections. The project personnel should review the SSHSP to become familiar with all the aspects of this document.

All ODOT personnel entering the contamination zone must wear the personal protective equipment (PPE) listed in the SSHSP. The training and equipment may be obtained by contacting the District Environmental Coordinator or Safety Coordinator. If the required equipment and training are not available to ODOT personnel, then this training may be paid for under third party billing through the Contractor.

Absence of a SSHSP

In the absence of a project SSHSP, the RWPE should contact the District Environmental Coordinator to determine the need for an SSHSP. There will be instances where an SSHSP is not required. Some solid waste or petroleum contaminated soil operations will generally not require an SSHSP.

Regulated Waste Designated for Removal in the Contract

General

Most hazardous waste sites are identified through environmental site assessment during the preliminary development process. These sites are avoided where possible. When these sites cannot be avoided, plans or notes will be placed in the contract to instruct the project personnel how to safely remove, cap, or remediate the contaminated material. Some typical plan notes are shown in the section, Typical Regulated Waste Plan Notes, of this manual.

Projects involving the removal of regulated material may quickly become complicated from an administrative perspective. The District Planning and Production staffs should coordinate the plan notes and specialized requirements for each project with the District Construction staff to ensure that the construction inspection staff, including the Project Engineer, understands why the special notes are in the plans and what special administrative requirements are necessary. If necessary, time should be allotted to develop contracts for outside environmental inspectors and to determine if specific training is needed for ODOT inspectors.

Construction projects with complicated remediation work, which requires specific equipment, project staff, or time, may be separated from the highway construction project to avoid overly complicating the project. Proper management and disposal or remediation of regulated waste and USTs are essential to prevent future liability for the Department.

The Contractor is responsible for the proper removal of regulated waste. The project personnel are responsible to control the Contractor’s work according to the contract documents and all applicable laws and regulations.

Reference Material for Regulation Requirements

The Hazardous Waste Program Manual is an excellent reference to help the project personnel to familiarize themselves with the regulation requirements and the waste types, characteristics, and generation requirements. Consult the 24-hour Construction HAZWOPER training manual when dealing with these regulated wastes.

Plan Notes

The plan notes and/or environmental site assessment reports are available to the project construction personnel to help familiarize them with the type of contamination that will be encountered on the project. These reports should be available through the DEC, production, or the Office of Environmental Services in Central Office.

The specialized plan notes may require department or consultant environmental inspectors to field screen samples and analyze soils excavated from areas of environmental concern. Contractors may be required to stockpile, containerize, or dispose of contaminated soils. The plan notes should allow the project to efficiently manage the disposal of the regulated wastes and/or USTs encountered on the project.

The plan notes will outline who is responsible for what operation on the project. The RWPE should review the plan notes before the Contractor starts work. The following is a general outline of responsibilities.

Pre-Excavation Checks

The regulated wastes are usually located on the plans. Work can begin in these areas once the Project Engineer is satisfied that all of the following are complete:

1. The SSHSP is present on the project.
2. The Department has appropriate environmental inspectors.
3. The Contractor has the appropriate work force to proceed with the work.
4. The Contractor has set up the appropriate zoning as noted in the SSHSP.

The zoning includes, but is not be limited to all of the following: Contamination Zone, Decontamination Zone, and the Safe Zone. These areas must be secured at all times and are usually separated by a construction fence.

Excavation

Contamination areas are sometimes marked in zones designated as hazardous, solid, or other waste classifications. This gives the Project Engineer an insight into the general classification of the material in the contamination zones. This classification is generally not used for final disposal. The Environmental Inspector may field screen the regulated material prior to the stockpiling, but all materials are stockpiled and tested prior to the final disposal of the material.

In some cases, and with the permission of the regulatory agency and the District Environmental Coordinator (or as allowed by the plan notes), the material may be excavated and directly placed in trucks for disposal at the landfill. This may require additional testing of the excavation area. Substantial savings may be obtained when this method is used.

The plans generally call for the removal of enough material to build the highway. Unless otherwise called for in the plans, the Department does not clean up all the regulated material in the right-of-way. Contact the District Environmental Coordinator for cleanup instructions, unless a regulatory authority is overseeing this portion of the project.

Temporary Storage

The contract documents give general details about the temporary storage methods. The RWPE should review the Contractor's proposed storage method and determine if the proposed method meets the intent of the plans. The project should review the storage locations daily to ensure the work is progressing satisfactorily. A sample inspection form is in the Hazardous Waste Management Program Manual (HWMPM) in appendix k. When work is not in progress, all storage areas must be inspected weekly, as per Section 507 in the HWMPM.

Material Sampling

The Contract or Plan may require that the State's Environmental Consultant or Contractor's Environmental Specialist test the regulated waste after it is stockpiled. The testing amount and location will be detailed in the plan or determined by the Environmental Consultant.

ODOT employees should not test or sample suspected hazardous waste material. This should be done by an environmental consultant. The Contractor is responsible for any other tests required by the landfill for disposal purposes. The Contractor is required to give all the test results to the project.

The test results shall be kept according to Section 1104 in the HWMPM.

Evaluation

Once the material is tested and the results are known, the material may be classified into a regulatory category, such as hazardous waste, solid wastes, petroleum contaminated waste, special, or non-regulated wastes. The material may be shipped to the appropriate landfill or onto other areas of the project if allowed. Petroleum contaminated soil is allowed under 203.02.K to be used as fill.

Manifesting

The manifest documents must be filled out and completed prior to the disposal of any hazardous waste material. Manifest documents are prepared by the Contractor and signed by the RWPE on behalf of the Department.

The RWPE receives one copy of the manifest; the remaining copies go out with the trucker.

The destinations of the various copies of the Manifest are as follows:

1. Landfill: Original signed copy.
2. Project: First copy signed by Landfill.
3. Contractor: Second copy signed by Landfill.
4. Trucking Company: Third copy signed by Landfill.
5. Project: Fourth copy kept by the Regulated Waste Project Engineer (RWPE) after they sign the manifest; it does not go with the load. The RWPE matches it with the Landfill signed first copy that is returned to the Project. The RWPE verifies that the two copies match.

The manifest form has these terms for the various parties:

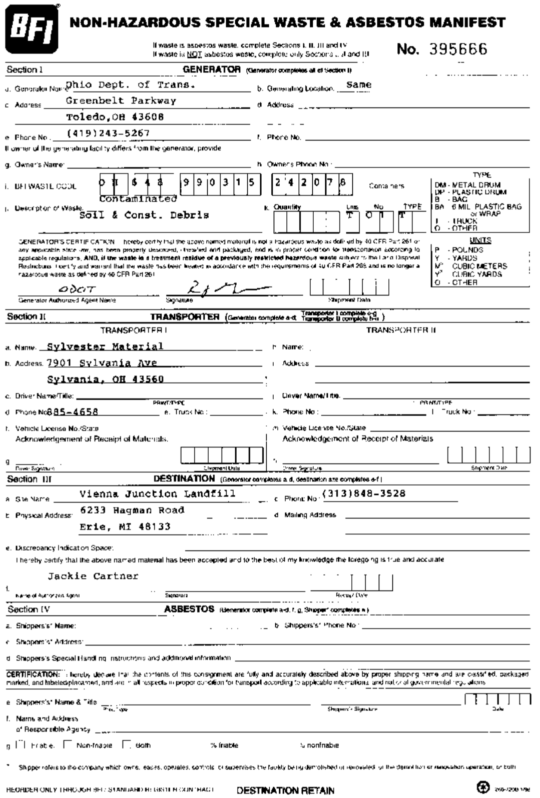
Party	Form Term
Landfill	DESTINATION

ODOT Project	GENERATOR
Contractor	OPERATOR
Trucking Company	TRANSPORTER

There are four carbon copies, so the RWPE musty sign the forms with a lot of pressure.

One copy of the manifest comes back to the project when the regulated material is disposed at the regulating facility. The RWPE must ensure that all copies and material quantities are accounted for in a timely manner. See Section 603 in the Hazardous Waste Management Program Manual for information about the action to be taken when a manifest does not come back to the project.

Examples of Manifests and a full description are shown in the Hazardous Waste Management Program Manual (HWMPM) in Section 602. Most of the regulated material removed from construction projects will be either petroleum contaminated soils or a solid waste. Manifesting is required, but there will not be an RCRA generator number on a solid waste manifest. An example of one is on Figure 202-1.


BFI NON-HAZARDOUS SPECIAL WASTE & ASBESTOS MANIFEST

If waste is asbestos waste, complete Sections I, II, III and IV
If waste is NOT asbestos waste, complete only Sections I, II and III

No. 395666

Section I GENERATOR (Generator completes all of Section I)

a. Generator Name: Ohio Dept. of Trans.
b. Generating Location: Same
c. Address: Greenbelt Parkway, Toledo, OH 43608
d. Address:
e. Phone No.: (419)243-5267
f. Phone No.:
If owner of the generating facility differs from the generator, provide
g. Owner's Name:
h. Owner's Phone No.:
i. BFI WASTE CODE: 0 1 6 4 8 | 9 9 0 3 1 5 | 2 4 2 0 7 8
j. Description of Waste: Contaminated Soil & Const. Debris
k. Quantity / Units: T / Containers No: 0 1 / TYPE: T

TYPE: DM - METAL DRUM; DP - PLASTIC DRUM; B - BAG; BA - 6 MIL PLASTIC BAG or WRAP; T - TRUCK; O - OTHER

UNITS: P - POUNDS; Y - YARDS; M³ - CUBIC METERS; Y³ - CUBIC YARDS; O - OTHER

GENERATOR'S CERTIFICATION: I hereby certify that the above named material is not a hazardous waste as defined by 40 CFR Part 261 or any applicable state law, has been properly described, classified and packaged, and is in proper condition for transportation according to applicable regulations; AND, if the waste is a treatment residue of a previously restricted hazardous waste subject to the Land Disposal Restrictions, I certify and warrant that the waste has been treated in accordance with the requirements of 40 CFR Part 268 and is no longer a hazardous waste as defined by 40 CFR Part 261.

ODOT — Generator Authorized Agent Name; Signature; Shipment Date

Section II TRANSPORTER (Generator complete a-d; Transporter I complete e-g; Transporter II complete h-n)

TRANSPORTER I
a. Name: Sylvester Material
b. Address: 7901 Sylvania Ave, Sylvania, OH 43560
c. Driver Name/Title: (PRINT/TYPE)
d. Phone No.: 885-4658
e. Truck No.:
f. Vehicle License No./State
Acknowledgement of Receipt of Materials
g. Driver Signature; Shipment Date

TRANSPORTER II
h. Name:
i. Address:
j. Driver Name/Title: (PRINT/TYPE)
k. Phone No.:
l. Truck No.:
m. Vehicle License No./State
Acknowledgement of Receipt of Materials
n. Driver Signature; Shipment Date

Section III DESTINATION (Generator completes a-d, destination site completes e-f)

a. Site Name: Vienna Junction Landfill
c. Phone No.: (313)848-3528
b. Physical Address: 6233 Hagman Road, Erie, MI 48133
d. Mailing Address:
e. Discrepancy Indication Space:
I hereby certify that the above named material has been accepted and to the best of my knowledge the foregoing is true and accurate.
f. Jackie Cartner — Name of Authorized Agent; Signature; Receipt Date

Section IV ASBESTOS (Generator complete a-d, f, g; Shipper* completes e)

a. Shipper's* Name:
b. Shipper's* Phone No.:
c. Shipper's* Address:
d. Shipper's Special Handling Instructions and additional information:

CERTIFICATION: I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name and are classified, packaged, marked, and labeled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations.

e. Shipper's* Name & Title (Print/Type); Shipper's Signature; Date
f. Name and Address of Responsible Agency
g. Friable / Non-friable / Both; % friable; % nonfriable

* Shipper refers to the company which owns, leases, operates, controls or supervises the facility being demolished or renovated, or the demolition or renovation operation, or both.

REORDER ONLY THROUGH BFI STANDARD REGISTER CONTRACT — DESTINATION RETAIN

Figure 202.A – Non-Hazardous Manifest

For more information regarding manifesting, see Sections 603 and Appendix I of the HWMPM.

Pre-Transportation Requirements and Placarding

The Hazardous Waste Management Program Manual (HWMPM) is an excellent resource to determine the pre-transportation and placarding requirements. Sections 504, 605 and appendix P of the HWMPM provide a pre-transportation requirements and checklists. The Contractor is required to provide all of the material and manpower to provide for the proper identification, transportation, and disposal of the regulated waste. The RWPE must ensure that the packaging, labeling, and placarding are done according to the regulations.

Records of the Disposal

All documentation of the regulated waste operations should be recorded in SiteManager and in the daily diaries. All records should be kept with the project files. The Regulated Waste Project Engineer must ensure that the records are kept in the District for future reference. The records need to be kept by the District Environmental Coordinator in the District.

If regulated waste is classified as a hazardous waste, then all of the records keeping requirements listed in Section 1101 in the HWMPM apply.

Weekly Project Inspections

When the project conducts hazardous waste removal operations, then the RWPE will perform the weekly inspection requirements in 1107 in the HWMPM.

Regulated Wastes Found During Construction

General

Special procedures must be followed when the Contractor encounters potential regulated materials that were not anticipated by the plans. Section 203.04 of the C&MS describes the process for notifying Contractors and Department personnel of these special procedures.

Limit Access to the Suspect Area

Suspected regulated material must be left in place until identified by a qualified specialist. This may require the temporary discontinuance of work in the area of the suspected materials. The area in question should be secured to prevent access. This can be accomplished by cordoning off the area with rope or construction fence and posting a guard. On large projects, work may continue at locations sufficiently removed from the site in question.

Notification

The Project Engineer must be notified immediately and should contact the RWPE. The Department will evaluate the level of risk to workers and the public, and notify all responsible parties and regulatory agencies as required. The District will consult with

the appropriate environmental regulatory agencies and ODOT staff with specialized expertise in the hazardous waste field in the Office of Construction Administration, or the Office of Environmental Services, to determine a course of action. If it is determined that the area in question is or may be contaminated with environmentally regulated substances, the District will initiate the evaluation and remediation of the problem area as described below. In the event of a life-threatening situation to human health outside the project, contact the Local Fire Department and the Local Police. Report the incident to the District Construction Administrator and the Highway Manager to determine if local involvement is required. When local involvement is required, notify the County Emergency Manager Director listed in the current version of the Incident Management System Responders Listing.

Releases

If a hazardous chemical in excess of its reportable quantity is released into a body of water or leaves the project site, all of the following must be notified:

1. RWPE or DEC.
2. Local Fire Department.
3. The Ohio EPA at 800-282-9378.

Reportable chemicals may be between 1 and 500 pounds depending on the chemical. The following website refers to the Code of Regulation (CFR) that gives the reportable quantities limits. In addition, it gives explicit instructions about what action should be taken by the project personnel:

www.epa.state.oh.us/derr/ersis/er/er.aspx

The project should hire an environmental consultant to help with required paperwork and technical advice.

Obtaining Technical Advice or Inspection

It is imperative that action be taken to mitigate the problem in a timely manner.

If required, the District may seek the services of a qualified consultant who specializes in regulated waste assessment and remediation, and billing through the Contractor or the District or Central Office task order contract.

The District or Central Office Environmental Site Assessment Task Order Contract can be used to provide specific environmental expertise for the consultation, evaluation, and testing in these situations. The District's Planning and/or Environmental staff can aid in developing a proposal request for these services when the Task Order Contract is used. This can be provided at no cost to the project.

The specific consultation, testing, or inspectors hired through the Task Order Contract or other contracts should specify the type of environmental expertise needed. For example, a project involving underground storage tanks or petroleum contaminated soils requires knowledge of BUSTR rules and regulations, operation of organic vapor analyzers, and the ability to interpret laboratory data. A good minimum qualification for these projects would be a Certified Installer or Inspector under BUSTR’s rules. Projects involving hazardous solid wastes or other types of wastes require the appropriate type of expertise.

Development of the Remediation or Disposal Plan

The chosen environmental consultant must submit a sampling plan for the Department and OEPA (if applicable) for approval. Upon approval, the environmental consultant will perform the required sampling, testing, mitigation, and possible disposal.

If it is determined that no contamination exists, or that the problem has been resolved on the site, the Contractor will be directed to return to work.

If required, the Environmental Consultant or Contractor will develop a removal or remediation plan in consultation with ODOT, OEPA, or BUSTR (if applicable).

Implementing the Plan

Once the contaminant is known, and a plan to eliminate or mitigate the regulated material is determined, the Department may seek competitive bids from a qualified regulated waste disposal firm contractor to remove or mitigate the waste.

If the project cannot tolerate the time it would take to obtain competitive bids, the Department may request a waiver of competitive bidding from the Controlling Board and award it to an approved, qualified environmental firm via third party billing through the Contractor.

Where treatment or disposal of the regulated material must be conducted concurrently with construction, it may be made a part of the construction contract.

Disposal and Remediation

A remediation contract will be initiated once all the approvals are obtained. The Environmental Consultant, Contractor, or Subcontractor will perform work according to this manual and the approved remediation plan.

The Department will keep complete records of all activities performed in the treatment, removal, transport, and disposal according to all applicable laws, rules, and regulations. These records are the same as detailed in the Regulated Waste Designated for Removal in the Contract section of this manual.

All of the disposal requirements of a regulated waste outlined in the Regulated Waste Designated for Removal section in the Contract still apply. A plan note, similar to the ones in the Typical Regulated Waste Plan Notes section of this manual; an excavation plan; and a SSHSP should be developed before the work begins.

Other Wastes and Environmental Considerations

It is important to be aware of other common construction materials that can cause environmental problems during or after construction. The most common materials are construction and demolition debris, landscape waste (buried or burned on-site), and asbestos pipe. These materials were detailed in Sections 105.16, 105.17, 201, and 202. Other materials such as slag, scrap tires, railroad ties, and recycled materials are detailed in this section.

Slag Use on the Projects

Air-Cooled Blast Furnace Slag

Air-Cooled Blast Furnace slag (slag made from making iron) has been known to produce a green, yellow, white, or black runoff, which can smell like rotten eggs. The color is usually pH driven and goes away in about six months, but not always. The runoff may exceed the allowable pH limits under the Clean Water Act.

To minimize these problems, all Air-Cooled Blast Furnace slag must pass the Sulfur Leachate Test detailed in Supplement 1027.

The problems first showed up in Cleveland around 1992. The Ohio EPA wanted the slag industry to regulate themselves and change the ACBF slag chemistry by adding chemicals. This did not work well, and in 1998, the Ohio EPA requested that the Department specify the Bucket Test. The Bucket Test was pre-2002 SS-907 and was successfully used in Chicago. The Bucket Test can detect if the sulfur content in the slag is too high. The Bucket Test was implemented by SS-907 in 1998.

Then the Ohio EPA found several more projects with environmental problems. One of the projects was ODOTs. This Department project used RPCC (Recycled Portland Cement Pavement) and ACBF slag. The RPCC was used in the undercut and the ACBF Slag was used in the 304 material. The Department was cited for violating the Clean Water Act. This problem has cost approximately $120,000 and has led the Department to hire an Environmental Consultant to remediate the problem.

The environmental problems on non-ODOT projects were clearly caused by the ACBF slag. One of the projects cost millions of dollars to remove the ACBF slag due to environmental problems. Another project has cost thousands of dollars a month to contain and remove the runoff. By reviewing the Ohio Administrative Code, environmental reports, and performing lab tests, ODOT developed the following solution in Supplement 1027:

1. Lengthen the time of the Bucket Test.
2. Incorporate some of the Ohio Administrative Code Water Quality requirements.
3. Test for pH, conductivity and total dissolved solids.

These tests will minimize ODOT’s environmental liability. It is important that the project personnel recognize these requirements and only use materials that meet these specifications.

Steel Slag

Steel slag can expand and produce tufa, which can block underdrains. All steel slag is restricted in 703.01.E and 703.14 in the C&MS.

There are three types of slag detailed in these specifications: Open Hearth, Basic Oxygen Furnace, and Electric Arc slag. All slags are byproducts of making steel or iron. Open Hearth slag (OH slag) was produced pre-1970. Basic Oxygen Furnace slag (BOF slag) and Electric Arc Furnace (EAF slag) are produced from a newer and faster process for making steel. Basic Oxygen Furnace slag tends to have more problems than Open Hearth slag because the OH process is slower, and the slower process burns more chemicals out

of the OH slag. Very little Electric Arc Furnace slag was used for ODOT work, but it has more detrimental effects than any of the other steel slags.

Background on Open Hearth and Basic Oxygen Slag Restrictions

In the mid-1970s, the Department had severe expansion problems associated with bedding, backfill, and base material placed using OH and BOF steel slag. This problem caused the Department to spend hundreds of thousands of dollars due to premature failures.

As result of several years of research, the Department required a 6 month aging of all OH and BOF slags to solve the problem. It also eliminated the use of OH or BOF slags in confined areas such as pipe bedding and backfill, underdrains, and around structures.

In the late 1970's and early 1980's, OH and BOF slags were found clogging up underdrain systems. The use of OH and BOF slags was eliminated in Items 304 and 310 - Subbase.

In the early 1990's, the Department allowed the use of some OH slags if the field performance proved that the OH slag did not block underdrains.

In the 1997 specification book, the Department allowed OH slag in Items 203, 304, 306 & 310 (drainable bases), 410, 411, 603, and 617. BOF slag was allowed for Items 203, 410, 411, and 617. Changes made to the 1997 and 2002 specifications were based on the following reasoning:

1. ODOT consulted with Industry, Illinois, Indiana, Pennsylvania, and the Ohio Turnpike on this matter. ODOT reviewed past research and consulted with John Hurd, Stu Schwotzer, and Phil Hall who performed the majority of the research done in the past.
2. The words, "from sources on file at the Laboratory," were being misinterpreted in Items 304, 410, 411, and 617. The intent was to verify tufa performance before the sources were used. This was clarified.
3. The expansion potential of OH and BOF slags are related to the concentrations of CaO and MgO. CaO leaches out during the aging process, while MgO may not. A test method was recommended to help determine the expansion risk. The recommended expansion test has a 20-year field performance related history.
4. The risk was too great to allow BOF slag in base material. Therefore, clear identification of OH slag was critical to base performance. A procedure to verify the material source as OH slag was detailed.
5. Water and confining pressures cause additional expansion potential in OH and BOF slag. Therefore, all OH and BOF slag was eliminated in areas where the material is confined.

Summary

The problems found in the mid-1970's were primarily from projects built in the mid-1960's. Tufa was not found blocking underdrains for about 10 years. Problems associated with ODOT projects built today may not arise for 10 years or more.

The easiest way to avoid problems is to eliminate the use of OH and BOF slag in all Department items of work. Certainly the Department has documented enough bad

performance related problems associated with OH and BOF slag to justify this elimination.

Most states do not allow steel slag for any base or confined areas. Instead, we have implemented a method and procedure that allows the use of OH and BOF slag in certain applications to minimize the potential for premature failures.

The restrictions on the use of OH and BOF slag are intended to ensure we do not revisit those past expansion and tufa problems. Using materials that comply with the specifications minimizes environmental and engineering concerns.

Tufa Removal

Lime precipitant from slags used in the bases of older projects can create deposits that form on the side slopes. The deposited material will have a high pH and may have to be taken to a solid waste landfill. The material may be a hazardous waste if the pH is above 12.5.

When the project personnel notice these materials within the project limits, the deposits should be tested and removed as follows:

1. This material should be tested under the task order contract.
2. The Contractor should perform the removal by force account.

Some projects may have special plan notes for the removal operations. The following plan note will be used to remove the tufa. If a large amount of tufa is on the project there may be other removal notes.

Environmental Work General Tufa Note (11/28/01)

A field review has determined that there are tufa deposits located between stations ______and stations _______ at the underdrain outlets. If these materials are encountered, manage this material according to the following.

Obtain all necessary testing for disposal, permits and approvals, and transportation of the material to a licensed (by the local health department) and permitted (by the state environmental protection agency) solid waste disposal facility.

Provide areas to stockpile the material. Stockpile the materials in a leakproof and covered container.

Ensure that all transport vehicles used for the movement of regulated material meets all applicable Local, State, and Federal requirements. Maintain records (such as manifests, landfill tickets, daily logs, etc.) to document the source, movement, and destination of each truckload of contaminated material. Submit one copy of each of these records to the Engineer.

Furnish all the labor, equipment, and materials necessary to excavate, store, test, transport, and dispose of the tufa material, including any required permits, approvals, or fees, within the aforementioned limits.

The Department will pay for this work according to 109.05 (C&MS).

Scrap Tires

Scrap Tires found on the project are transported under OAC 3745-27-56. The tires must be disposed of at a registered and permitted scrap tire facility as per OAC 3745-27-61 thru 65.

Use the following link to the OAC:

http://codes.ohio.gov/oac

Under these requirements, the transportation company and the disposal facility are regulated by the OEPA. Shipping papers are required to ship the tires to and from the facility. The District Environmental Coordinator or 24-hour trained Regulated Waste Project Engineer will sign the shipping papers for the Department. The records must be kept for 3 years.

Railroad Ties

The Ohio EPA encourages the use of railroad ties as landscape materials or other uses. When disposed, they are disposed of in a construction and demolition debris site or a solid waste facility.

To date, creosote in railroad ties does not pose an environmental threat.

Recycled Materials

Supplemental Specification 871 allows the use of fly ash, bottom ash, foundry sand, glass, and tires in fills.

Recycled materials are defined in the C&MS in 203.02.N Recycled materials may be fly ash, bottom ash, foundry sand, glass or tires.

Under certain circumstances, petroleum contaminated soil in 203.02.K may also be used in fills. The environmental requirements are in 203.03.J on page 101.

The recycled materials are allowed in the interior sections of the fills. The approval on existing contracts will be on a case-by-case basis or if SS-871 is in the Contract. Recycled materials are not allowed under the terms of the Contract unless SS-871 is included.

The following Designer Note should be reviewed prior to considering the use of Supplemental Specification 871 Embankment Using Recycled Material:

> *The specification was written to allow the Districts to use recycled materials in embankment construction. It was written to safely use these recycled products without jeopardizing the embankment or pavement integrity or long-term performance. The Department does not require the use of recycled materials because this specification does not eliminate all risk or liability to the Department. It only minimizes these risks. The utilization of SS-871 is at the District's discretion. Districts are advised to consider all the benefits and potential problems prior to allowing these materials.*

Benefits

Recycled materials can be cheaper and provide engineering improvements to the embankment construction. For example, fly ash and tires can provide lighter weight materials.

By using these materials, the Department will save landfill space in the state. The Department may minimize potential legislation in the future that would require the use of these materials. (Note: In 1995, the state legislators required ODOT to allow petroleum-contaminated soil for embankment material, now under 203.02.K).

Potential Problems

Once these materials are placed on ODOT property, the recycled materials become the responsibility of the Department. ODOT will assume any future liability and costs for removal and proper disposal of material according to future EPA regulations. If this embankment is repaired in the future, the material may have to be disposed of in a landfill if required by Ohio EPA regulations.

A small percentage of tire fills have spontaneously caught fire. Fly ash is a silt and may be susceptible to frost heave and capillary action. Both problems are minimized by the engineering controls in the specification.

The District may pick and choose which recycled material to use or they may allow the use of all recycled materials.

The District may allow different materials at certain locations along the project.

No change in the cross sections is needed to include SS-871 in the plans. This specification delineates the areas in which recycled materials are allowed.

The following plan note can be used to incorporate SS 871 in the contract.

> ***Embankment Construction Using Recycled Materials***
>
> *On this project, Supplemental Specification 871 Embankment Construction Using Recycled Materials applies. ____________________________ (Put in the materials wanted or needed) may be substituted for Item 203 Embankment in the contract. The Department will measure and pay for all work detailed in SS-871 according to the Unit Bid Price for Item 203 Embankment.*

Typical Regulated Waste Plan Notes

Typical Plan Note for: Non-Regulated Materials, Petroleum Contaminated Soil and Underground Storage Tanks

> **ENVIRONMENTAL WORK**
>
> **1. Introduction**
>
> Soil adjacent the New Hamlet Cleaners property (SE corner of SR 132 and SR 125) was tested and contained petroleum substances. These substances are present within the excavation limits for proposed underdrains, proposed 36-inch storm sewer, other utilities and/or roadway construction from Station 1+50 Lt. along SR 132 Station 370+70 Right along SR 125 (see Sheet 22/57).

This material must be handled by the Contractor according the following notes. In addition, the Contractor shall remove four underground storage tanks located within the proposed right-of-way limits in accordance with Item 202 of ODOT's Construction and Material Specification (C&MS).

1.2 Site Specific Health and Safety Plan (SSHSP)

The Contractor shall certify in writing to the Engineer within 2 weeks after contract execution that the Contractor has prepared a SSHSP in accordance with OSHA 29 CFR Part 1910.120 for operations involving hazardous substances within the aforementioned limits. The Contractor shall make the SSHSP available at the project site. Copies of the environmental studies are available for examination in the Office of Contracts and the ODOT District 12, Office of Planning. This information may be used by the Contractor to develop the SSHSP.

1.3 Material Sampling

The Contractor shall provide the Engineer with 5 days' notice prior to beginning any excavation within the aforementioned limits to permit arranging for the necessary testing services. All material excavated by the Contractor between these limits during construction shall be subject to testing by an Inspector provided by the Engineer. The Inspector shall field-screen the excavated material for petroleum contamination using an organic vapor analyzer (OVA). At the discretion of the Inspector, the excavated material, which exhibits petroleum contamination, shall be stockpiled and segregated while samples of the material are analyzed by an independent analytical laboratory. Field-screening results and visual observation will be the basis for segregating excavated material. Soil samples shall to be tested for BTEX (Benzene, Toluene, Ethyl benzene, and Xylene) by Method 8020 and TPH by Method 8015. If the BTEX and/or TPH levels exceed levels set forth by the Ohio EPA Petroleum Contaminated Soil Policy, the material shall be treated as petroleum-contaminated soil. All field-screening instruments and initial sampling and analysis of soils will be provided by the Engineer at no cost to the Contractor.

1.4 Temporary Storage of Contaminated Soils

All excavated material, which is determined to be potentially contaminated with petroleum substances, shall be stockpiled in an area provided by the Contractor and approved by the Engineer. The Contractor shall stockpile the material in a leak proof, covered container provided by the Contractor. The material shall remain on-site until analytical results are received by the Engineer.

As an alternate, the Engineer may permit temporary storage of suspected contaminated soils on an impermeable membrane. The membrane should be surrounded by bales of straw to prevent the suspect soils from coming in contact with the original soils. An impermeable membrane shall be placed over the stockpile to prevent contact with precipitation and/or surface run-off.

1.5 Material Evaluation

The Inspector shall use the analytical results to determine the regulatory classification of the excavated materials. The excavated material may be classified in one or all of the following three categories:

1.5.1 ITEM SPECIAL - Work Involving Non-regulated Materials

The Inspector will determine if the excavated material is non-regulated. The work involved in this Item Special includes developing and complying with a SSHSP; handling, storage, and disposal/use of non-regulated materials. This material may then be used as backfill for other project purposes, if it meets the appropriate ODOT specifications.

1.5.2 ITEM SPECIAL - Work Involving Petroleum-Contaminated Soil

The Inspector will determine if the excavated material is petroleum-contaminated soil (PCS) based on the analytical test results. The Engineer will provide the Contractor with these test results. The Contractor shall be responsible for obtaining all necessary permits and approvals and to transport the material to a licensed (by the local health dept.) and permitted (by the Ohio Environmental Protection Agency) solid waste facility or a Petroleum Contaminated Soil Remediation Facility (PCSRF) for proper disposal or remediation. Prior to disposal, the Contractor shall contact the proposed facility to determine the additional testing required for disposal or remediation at that facility. The prices for these tests are to be included in the above pay item. The work involved in this pay item includes developing and complying with a SSHSP; handling, storage, testing (for disposal or remediation); and disposal or remediation of PCS. When directed by the proposed facility, the Contractor shall have an independent laboratory collect samples and test the excavated or stored materials for PCS disposal or remediation approval.

1.5.3 Work Involving Hazardous Waste

In the event the analytical test results for disposal purposes show the excavated material is a hazardous waste, disposal of this material shall to be paid for in accordance with Section 109.04 of ODOTs C&MS.

1.6 Backfill of Excavated Areas

All excavated areas shall be backfilled with suitable material in accordance with the project plans, applicable ODOT specifications, and/or as directed by the Engineer. All surplus or unsuitable excavated material that can be used in embankments shall be disposed of in accordance with Item 203.05 of ODOTs C&MS.

1.7 General Notes

All transport vehicles used for the movement of regulated soils and/or water shall meet applicable local, state, and federal requirements. The Contractor shall maintain records such as daily logs, landfill tickets, manifests, etc. that document the source, movement, and destination of each truckload of contaminated soil. One copy of each of these records shall be submitted to the Engineer.

1.8 Basis of Payment

The Contractor shall furnish all the labor, equipment, and materials necessary to properly develop and comply with a SSHSP, excavate, store, test (for disposal), transport, and dispose of contaminated materials, removal of underground storage tanks, including any required approvals or fees within the limits identified above. Payment for this work shall be made at the contract prices bid per ton and per regulated underground storage tank. Work involving hazardous waste shall be paid for in accordance with Section 109.04 of ODOTs C&MS.

The following estimated quantities have been included in the General Summary for the work noted above:

Item Special - Work Involving Non-regulated Materials, 160 Ton

Item Special - Work Involving Petroleum-Contaminated Soil, 160 Ton

Item 202 - Regulated Underground Storage Tank Removed, 4 each

Typical Plan Note for: Solid Waste, Water, and Regulated Water

ENVIRONMENTAL WORK (CUY - Aerospace Parkway, PID 16802)

1.1 Introduction

Environmental studies have shown that regulated material (foundry sand, etc.) is present within the following excavation limits:

All excavations within the aforementioned limits shall be paid for under the original plan bid items. The Contractor shall manage this material according to the following notes. The estimated quantity has been included in the General Summary for this work.

1.2 Site Specific Health and Safety Plan (SSHSP)

The Contractor shall determine if a SSHSP is required in accordance with 29 CFR Part 1910.120. Environmental studies information is available for examination at ODOT District 12, Planning Dept., 5500 Transportation Blvd., Garfield Heights, OH 44125.

1.3 Material Handling

All material excavated by the Contractor between these limits may be stockpiled in an area provided by the Contractor and approved by the Engineer. The Contractor shall stockpile the material in a leak proof, covered container provided by the Contractor.

The Engineer may permit temporary storage of the regulated soils on an impermeable membrane. The membrane shall be surrounded by bales of straw to prevent the suspected soils from coming in contact with the original soils. An impermeable membrane shall be placed over the stockpile to prevent contact with precipitation and/or surface run-off.

As an alternative, the Engineer may permit the Contractor to direct load the excavated regulated soils (located within the aforementioned limits) into trucks for subsequent disposal.

1.4 Material Sampling and Disposal

The Contractor shall provide the Engineer with 5 days' notice prior to any excavations within the aforementioned limits to permit arranging for the necessary testing services. All material excavated by the Contractor between these limits shall be subject to testing by an Inspector provided by the Engineer. The Inspector will conduct sampling and testing every 100 cubic meters of material excavated. Samples will be tested by the following USEPA test methods:

The Contractor shall properly transport and dispose of the excavated material that is considered surplus or unsuitable material in a licensed (by the local health department) and permitted (by the Ohio Environmental Protection Agency) solid waste facility. If required by the solid waste facility, the Contractor shall be responsible for conducting any additional sampling and analysis of the excavated material.

In the event the analytical test results for disposal indicate the excavated materials are hazardous and/or TSCA waste, disposal shall be paid for in accordance with Section 109.04 of ODOT's C&MS.

1.5 Backfill of Excavated Areas

All excavated areas shall be backfilled with suitable material in accordance with the project plans or as directed by the Engineer.

1.6 Potential Dewatering Of Excavated Areas

If excavations within the aforementioned limits require dewatering for construction purposes, the Contractor shall dewater and subsequently dispose of waters by methods approved by the Engineer. All water containerized by the Contractor between these limits shall be subject to testing by an Inspector provided by the Engineer. Samples will be tested by the following USEPA test methods:

1. The Contractor shall obtain all the necessary permits and/or authorizations needed to store, transport and dispose of the water in accordance with applicable local, state or federal regulations.
2. The Engineer will classify the water removed from the excavation into one of the two following categories.

1.6.1 ITEM SPECIAL - Work Involving Water

The Engineer will determine if the water is non-regulated. The method for disposing of the non-regulated water shall be approved by the Engineer. Work involved with this Item Special includes the handling, storage, and disposal of the non-regulated water.

1.6.2 ITEM SPECIAL - Work Involving Regulated Water

The Engineer will determine if the water is regulated. The Contractor shall be responsible for disposal of the regulated water. The method for disposing of the regulated water shall be approved by the Engineer. The work involved in this Item Special includes the handling, storage, testing, and disposal of regulated water.

1.7 General Notes

All transport vehicles used for the movement of regulated soils shall meet applicable Local, State, and Federal requirements. The Contractor shall maintain records, such as manifests, landfill tickets, daily logs, etc., to document the source, movement, and destination of each truckload of contaminated soil. One copy of each of these records shall be submitted to the Engineer.

1.8 Basis of Payment

The Contractor shall furnish all the labor, equipment, and materials necessary to properly handle, store, test, transport, and dispose of regulated materials, including any required permits, approvals, or fees within the limits identified above. Payment for this work shall be made at the contract price bid per metric ton and/or cubic meter. The basis for conversion from cubic meter to metric ton is 2 metric ton/cubic meter. The following estimated quantities have been included in the General Summary for the work noted above:

690M65010 Item Special - Work Involving Solid Waste, Mton

690M65020 Item Special - Work Involving Water, Cubic Meter

690M65024 Item Special - Work Involving Regulated Water, Cubic Meter

Typical Plan Note for: Ground Water Monitoring, Regulated Underground Storage Tanks and Scrap Tires

Environmental Work (HAM - 127 - 5.47, PID 9135)

Abandonment of Ground Water of Monitoring Wells

A total of three monitoring wells are present on the vacant lot located at 4135 Virginia Avenue (corner of Chase and Virginia). These wells shall be abandoned in accordance with the Ohio Department of Natural Resources' (ODNR) Technical Guidelines for Sealing Unused Wells (Appendix 4, Sealing Monitoring Wells and Boreholes). Payment for this work shall be as per Item Special - Ground Water Monitoring Well Abandonment.

Removal of Underground Storage Tanks

The Contractor shall remove two petroleum underground storage tanks in accordance with ODOT Construction and Material Specifications (C&MS) Item 202. These tanks are located at 4135 Virginia Avenue (corner of Chase and Virginia).

Removal and Disposal of Scrap Tires

Scrap tires are located throughout the project area. The Contractor shall be responsible for removing, transporting, and disposing of these scrap tires as per this plan note.

The Contractor shall ensure that the tires are removed and transported in a manner that satisfies all the appropriate OEPA regulations. Specifically, the transportation of tires is governed by OAC 3745-27-56. The disposal of tires

shall be at a registered and permitted scrap tire facility as per OAC 3745-27-61 thru 65. Payment for this work shall be as per Item 202 Removal Miscellaneous: Scrap Tires.

Basis of Payment

The Contractor shall furnish all the labor, equipment, and materials necessary to perform the aforementioned work. The following estimated quantities have been included in the General Summary for the work noted above:

Item Special - Ground Water Monitoring Well Abandonment, three each

Item 202 - Regulated Underground Storage Tank Removed, two each

Item 202 - Removal Miscellaneous: Scrap Tires, Lump Sum

Typical Plan Note for: Asbestos Abatement

Environmental Work (MIA - 48 - 8.534, PID 12860)

Asbestos Abatement

An asbestos survey of the bridge structure scheduled for demolition was completed 6/99 by a certified asbestos hazard evaluation specialist (CAHES). Approximately 440' of conduit, which contains asbestos materials, was identified on the bridge structure. A copy of the Ohio Environmental Protection Agency Notification for Asbestos Demolition and Renovation Form with Sections I-VII, XVII, XVIII completed is available at the District 7 ODOT office (Planning Department). The form must be submitted to OEPA-SWDO, DAPC (401 E. Fifth Street, Dayton, OH 45402) at least 10 days prior to demolition/renovation activities.

The Contractor shall take whatever precautions are possible to ensure that the asbestos containing material (ACM) does not become friable. To ensure that the non-friable asbestos material does not become friable, or in the event that the non-friable material becomes friable, the Contractor shall provide an individual trained in the provisions of NESHAP that will be on-site during the demolition and/or removal of the ACM conduit. All ACMs shall be properly containerized, transported, and disposed of in accordance with the state and federal regulations.

Basis of Payment

The Contractor shall furnish all the labor (including a CAHES), equipment, and materials necessary to complete, submit, and comply with the OEPA notification for and to remove, transport and dispose of asbestos containing materials in a licensed (by the local health department) and permitted (by the OEPA) solid waste facility. Payment for this work shall be made at the contract prices bid Lump Sum. The following quantity has been included in the General Summary for the work noted above:

690M98400 Item Special - Misc.: Asbestos Abatement, Lump Sum

Typical Plan Note for: Removal and Disposal of Scrap Tires

Removal and Disposal of Scrap Tires (GRE - 42 - 14.25, PID 13134)

Scrap tires are located at approximately STA 23+660 to STA 23+720. The Contractor shall be responsible for removing, transporting, and disposing of these scrap tires as per this plan note.

The Contractor shall ensure that the tires are removed and transported in a manner that satisfies all the appropriate OEPA regulations. Specifically, the transportation of tires is governed by OAC 3745-27-56. The disposal of tires shall be at a registered and permitted scrap tire facility as per OAC 3745-27-61 thru 65.

Basis of Payment

The Contractor shall furnish all the labor, equipment and materials necessary to remove, transport and dispose of scrap ties in a registered and permitted scrap tire facility. Payment for this work shall be made at the contract price bid Lump Sum. The following estimated quantity has been included in the General Summary for the work noted above:

Item 202 - Removal Miscellaneous: Scrap Tires, Lump Sum

Typical Plan Note for: Solid Waste and Regulated Water

ENVIRONMENTAL WORK (TRU - Belmont Avenue, PID 11910) 3/8/00

1.1 Introduction

The Ohio Department of Health has issued a Contact Advisory for the sediments of the Mahoning River for polycyclic aromatic hydrocarbons (PAH's), polychlorinated biphenyls (PCB's), Mirex (a pesticide) and phthalate esters. Environmental studies conducted on sediments in the project area have shown that low levels of PAH's and metals are present within the stream bed. The Contractor shall manage all material required to be excavated from the river bed according to the following notes. Estimated quantities have been included in the General Summary for this work.

1.2 Site Specific Health and Safety Plan (SSHSP)

The Contractor shall certify in writing to the Engineer within 2 weeks after contract execution and prior to any excavation that would disturb the sediment in the river bottom that the Contractor has prepared a SSHSP in accordance with 29 CFR Part 1910.120 for operations involving hazardous substances within the aforementioned limits. The Contractor shall make the SSHSP available at the project site. Copies of the environmental studies are available for examination in the Office of Contract Sales (Room 118) and the District 4 ODOT office (Planning Dept.). This information may be used by the Contractor to develop the SSHSP.

1.3 Material Handling and Disposal

The Engineer may permit temporary storage of the excavated material in a lined and covered roll-off box. As an alternative, the Engineer may permit the Contractor to direct load the excavated material into trucks.

The Contractor shall properly transport and dispose of the excavated material in a licensed (by the local health department) and permitted (by the Ohio Environmental Protection Agency) solid waste facility. If required by the solid

waste facility, the Contractor shall be responsible for conducting sampling and analysis of the excavated material.

1.4 Potential Dewatering Of Excavated Areas

If the excavations in the aforementioned sediments require dewatering for construction purposes, the Contractor shall dewater, containerize, test, and subsequently dispose of waters by methods approved by the Engineer. The Contractor shall obtain all the necessary permits and/or authorizations needed to store, test, transport and dispose of the water in accordance with applicable local, state, or federal regulations.

1.5 General Notes

All transport vehicles used for the movement of regulated sediments or water shall meet applicable local, state, and federal requirements. The Contractor shall maintain records, such as manifests, landfill tickets, daily logs, etc., to document the source, movement, and destination of each truckload of contaminated sediments and/or water. One copy of each of these records shall be submitted to the Engineer.

1.6 Basis of Payment

The Contractor shall furnish all the labor, equipment, and materials necessary to properly develop and comply with a SSHSP, and handle, store, test, transport, and dispose of regulated materials, including any required permits, approvals, or fees within the limits identified above. Payment for this work shall be made at the contract price bid per metric ton and cubic meters.

The following estimated quantity has been included in the General Summary for the work noted above:

Item Special - Work Involving Solid Waste, 50 MTON
690M65010

Item Special - Work Involving Regulated Water, 5 CU M

690M65024

Method of Measurement / Basis of Payment (202.12 and 202.13)

In general, when the Contractor must remove an item in order to perform other work, then there should be a separate pay item for the removal. For example, when the contractor must saw cut sections of the pavement and curb and gutter in order to excavate and install a pipe, then there should be pay items for Pavement Removed and Curb and Gutter Removed. In this example, there should also be pay items for the new pavement and curb and gutter. However, if the Contractor damages the roadway, pavement, or other items due to his own negligence, then the Contractor must repair or replace the item at no expense to the Department.

Project File Requirements

Regulated waste work may be inspected and documented by the District Environmental Coordinator, District Hazardous Waste Coordinator, or Regulated Waste Project Engineer. When the inspection is performed by these individuals it will be denoted daily diary.

In addition, clearances or reviews need to be performed by other offices or individuals in the Department will be noted. These are as follows, District Office of Planning and Engineering, Office of Geotechnical Engineering.

Obtain a copy of the waste agreement from approved landfill or the property owner whose land was used for the waste area. Report all significant changes (Project).

Health and safety requirements (DEC, DHWC, or RWPE).

203 Roadway Excavation and Embankment

Introduction

After many years of solving soil and rock problems throughout the state, the author of this section can assure the reader of 'One Constant.'

"Soil and Rock Conditions Vary, Vary and will Vary Again."

The author could repeat this statement a hundred times throughout this manual and it would be a hundred times too few.

Earthwork consists of roadway excavations (cuts) and roadway embankments (fills) for highways and associated items of work. Earthwork includes all types of materials excavated and placed in embankment, including soil, granular material, rock, shale, and random material. Associated items of work, include preparation of foundations for embankment, disposal of excavated material, borrow, preparation of the subgrade, proof rolling, rock blasting, base construction, and berm aggregate construction.

If pavement is to remain smooth and stable during years of service under traffic, the earthwork on which it is built must be stable and must furnish uniform support. Where roughness, settlements, and other distress develop in pavement during service under traffic, the cause often is a deficiency in the stability of earthwork that supports the pavement.

Uniformity of earthwork is necessary and important to obtain high stability and long-term performance at all locations throughout the length and width of the project. Consider, for example, a highway project where 95 percent of the earthwork was performed according to the specifications, but five percent was non-specification and low-stability material, which appeared in many small areas throughout the project. Pavement roughness and distress developed in these areas during service under traffic loading. Such a project would be evaluated by the traveling public as a rough job or a poorly constructed project. No notice or credit would be given to 95 percent of the work that was constructed properly. The entire project might be discredited and be considered poor because a small proportion of the project was constructed with poor earthwork construction procedures or practices.

The foregoing example is intended to illustrate the need for consistent compliance with earthwork specifications in all areas, both large and small, throughout the length of the project, and from the beginning to the end of earthwork construction.

Importance of Proper Embankment Construction

The embankments that ODOT constructs are structures. The success of these structures is directly proportional to the project's emphasis on correct embankment techniques.

The importance of proper construction practices cannot be overemphasized. The results of improper construction practices may or may not show up during construction. However, improper practices will eventually become evident at some point during the life of the embankment structure.

The construction requirements in the specifications are written to maximize the embankment structure's life. When the specifications are not followed, the life expectancy will decrease, and the future maintenance cost will increase.

The embankment structure is shown in Figure 203.A. The structure consists of four main components:

1. Foundation.
2. Embankment.
3. Subgrade
4. Pavement.

A geotechnical engineer ensures that the embankment will be stable as designed. The pavement is constructed on top of the embankment.

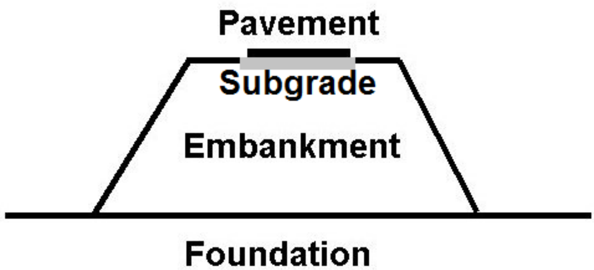


Figure 203.A – Embankment structure

The embankment that is shown in the plans structurally bridges the foundation and supports the pavement. The embankment is built by compacting layers of materials in horizontal lifts, as shown in Figure 203.B. These lifts consist of soil, granular material, rock, shale, asphalt, concrete, or recycled materials. The embankment's resistance to movement relies on the proper construction of these lifts. These lifts work together as a unit to resist the loads.

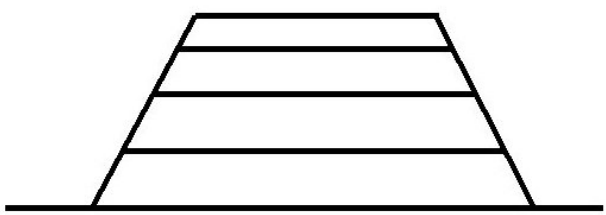


Figure 203.B – Embankment layers

A condition, such as the one in Figure 203.C, can occur if an embankment is not properly constructed. When this condition occurs, the factor of safety is less than 1.0 and the embankment fails.

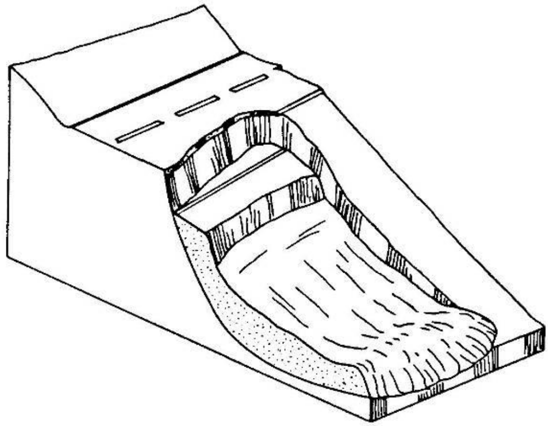


Figure 203.C – Embankment failure

A factor of safety is the ratio of the resisting forces divided by the driving forces, as shown in the following equation.

$$\text{Factor of Safety} = \frac{\text{Resisting Forces}}{\text{Driving Forces}}$$

Typically the minimum factors of safety for embankment structures are from 1.3 to 1.5. Figure 203.D illustrates the resisting and driving forces. The weight of the fill works to move the foundation and the embankment counter clockwise to the right. The internal strength of the embankment layers and the foundation work together to support the pavement. Failure may occur in a circular fashion as shown, in a semi-circle, in a block mode, or wedge. The basic principles are the same in all three modes of failure.

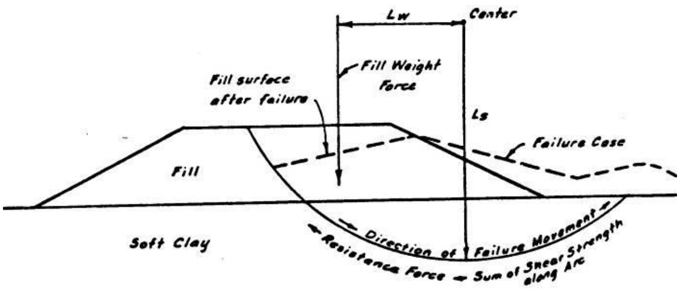


Figure 203.D – Resisting and driving forces for embankment failure

Importance of Proper Excavation

Proper excavation techniques in cut sections are just as important as embankment construction. The only difference is that when it fails, the rock or soil falls onto the roadway instead of the roadway failing.

This is illustrated in Figures 203.E-1 and 203.E-2. If a soil cut is cut too steep, then the soil can flow onto the roadway as illustrated in 203.E-1. This figure shows a deep-seated wedge failure. This failure can also occur in an embankment condition.

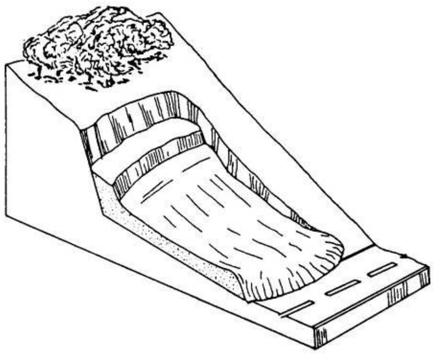


Figure 203.E-1 – Cut slope failure (deep seated wedge)

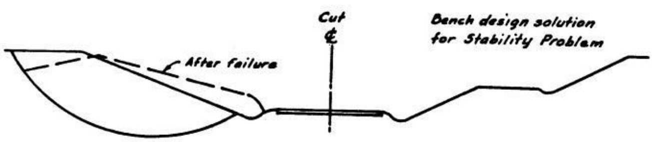


Figure 203.E-2 – Cut slope failure (rotational failed condition)

Figure 203.E-2 details a rotational failed condition on the left. The right side shows a design that is properly benching so that it reduces the driving forces. If a rock cut is cut too steep, the rock can fall onto the roadway.

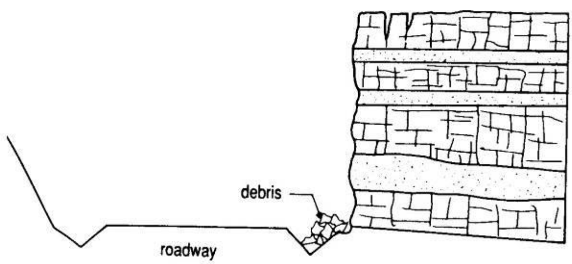


Figure 203.F – Falling debris from vertical or nearly vertical faces near roadway

The above rock and soil conditions can be avoided during the design or construction of a project. Ensure that the plan intent is followed in these cut locations on the project. Rock and shale excavations will be detailed under Section 208 Rock Blasting.

Materials (203.02)

In the 2002 version of the specification, the definitions and material requirements were changed for the different types of material allowed under the specifications.

In order to properly detail the requirements, it was necessary to divide up natural and recycled material requirements. Too many times in the past Contractors would try to obtain approval for materials that were not intended under the specifications.

A natural material is a material that was created by nature; a material that is mined or excavated and graded is a natural material. A material that is chemically altered by a manufacturing process such as concrete, asphalt pavement, fly ash, foundry sand, or slag is a recycled material.

Materials are defined in 203.02. All of the allowed materials are detailed in 203.02.R as “Suitable Materials.” Specific, more detailed material requirements are located in 703.16.

In the following sections the materials will be detailed in the specific 203.02 sections for clarity.

If there is any doubt on the condition, status, acceptability, or approval of the materials throughout the following sections, then the project should contact one of the following: the District Testing Engineer, the District Geotechnical Engineer, the State Construction Geotechnical Engineer, the Aggregate Section of the Office of Materials Management, or the Office of Geotechnical Engineering.

Natural Soil (203.02.I)

The definition for natural materials in 203.02.I is as follows: “All natural earth materials, organic or inorganic, resulting from natural processes such as weathering, decay, and chemical action.”

Allowable materials are materials such as clay, silt, sand, or gravel. These are allowed as suitable materials and are further defined in 703.16.A.

Department Group Classifications A-4a, A-4b, A-6a, A-6b, and A-7-6 are allowed. All of these materials are fine grained and have more than 35 percent of the particles passing the No. 200 sieve. More detail can be found by examining Figure 203.G. These classifications are further defined on the right side of the chart under Silt-Clay Materials.

Materials must have a maximum dry density of at least 90 pounds per cubic foot (1450 kg/m^3). Materials that are less than this density usually have too much organic matter or clay materials.

Soils that have a liquid limit in excess of 65 or identified as Department Group Classifications A-5, or A-7-5 are not allowed. The A-5 material is highly elastic by virtue of its high liquid limit. The A-7-5 material is highly elastic and subject to volume change.

Natural Granular Materials (203.02.H)

These materials are defined in 203.03.H as follows: “Natural granular materials include broken or crushed rock, gravel, sand, durable siltstone, and durable sandstone that can be placed in an 8 inch (200 mm) loose lift.”

These materials are allowed in 203.02.R, Suitable Materials. The material requirements are further detailed in 703.16.B and 703.16.C.

Under 703.16.B, Department Group Classifications A-1-a, A-1-b, A-3, A-3a, A-2-4, A-2-6, or A-2-7 are allowed. All of these materials generally are mixtures of coarse and fine grained materials. These materials have less than 35 percent of the particles passing the No. 200 sieve. More detail can be found by examining Figure 203.G. These classifications are further defined on the left side of the chart under Granular Materials.

Granular material classified as A-2-5 is not allowed because of its low weight, high optimum moisture, high LL, low PI, and its propensity to slough.

Section 703.16.C allows durable sandstone and durable siltstone. If these materials meet the slake durability requirements in ASTM D 4644, then the material is considered equivalent in strength and durability to other natural granular materials.

Section 703.16.C allows slags and recycled portland cement concrete to be used as granular material types.

Contact the Office of Geotechnical Engineering to arrange for the appropriate materials testing if sandstone or siltstone is used for this application.

General Classification	Granular Materials								Silt-Clay Materials						
	35 percent or less of total sample passing No. 200 (75 µm)								More than 35 percent of total sample passing No. 200 (75 µm)						
Group Classification	A-1		A-3 [1]		A-2				A-4		A-5	A-6		A-7	
	A-1-a	A-1-b	A-3	A-3a	A-2-4	A-2-5	A-2-6	A-2-7	A-4a	A-4b		A-6a	A-6b	A-7-5	A-7-6
Sieve analysis, percent passing:						*				**	*			*	
No. 10 (2 mm)	50 max														
No. 40 (425 µm)	30 max	50 max	51 min	[2]					[3]	[4]					
No. 200 (75 µm)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	35 max	36 min	50 min	36 min	36 min		36 min	
Characteristics of fraction passing No. 40															
Liquid limit	—	—	Non-	—	40 max	41 min	40 max	41 min	40 max		41 min	40 max		41 min	
Plasticity index	6 max	6 max	Plastic	6 max	10 max	10 max	11 min	11 min	10 max		10 max	11 – 15	16 min	≤LL-30	>LL-30
Group Index	0						4 max		8 max		12 max	10 max	16 max	20 max	
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Sand	Silty or clayey gravel and sand				Silty soils			Clayey soils			
General rating as subgrade	Excellent to good								Good to fair						

Notes

With the test data available, the classification of a soil is found by proceeding from left to right on the chart. The first classification that the test data fits is the correct classification.

* A-2-5 is not allowed under 703.16.B. A-5 and A-7-5 is not allowed under 703.16.A. See "Natural Soil and Natural Granular Soils" (203.02.H) in this manual

** A-4b is not allowed in the top 3 feet (1.0 m) of the embankment under 203.03.A.

[1] The placing of A-3 before A-2 is necessary in the "left to right" process, and does not indicate superiority of A-3 over A-2.

[2] A-3a must contain a minimum 50 percent combined coarse and find sand sizes (passing No. 10 but retained on No. 200, between 2 mm and 75 µm).

[3] A-4a must contain less than 50 percent silt size material (between 75 µm and 5 µm).

[4] A-4b must contain 50 percent or more silt size material (between 75 µm and 5 µm).

Figure 203.G – Department soils classification chart

Identifying Soil and Granular Materials in the Field

It is sometimes necessary to make field decisions based on very little (if any) laboratory soils information. It may be necessary to verify the accuracy of plan soil borings in the field. In these two cases, and on other occasions, it is important to have a basic understanding of how to identify types of soils and granular materials in the field. The following are some, but certainly not all, of the methods that can be used to identify these materials in the field.

Granular Soils

Granular soils are easily identified by their particle size in the field. A sample may be taken inside and spread on a table to dry. A rough estimate of the material retained or passing each sieve may be obtained by examining the material when dry. Finer materials such as clays and silts cannot be separated and can only be distinguished between one another by a settling technique. This can be accomplished by using a hydrometer or by performing a crude settling test. This technique is beyond the scope of this manual.

Fine Grained Soils (Clays and Silts)

It is more important, yet harder to distinguish between a clay and silt material in the field. Clays and silts should be treated and used differently in the field because of their difference in engineering and compaction properties. Refer to properties of soils in the next section.

A clay material can be easily rolled into a thread at a moisture content near, or above, the plastic limit of the material. Clays can often be rolled into 1/8 inch (3 mm) diameter threads (about half the diameter of a pencil). See the plastic limit test later in this manual for further information. As the clay content increases, the thread may be easier to roll into smaller sizes. No matter what the soil content is you cannot roll a pure silt material into a 1/4 inch (6 mm) thread.

Clay forms hard pieces that cannot be broken by hand pressure when it is dry. Place an irregular piece of dry soil between the index finger and the thumb, and try to break the material. If the material is difficult or impossible to break, it is probably clay. A silt or sandy material will generally break easily with this amount of hand pressure.

Clay fines are generally greasy, soapy, and sticky. Wet clay dries much slower than silt.

When performing these hand techniques, observe the soil residue found on your hands for further information. If the soil on your hands is difficult to remove, and the hands need to be rubbed briskly together to remove the soil, the material is probably clay. A silt material is easily removed when hands are rubbed together.

A silt material will react to vibration or shaking. Place a small amount of pliable soil in your hand. Hold the material in one hand and drop that hand on the other hand or a hard surface. Water will form on the surface of a silt material. You can also put the soil in a bowl and tap it on a table to get the same result. Clay will not react to this test.

The aforementioned identification techniques should not replace classification by the laboratory, but should be used as a supplement.

If there is any concern, send a sample to the District Testing Engineer for further classification.

Engineering Properties of Soil and Granular Materials

The following are general statements regarding the engineering properties of soil and granular materials. Consider these properties when solving field problems.

Properties of Granular Soils

1. Good foundation and embankment material.
2. Not frost susceptible, if free draining.
3. May erode on embankment side slopes.
4. Identified by the particle size.
5. Easily compacted when well graded.

Properties of Fine Grained Soils

1. Often have low strengths.
2. Plastic and compressible.
3. Lose part of their shear strength when wet or if disturbed.
4. Practically impervious.
5. Slopes are prone to slides.

Properties of Silts

1. High capillary action and frost susceptible.
2. No cohesion and non-plastic when pure silt.
3. Highly erodible.
4. Difficult to compact.
5. Release water readily when vibrated.
6. Acts like an extremely fine sand during compaction.

Properties of Clay as They Relate to Silt

1. Better load-carrying qualities.
2. Less permeable than silt.
3. Easier to compact than silt. (Any soil is easier to compact than silt.)
4. More volume change potential.
5. Plastic or putty-like property.
6. Clays are weaker when compacted wet of optimum.

Moisture Effects on Soils

Granular soils are less affected by moisture content than clays and silts; have larger voids; and are free draining. Granular materials have relatively larger particles than silts and clays.

Moisture content (also called water content) has a large effect on the physical properties of fine-grained soils. The Atterberg Limits are used to describe the effect of varying moisture contents on the consistency of fine-grained soils. See Figure 203.H.

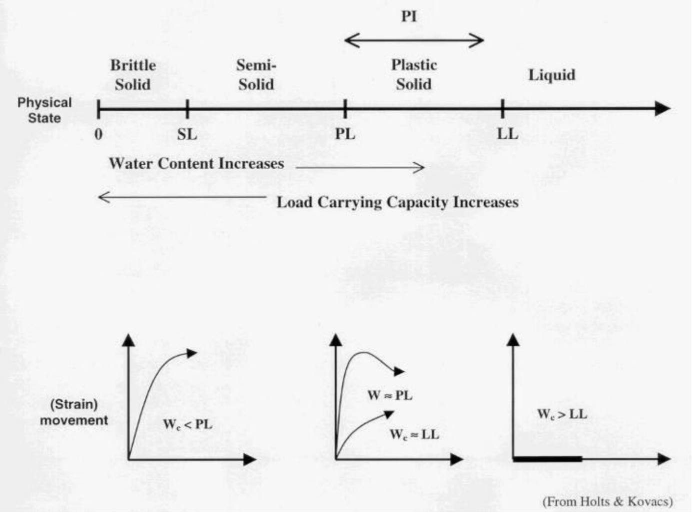


Figure 203.H – Atterberg Limits

The plasticity index (PI) is used to classify soils. The plasticity index is calculated by subtracting the plastic limit (PL) from the liquid limit (LL) (e.g. PI = LL – PL). The liquid limit and plastic limit are the moisture contents at the condition of the test.

Liquid Limit

1. Transition between the plastic solid and liquid state.
2. At liquid limit of 100 the soil contains equal weights of soil and water (i.e., Wc = Ww/Ws = 50/50).
3. At liquid limit of 50, the soil is 2/3 soil and 1/3 water (example Wc = 33/66).
4. High liquid limit indicates soils of high clay content and low load carrying capacity.

Plastic Limit

1. Transition between semi-solid and the plastic solid.
2. The soil condition, when it contains just enough moisture to be rolled into a 1/8-inch diameter thread without breaking, just starts to break-up.
3. Governed by the clay content.
4. The greater the clay content, the higher the plasticity (PI = LL – PL) and cohesiveness.
5. Load carrying capacity increases rapidly as the moisture content decreases below the plastic limit.

The following is a brief description of the characteristics of soils in the physical states.

Liquid Soil State Characteristics

1. Highly saturated state.
2. Flows under its own weight.
3. Very little or no friction between the particles.

Plastic State Characteristic

1. Soil can be remolded into various shapes.
2. Like modeling clay.

Semi-Solid Soil State Characteristics

1. No longer pliable.
2. Sample will crumble when rolled.

Brittle Solid Soil Characteristics

1. Soil ceases to change volume due to the loss of water.
2. No real engineering application.

Detailed Soil Property Explanation

Each term used in geotechnical engineering has specific meaning and application. Each soil test has specific meaning and application and indicates certain soil properties. Using correct terminology will prevent confusion and misunderstanding.

Soil

Soils have properties that influence their behavior and value. The properties of soil will vary with gradation (composition), moisture content, vertical position in relation to the surface of the ground, and geographical location. The more common properties encountered and used in highway work are defined and discussed in Section 203.

Most soils were originally solid rock. Time and climate have broken the rock into progressively smaller particles. This can be shown in the laboratory by taking two or three pieces of gravel or stone and pulverizing them. First, sand-sized particles can be made, then silt-sized particles, and finally clay-sized particles. Chemical changes take place as nature reduces rock into finer particles; therefore, clay produced by nature over a period of many years will vary from clay-sized material produced in a short time in a laboratory.

Particle Size

By naming and defining the size of soil particles, all soil tests are placed on a common ground for comparison. The amount of soil retained or passing each sieve is one of the major tools used to judge, analyze, and classify soil.

The quantities of each are determined by a laboratory analysis that separates the soil into groups of particle sizes. The standard methods of test prescribed by AASHTO T-88 and ASTM D-422 have been used widely in highway engineering and are used by the Department.

The distribution of particle sizes larger than 0.074 mm retained on the No. 200 (75 µm) sieve is determined by sieving, while the distribution of particle sizes smaller than 75 µm is determined by a sedimentation process, which uses a hydrometer to determine the necessary data.

Size definitions used by the Department are the same as definitions used by AASHTO T-88 with the exception of clay:

Component		Size
Boulders		Larger than 12 inches (300 mm)
Cobbles		3 to 12 inches (75 to 300 mm)
Gravel	Coarse	¾ to 3 inches (19 to 75 mm)
	Fine	#10 sieve to ¾ inch (2 to 19 mm)
Sand	Coarse	#40 sieve to #10 sieve (0.42 to 2.0 mm)
	Fine	#200 sieve to #40 sieve (0.074 to 0.42 mm)
Silt		0.005 to 0.074 mm
Clay		Smaller than 0.005 mm

Texture

The amount of each soil type (i.e., boulders, cobbles, silt, and clay) contained in a soil mixture determines its texture or feel. Soil classifications by texture must not be confused with soil classifications for engineering purposes. Sometimes these classifications are similar, but other times they may be different. The amount of each soil type in a soil mixture is determined by laboratory tests. The test results are then compared with texture definitions in order to determine texture name.

Soil texture is classified after its sieve size is determined. It is possible to make approximations of texture by the feel of moist soil when rubbed and ribboned between the thumb and index finger.

The texture of soil tells a lot about the soil. Using texture classification, approximations and estimations can be made of soil properties, such as bearing value, water-holding capacity, probability to frost heave, permeability, etc.

Soil Components (Major and Secondary)

It is the practice of the Department to describe soil components and texture of a soil as follows:

Major Components

Major components are described as gravel, sandy gravel, gravelly sand, sand, silty sand, clayey sand, sandy silt, silt, clayey silt, silty clay or clay. More than 35 percent of the total sample is required in order to classify a major component. Where two words are used to describe the major component, the second word describes the greater quantity.

Examples: Sand predominates in silty sand while silt predominates in sandy silt.

Secondary Components

Descriptions of secondary components are preceded by the term listed below, according to the percent of total sample indicated:

Term	Percent of Total Sample
Trace	0 to 10
Little	10 to 20
Some	20 to 35
And	35 to 50

Examples of material texture descriptions based on component test results are as follows:

Material Components	Texture Description
Sand 30%, silt 55%, clay 15%	"sandy silt with little clay"
Sand 8%, silt 55%, clay 37%	"silt and clay with trace sand"
Gravel 20%, sand 68%, silt 12%	"gravelly sand with little silt"
Gravel 2%, sand 12%, silt 42%, clay 38%	"silt and clay with little sand, trace gravel"

Internal Friction

Internal friction is defined as the resistance to sliding within the soil mass. Gravel and sand impart high internal friction and the internal friction of a soil increases with sand and gravel content. For sand, the internal friction is dependent upon the gradation, density, and shape of the soil particle, and is relatively independent of the moisture content. Clay has a low internal friction, which varies with the moisture content. A powder-dry, pulverized clay has a much higher internal friction than the same soil saturated with moisture since each soil particle can slide on adjoining soil particles much more easily after it is lubricated with water.

Various laboratory tests have been devised to measure internal friction. It is defined as the angle whose tangent is the ratio between the resistance offered to sliding along any plane in the soil and the component of the applied force acting normal (perpendicular) to the plane. Values are given in degrees. Internal friction values range from 0 degrees for clay, just below the liquid limit, to as high as 34 degrees or more for a dry sand. Very stiff clay may have a value of 12 degrees.

The governing test should be based on the most unfavorable moisture conditions that will prevail when the soil is in service. This "angle of internal friction" is not the same as the natural angle of repose or degree of slope on the soil in fills.

Cohesion

Cohesion is defined as the mutual attraction of particles due to molecular forces and the presence of water. The cohesive force in a soil varies with its moisture content. Cohesion is very high in clay but of little or no significance in silt and sand. Powder-dry, pulverized clay has low cohesion. However, as the moisture content is increased, the cohesion increases until the plastic limit is reached. The addition of more moisture reduces the cohesion. By partially over-drying wet clay, most free water is removed and the remaining moisture will hold the clay particles firmly together. This will give the soil such high cohesion that a hammer may be required to break the particles apart. These conditions are illustrated by the dry dirt road in summer that dusts easily, but carries large loads; the muddy, slippery road of spring and fall; and the hard-baked surface of a road immediately after summer rains.

Various laboratory tests have been devised to measure cohesion. Results are usually given in pounds per square foot (psf) or kilopascals (kPa) and may vary from 0 psf in dry sand and wet silt to 2,000 psf (96 kPa) in very stiff clays. Very soft clays may have a value of 200 psf (10 kPa). The governing test should be based on the most unfavorable moisture condition that will prevail during service.

Internal Friction and Cohesion

The stability and the structural properties of soil are determined largely by the combined effects of internal friction and cohesion. In most soils these combine to make up the

shearing resistance. The combined effects are influenced by other basic factors, such as capillary properties, elasticity, and compressibility.

All of these factors, plus the site on which the soil is located, determine the moisture content that will prevail in the soil in service. They also govern the load-carrying capacity of a soil, which is the primary concern. The clay-gravel road made up largely of gravel and sand, with a small amount of silt to fill voids, and a small amount of clay to give cohesion, illustrates a soil of high bearing value. This soil is produced by high internal friction due to sand and gravel and high cohesion due to clay. Clay illustrates a soil of low bearing value. When clay is wet, internal friction is negligible since no coarse grains are present, and cohesion is low since it has been destroyed by moisture. The same clay, air-dry, will have high bearing value due to high cohesion brought about by the removal of moisture.

Capillarity

Capillarity is defined as the action by which a liquid (water) rises in a channel above the horizontal plane of free water. The number and size of the channels in a soil determine its capillarity. This soil property is measured as the distance moisture rises above the water table and will range from 0 in some sand and gravel to as high as 30 feet (9 meters) or more in some clay soils. It often requires a long period of time for water to rise to the maximum possible distance in clay soils because the channels are very small and frequently interrupted, and the frictional resistance to water is great in the tiny pores.

Moisture in silt soils may be raised by capillarity only 4 feet (1 meter) or so. Since the capillary pores are larger than for clay, a larger quantity of water is raised in a few days rather than over a long period. Silts are considered to have “high capillarity” by geotechnical engineers because of this rapid rise of water. The capillary rise in gravels and coarse sands varies from zero to a maximum of a few inches.

Complete saturation of soil seldom occurs at the upper limits of rise in capillary moisture. Capillarity of a soil and the elevation of the water table under the pavement determine whether the subgrade will become saturated in this manner. Whether or not the subgrade becomes saturated from capillary action, or from condensation, seepage, etc., determines the bearing value of the soil to a considerable extent. Subgrade saturation by capillarity determines whether frost heave and similar occurrences in subgrade will create a problem requiring treatment for satisfactory performance in service.

Compressibility and Elasticity

Compressibility and elasticity are the properties of a soil that cause it to compress under load or compaction effort and to rebound or remain compressed after compaction. Most soils are compressible. Silty soils of the A-5 group are the most elastic of Ohio soils and make poor subgrades for pavements. Fortunately, A-5 soils are limited in occurrence in Ohio. The A-7 soils in Ohio are moderately elastic, but do not present special problems in embankment or subgrade. A-4 soils are elastic under some moisture conditions, and sometimes present problems of stability during construction, but provide adequate support for pavements where good design and construction practices have been followed.

Soil elasticity measurement is determined by special tests that simulate moisture changes and loading conditions anticipated in the field.

Elasticity and Deformation of Soils

When heavy rubber-tire construction equipment moves over an embankment layer foundation of wet, fine-grained soil, some movement of the embankment surface occurs. Elastic movement occurs when a tire moves onto an area, the surface is deformed, and when the tire moves off the area, the surface rebounds, or springs back, with little or no permanent rutting of the surface. Cracking of the surface may or may not occur following this type of movement.

Cracking may occur in cases of pronounced elasticity. In the case of pronounced elasticity or deformation, there is displacement of surface soil to each side of the tire, which results in deformation, rupture, cracking, and rutting.

The magnitude of the elastic movement or deformation may depend on one or more factors:

1. Weight of equipment.
2. Size of tires.
3. Tire pressure.
4. Soil moisture.
5. Type of soil.
6. Depth of soil layer.
7. Stability of material underlying the soil layer being observed.

Some embankment elasticity and deformation is expected under construction equipment loading. Moderate movement of less than a 1/2 inch (13 mm) can occur with heavy equipment weighing around 35 tons on embankments of satisfactory stability. This moderate movement is not considered detrimental. Greater movement is likely on adequately stable embankments under very heavy equipment weighing greater than 35 tons. Except for specialized situations, such as soft foundation soil at shallow embankment depth, under the layer being observed, the greater movement due to these very heavy loads is not detrimental. In general, elastic or deformation movement under heavy or very heavy loads should be permitted if the moisture of the embankment is at least 2 percent below optimum.

Moisture control specifications are not intended to limit or restrict the use of very heavy construction equipment on embankment construction. The intent of the specifications is to limit the moisture to obtain a stable embankment.

The amount of elasticity and permissible deformation under any given load varies with job circumstances. For example, for the first layer over a soft, original ground embankment foundation, considerable movement under loaded construction equipment is inevitable due to the soft foundation material. The resistance to deformation is more critical in the top portion of embankment, near the subgrade, than in lower portions of the embankment. If the lower embankment layers are low-stability material, such as wet silt, elasticity and deformation of the lower embankment layer must be closely monitored. This would not be necessary if successive embankment layers were made of high stability material, such as rock, shale, granular material, or dry soil.

Equipment which can be used successfully to test for embankment stability includes rubber-tired roller, grader, loaded scraper, or loaded truck. More movement is to be expected under very heavy equipment than under heavy equipment ordinarily used in highway work. When rubber-tire construction equipment, such as scrapers, graders, or rollers are being used over the entire general area during normal embankment construction operations, and observation shows no area of questionable stability; it is not

necessary to have a piece of testing equipment systematically cover the entire area to observe stability.

When the Engineer or Inspector questions or desires to check the stability of an area during embankment construction, they are authorized to require that the Contractor moves suitable equipment over the area to check for pronounced elasticity or deformation.

The determination of pronounced elasticity or deformation under the action of loaded rubber-tire construction equipment is based on the description given in the second paragraph of this section.

The administration of this requirement should be tempered with sound judgment backed by construction experience.

Shrinkage

Shrinkage refers to the apparent decrease in volume of a soil during its removal from the cut or borrow and its placement in the embankment. Shrinkage is caused by a greater density in the fill than in the cut or borrow area. Shrinkage is not accounted for nor contemplated in the design of the project.

The amount of shrinkage resulting from increased density in the embankment material may be estimated by using a volume or dry density basis.

Either one of the following equations can be used to calculate the Shrinkage Factor (SF).

$$\mathrm{SF} = \frac{\text{Excavated Material Volume}}{\text{Compacted Material Volume}} \qquad \mathrm{SF} = \frac{\text{Average Dry Density of Borrow}}{\text{Average Dry Density in Fill}}$$

Example of the use of a shrinkage factor:

$$\text{Payment adjustment} = \frac{[\text{Borrow or Cut}]}{\mathrm{SF}}$$

The adjustment due to shrinkage is only used where the material is measured in a borrow pit and the embankment is placed outside of the plan allowed tolerances. Due to specification and design changes, the use of borrow as a pay item should be minimized in the future.

Settlement and Scalping Losses

Losses due to scalping are usually insignificant as a percentage of the overall embankment construction quantities. Scalping losses of around 6 inches from the original cross-sections can be expected during construction. This is not compensated by the Department. If there is significant losses beyond this, it can be accounted for by taking cross-sections and then compensation should be made.

Settlement of the embankment foundation can be an area where the contractor can lose material that is not measured directly. It can be accounted for in the earthwork quantity calculations.

Losses due to settlement of the embankment foundation, where the foundation is compressible, can be calculated by using settlement platforms. A settlement platform,

or several platforms, can be placed on the foundation. The platform is measured throughout the life of the embankment construction. A settlement verses time curve can be used to determine the amount of additional payment that is due. See Figure 203.I.

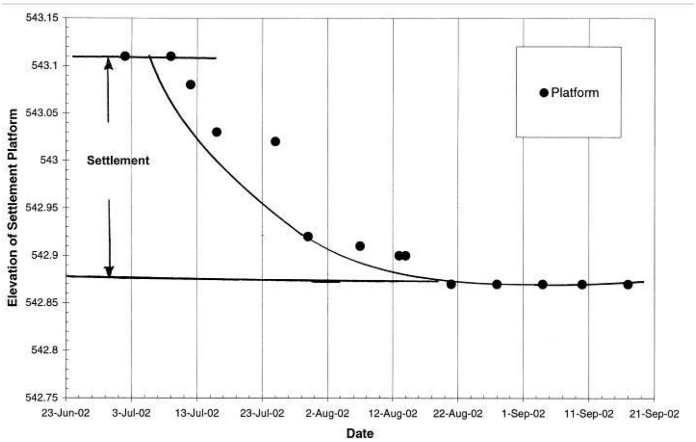


Figure 203.I – Settlement curve

The amount of settlement that occurred over the life of the embankment construction is a function of this Total Settlement Curve. To make the additional embankment payment, multiply the settled amount by the length and width of the settled area. This length and width should be calculated at the half height of the embankment in the affected area. Some judgment is required regarding the length of influence of individual or multiple settlement platforms.

Example of total settlement:

$$543.11 - 542.88 = 0.23 \text{ feet}$$

Permeability

Permeability is a property of soil that allows it to transmit water. It is defined as the rate at which water is transmitted by soils. Permeability depends on the size and number of soil pores as well as the difference in height of water at the point where it enters the soil and the point where it emerges. It is determined by tests on a representative soil sample and expressed as the coefficient of permeability, and it equals the velocity of water-flow in centimeters per second (cm/sec) under a hydraulic gradient of 1. A hydraulic gradient of 1 exists when the pressure head (or height of water) on the specimen in centimeters divided by the depth of the specimen in centimeters equals 1.

The permeability of a soil varies with factors such as void ratio, particle size and distribution, structure, and degree of saturation. The permeability of a particular soil will vary with the degree of compaction since this will influence the size of soil pores. A particular soil, loosely packed, will be more permeable then the same soil tightly packed. Nature produces these differences along with shrinkage forces that may be present by

surface freezing in winter (loosening a soil) and by repeated wetting and drying in the summer (consolidating the soil).

The coefficient of permeability, k, is used to determine the quantity of water that will seep through a given time and distance under a known head of water. It is calculated using the following equation.

$$k = \frac{QL}{HAt}$$

The equation can be rearranged to find the quantity of seepage, Q, as shown below.

$$Q = \frac{kHAt}{L}$$

Q	=	Quantity of water, in cubic centimeters (cm^3)
k	=	Coefficient of permeability, in centimeters per second (cm/sec)
H	=	Hydrostatic head, in centimeters
L	=	Thickness of soil, in centimeters, through which flow of water is determined under hydrostatic head H;
A	=	Cross-sectional area of material, in square centimeters (cm^2);
t	=	Time, in seconds (sec).

Tile can drain very porous soils, such as sands that have a k of 1.0 to 10^{-3} (0.001) cm/sec. Silty and clayey sand soils have a k of about 10^{-3} (0.001) to 10^{-7} (0.0000001) cm/sec. Highly cohesive clays have a k of less than 10^{-8} (0.00000001) cm/sec. It is difficult, if not impossible, to reduce the water content of soils by tile drains when the permeability coefficient is less than 10^{-3} (0.001). For earth dams, the U.S. Bureau of Reclamation classifies soil with k values approximately 10^{-4} (0.0001) as pervious and soil with k below 10^{-6} (0.000001) as impervious.

Soil Group classifications A-6a, A6b and A-7-6 are generally considered impervious.

Plastic Limit

The plastic limit (PL) of soils is the moisture content at which a soil changes from a semisolid to a plastic state. This condition is said to prevail when the soil contains just enough moisture that it can be rolled into 1/8 inch (3.18 mm) diameter threads without breaking. The test, ASTM D-424 or AASHTO T-90, is conducted by trial and error, starting with a soil sufficiently moist to roll into threads 1/8 inch (3.18 mm) in diameter. The moisture content of the soil is reduced by alternating manipulation and rolling until the thread crumbles.

Clay content controls the plastic limit. Some silt and sand soils cannot be rolled into 1/8-inch (3.18 mm) threads at any moisture content; these have no plastic limit and are termed non-plastic. The test is of no value judging the relative load-carrying capacity of non-plastic soils.

A very important change in load-carrying capacity of soils occurs at the plastic limit. Load-carrying capacity increases very rapidly as the moisture content is decreased below the plastic limit. On the other hand, load carrying capacity decreases very rapidly as the moisture content is increased above the plastic limit.

Liquid Limit

The liquid limit (LL) is the moisture content at which a soil passes from a plastic to a liquid state. The test, ASTM D-423 or AASHTO T-89, is performed by determining, for various moisture contents, the number of blows of the standard cup needed to bring the bottom of the groove into contact for a distance of more than 1/2-inch (12.7 mm). These data points are then plotted and the moisture content at which the plotted line (called flow curve) crosses the 25 blow line is the liquid limit.

Sandy soils have low liquid limits of the order of 20. In these soils the test is of little or no significance in judging load-carrying capacity.

Silts and clays have significant liquid limits that may run as high as 80 or 100. Most types of clay in Ohio have liquid limits between 40 and 60.

High liquid limits indicate soils of high clay content and low load-carrying capacity.

Liquid limit can be used to illustrate the interpretation of moisture content as a percentage of the oven-dry weight of the soil. See an example in the previous section on liquid limit.

Plasticity Index

The plasticity index (PI) is defined as the numerical difference between liquid limit and plastic limit. Calculation details are included in ASTM D-424 and AASHTO T-90. The plasticity index gives the range in moisture contents at which a soil is in a plastic condition. A small plasticity index, such as 5, shows that a small change in moisture content will change the soil from a semisolid to a liquid condition. Such a soil is very sensitive to moisture unless the combined silt and clay content is less than 20 percent. A large plasticity index, such as 20, shows that considerable water can be added to the soil before it changes from a semisolid to a liquid.

When the liquid or plastic limit cannot be determined, or when the plastic limit is equal to or higher than the liquid limit, the plasticity index is considered non-plastic (NP).

The moisture conditions at the plastic limit and liquid limit, and the plasticity index, often are called the "Atterberg Limits" (named after Albert Atterberg, the Swedish agricultural scientist who developed the concept).

Detailed Description of the Soil Classification Groups

The following is a brief description of the materials in each classification group detailed in Figure 203.G.

Group A-1

The typical material of this group is a well-graded mixture of gravel stone fragments, coarse sand, fine sand, and a non-plastic or feebly plastic soil binder. However, this group may also include the same material without the soil binder.

Subgroup A-1a

This material predominantly consists of stone fragments or gravel, either with or without a well-graded soil binder.

Subgroup A-1b

This material predominantly consists of coarse sand with or without a well-graded soil binder.

Group A-3

The typical material of this group is fine beach sand without silty or clay fines or with a very small amount of non-plastic silt. The group also includes stream-deposited mixtures of poorly-graded fine sand and limited amounts of coarse sand and gravel. These soils are sometimes difficult to compact, similar to the A-4 group. The fineness of the material and the silt fines make stabilization difficult. See the group A-4 for further explanation.

Subgroup A-3a

This material consists of mixtures of coarse and fine sand with limited amounts of low plasticity silt.

Group A-2

This material consists of a wide variety of granular materials which borderline between Groups A-1 and A-3 and the silt-clay materials of Groups A-4, A-5, A-6 and A-7. It includes all materials containing 35 percent or less passing the No. 200 (75 µm) sieve which cannot be classified as A-1, A-3 or A-3a, due to fines content or plasticity (or both) in excess of the limitations for those groups.

Subgroups A-2-4 and A-2-5

This material consists of various granular materials containing 35 percent or less passing the No. 200 (75 µm) sieve and with a negative No. 40 (425 µm) portion which have the characteristics of the A-4 and A-5 groups.

This material consists of materials such as gravel and coarse sand with silt contents of plasticity indexes in excess of the limitations of Group A-1, and fine sand with non-plastic silt content in excess of the limitations of Group A-3. A-2-5 soils are unsuitable embankment material under 703.16.B because of its low weight, high optimum moisture, high LL, low PI, and its propensity to sloughing in service.

Subgroups A-2-6 and A-2-7

This material consists of materials similar to those described under Subgroups A-2-4 and A-2-5 except that the fine portion contains plastic clay which has the characteristics of the A-6 or A-7 group. The approximate combined effects of plasticity indexes in excess of 10, and percentages passing the No. 200 (75 µm) sieve in excess of 15, are reflected by group index values of 0 to 4.

Group A-4

The typical material of this group is a non-plastic, or moderately plastic, silty soil usually having 75 percent or more passing No. 200 (75 µm) sieve. This group also includes mixtures of fine, silty soil and up to 64 percent of sand and gravel retained on No. 200 (75 µm) sieve. The group index values range from 1 to 8, with increasing percentages of coarse material being reflected by decreasing group index values. The A-4 group soils

are usually very difficult to compact or stabilize. Minimizing the water content to obtain the required density and stability usually works. It is not unusual, nor is it a change in condition, to have difficulty in stabilizing or compacting these soils. This condition should be expected for this type of material.

Subgroup A-4a and A-4b

Subgroup A-4a contains less than 50 percent silt sizes. Subgroup A-4b contains more than 50 percent silt sizes. A-4b is only allowed 3.0 feet (1.0 m) below subgrade elevation because of frost heave potential. Both are susceptible to erosion.

Group A-5

The typical material of this group is similar to that described under Group A-4, except that it may be highly elastic as indicated by the high liquid limit. The group index values range from 1 to 12, with increasing values indicating the combined effect of increasing liquid limits and decreasing percentages of coarse material. This soil is unsuitable under 703.16.A for use as embankment material because of its elasticity.

Group A-6

The typical material of this group is a plastic clay soil which has 75 percent or more passing the No. 200 (75 µm) sieve. The group includes mixtures of fine clayey soil and up to 64 percent of sand and gravel retained on the No. 200 (75 µm) sieve. Materials of this group usually have high volume changes between wet and dry states. The group index values range from 1 to 16, with increasing values indicating the combined effect of increasing plasticity indexes and decreasing percentages of coarse material.

Subgroup A-6a and A-6b

Subgroup A-6a contains material with plasticity index of 15 or less. Subgroup A-6b contains material with a minimum plasticity index of 16.

Group A-7

The typical material of this group is similar to that described under Group A-6, except that it has the high liquid limit characteristics similar to that of group A-5, and may be elastic as well as subject to high volume change. The range of group index values is 1 to 20, with increasing values that indicate the combined effect of increasing liquid limits and plasticity indexes and decreasing percentages of coarse material.

Subgroup A-7-5

Includes those materials with moderate plasticity indexes in relation to liquid limit and may be highly elastic as well as subject to considerable volume change. This soil is unsuitable under 703.16.A because of its elasticity.

Subgroup A-7-6

Includes those materials with high plasticity indexes in relation to liquid limit and are subject to extremely high volume change.

Slag Materials (203.02.Q)

Slags are by-products from manufacturing steel or iron. Under 203.02.Q, Air-Cooled Blast Furnace slag (ACBFS), Granulated slag (GS), Open Hearth (OH) slag, Basic Oxygen Furnace (BOF) slag, and Electric Arc Furnace (EAF) slag that meet the requirements in 703.16 are allowed under Item 203.

Air Cooled Blast Furnace Slag

Air Cooled Blast Furnace slag is a by-product from making iron. It is a very hard and durable aggregate, which contains visible holes. ACBFS may have a maximum dry density of approximately 80 lbs/ft^3 (1280 kg/m^3) and is lighter than most soils.

ACBFS can produce a green, yellow, white, or black runoff; the color is usually pH driven. This runoff can smell like rotten eggs and usually goes away in 6 months, but not always. The runoff may exceed the allowable limits under the Clean Water Act.

The potential for the runoff to exceed the Clean Water Act is based on the following factors:

1. The contaminate concentration of the ACBFS.
2. The permeability of the ACBFS.
3. The geometry of the in-place system. ACBFS next to an underdrain has a higher potential than ACBFS located in a fill surrounded by clay.
4. The amount of water flowing through the system.
5. Time of contact with the slag. Stagnant water around slag increases the potential for problems.

To minimize this problem in embankment construction, ACBFS must pass the Sulfur Leachate Test described in Supplemental Specification 1027. The manufacturers are required to certify that their material meets this requirement. Contact the District Testing Engineer or the Aggregate Section of the Office of Materials Management to verify that the material may be used.

Further details about the potential problems can be found in Other Wastes and Environmental Considerations in Section 202, Regulated Waste Requirements, of this manual.

Granulated Slag

Granulated Slag (GS) is a by-product of making iron or steel. GS is a slag that has been quenched with water during the cooling process instead of air-cooling. Most of the granulated slags are iron slags. If steel slags are quenched with water they may cause explosions. Steel slag has about 20 to 25 percent iron in the slag, while iron slag has less than 1 percent. It is a very light and brittle material, almost like powder in the pre-compaction condition. After compaction, it is very hard, durable, and almost impermeable. This material sets up like concrete in service. The maximum dry density can range from 50 to 90 lbs/ft^3.

Steel Slags

Steel slags are by-products of making steel. There are three kinds of steel slag defined in 203.02.Q: OH slag, BOF slag, and EAF slag. OH slag is the slag that was produced mainly pre-1970; however, some OH slag was made in the 1970's. BOF and EAF slags

are newer and faster processes for making steel; however, some BOF plants were in operation in the late 1950's.

The problems associated with steel slags are worse for EAF and BOF slags than for OH slag. The process for making OH slag is slower than the other two materials. This slower process allows more of the harmful chemicals to be burnt out of the OH slag. Consequently, OH slag is a better product for embankment applications.

Some steel slags can expand, clog up underdrains, or have a high pH runoff. The specifications were written to minimize these problems. Similar to ACBFS, the following factors were considered when writing the specification requirements:

1. The contaminate concentration (mainly MgO and CaO) of the steel slag.
2. The permeability of the steel slag.
3. The geometry of the in place system.
4. The amount of water flowing through the system.
5. Time of contact with the slag. Stagnant water around slag increases the potential for problems.
6. The load or weight on the material.

Further details can be found in Other Wastes and Environmental Considerations in Section 202 Regulated Waste Requirements. OH, BOF, and EAF slags may be used in embankment construction if the materials comply with Section 703.16.

Section 703.16 requires that OH, EAF, and BOF slag be blended with natural soil or natural granular material. For OH slag, the blend must be at least 30 percent natural soil or natural granular materials. For BOF or EAF slags, the blend must be at least 50 percent natural soil or natural granular material.

The OH, EAF, and BOF slag must also comply with Section 703.15, which states that the aging, stockpiling, deleterious substances, and crushing requirements of 703.14 apply.

OH, EAF, and BOF slag and blends are further restricted in 203.03.E and 203.03.F. These materials must be at least 1 foot (0.3 m) below the underdrains to minimize underdrain clogging. These materials cannot be used underwater because of the potential pH problems.

All of the above restrictions minimize the factors that can lead to expansion, clogged underdrains, or high pH runoff problems.

Granular Material Types (703.16.C)

These materials are granular materials having defined gradations that provide an engineering or designed need in the plans. In 703.16.C, the following kinds of material are allowed: limestone (crushed carbonate stone or CCS), gravel, ACBFS, durable sandstone, durable siltstone, GS, or blended natural soil or granular materials with OH, BOF, EAF, or RPCC.

Durability requirements for sandstone and siltstone were previously covered in this manual under Natural Granular Materials 203.02.H. The slag requirements were previously covered in, Slag Materials 203.02.Q, of this manual. RPCC will be covered later in this manual and must be blended similar to the slags. GS was previously covered and is not required to have a specific gradation.

Six different gradations, or types, are available for use in construction. Below is a general description of these materials:

1. Type A Granular Material has less than 25 percent passing the No. 200 (75 µm) sieve.
   a. Used as a general granular material with less fines.
   b. Probably going to get sand most of the time. Sand is less expensive and widely available.
   c. Gradation is too broad for bridging soft areas in the subgrade.
   d. Can be used to cover soft embankment foundations in thick lifts, such as in swamp treatment construction or with wick drains.
2. Type B Granular Material has the gradation of Items 304, 411, or 617, except 0 to 20 percent can pass the No. 200 (75 µm) sieve:
   a. Well-graded and stable material.
   b. Can be used to bridge soft subgrades or foundations.
   c. Must be drained to be effective.
   d. Unstable in the presence of free water.
3. Type C Granular Material has a top size of 3 inches (76 mm):
   a. It is well graded.
   b. Stable material and resistant to water influences.
   c. Can bridge soft areas better than Type B.
   d. Underdrains are difficult to construct through this material.
4. Type D Granular Material has a top size of 8 inches (200 mm):
   a. It is well graded.
   b. Stable material and resistant to water influences.
   c. Can bridge soft areas better than Type B or Type C.
   d. Underdrains cannot be constructed through this material.
   e. Consider placing geotextile fabric or 304 to prevent piping. (See Figures 203.J and 203.K)
5. Type E Granular Materials are very free draining and open materials:
   a. Coarse aggregates from No. l through 67 are used.
   b. Used to bridge areas that cannot be drained.
   c. Surround with geotextile (712.09, Type D) or Type B or C Granular Material to prevent piping. (See Figures 203.J and 203.K)
6. Type F Granular Material only has general requirements:
   a. Well graded material.
   b. Top size from 8 to 3 inches (76 mm) with a bottom size of No. 200 (75 µm) sieve.
   c. Evenly graded material between the top and bottom sizes.
   d. Compactable, stable, and serves the intended use.
   e. Almost never specified.
   f. Can mainly be used to accept materials that do not meet the specific requirements of Types A through E.

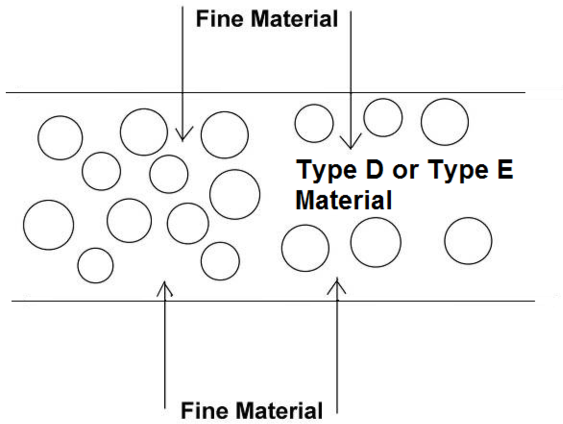


Figure 203.J – Fine material migration into open spaces in Type D or E

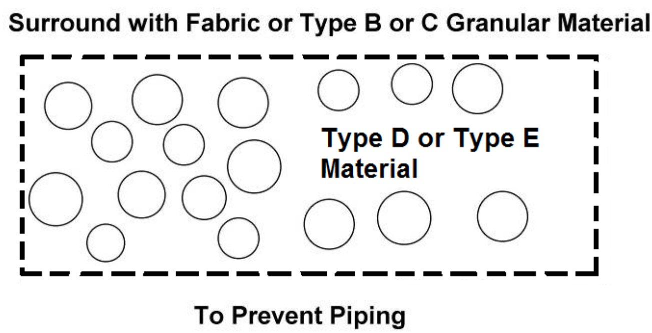


Figure 203.K – Preventing piping

Rock (203.02.O)

The following rock description is in the specifications: "Sandstone, siltstone, limestone, dolomite, glacial boulders, brick, and RPCC too large to be placed in an 8-inch (200 mm) loose lift." Rock fills are constructed differently than the construction of soil or shale fills; therefore, it is important to clearly identify them in the field.

Rock Identification

It is important to understand the differences in these materials and to have a basic understanding of their origins.

Almost all rock in the state of Ohio is sedimentary rock. Sedimentary rock is formed by cementation, precipitation from solutions, or by consolidation.

Sandstone is a deposition of sand from rivers, wind, or oceans. This material was cemented together under earth pressure or consolidation. Coarse sandstone can be

readily identified by the sand grains in the field. Fine-grained sandstone can be confused with siltstone or limestone.

Limestone is calcite formed from ocean deposits of sea organisms (seashells) that were cemented chemically and/or by pressure. Chert is similar to limestone, but it consists of silica minerals rather than calcite. Dolomite is limestone with magnesium and calcium carbonate.

Limestone or Dolomite can be readily identified by using a solution of diluted hydrochloric acid. When hydrochloric acid is dropped on the limestone or dolomite, the acid will fizz or bubble. The amount of fizzing depends on how much calcium is in the rock. A pure dolomite may not fizz unless the fines of the rock are tested.

Rock boulders are materials brought from Canada during the glaciers and can consist of just about any stone. The amount of earth pressure or chemical crystallization greatly influences the hardness of the stone.

Shale (203.02.P)

According to the specification, shale is defined as “A fine-grained sedimentary rock formed from the lithification of clay, silt, or mud. Shale has a laminated structure, which splits easily (is fissile). For the purpose of this specification, mudstone and claystone are also considered to be shale.” Laminated means that it is made up of thin layers or sheets. Fissile means that the layers are easily split apart.

The way we evaluate shale in the field has changed from earlier versions of the specification. In the past, shale was identified and compacted “as directed by the Engineer.” The current approach gives the Engineer a systematic approach to evaluate the shale to ensure long-term durability of the shale fill. It enables the Engineer to identify these materials and to distinguish between durable and nondurable shale.

Shale Identification (703.16.D)

Shale is a sedimentary material that consists of silt or clay particles. Shale was formed when earth pressure squeezed water out of silt and clay mud. Some shale may be crystallized or cemented together into a stone like form.

Shale is evaluated for durability as described below. The procedure is detailed in C&MS 703.16.D. It is commonly called the Bucket Test.

1. Obtain a piece of shale that is typical and representative of the rest of the shale. The size of the piece should be about 6 inches (150 mm). If a 6-inch (150 mm) sample is not available, then the shale is nondurable.

2. Place the piece of shale in a bucket of water. Examine the deterioration or slaking of the shale after 48 hours. If the shale has deteriorated, then the shale is nondurable.

3. If the shale has not deteriorated after being in water for 48 hours, then break down the shale over a 3/4-inch (19.0 mm) sieve by hand pressure. If 75 percent or less of the shale is retained on the 3/4-inch (19.0 mm), then the shale is nondurable.

4. If more than 75 percent of the shale is retained on the 3/4-inch (19.0 mm) sieve or, then perform a field test for durability. The field test for durability consists of compacting the shale with six passes of a steel drum roller which has a minimum compaction force of 500 pounds per lineal inch (57 kN/mm) of roller drum width. Ask

the contractor for documentation to verify the roller meets the compaction force requirement.

a. If more than 40 percent of the shale breaks down, by visual inspection, then the shale is nondurable.

b. If less than 40 percent of the shale breaks down, by visual inspection, then the shale is durable.

Different materials will always be mixed together in a fill situation. However, the durability test will give you a good indication of how the material should break down during compaction. It also provides a ready means to determine the test method to use for compaction acceptance. The compaction testing procedure for shale is described in Supplement 1015 Compaction Testing of Unbound Materials, but it is also summarized below.

1. For durable shale, treat it like Rock. This means compacting it according to C&MS 203.06.C. There is no compaction testing for durable shale.
2. For nondurable shale, if less than 25 percent is retained on the 3/4-inch (19 mm) sieve after the Bucket Test, then compact and test the shale the same as soil. This means using direct transmission mode of operation for the nuclear gauge and a one-point Proctor test for determining the maximum dry density. If the amount retained on the 3/4-inch sieve (19 mm) is between 10 and 25 percent, then also use an aggregate correction to determine the maximum dry density.
3. For nondurable shale, if more than 25 percent is retained on the 3/4-inch (19 mm) sieve after the Bucket Test, then compact and test the shale the same as granular material. This means using backscatter mode of operation for the nuclear gauge and a test section for determining the maximum dry density.

The color of the shale can be a good indication of the durability of the shale. Red shale in Ohio is always nondurable, while grey, green, and black shale is generally, but not always, nondurable. Most durable shale in Ohio is grey or green. Of course, the color of the shale is just a general guideline, and should never be used as the sole criteria for durability. The durability of shale will change depending on the project location and geologic formation.

Random Materials (203.03.L)

By definition, random materials are “Mixtures of suitable materials that can be placed in 8-inch (200 mm) loose lifts.”

Other Allowed Materials under 703.16 and 203.02

Asphalt Concrete (203.02.A and 703.16)

Recycled asphalt concrete (RAP) is allowed if the material is less than 4 inches and is blended with at least 30 percent natural soil or natural granular material. The mixing and maximum size requirements are used to minimize the effects of water on the asphalt consistency.

In addition, this material is restricted in 203.03.A & B.

Portland Cement Concrete (203.02.M and 703.16)

Recycled portland cement concrete (RPCC) is allowed if the material is blended with at least 30 percent natural soil or natural granular material. Additional mixing requirements are in 203.06.D when used as random material. This material is further restricted in 203.03.B, E & F. This material can clog underdrains and produce a lime rich, high pH runoff similar to steel slags as discussed earlier.

Petroleum Contaminated Soil (203.02.K and 203.03.J)

The use of Petroleum Contaminated Soil (PCS) is regulated by law. The legal contamination level of this material is listed in 203.03.J.

This material is usually found around underground storage tanks. The level of contamination is so low that you may not be able to see or smell the petroleum in the soil.

Section 203.03.J requires that an environmental consultant review the proposed use and test the material. Submit the report to the Chemical Section in the Office of Materials Management for approval.

Coal (703.16)

Coal is a very lightweight material and is not very durable. It is allowed in natural embankment materials when it comprises less than 10 percent of the blend. It is impossible to keep this material out of the fill on large earthwork construction projects.

Recycled Materials (203.02.N, 203.02.R and SS-871)

The specifications define recycled materials as fly ash, bottom ash, foundry sand, recycled glass, tire shreds, other materials, or manufacturing by-products not specifically named as suitable materials in 203.02.R.

The construction and acceptance details are in Supplemental Specification 871. These materials may have levels of contamination that must be controlled and regulated by law. Like all other materials ODOT uses, these materials are restricted and have certain engineering properties that must be accounted for in the specifications.

A general discussion of the specification is in Section 202, Regulated Waste Requirements, of this manual. All supplemental specifications can be found on the Division of Construction Management's webpage on the Department's website.

The specification requires environmental and geotechnical approval. Submit the environmental report to the Chemical Section in the Office of Materials Management for approval. The geotechnical report and materials acceptance is approved by the Office of Geotechnical Engineering.

Figure 203.L is a typical application of recycled materials. These materials are used in the inner core of the embankment structure. This controls the chemicals leachate and minimizes the detrimental engineering properties.

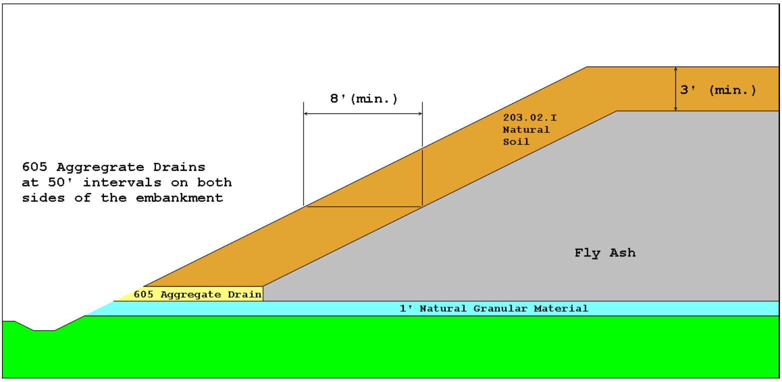


Figure 203.L – Typical cross-section for recycled materials

Restrictions (203.03)

Section 203.03 lists materials restricted by the specifications. These restrictions ensure that the embankment structural integrity is sound in the short- and long-term. Keep in mind that what seems to be a good product in the field may have serious long-term consequences once in place. Many of these restrictions were detailed in the previous sections in this manual.

Many embankment materials are allowed in several locations throughout the embankment structure. These allowable material types are further restricted in the top 2 to 3 feet of the embankment to ensure long-term structural integrity of the pavement.

Some of the general reasons for these restrictions are:

1. Water accumulates under the pavement and deteriorates the material.
2. Frost causes some materials to heave and break down to smaller pieces.
3. The load or stress at this location is higher.

General Construction (203.04)

This section details general information about earthwork construction. No explanation is needed for most of this section except for the following subsections.

Drainage and Maintenance of the Work (203.04.A)

It is vital to the embankment for the Contractor to maintain a well-drained construction operation. Contractors can provide proper drainage without an enormous effort.

Here is some relevant text from the specifications.

> *"Maintain a well-drained embankment and excavation operation. ... Construct the embankment with sufficient cross-slope to drain in case of rain."*

Maintained cross-slopes ensure that the rain runs off the embankment construction area instead of seeping into the embankment. It is difficult to remove water once it is in the embankment. Further embankment construction is compromised once the existing embankment is saturated.

Using a saturated embankment as a haul road can destroy the embankment structure and density. The following sentences are from the specification.

> *"If precipitation saturates the embankment construction, stay off the embankment construction until the embankment dries or stabilizes. Expedite the construction by removing the saturated embankment or dry the embankment by scarifying, plowing, disking, and recompacting the embankment."*

The specifications continue to give the project significant leverage to use with the following passage.

> *"Throughout the embankment construction operation and at the end of each day's operation, shape to drain, compact, and recompact the work area to a uniform cross section. Eliminate all ruts and low spots that could hold water.*
>
> *If using embankment construction or cut areas to haul on, continuously move the hauling equipment around on the area to take advantage of the compactive effort. Continually re-grade and compact the haul roads and maintain the construction according to 105.13 and 105.14."*

Contractors will use a multitude of excuses to avoid maintaining a well-drained embankment area. Some of them are legitimate and some are not. The project will have to use common sense in evaluating them.

Staged Construction (203.04.G)

Plans will often have fill restrictions that mandate the monitoring of the fill height. The plans may call for limiting the fill construction to 3 to 5 feet a week and may require waiting periods of 30 to 90 days.

In any case, these restrictions usually mean that the embankment will be constructed on a soft foundation. Limiting the load allows the foundation to consolidate slowly and allows the pore pressure to dissipate so that the embankment does not fail.

In many cases it is required that the project monitor the fill height, pore water pressure, and settlement versus time. Figure 203.N shows such a plot.

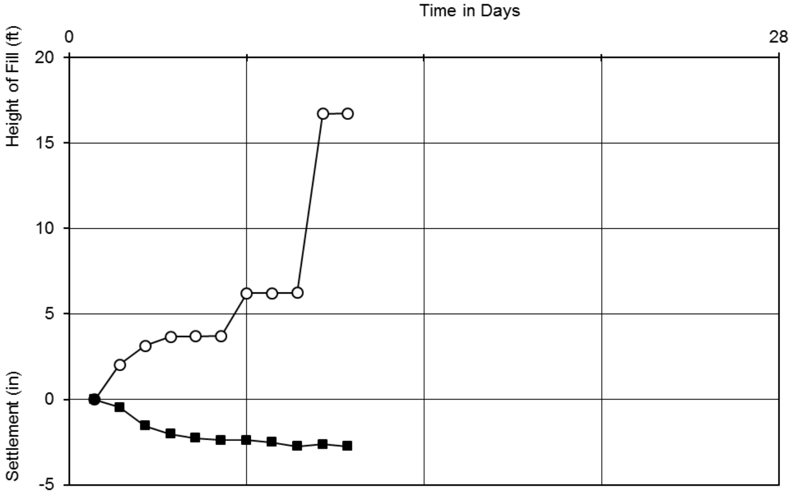


Figure 203.N – Settlement plot

On the horizontal axis is a plot of time, usually plotted in days. The vertical axis shows both settlement and the fill height. You can obtain a spreadsheet that will generate the settlement plot from the Office of Geotechnical Engineering.

The plans will usually specify a settlement waiting period. This is an estimate by the designer as to how long the settlement will take. However, the actual amount of time it takes for the foundation to settle under the new embankment load is dependent on the actual site conditions, and may be either more or less than the estimate shown in the plans. The standard plan note says that the Project Engineer may adjust the waiting period based on the settlement readings. As a general guideline, the settlement is usually considered complete when the settlement readings result in 1/8 inch or less of settlement over a week of time. The Contractor must include the plan specified waiting period in the construction schedule. If the waiting period ends up being shorter, then the Contractor can proceed ahead of schedule. If the waiting period ends up being longer, then the Contractor may be eligible for a time extension due to an excusable delay under C&MS 108.06.

The plans may also require monitoring of the pore water pressure in some cases. When the pore pressure readings exceed some threshold, the Contractor will have to suspend embankment construction until the pore pressures dissipate. The plan notes will give the pore pressure threshold, when to take baseline readings, and minimum reading schedule.

Embankment Construction Methods (203.05)

Foundation of Embankments

If you recall from Section 201.04, scalping is not required if the fill height is greater than 9 feet (3 m) and the existing slope is 8:1 or flatter. Both conditions must apply for the areas to be left un-scalped. Figure 203.O shows the conditions when scalping is required and when it is not.

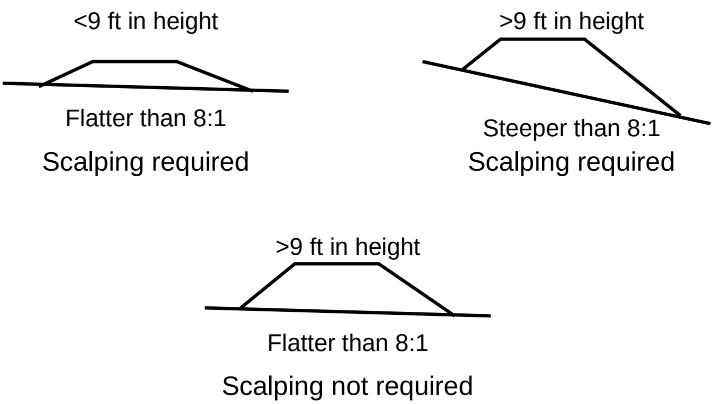


Figure 203.O – Scalping requirements

There is a minimum compaction requirement for all foundations that require scalping. The compaction requirement is 95 percent of standard proctor or 95 percent of the test section maximum value. This minimum value is easily achieved. An alternate method may need to be considered if density cannot be achieved.

Soft Foundations

Foundation conditions are occasionally encountered that require treatment to obtain stability either within or beyond what is proposed in the contract documents. These soft foundation conditions do not take into account the long-term settlement potential. The following details are to allow the project to correctly construct the embankment in order to ensure a stable embankment. There are two general conditions detailed below:

1. Moderately Soft Foundation:
    a. Low lying poorly drained areas with high moistures.
    b. Soil unstable due to extreme high moistures.
    c. Equipment rutting less than 12 inches (0.3 m).
    d. Elastic or pronounced elastic movement.
    e. All of the above are constructible with moderate changes.
2. Severely Soft Foundation:
    a. Peat deposits.
    b. Swampy areas that contain organic soil with high moisture.
    c. Underwater conditions.

   d. Buried equipment.
   e. Un-constructible with soil replacement.

The nature and degree of the foundation instability will vary considerably.

Moderately Soft Foundation

The first step in determining the proper treatment for a soft foundation and ensuring embankment stability is to determine and consider the following:

1. Planned embankment height above the foundation.
2. Allowed construction time frame.
3. Nature of the foundation material.
   a. Moisture content.
   b. Location of free water.
   c. Location of possible outlets for drainage.
   d. Extent in depth and area of unstable material.
4. Type of embankment material.

The following types of corrective measures have been used successfully for many years. Measures required to correct unstable foundations often are apparent when the cause and extent of the instability are known. The following sections consider three different, moderately soft conditions that can occur during construction.

Embankment heights greater than 12 feet (4 m)

The higher the fill height above the foundation, the better chance the project has in bridging over soft foundation locations with very little additional expense.

Section 203.05 allows the Engineer to increase the lift thickness to bridge soft foundation locations. The specifications refer to areas that do not support the weight of the trucks or hauling equipment (areas with less than 12 inches (305 mm) of rutting or a moderately soft foundation). For areas with more than 12 feet (4 m) of fill, this method should be the first alternative utilized.

Section 203.05 allows the following technique when placing material over the soft foundation:

1. Dump successive loads of material in a uniform lift.
2. Do not exceed the lift thickness required to support the equipment placing the material.
3. Manipulate, blade, distribute, level, and doze the material until the area is stabilized.
4. Once the bridging has been accomplished, construct the remaining lifts according to 203.06.

This is standard practice in soft foundation locations. Density controls during this initial construction are not required. If the soft foundation is just wet and does not have standing water, then soil dryer than optimum may be used.

If the foundation has standing water, consider placing construction underdrains or ditches to drain the soft areas (if the area can be drained). If the areas cannot be drained, then use rock, granular material, or hard durable shale in 1 to 3 foot lifts (0.3 to 1 m).

Observe the embankment stability once the bridging material is in place and make adjustments as required. Reevaluate the conditions when the embankment is 6 feet (2 m) below grade.

Embankment heights less than 12 feet (4 m), but more than 6 feet

Investigate the source of the problem. Evaluating foundation conditions is similar to evaluating the condition of a subgrade. Before determining the solution, first evaluate the foundation conditions by digging test pits, evaluating the soil borings and observing the rut depth.

Use the section, The Investigation, under Item 204 of this manual, Figure 204.G Subgrade Test Pit Investigation and Figure 204.H Subgrade Treatment Chart, to help evaluate the foundation.

Determine the average N_{60}, average HP, and rut depth values using the above sections. Evaluating soft subgrade and soft foundations is similar with a slight variation. If the soft material is less than 2 feet (0.6 m) in depth, remove it and replace with soil.

If the average HP > 0.5 tons/ft^2, average N_{60} > 5, and the rut depth is less than 6 inches (150 mm), then use an initial lift of soil that is about 1 to 3 feet (0.3 to 1 m) thick. The soil moisture should be less than optimum moisture.

Do not use soil to bridge areas with standing water or in conditions where some embankment has already been placed as in the previous section.

If the soil conditions are worse than these values or the rut depth is more than 6 inches (150 mm), then use an initial lift thickness of 1 to 3 feet (0.3 to 1 m) of rock, granular material, or hard durable shale.

If the slope allows the area to be drained, drain the soft foundation by using construction underdrains or ditches. Continue to evaluate the conditions when constructing the remaining fill and adjust when required.

Embankment heights less than 6 feet (2 m)

If the source of the problem has not been previously evaluated, then investigate the source of the problem as detailed in the previous section.

Determine the average N_{60}, average HP, and rut depth values. Again, evaluating soft subgrade and soft foundations are similar with slight variations.

To determine the correct fix, use the Subgrade Treatment Chart in Figure 204.H and find the correct undercut depth or stabilization depth.

Subtract the fill height from the recommended undercut depth to determine the required undercut depth in the foundation. See Figure 203.P

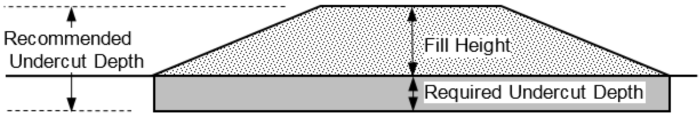


Figure 203.P – Fill undercut depth

Example:

Given:

New Construction Project
1.5 feet (0.5 m) of fill
HP=0.4 tons/ft^2, N_{60}=4 and Ruts > 9 inches (230 mm)
From Figure 204.H Subgrade Treatment Chart,
recommended undercut depth = 2.5 feet (0.75 m)

Solution:

Required undercut is 1 foot and place 2.5 feet (0.75 m) of Granular Material for the fill. As an alternative, consider stabilizing the foundation with cement or lime and then placing 1.5 feet (0.5 m) of stabilized soil.

Severely Soft Foundations

Severely soft foundations are conditions that cannot be constructed without using rock or granular material. These conditions usually are in standing water or even underwater. Construction equipment either gets buried in the areas or cannot operate in these locations. Peat deposits or swampy areas that contain organic soil with high moisture are the norm in these locations.

Unless these areas are called out in the plans, it is best to contact the District Geotechnical Engineer or the Office of Geotechnical Engineering to evaluate the depth and extent of the required undercut.

This section examines two different methods to remove and replace this soft material:

1. Total Excavation Method.
2. Partial Excavation and Displacement Method.

There will be plan notes associated with these methods. The following is a brief description of the construction methods of these two.

Total Excavation Method

Below is a cross-sectional view of the total excavation method. This method, as the name implies, is used to where all of the soft material can be removed down to a firm foundation.

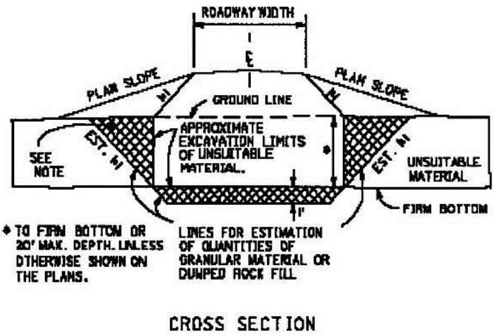


Figure 203.Q – Cross section view of a total excavation

The excavation and backfilling progresses across the soft foundation for depths up to 20 feet (6 m) deep or the reach of the track hoe. Below is a plan view of the same operation. The filling progresses at the same time as the excavation.

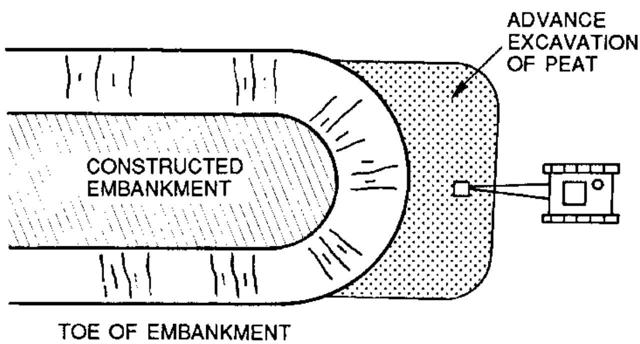


Figure 203.R – Plan view of the filling and excavation

Many times the excavation is performed on the same side as the filling, the embankment side, but this takes some coordination by the Contractor. Below is the longitudinal view of the same operation. The filling operation normally keeps the fill at least 1 foot (0.3 m) above the soft material or water level.

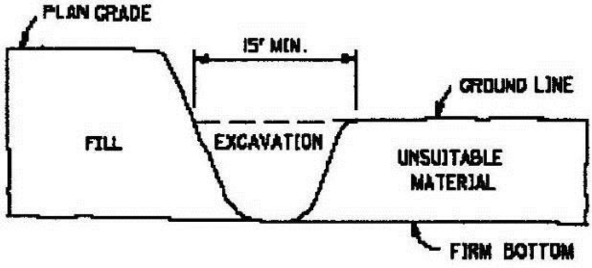


Figure 203.S – Longitudinal view of the total excavation

Partial Excavation and Displacement Method

At times it is economical to only remove portions of the soft foundation. The cross-section view is shown below.

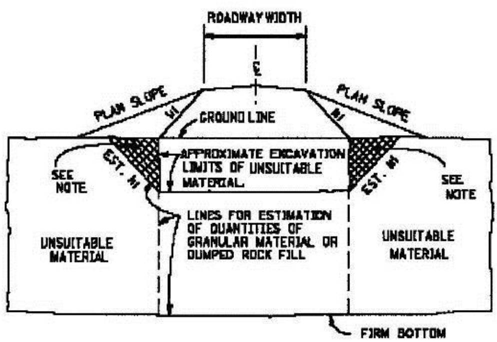


Figure 203.T – Partial depth removal

Below is a longitudinal view of the partial depth operation. A surcharge of material is required to displace the soft material forward as much as possible. The work needs to progress across the soft foundation such that soft material does not get entrapped in the replacement material. This is true for either full- or partial-depth replacement.

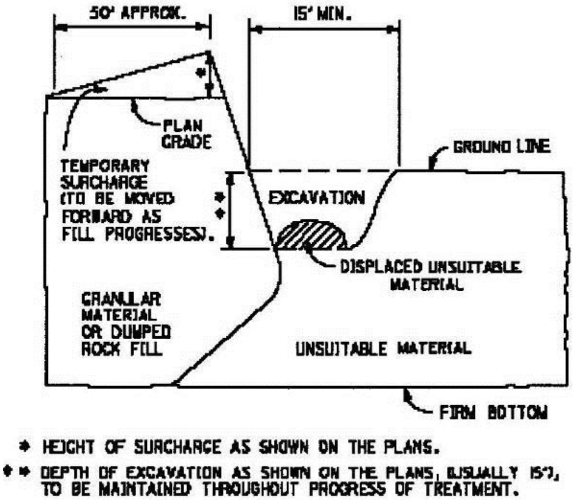


Figure 203.U – Longitudinal view of partial depth

In these operations, the plan will denote which method of excavation is to be used for the work. In the past, the volume of the work was very difficult to quantify. A new plan note has been developed to simplify this measurement. The designer will choose the type of replacement material that will replace the soft foundation material. Use a table similar to the one below to convert the weight of the replacement material to volume.

Table 203.A – Conversion factors for replacement materials

Granular Materials		Dumped Rock Fill	
Type	Tons/Cubic Yard	Type	Tons/Cubic Yard
A	1.6	A	1.9
B	1.9	B	1.9
C	1.8	C	1.8
D	1.8	D	1.7
E	1.6		

The replacement material may be granular material or dumped rock fill. Prior to the material being dumped into the soft foundation, weight tickets are taken to finalize the replacement quantities estimated in the plans.

After the quantities for the replacement materials, in tons, are known, the quantity is converted to cubic yards using the above table. This cubic yardage is used to determine the quantity of excavation to be paid. This simplifies the measurement of the material that normally cannot be measured directly in the field.

Materials

The material used for this operation may be granular material or rock fill types. Usually Granular Material Type C or D is used for these conditions. Dumped Rock is usually specified for depths greater than 10 feet (3.3 m). The project should check the potential for piping. See Figures 203.J and 203.K.

Disposal of Material

The unsuitable excavated material may temporarily be left in place or used for flattening adjacent slopes outside the plan lines. This material must either be shaped into the final slope or disposed of 2 weeks prior to paving the project.

Consolidation Method

There is another method to bridge a soft foundation. It is the consolidation method. It was mentioned in Section 203.04.G. It is beyond the scope of this manual but a typical cross-section is presented below.

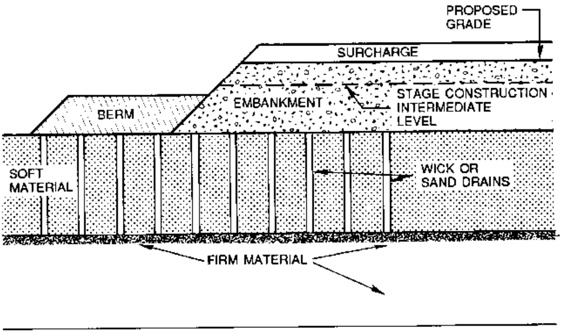


Figure 203.V – Consolidation method

A layer of sand is placed to bridge over the soft foundation usually around 3 feet thick. Wick drains are then placed through the foundation soils. These wick drains allow the pore pressure to dissipate faster as the fill is constructed.

Benching

Beginning with the 2002 C&MS, explicit language was put in the C&MS to ensure that benching is properly performed in the field. Figure 203.W details where benching is required. Benching is required for all embankments placed on or against a slope steeper than 8:1. Of course, the existing slope has to be scalped first. This applies to all embankment areas whether the existing embankment cross-slope is in the transverse or the longitudinal direction.

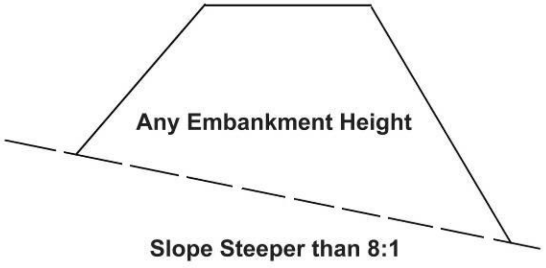


Figure 203.W – Benching required

Figure 203.X details the bench into the existing embankment. For side hill fills, the existing embankment is physically notched out and connected to the new embankment. Benching requires horizontal cuts in the existing slope.

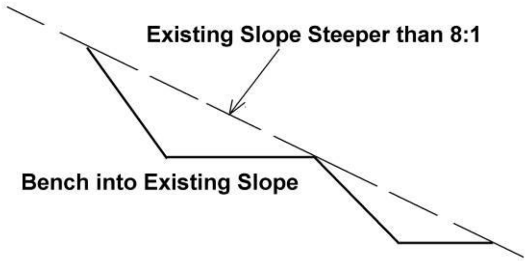


Figure 203.X – Benching

The bench needs to be wide enough to blend the new embankment with the existing embankment. In Figure 203.Y, the total width between point A and B must be the width of the dozer blade and the compaction equipment.

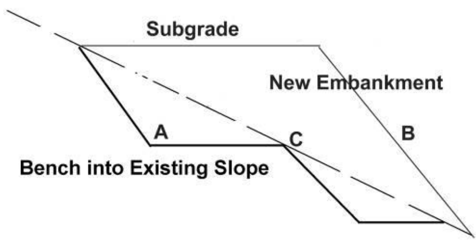


Figure 203.Y – Benching in new embankment

If the plan calls for a new embankment, or the distance between C and B is less than a blade width or about 8 feet, then the existing embankment must be benched in the difference, which is the distance from A to C.

In Figure 203.Z, the horizontal distance between points D and E is about 4 feet (1.3 m). Therefore, the existing embankment must be benched into about 4 more feet (1.3 m) to complete the bench.

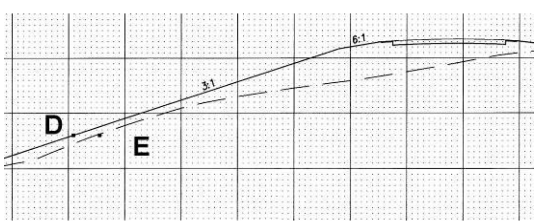


Figure 203.Z – Sliver fills

Bench into the slope as the embankment is placed and compact into layers. Begin each bench at the intersection of the existing slope and the vertical cut of the previous bench. The re-compaction of the cut materials is required.

Benching is nothing more than a side hill foundation. Benching knits two embankments together to ensure that a failure plane does not occur. Figure 203.AA details typical benching seen on some plans.

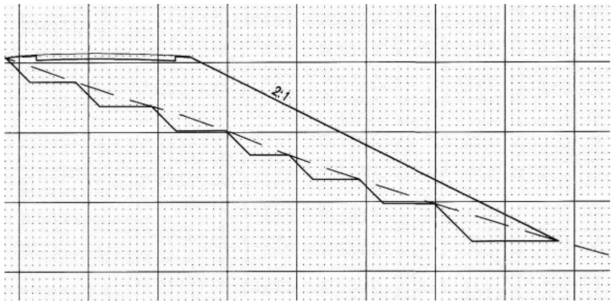


Figure 203.AA – Typical benching

In this case, the designer anticipated that there was a stability problem, or weak soils, in the existing embankment (or both). This is called special benching.

Side hill embankments present unique problems; they may be stable when originally constructed, yet become unstable later. The result is usually a landslide.

If the bench is not benched far enough into the existing embankment, a weak plane can develop as shown in Figure 203.BB. A failure may occur along this weak plane and the bench material will move laterally. The project should evaluate the existing soil conditions and determine if more benching is required than is shown on the plans or required by the specifications.

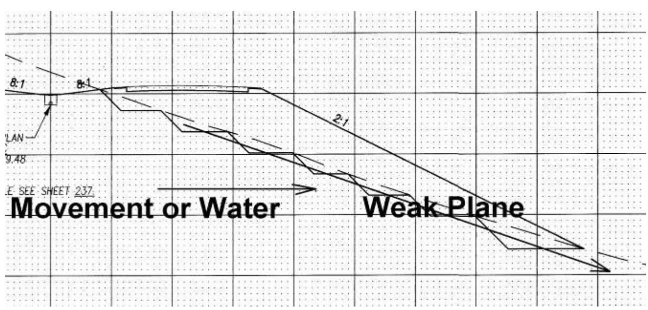


Figure 203.BB – Benching problems

Bench Drainage

In many cases, the main cause of an embankment benching failure is water related. Seeping water into the embankment from the side hill or foundation can cause considerable instability in the existing and the new embankment. Due to many factors, water is an elusive quantity to capture during the design phase. Notice in Figure 203.BB how water can move into the bench material and weaken it.

Special attention must be given to side hill embankments. Consult the plans and soil profile to see where special benching, if any, is required; to see whether or not spring drains are provided; and to see if any potential spring or wet zones are mentioned. The areas should be inspected in detail for possible springs. In dry seasons, green or lush

vegetation are often indicative of a semi-dormant spring that may become active during prolonged periods of precipitation. If spring zones are encountered, and no spring drains are provided in the plans, then drains should be added to the work.

If there is any indication of water, drainage should be added if it is not already detailed in the contract. The following pages detail typical solutions to use in the field.

Spring drains are detailed on the plan by plan note D109 and on the second sheet of Standard Drawing DM 1.1. Plan note D109 can be found in Location & Design Manual – Volume 2, *Drainage Design*. Links to the Location & Design Manuals and the standard drawings can be found on the Design Reference Resource Center on the Department's web site.

The standard drawing is partially shown in Figure 203.CC. The standard drawing does not call for it, but it is recommended to use non-perforated pipe outside the No. 57 stone and perforated inside the No. 57 stone. Wrap or coil the pipe inside the No. 57 stone for maximum efficiency. Completely wrap the No. 57 stone with Type A geotextile fabric. In many cases No. 8 stone can be substituted for the No. 57 stone without sacrificing much drainage capacity and it also reduces the risk of piping. The application of a spring drain is used for local wet spots.

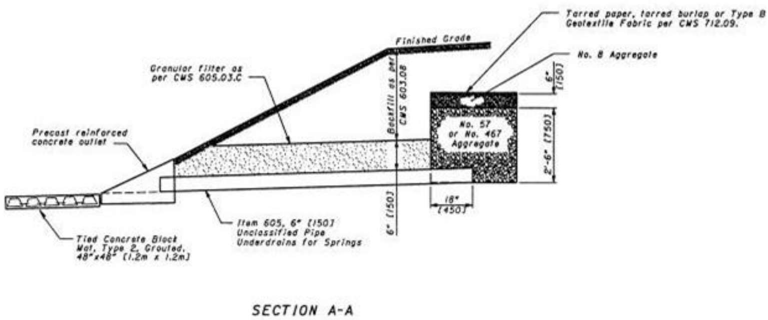


Figure 203.CC – Spring drains

Severe Bench Drainage Problems

Drainage always should be added when the benching embankment is placed next to a rock or shale cut. In this case, add drainage along the entire length and width of the shale/rock benching interface. Experience has shown that water always seeps from this interface. If a large quantity of water is coming into the bench, or water is seeping from several locations and elevations, drainage should be added across the entire bench face. In both examples above, a different approach needs to be taken due to the severity of the water issue. There are two potential solutions to the severe drainage problems.

Adding Drainage when Benching from the Top Down

If the slide repair benching plan has 1 to 1 back slopes and consists of minimum 10 foot wide and high benches and the slope can be excavated from the top of the cut all the way to the bottom, then the following drainage should be considered.

The use of geotextile fabric and No. 8 stone to take the water flow, as detailed in Figure 203.DD, is one solution to solve the drainage issue. The geotextile is used to stop the

migration of fines into the No. 8 stone. Notice that the geotextile fabric is used on both sides of the No. 8 stone to prevent migration from either side.

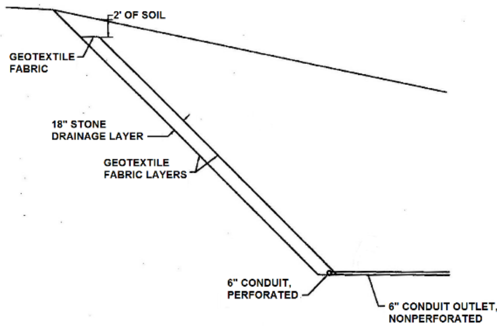


Figure 203.DD – Severe water problems in a bench

The geotextile fabric generally used is 712.09 Type A geotextile. The drainage aggregate can be No. 8, No. 9, or No. 89 size. The drainage pipe going into the page is a 6 inch, Item 605, 707.33 perforated pipe. The lateral outlet drain is a 6-inch, Item 611, Conduit Type F non-perforated. This lateral drain backfill should be surrounded by at least 12 inches (300 mm) of sand. This will provide a secondary outlet if the pipe gets clogged.

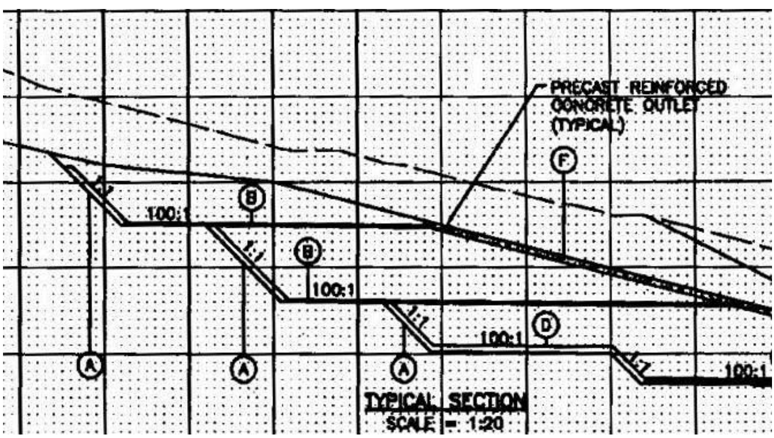


Figure 203.EE – Multiple bench layout

These benches can be interconnected and outlet as detailed in Figure 203.EE. Item A is the No. 8 stone and the geotextile fabric. Item B is the non-perforated outlet pipes that flow into an aggregate surface drain, Item F. Notice that the bench and the outlet pipe are using a one percent grade or 100:1 slope. This ensures that the water can effectively be removed from the system without seeping into the soil mass.

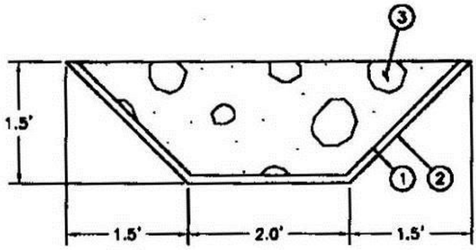


Figure 203.FF – Detail for aggregate surface drain F

Figure 203.FF details the outlet configuration. Item 2 is a 20 mil plastic to prevent the water from entering the soil along the slope. Item 1 details 712.09, Type D geotextile fabric, which serves to protect plastic from getting torn during rock installation. Item 3 details the Rock Channel Protection. In this case, the rock type was Type C. This rock type should be used in most cases.

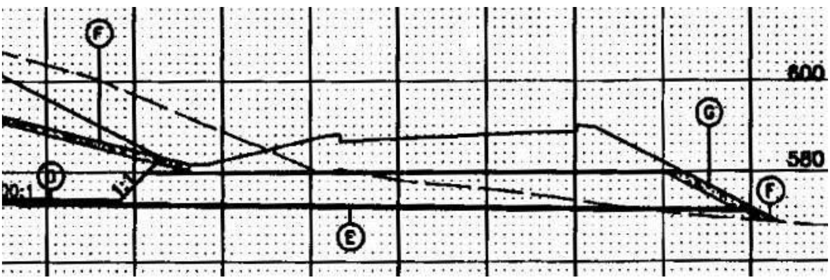


Figure 203.GG – Lower bench outlet

Figure 203.GG details the lower benching. In the above slide repair, the lower embankment was preexisting and did not require reconstruction, but the lower benches did need to be drained. The bench and pipe drainage into the page of the cross-section was sloped at a one percent grade. The slope of the outlet, Item E, from left to right is sloped at a one percent grade. The outlet pipe excavation was about 20 feet deep. This is a high risk operation during construction. If necessary, this construction can be done without trench boxes or laying back the slope. The trench is excavated in maximum 50 foot lengths. The pipe is jointed together above ground and dropped into the hole. Grade is kept by conventional methods or by GPS. In this case, sand is dumped in the trench up to an elevation 580. The sand should be hoe rammed in place in thick lifts. In this case, compaction requirements are secondary to the ability of keeping the trench from collapsing. Keep the open trench as small as possible and no personnel are to enter the trench during these operations.

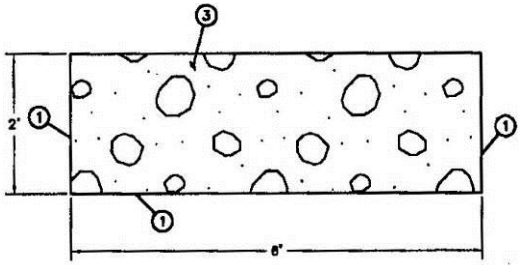


Figure 203.HH – Detail for slope protection G

After the outlet is constructed, the outer slope will be sand for about 6 feet wide. Item G in Figure 203.HH, details the erosion protection required. A 712.09 Type D geotextile (Item 1) is placed around Type C Rock Channel Protection (Item 3). The width of the material should be the width of the sand.

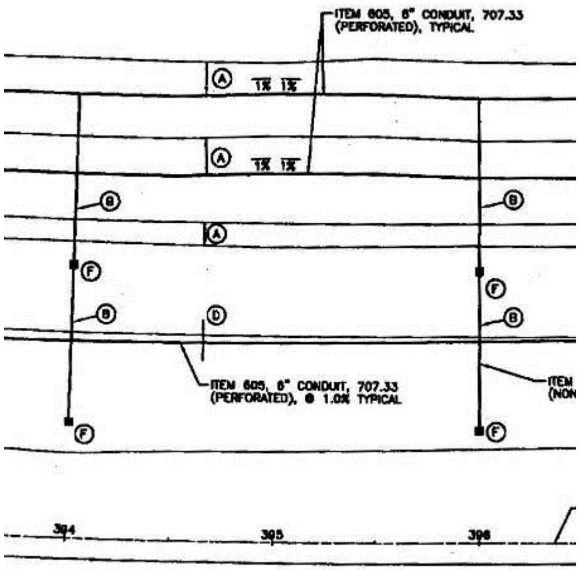


Figure 203.II – Top view of the drainage

Figure 203.II details the plan view of the drainage pattern in the slide repair. You will notice that the outlets are spaced at 200-foot intervals and the benches are sloped at a one percent grade toward them. Notice that the high point on the bench is 100 feet from the outlets and goes in both directions toward the outlets.

When the benching cannot be performed from the top down or the benches are small, another method of adding drainage to the benching plan needs to be considered. Figure 203.JJ, shows adding a 20-foot drainage trench to drain an upper, unstable slope (to the left) and to prevent the embankment from becoming saturated. The drainage into the page is sloped at a one percent grade.

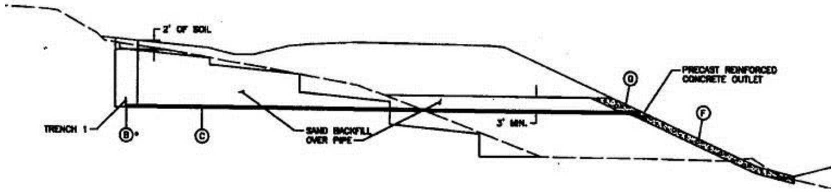


Figure 203.JJ – Using trenching and sand

Since this trench is around 20 feet deep it is a high risk operation during construction. If necessary, this construction can be done without trench boxes or laying back the slope. The trench is excavated in maximum 50-feet lengths. By keeping the trench length to a small interval it minimizes the potential for collapse or upper slope damage. The pipe is jointed together above ground and dropped into the hole. Grade is kept by conventional methods or by GPS. Sand is dumped in the trench approximately 3 feet below ground level. The sand should be hoe rammed in place in thick lifts. Compaction requirements are secondary to the ability of keeping the trench from collapsing.

In Figure 203.KK below, the above trenching technique is expanded to drain the entire counter berm. The drainage at the toe is provided by the rock fill while the three trench drains to the left drain at third point intervals along the existing new fill interface. The center two sand drains are placed at the interface of the existing ground and the new embankment. The construction of the middle two sand drains is slightly different than the other sand drain, but only slightly. The embankment is constructed to the top elevation of the sand trench and the sand trench, pipe, and outlets are constructed as previously described.

The sand that is generally used for these operations is asphalt, concrete, or masonry sand. There is a possibility that the soil will pipe into the sand or the soil will clog the sand. The possibility of this happening is considered a small risk and is beyond the scope of this manual.

In Figure 203.JJ, the pipe in Item B is perforated and wrapped with geotextile fabric to prevent the sand from piping into the pipe.

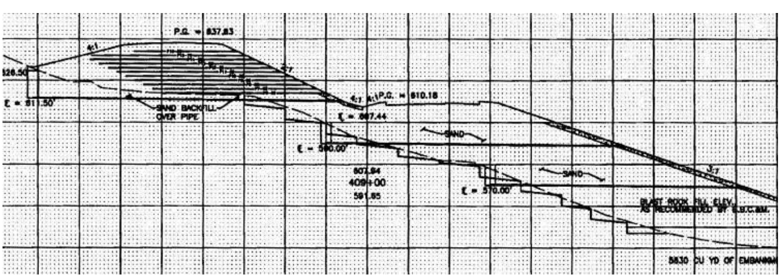


Figure 203.KK – Multiple benching with sand

Figure 203.LL details the plan view of the drainage system, which is similar to that previously detailed. The outlets are spaced every 200 feet and everything drains at a one percent slope.

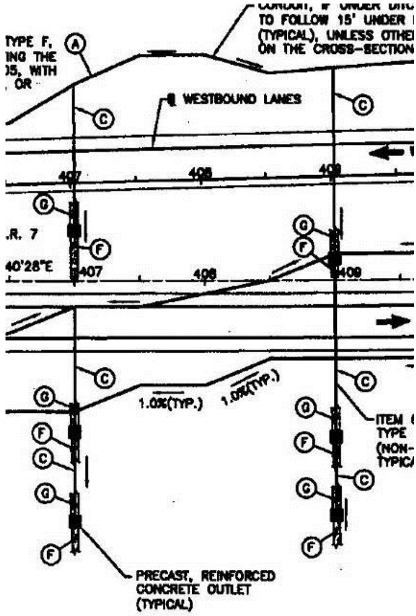


Figure 203.LL – Plan view of drainage

Spreading and Compacting (203.06)

This section covers a general description of spreading and compacting materials. A more detailed explanation can be found in this manual in Section 1015 Compaction Testing of Unbound Materials.

The procedures outlined in this section will make or break the quality of the earthwork construction. Control over the lift thickness and compaction of the materials is vital to the success of the project.

Certain materials require compaction at thinner lifts than others in order to obtain their maximum strength. Other materials can be compacted in thicker lifts without sacrificing quality. Some materials require the addition of water to help the compaction effort or to help break down the material, while other materials require mixing to get the desired results.

All embankment materials, except for rock in 203.06.C. and RPCC in 203.06.D, are spread in horizontal, loose lifts, not exceeding 8 inches (200 mm). All embankment material lifts, except for rock and durable shale, are compacted to a specified density and moisture requirement in 203.07.

The material is spread using dump trucks, scrapers, and dozers. In general, a footed drum roller is used to compact rock, shale, clay, and silt material. Granular materials are generally compacted using a smooth drum vibratory roller.

To record the embankment construction operations, an inspection sheet was created to help document the work and referred to as the "Daily Earthwork Inspection Form". There are several sections to check off on the form that denote project information, location of

the work, type of equipment used, and embankment operation information. This form should make it easier for the earthwork inspector to determine what the minimum inspection requirements are during the earthwork operations.

Soil and Granular Embankment (203.06.A)

Use a maximum lift thickness of 8 inches (200 mm) for soil and granular embankment. Compaction acceptance for soil is based on a percentage of maximum dry density. The appropriate maximum dry density value is determined from a one-point Proctor test, one-point Proctor test with aggregate correction, or a test section. Compaction acceptance for granular material is also based a percentage of maximum dry density, but the maximum dry density value is always determined from a test section.

These methods for determining the maximum dry density are covered in Section 1015 Compaction Testing of Unbound Materials of this manual.

Shale (203.06.B)

Shale is consolidated mud. Shale may seem hard, but in many instances it can be broken down to soil size with very little effort. See 203.02.P and 703.16.D in this manual for a full description of the material.

Some hard, durable shale can be excavated or blasted in very large sizes. Contractors control the size of the material by the way they blast the material. During the typical rock blasting operation, the bench height/burden (L/B) ratio is greater than one, the production hole spacing (S) is 10 to 15 feet (3.3 to 5 m), and the production hole diameter (D) is 6 inches (150 mm). These dimensions are typical in order to maximize production. In addition, it generally leaves large chunks of rock or shale. These large pieces are fine for rock fills, but are not conducive to shale fills.

To produce smaller shale or rock fragmentation, the blaster can increase the L/B ratio to about 3, decrease S to 6 to 8 feet, and reduce D to about 4 inches (100 mm). These dimensions are changed in a trial and error method. The most efficient method depends on the shale and rock formations.

If the Contractor does not control the material size during the excavation or blasting, the amount of spreading, manipulation, compacting, and watering will be extensive in order to get the material into 8-inch (200 mm) lifts.

All shale material is placed and compacted in 8-inch (200 mm) lifts. If the material is placed and compacted in thicker lifts, then a situation such as in Figure 203.MM can occur. Loose, nondurable shale, intermixed within the lift can later deteriorate when water runs though the material.

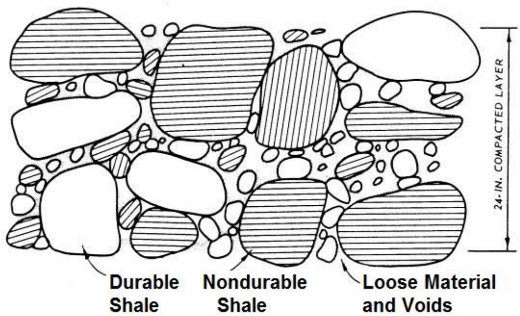


Figure 203.MM – Thick lift of shale

In many cases, when thick lifts are used, the compaction in the top 8 inches (200 mm) may pass. If the top 8 inches (200 mm) is removed, the lower material is made of loose and large chunks of soft shale.

Figure 203.NN details what happens when shale is not properly placed and broken down. The embankment load on the shale, along with the water going through the embankment, can cause the nondurable shale to break down.

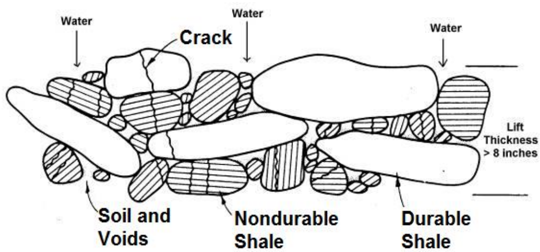


Figure 203.NN – Inadequate shale compaction and breakdown

In order to ensure long-term durability, the project needs to determine how much to break the shale down in the field. The amount of breakage during construction is directly related to the durability of the shale. The durability is correlated to the Bucket Test and roller pass methods in the specifications.

The specifications require that the shale be tested for compaction and broken down according to the Bucket Test and the subsequent roller pass evaluation.

A summary of this evaluation follows:

1. Perform initial test for durability in 703.16.D (Bucket Test).
2. Consult the following:
    a. If less than 25 percent is retained on 3/4-inch sieve, then shale should be broken down to soil size.
    b. If 25 percent to 75 percent is retained on 3/4-inch sieve, then an even percentage of soil, small-, and coarse-sized shale are obtained (maximum contact with all particles). Shale should have a granular texture when properly broken down in the field (see Figure 203.OO).
    c. If more than 75 percent is retained on 3/4-inch sieve, field test for durability (703.16.D).

3. Use six passes with rollers specified in 703.16 to field test for durability.
4. Consult the following:
    a. If greater than 40 percent breaks down, break material into a granular texture as detailed in Figure 203.OO.
    b. If 40 percent or less breaks down, use the procedure in Section 203.06.B in C&MS (Durable Shale): 10 passes with a 15 ton roller and fill the voids.

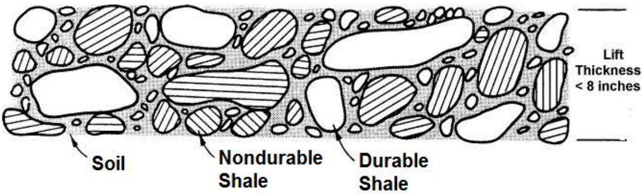


Figure 203.OO – Granular texture shale

The above procedure is a systematic approach to evaluating potential shale breakage in the field. In practice, field results will vary because of variability of shale and the mixing of different types of shale and rock. Some judgment is required during construction.

The most important factors in the long-term quality of shale fills are:
1. Water shale until the material is at least 2 percent above optimum moisture throughout the lift.
2. Manipulate or mix by dozing until a maximum 8-inch (200 mm), loose lift is achieved. Remove large chunks of shale or rock that exceed this lift thickness.
3. Compact each lift to a maximum dry density, except for durable shale.
4. Typically about 5 to 10 passes are sufficient for compaction of nondurable shale.
5. For durable shale, use 10 passes with a 15 ton roller in 203.06.B.

Rock (203.06.C)

Maximum loose lifts are as follows:
1. Six inches larger than the largest rock piece with a maximum lift thickness of 3 feet (1 m). Some examples follow for clarification:
    a. The maximum rock size in a 3-foot lift is 2-1/2 feet.
    b. If the largest rock size in a lift is 1 foot, then the maximum lift thickness is 1-1/2 feet.
2. Near bridges, within a length of 6 times the height of the fill at the abutment, use less than 18 inch (0.5 m) lifts.
   Example: Fill height is 20 feet (6 m). Thus within 120 feet of abutment

   (20 × 6 = 120 feet), the maximum lift is 18 inches.

The rock fill construction is outlined below:
1. Distribute full width of the lift.
2. Evenly distribute the larger rocks.
3. Reduce the voids.
4. Place the smaller rock in the upper portion of the lift.
5. Compact with 8 passes of a 10 ton (9 metric ton) roller.

When using other embankment materials with rock, use rock as:

1. Base of the embankment. It provides better support.
2. On the outer portions of the embankment. It provides better drainage.
3. Place the larger rocks on the outside side slopes. It provides better drainage.

Use other embankment material as follows:

1. On the inner portion of the fill.
2. Keep the top higher than the rock.
3. Construct wide enough for compaction.
4. When rock is on top of other embankment material, construct at a side slope grade of 4 percent prior to placing the rock. This provides better drainage.

When the rock fill contains more than 15 percent shale, compact like a shale fill.

Random Material (203.06.D)

Random materials are a wide variety of materials which do not fit any other groupings. They may be rock mixed with soil, brick, asphalt mixed with soil, or portland cement concrete mixed with soil.

Soil mixed with any other random material must be at least 2 percent below optimum. This will help the soil fill the voids and create a stable embankment.

Recycled asphalt or concrete are mixed with at least 30 percent natural materials.

Random material mixtures are placed in 8-inch lifts, except for RPCC:

1. Maximum size of the RPCC is less than 3 × 3 feet (1 m).
2. The mix is dozed and mixed to fill the voids.
3. Lift thickness is less than 12 inches (300 mm).
4. Use 18 inch lifts (0.5 m) when the lift is more than 50 percent RPCC.
5. Compact the natural material to a test section maximum.

Compaction and Moisture Requirements (203.07)

Except for Granular Material Types D and E, rock, and durable shale, the moisture and density controls in this section apply. Perform all compaction tests according to Supplement 1015. This supplement is detailed in this manual in Section 1015 Compaction Testing of Unbound Materials.

Moisture Controls (203.07.A)

Water is added or removed from a material in order to obtain the necessary density and stability. Note: for embankment material, there is no explicit range of acceptable moisture content (e.g. within 3 percent of optimum moisture content). The criteria for acceptable moisture content are that the Contractor can obtain the necessary density and stability.

Dry or add moisture throughout the lift. Expedite and manipulate the material by using plows or discs. For soils with pronounced elasticity or deformation, reduce the moisture content to ensure stability.

In a fill situation without a soft foundation, heavy equipment may deflect the soil, but no permanent rutting or cracking should be evident afterwards.

Some soils require moisture contents five percent below optimum to ensure stability. Materials such as A-4a, A-4b, and A6a's are notorious for this problem. These materials are difficult to compact during marginal weather conditions and directly after a rainy day.

The elasticity may be caused by foundation conditions. See Materials 203.02, Elasticity and Deformation of Soils.

Do not mix shale in the lifts to reduce the moisture content. The shale will bring the moisture down, and then break down later causing settlement or a landslide.

Compaction Requirements (203.07.B)

Table 203.07-1 details the Embankment Compaction Requirements. The percentage is based on the maximum dry density of the soil. This table is used for materials where the maximum dry density is determined using a one-point Proctor test or a one-point Proctor test with aggregate correction.

Table 203.B – Embankment Compaction Requirements

Maximum Dry Density (lb/ft^3)	Minimum Compaction Requirements in Percent of Maximum Dry Density
90 to 104.9	102
105 to 119.9	100
120 and more	98

Test sections are required to determine the maximum dry density for granular materials and some other materials. If a test section is used then the following apply:

1. Use at least 98 percent of the maximum dry density obtained in the test section for acceptance in the production area.
2. Use the same number of passes used in the test section for the production areas. Reduce the number of passes if detrimental to the compaction.
3. Construct a new test section when the material or supporting foundation changes.
4. Reduce the moisture content if the material becomes unstable.

More detail can be found in Supplement 1015 Compaction Testing of Unbound Materials.

Method of Measurement (203.09)

This section of the manual briefly outlines some of the methods used to determine earthwork quantities. Methods described in this section are acceptable for making this check. Many of these methods are outdated due to current GPS (GNSS) systems, but they are still presented.

Specification Requirements

The specifications require that the average-end-area method be used to determine volumes of earthwork for payment.

End Area Determinations

There are many acceptable methods for determining end areas for earthwork computations. Any method that gives accurate determinations may be used. Some of the most common methods for determining cross-section end areas are as follows:

Planimeter

In this method, an instrument with a wheel and a graduated dial is run around the perimeter of a cross-sectional end area. The area is found by multiplying the reading on the dial by a constant factor or by setting a factor on the planimeter and reading the area directly from the planimeter dial.

Counting Squares

In this method, the number of unit squares in a section is counted. This is only practical in very small sections.

Stripping

This is a method of tallying unit squares by making successive marks on a strip of paper to measure unit strips, accumulating all unit strips on a cross-section and converting to total cross-section area. This method is simple, rapid, and keeps the chance of error to a minimum.

Computer Method

In this method, data from cross-sections (usually in coordinate form) is input into a computer program, which follows a program set-up to finish areas and volumes.

CAD

Most plans are developed using Computer Aided Design (CAD) programs. The earthwork calculations are detailed in these files. Contact Planning and Engineering for these calculations.

Geometric Method

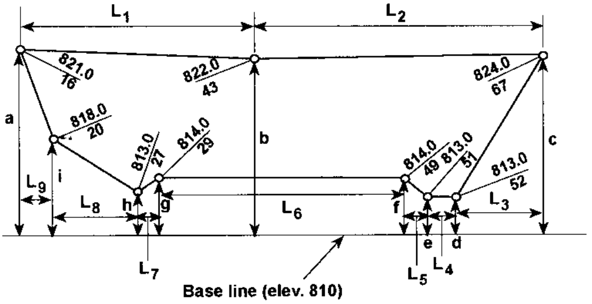
In this method, the section is broken into areas, such as triangles and trapezoids. Each area is then calculated by its geometry. The total area is found by the sum of the individual areas.

Arithmetic Calculation

This method calculates end area using a formula. Data for the formula is taken from a cross-section (or field notes) that show elevation and distance from a base line for each break in the cross-section line. A pocket calculator can be used for this calculation.

Determination of cross-section end areas by this method is exact and any two persons using the same information (field notes) will obtain the same answer, providing no errors are made in the calculator manipulation or arithmetic calculations. There is only one correct answer.

The two methods are described and illustrated in Figures 203.PP and 203.QQ.



Procedure: Select a base line either at or below the lowest elevation of the cross section. The equation for the area of the cross section for this example is as follows:

$$Exact\ Area = L_1 \frac{[a+b]}{2} + L_2 \frac{[b+c]}{2} - L_3 \frac{[c+d]}{2} - L_4 \frac{[d+e]}{2} - L_5 \frac{[e+f]}{2} - L_6 \frac{[f+g]}{2} - L_7 \frac{[g+h]}{2}$$

$$- L_8 \frac{[h+i]}{2} - L_9 \frac{[i+a]}{2}$$

Using a base line of 810.0 the area is:

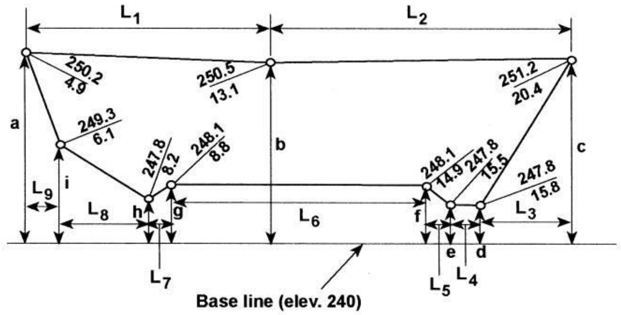
$$27 \frac{[11+12]}{2} + 24 \frac{[12+14]}{2} - 15 \frac{[14+3]}{2} - 1 \frac{[3+3]}{2} - 2 \frac{[3+4]}{2} - 20 \frac{[4+4]}{2}$$

$$- 2 \frac{[4+3]}{2} - 7 \frac{[3+8]}{2} - 4 \frac{[8+11]}{2}$$

Or: Exact Area = (27 x 11.5) + (24 x 13) - (15 x 8.5) - (1 x 3) - (2 x 3.5) - (20 x 4)

- (2 x 3.5) - (7 x 5.5) - (4 x 9.5) = $\boxed{321.5 \text{ sq. ft}}$

Figure 203.PP – End area determination Method 1



Procedure: Select a base line either at or below the lowest elevation of the cross section. The equation for the area of the cross section for this example is as follows:

$$\textit{Exact Area} = L_1 \frac{[a+b]}{2} + L_2 \frac{[b+c]}{2} - L_3 \frac{[c+d]}{2} - L_4 \frac{[d+e]}{2} - L_5 \frac{[e+f]}{2}$$

$$- L_6 \frac{[f+g]}{2} - L_7 \frac{[g+h]}{2} - L_8 \frac{[h+i]}{2} - L_9 \frac{[i+g]}{2} =$$

Using a base line of 810.0 the area is:

$$= 8.2 \frac{[10.2+10.5]}{2} + 7.3 \frac{[10.5+11.2]}{2} - 4.6 \frac{[11.2+7.8]}{2}$$

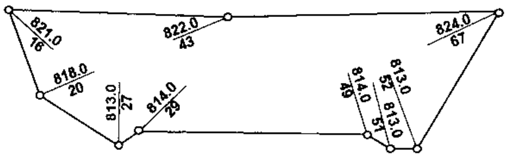
$$- 0.3 \frac{[7.8+7.8]}{2} - 0.6 \frac{[7.8+8.1]}{2} - 6.1 \frac{[8.1+8.1]}{2} -$$

$$- 0.6 \frac{[8.1+7.8]}{2} - 2.1 \frac{[7.8+9.3]}{2} - 1.2 \frac{[9.3+10.2]}{2}$$

$$= 8.2\ (10.35) + 7.3\ (10.85) - 4.6\ (9.5) - 0.3\ (7.8) - 0.6\ (7.95) - 6.1\ (8.1)$$

$$- 0.6\ (7.95) - 2.1\ (8.55) - 1.2\ (9.75) = \boxed{29.43\ m^2}$$

Figure 203.PP-M – End area determination Method 1 (Metric)



Procedure: Select the starting point, normally at the extreme left, and list the plotted coordinates in counter-clockwise sequence. For this example:

$$\frac{21}{16} \quad \frac{18}{20} \quad \frac{13}{27} \quad \frac{14}{29} \quad \frac{14}{49} \quad \frac{13}{51} \quad \frac{13}{52} \quad \frac{24}{67} \quad \frac{22}{43} \quad \frac{21}{16}$$

Multiply and accumulate the products of the denominator and the adjacent numerator to the right as follows:

(16 x 18) + (20 x 13) + (27 x 14) + (29 x 14) + (49 x 13) + (51 x 13)

(52 x 24) + (67 x 22) + (43 x 21) = <u>6257 sq. ft.</u>

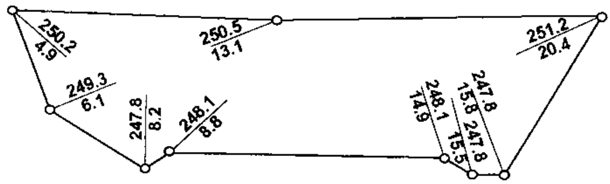
Multiply and accumulate the products of the denominator and the adjacent numorator to the left as follows:

(16 x 22) + (43 x 24) + (67 x 13) + (52 x 13) + (51 x 14) + (49 x 14)

+ (29 x 13) + (27 x 18) + (20 x 21) = <u>5614 sq. ft.</u>

$$\textit{Exact Area} = \frac{6257 - 5614}{2} = \boxed{321.5 \; \textit{sq. ft.}}$$

Figure 203.QQ – End area determination Method 2



Procedure: Select the starting point, normally at the extreme left, and list the plotted coordinates in counter-clockwise sequence. For this example:

$$\frac{50.2}{4.9}\quad\frac{49.3}{6.1}\quad\frac{47.8}{8.2}\quad\frac{48.1}{8.8}\quad\frac{48.1}{14.9}\quad\frac{47.8}{15.5}\quad\frac{47.8}{15.8}$$

$$\frac{51.2}{20.4}\quad\frac{50.5}{13.1}\quad\frac{50.2}{4.9}$$

Multiply and accumulate the products of the denominator and the adjacent numerator to the right as follows:

$4.9\,(49.3) + 6.1\,(47.8) + 8.2\,(48.1) + 8.8\,(48.1) + 14.9\,(47.8) + 15.5\,(47.8)$

$+ 15.8\,(51.2) + 20.4\,(50.5) + 13.1\,(50.2) = 5300.75$

Multiply and accumulate the products of the denominator and the adjacent numorator to the left as follows:

$4.9\,(50.5) + 13.1\,(51.2) + 20.4\,(47.8) + 15.8\,(47.8) + 15.5\,(48.1)$

$14.9\,(48.1) + 8.8\,(47.8) + 8.2\,(49.3) + 6.1\,(50.2) = 5241.89$

$$\textit{Exact Area} = \frac{5300.75 - 5241.89}{2} = \boxed{29.43\ m^2}$$

Figure 203.QQ-M – End area determination Method 2 (Metric)

Volume Determination

The end areas of English plans are detailed in square feet (ft^2), while end areas on metric plans are detailed in square meters (m^2). Make the appropriate volume calculation shown below using the end area found in Figure 203.PP or 203.QQ.

Formula

For base lines and center lines on tangent, and for center lines on curves where the center line of the curve coincides with the center of mass (centroid) of the cross-sections, the formula for computing volume from end areas are as follows:

English Units

$$V = \frac{(A_1 + A_2)}{2} \times \frac{L}{27}$$

Where

V	=	Volume in cubic yards (yd^3)
A_1	=	Cross-section one end area in square feet (ft^2)
A_2	=	Cross-section of other end area in square feet (ft^2)
L	=	Distance between A_1 and A_2 in feet (ft)

Metric Units

$$V = \frac{(A_1 + A_2)}{2} \times L$$

Where

V	=	Volume in cubic meters (m^3)
A_1	=	Cross-section one end area in square meters (m^2)
A_2	=	Cross-section of other end area in square meters (m^2)
L	=	Distance between A_1 and A_2 in meters (m)

Table

Figure 203.RR shows a table used for determining cubic yards (yd^3) from the sum of end areas for sections 100 feet apart and for conditions described above. This table cannot be used on metric projects.

CUBIC YARDS FOR SUM OF END AREAS

LENGTH OF PRISM 100 FEET

C.Y.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	C.Y.
0	0	54	108	162	216	270	324	378	432	486	540	594	648	702	756	810	864	918	972	0
2	1	55	109	163	217	271	325	379	433	487	541	595	649	703	757	811	865	919	973	2
4	2	56	110	164	218	272	326	380	434	488	542	596	650	704	758	812	866	920	974	4
6	3	57	111	165	219	273	327	381	435	489	543	597	651	705	759	813	867	921	975	6
7	4	58	112	166	220	274	328	382	436	490	544	598	652	706	760	814	868	922	976	7
9	5	59	113	167	221	275	329	383	437	491	545	599	653	707	761	815	869	923	977	9
11	6	60	114	168	222	276	330	384	438	492	546	600	654	708	762	816	870	924	978	11
13	7	61	115	169	223	277	331	385	439	493	547	601	655	709	763	817	871	925	979	13
15	8	62	116	170	224	278	332	386	440	494	548	602	656	710	764	818	872	926	980	15
17	9	63	117	171	225	279	333	387	441	495	549	603	657	711	765	819	873	927	981	17
19	10	64	118	172	226	280	334	388	442	496	550	604	658	712	766	820	874	928	982	19
20	11	65	119	173	227	281	335	389	443	497	551	605	659	713	767	821	875	929	983	20
22	12	66	120	174	228	282	336	390	444	498	552	606	660	714	768	822	876	930	984	22
24	13	67	121	175	229	283	337	391	445	499	553	607	661	715	769	823	877	931	985	24
26	14	68	122	176	230	284	338	392	446	500	554	608	662	716	770	824	878	932	986	26
28	15	69	123	177	231	285	339	393	447	501	555	609	663	717	771	825	879	933	987	28
30	16	70	124	178	232	286	340	394	448	502	556	610	664	718	772	826	880	934	988	30
31	17	71	125	179	233	287	341	395	449	503	557	611	665	719	773	827	881	935	989	31
33	18	72	126	180	234	288	342	396	450	504	558	612	666	720	774	828	882	936	990	33
35	19	73	127	181	235	289	343	397	451	505	559	613	667	721	775	829	883	937	991	35
37	20	74	128	182	236	290	344	398	452	506	560	614	668	722	776	830	884	938	992	37
39	21	75	129	183	237	391	345	399	453	507	561	615	669	723	777	831	885	939	993	39
41	22	76	130	184	238	392	346	400	454	508	562	616	670	724	778	832	886	940	994	41
43	23	77	131	185	239	393	347	401	455	509	563	617	671	725	779	833	887	941	995	43
44	24	78	132	186	240	394	348	402	456	510	564	618	672	726	780	834	888	942	996	44
46	25	79	133	187	241	395	349	403	457	511	565	619	673	727	781	835	889	943	997	46
48	26	80	134	188	242	396	350	404	458	512	566	620	674	728	782	836	890	944	998	48
50	27	81	135	189	243	397	351	405	459	513	567	621	675	729	783	837	891	945	999	50
52	28	82	136	190	244	398	352	406	460	514	568	622	676	730	784	838	892	946	1000	52
54	29	83	137	191	245	399	353	407	461	515	569	623	677	731	785	839	893	947	1001	54
56	30	84	138	192	246	300	354	408	462	516	570	624	678	732	786	840	894	948	1002	56
57	31	85	139	193	247	301	355	409	463	517	571	625	679	733	787	841	895	949	1003	57
59	32	86	140	194	248	302	356	410	464	518	572	626	680	734	788	842	896	950	1004	59
61	33	87	141	195	249	303	357	411	465	519	573	627	681	735	789	843	897	951	1005	61
63	34	88	142	196	250	304	358	412	466	520	574	628	682	736	790	844	898	952	1006	63
65	35	89	143	197	251	305	359	413	467	521	575	629	683	737	791	845	899	953	1007	65
67	36	90	144	198	252	306	360	414	468	522	576	630	684	738	792	846	900	954	1008	67
69	37	91	145	199	253	307	361	415	469	523	577	631	685	739	793	847	901	955	1009	69
70	38	92	146	200	254	308	362	416	470	524	578	632	686	740	794	848	902	956	1010	70
72	39	93	147	201	255	309	363	417	471	525	579	633	687	741	795	849	903	957	1011	72
74	40	94	148	202	256	310	364	418	472	526	580	634	688	742	796	850	904	958	1012	74
76	41	95	149	203	257	311	365	419	473	527	581	635	689	743	797	851	905	959	1013	76
78	42	96	150	204	258	312	366	420	474	528	582	636	690	744	798	852	906	960	1014	78
80	43	97	151	205	259	313	367	421	475	529	583	637	691	745	799	853	907	961	1015	80
81	44	98	152	206	260	314	368	422	476	530	584	638	692	746	800	854	908	962	1016	81
83	45	99	153	207	261	315	369	423	477	531	585	639	693	747	801	855	909	963	1017	83
85	46	100	154	208	262	316	370	424	478	532	586	640	694	748	802	856	910	964	1018	85
87	47	101	155	209	263	317	371	425	479	533	587	641	695	749	803	857	911	965	1019	87
89	48	102	156	210	264	318	372	426	480	534	588	642	696	750	804	858	912	966	1020	89
91	49	103	157	211	265	319	373	427	481	535	589	643	697	751	805	859	913	967	1021	91
93	50	104	158	212	266	320	374	428	482	536	590	644	698	752	806	860	914	968	1022	93
94	51	105	159	213	267	321	375	429	483	537	591	645	699	753	807	861	915	969	1023	94
96	52	106	160	214	268	322	376	430	484	538	592	646	700	754	808	862	916	970	1024	96
98	53	107	161	215	269	323	377	431	485	539	593	647	701	755	809	863	917	971	1025	98
C.Y.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	C.Y.

SUM END AREAS	C.Y.
2000	3704
3000	5556
4000	7407
5000	9259
6000	11111
7000	12963
8000	14815
9000	16067
10000	18519

EXPLANATION: Find sum of end areas in body of table. Then at top or bottom of vertical column find hundreds of cubic yards and at extreme right or left of horizontal line find cubic yards below 100.

EXAMPLE: $A_1 = 420^{ft^2}$, $A_2 = 472^{ft^2}$, Sum = 892^{ft^2}, which is found under 16 hundred and to the right or left 52.

ANSWER: 1652 cubic yards.

Figure not converted to metric

Figure 203.RR – Cubic yards for the sum of the end areas

Earthwork Quantity Calculations

Figure 203.SS Earthwork Calculations depicts a form that can be used to summarize the earthwork calculations.

CONTID ____________ Co-Rt-Sec ____________ Date ____________
ALTID ____________

Station	CUTS Prop Line # ______ End Area ft²	Average End Area ft²	Length Between Stations ft	Volume yd³	FILLS Prop Line # ______ End Area ft²	Average End Area ft²	Length Between Stations ft	Volume yd³
			Total cuts, yd³	______			Total fills, yd³	______

(Area 1 + Area 2) ÷ 2 = Average End Area — Average End Area × Length ÷ 27 = Volume
ft² — square foot — yd³ — cubic yard

____________ Calculated by ____________ Date — ____________ Checked by ____________ Date

ODOT Form date: 2/22/14

Figure 203.SS – Earthwork quantity calculations form

Figure 203.TT shows a completed calculation form.

CONTID ______ Co-Rt-Sec ______ Date ______
ALTID ______

	CUTS Prop Line # 18				FILLS Prop Line # 19			
Station	End Area ft²	Average End Area ft²	Length Between Stations ft	Volume yd³	End Area ft²	Average End Area ft²	Length Between Stations ft	Volume yd³
351+50	25.68				0.00			
		37.64	50.00	69.70		0.00	50.00	0.00
352+00	49.60				0.00			
		102.81	50.00	190.38		0.00	50.00	0.00
352+50	156.01				0.00			
		222.23	50.00	411.54		0.00	50.00	0.00
353+00	288.45				0.00			
		239.58	50.00	443.66		0.00	50.00	0.00
353+50	190.70				0.00			
		143.88	50.00	266.44		12.94	50.00	23.96
354+00	97.06				25.88			
		70.87	50.00	131.24		68.50	50.00	126.84
354+50	44.68				111.11			
		22.34	50.00	41.37		154.22	50.00	285.59
355+00	0.00				197.33			
		0.00	50.00	0.00		136.99	50.00	253.68
355+50	0.00				76.64			
		0.00	50.00	0.00		54.22	50.00	100.41
356+00	0.00				31.80			
				Total cuts, yd³ 1,554.33				Total fills, yd³ 790.48

(Area 1 + Area 2) ÷ 2 = Average End Area Average End Area × Length ÷ 27 = Volume
ft² — square foot yd³ — cubic yard

Calculated by ______ Date ______ Checked by ______ Date ______

ODOT Form date: 2/22/14

Figure 203.TT – Completed earthwork quantity calculations form

Volume Determination on Curves

Where cross-sections are at right angles to curve center lines, and the center line is not located at the center of mass (centroid) of cross-sections, corrections must be applied to volume calculations in order to obtain accurate results. This is especially true for curves of short radius's, such as those commonly used on ramps. Inaccuracies of considerable magnitude may result unless proper corrections have been used in calculating earthwork volumes. General methods for determining accurate quantities in such cases are detailed in Section 1310.3.2 in the Location & Design Manual – Volume 3, Highway Plans. Links to the Location & Design Manual can be found on the Design Reference Resource Center on the Department's website.

Basis of Payment (203.10)

There are a multitude of statements that denote when the Department will and will not pay for earthwork quantities based on different field circumstances. The project should review this section. In this manual we will focus on the final quantity measurements.

The GPS (GNSS) methods are not detailed in Section 203.09 or 203.10 of this manual. Electronic devices connected to graders or dozers are allowed in Item 623 of the C&MS.

Final Earthwork Quantities

Check measurements are made in areas where earthwork is being performed. A sufficient number of these checks must be recorded according to the instructions in this manual to provide a satisfactory record of the checks. The purpose of these measurements and records are:

1. To ensure that earthwork is being constructed to plan lines within specified tolerances.
2. To provide a simplified method of earthwork measurement so that payment may be based on corrected plan quantities.

This will result in the savings of engineering man-hours required to arrive at payment quantities and make it possible for the Contractor to receive prompt final payment after the completion of the work.

Measurement by Final Cross-Sections

Final cross-sections of roadway earthwork are usually not required, provided that the plan quantities are checked for accuracy and adequate checks have been made (and recorded) during construction. This establishes that plan quantities of earthwork have been performed within specified tolerances.

Final cross-sections may be called for where, by inspection or other knowledge of the project, it is indicated that measurement by final cross-section is necessary or desirable.

Procedure for Check Measurements and Check Calculations:

1. Before earthwork construction has begun, make a plan-in-hand inspection to verify the ground line shown on the plan cross-sections, and if significant changes in topography indicate the need for additional cross-sections at intermediate locations. Where this inspection indicates the need, arrange for further checks by ground or aerial survey.
2. State in the project diary that this inspection has been made.
3. Ensure that slope stakes are set by the calculation method. The initial point for calculations should generally be a profile grade elevation.
4. Obtain a copy of the survey notes, whether the staking is done by a Department or Contractor survey crew, and plot horizontal and vertical locations of the slope stakes on the cross-section sheets. Check the accuracy of original plan ground cross-sections at slope stake locations. Record errors noted and correct plan sections promptly.
5. Check the accuracy of the original ground lines shown on plan cross-sections as follows:

a. In order to verify the original ground lines shown on plan cross-sections, the Engineer shall field check cross-sections every 300 to 500 feet (100 to 150 meters) by either ground or aerial survey methods prior to the beginning of construction operations. If any appreciable variations from plan elevations are found, check sections must be taken at closer intervals in order to determine the extent of plan errors and amount of additional cross-sectioning required to provide accurate earthwork quantities. Use the corrected ground line where plan cross-section lines have been found in error.
b. Plan quantities resulting from computations that have been properly documented and made a part of the project records are to be used as final pay quantities. Any additions to, or deductions from, plan quantities necessitated by change orders shall be computed by project personnel in order to determine final pay quantities for adjusted items.
c. The Department will make revisions to the pay quantity for changes for the following:
    i. Total quantity changes greater than 1,000 cubic yards.
    ii. Two consecutive end areas varying by more than 5 percent.
    iii. Undercutting.
    iv. Foundation settlement.
    v. Changes in the grades or slopes.
    vi. Removing slides.
    vii. Arithmetic errors.
d. Final pay quantities computed or adjusted by project personnel shall be checked in the Project Office of the District Office by competent Department personnel who have been assigned to the project for construction control, supervision, etc.
e. All computations of adjustments shall be properly validated by the signed initials or names of persons who computed the adjusted pay quantities and those who performed the checking operations. Also, the dates that these functions were performed shall be indicated. These adjustment computations shall be made a part of the official project records.

6. Where the plan quantities have been checked and validated on the plans or on computation sheets provided by the design unit preparing the plans, it is not necessary during construction to make a detailed check of accuracy of plan earthwork quantities. If an error in validated plan quantities is noted, recalculate the end areas and volumes in question. Check all plan earthwork quantities for accuracy when plan quantities have not been checked and validated on the plans or on computation sheets provided by the design unit preparing the plans. Especially check locations where there are curves of short radius, such as ramps. Plan quantities are frequently in error by significant amounts at such locations. Where plan quantities are not correct, strike out the plan figures and write in the correct figures. Check the summary to see that quantities have been transferred accurately from cross-section sheets.
7. Make check measurements during construction to ensure work is being done within allowable field tolerances. Project personnel should perform these checks, supplemented by occasional use of the Department survey crew when needed. Make sufficient checks to ensure that the work is being performed

within allowable tolerances. The frequency of these check measurements should be determined by the Engineer.

8. The Contractor is required to correct all deviations from plan lines in excess of allowable tolerances as determined by check measurements. During rough grading, it is acceptable to permit cuts and fills to exceed tolerances by an amount which will be corrected during fine grading by practical construction methods. In the case of fills, require prompt corrections of deviations inside allowable tolerances so that specified compaction of the outer edges will be obtained as the work progresses. In the case of deep cuts with steep slopes in rock or shale, prompt correction of deviations in excess of allowable tolerances is required, so that adjustments can be made as the work progresses while the slope areas in question are within reach of the equipment being used.
9. Record necessary check measurements in appropriate notebooks, inspector report forms, or daily entry in the project diary. These notations should state the location where check measurements were made.
10. Maintain a set of plan cross-sections in the Project Office. Plot check measurements, changes, and errors in plan lines on all projects where there is authorized work beyond plan lines, such as excavation of soft subgrade. Measurements of this authorized, additional work are required.

Borrow Pay Quantity

Specifying borrow happens rarely and only when the measurement in the final location is impractical. An example would be underwater or linear grading operations. Borrow will be specified by weight, when practical.

Natural Formations

Volume Measurement

When borrow is specified by the cubic yard, measurement may be taken in the borrow pit just as in regular embankment construction. Use the average end areas.

Only use Department personnel to take measurements of the borrow material. Contractor's employees may be used to assist in check measurements and measurements of authorized excavations beyond plan lines where the quantity at each location is less than 2,000 cubic yards (yd^3) [1,500 cubic meters (m^3)]. This assumes that project personnel only are responsible for collecting, plotting, and calculating of the data and quantities.

Weight Measurement

When borrow is specified by cubic yards, weight measurements may be used to calculate the payment quantity:

1. Take a series of density tests in the borrow areas and average the test results. This value is the wet density, called WD (lbs/yd^3).
2. Calculate the total weight from the weight tickets. This value is called W (lbs).
3. Use the following equation to calculate the payment quantity.

$$\text{Payment quantity}\left(yd^3\right)=\frac{W}{WD}$$

This can be used as a check or if cross-sections are not available.

Other than Natural Formations

Volume Measurement

1. Take a series of density tests in place and average the test results. This value is the wet density, called WD (lbs/yd^3).
2. Calculate the total weight from the weight tickets. This value is called W (lbs).
3. Use the following equation to calculate the payment quantity:

$$\text{Payment quantity}\left(yd^3\right)=\frac{W}{0.95\times WD}$$

Weight Measurement for Borrow

When borrow is specified by weight use the following:

1. Weight tickets minus excess moisture.
2. Collect weight tickets according to C&MS 109.01.

Adjustment to Borrow Quantity

The quantity of borrow for payment is the measured quantity as detailed above minus:

1. Suitable excavation wasted.
2. Excess fill adjusted for shrinkage.
    a. The shrinkage factor used is detailed in Section 203.02, Estimating Shrinkage and Settlement, of this manual.
    b. Use the following equation to calculate the payment quantity:

$$\text{Payment Quantity} = \text{SF} \times \text{Borrow Quantity}$$

Example: 100,000 CY total borrow, 10,000 CY excess, borrow density is 110 lbs/ft^3, and embankment density 120 lbs/ft^3.

Solution:

Shrinkage Factor, SF=110/120= 0.92

100,000 - 0.92 (10,000) = 100,000 – 9,200= 90,800 CY

Explanation:

Borrow was measured at the borrow site. A larger amount of borrow fit into the embankment. Density is greater at the embankment location. Therefore, we subtract less borrow from the final pay.

Be careful about which way you apply the shrinkage factor.

Records

Record all check measurements and check calculations on the appropriate form, date and sign, or initial the form, and place it in the project records.

Records of check measurements must be kept up-to-date at the Project Office during construction and will be reviewed by the Office of Construction Administration during their routine visits to the project.

After completion of the earthwork, prepare a tabulation of earthwork pay items showing plan quantities, where applicable, and listing appropriate measured quantities for all areas where there was deviation from plan lines beyond specified tolerances, which affect the pay quantities, showing total quantities for payment.

This tabulation, together with records of check measurements, constitutes the earthwork report for the project. After processing, these reports shall be filed in the District Office.

204 Subgrade Compaction and Proof Rolling

Importance

During 2000 and 2001, over 25 million dollars of extra work was used to stabilize unstable subgrades. This extra work has been minimized in recent years because of the construction and design criteria created since that time.

This section will help the project construct stable subgrades for pavement construction. Proper subgrade treatment ensures a constructible pavement, enhances pavement performance over its life, and ensures that the pavement design intent is carried through into the construction phase. This section is based on research performed by the Department from the 1960's through today. This section should not be used as the ultimate answer to solve all subgrade problems.

This section is detailed in such a manner so that construction personnel can easily apply information from the field and subsurface investigation to provide reasonable adjustments to the plan subgrade treatment.

Specification and Plan Requirements

Subgrade Compaction consists of preparing, compacting, and grading suitable material to form a stable subgrade. This includes removing unsuitable material from the subgrade, as well as removing unstable subgrade material. Unsuitable subgrade materials are soils and bedrock that negatively affect either construction or long term support of the pavement. Unstable materials are suitable materials that conform to 204.02 and cannot be processed and compacted into a satisfactory stable subgrade.

Item 204 requires the top 12 inches of the subgrade to be compacted. Item 204 requires the subgrade to be proof rolled. If subgrade chemical stabilization or undercutting is designed for the entire project, then proof rolling is only used to verify the stability of the stabilized subgrade. If special subgrade treatment is provided in the plans at spot locations, proof rolling is specified to identify these areas and then performed afterwards to verify the undercut stability.

Proof rolling deflections and soil conditions that are observed during construction determine if the plan subgrade treatment must be adjusted. Adjustment of subgrade treatment to fit field conditions is essential and is the responsibility of the Project Engineer.

Subgrade Correction Prior to Proof Rolling

The Engineer must observe the effect of heavy equipment, which operates on the subgrade during rough grading. When rutting and deflection under heavy equipment indicates unstable subgrade, the Engineer should authorize the correction. See Elasticity and Deformation of Soils in Section 203.02 of this manual.

Do not delay the correction until it can be checked by proof rolling. Investigate the extent of the problem by using the Investigation section of this Item. Be aware that the condition

can be improved by time, drainage, and hauling as detailed in the section, Draining and Hauling, of this item.

If needed, make the correction by excavating and disposing of unstable soil and replacing it with suitable material as detailed in the section, Undercut Depth and Stabilization Determination, of this item.

Drainage and Hauling

Excess water in fine-grained soil is the principal cause of unstable soil conditions. The Engineer has a responsibility to ensure adequate drainage during construction. If the investigation indicates the need for underdrains or the cleaning of the existing underdrain outlets, the Engineer must order the work as soon as possible.

Some examples of these conditions are as follows:

1. Existing underdrains with clogged outlets on reconstruction projects.
2. Free water in the subgrade.
3. Saturated soils of moderately high permeability, such as sandy silt and silty clay of low plasticity.
4. Ground water seepage through layers of permeable soil.
5. Water seeping into test pits.
6. Water seeping from higher elevations into cut locations.
7. Water flowing on the top of the rock or shale in subgrade undercuts.

Note: It is difficult to remove water from hard clay soils with PI's greater than 20 with construction underdrains.

Subgrade stability can be significantly improved by cleaning out the existing underdrain outlets on reconstruction projects and by adding construction underdrains on new or reconstruction projects. Once the underdrain systems are in place and functioning, the drainage system can reduce the subgrade soil moisture content from 3 percent over optimum moisture to the optimum moisture content in 6 to 8 weeks. Moisture contents that exceed 3 percent over optimum must be dealt with by other means.

For reconstruction projects, the Contractor should be instructed to unclog the underdrain outlets immediately. Try to perform this work in the time frame listed above. If the project consists of several phases, instruct the Contractor to perform the outlet cleaning for the entire project at the same time.

For new or reconstruction projects, subgrade stability can be achieved by constructing the plan or construction underdrains as soon as the water problem is found. On new construction projects, a longer period of time can be allowed for the underdrain system to work. Opportune times for this work are at the beginning of construction and before winter shut downs.

The plan underdrains should be placed only when they will not be contaminated by further construction. If contamination is a concern, then sacrificial construction underdrains should be used on the project.

Item 605 in the C&MS details the construction of construction underdrains. Construction underdrains are usually placed in the centerline of the roadway, but can be placed in other locations too. They may be placed in the ditch line if water is coming in from a cut section at a higher elevation. The porous backfill is extended to the subgrade elevation.

The outlets for the construction underdrain are the same pipe material and backfill as regular underdrains. The underdrains can be outlet to any convenient location, such as catch basins, manholes, pipe, or ditches. The project should not be concerned with contamination in the upper portion of the underdrain backfill. Construction underdrains are sacrificial underdrains that will continue to work throughout the life of the contract and afterwards, even though the upper portion is contaminated.

In Figure 204.A, the subgrade is saturated and the soil acts like a waterbed when the subgrade is Proof Rolled or hauled on. However, once the underdrains are in place and the soil is loaded, as shown in Figure 204.B, then the water has a place to go. As the soil is loaded or hauled on, the water is squeezed out and the subgrade conditions will improve.

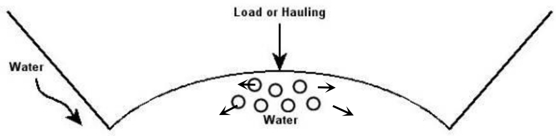


Figure 204.A – Water in the subgrade without drainage

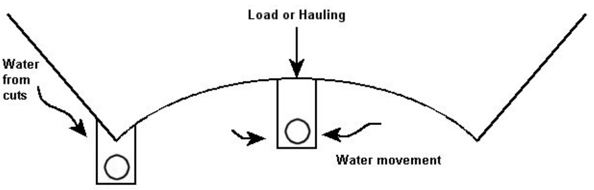


Figure 204.B – Water in the subgrade with drainage

By placing the drainage system prior to loading or hauling on the subgrade, the water is given a location to escape the subgrade system. If the drainage system is not in place before hauling or loading, the subgrade will rut or crack and have a detrimental effect on the subgrade and not improve with loading.

Drainage and hauling can work together to correct unstable subgrades under the above given guidelines.

Figure 204.C, Shale and Rock Undercuts, came from Figure 1009-10 in Location & Design Manual, Volume 2, *Drainage Design*. The specification requirements are detailed in 204.05. Shale and rock are cut 24 inches (610 mm) below the bottom of the pavement. This ensures that the pavement gets uniform support and good drainage. When rock is blasted and excavated, the resulting surface is very rough and tends to collect water. Accumulated water will cause some rock and shale to deteriorate. By undercutting the rock, we ensure that any water that collects in the irregular surface does not affect the pavement. In the past, pavement placed on rock and shale started to develop problems immediately after opening to traffic.

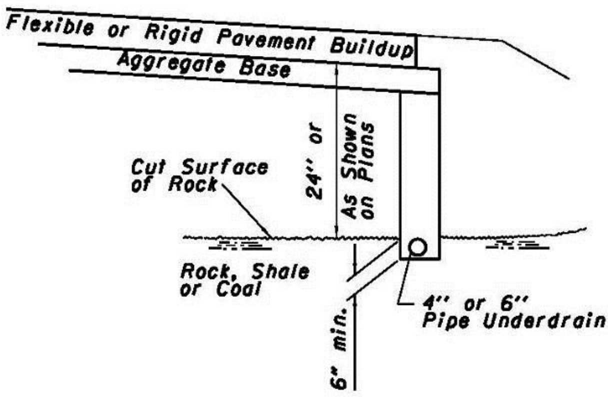


Figure 204.C – Shale and rock undercuts

The underdrains in these rock and shale cuts should extend at least 6 inches (150 mm) into the existing rock or shale formation. If the underdrains are too high, the water will accumulate at the rock and soil interface and cause subgrade instability.

Construction or rock underdrains can be placed in the ditches and other strategic locations in cut sections to minimize water coming under the pavement. Water under the pavement without drainage causes the subgrade to act like a waterbed. With drainage, the conditions improve and become more stable.

When to Proof Roll

For areas where subgrade appears to be stable without undercutting, proof roll after the top 12 inches (305 mm) of the subgrade meets the compaction requirements and after the subgrade has been brought to approximate shape within 0.1 to 0.2 feet (30 to 60 mm) required by plan lines.

For areas that are obviously unstable and require undercutting, do not proof roll unnecessarily to demonstrate that subgrade correction is required.

The proof rolling should be done immediately after the subgrade compaction operation, when the moisture content of the subgrade soil is near the moisture content that was used to achieve compaction. This minimizes the subgrade becoming too wet or too dry for an effective proof rolling evaluation. If the subgrade is too wet, the material will displace and rut. If the subgrade is too dry, a hard surface crust may carry the proof roller over an undesirable, soft, wet, underlying material without rutting or deflection, and the unstable subgrade may not be detected.

Proof rolling may be done either before or after pipe underdrains are installed. If done after underdrains are installed, rolling should not be done directly over the underdrains. In C&MS 204.06, proof rolling must be performed at least 1.5 feet (0.5 m) away from the underdrains because of the potential damage to the underdrains.

Proof Rolling (204.06)

A "Proof Rolling Documentation Form" is used to document the proof rolling operation. It is imperative that the stations, deflections, weight of the proof roller, and comments are well documented. Digital photographs of subgrade distress are highly recommended.

The primary purposes of proof rolling are to locate unstable areas, to check the subgrade compaction, to demonstrate the design intent, and to provide uniform support for the pavement structure. Unstable subgrade areas that are located will be corrected so that the subgrade density can be maintained throughout the construction. If done correctly, the pavement design intent will be carried through the construction process.

One trip with a proof roller is adequate to achieve satisfactory proof rolling results.

An over loaded proof roller for a soil type may cause satisfactory subgrade to become unstable during proof rolling. Conversely, unstable areas will not be found if the proof roller is too light for the soil type.

Selection of Proof Roller Weight

In view of the many variations in soil and moisture conditions which must be expected in Ohio, the Engineer is given authority to vary the weight and tire pressure of the proof roller to fit the conditions. The weights and tire pressures for the different soils are detailed in C&MS 204.06.

It is imperative that the project chooses the correct proof load for the type of soil on the project. These loads and tire pressures are soil type sensitive when evaluating the subgrade. For A-3, A-4, A-6, and A-7, soils use a 35 ton (32 metric ton) roller with a tire pressure of 120 psi (820 kPa). This weight and tire pressure is used on most projects because these are the most common soils found in the State of Ohio.

For granular soils and soil, rock, and granular mixtures, use a 50 ton (46 metric ton) roller with 120 psi (820 kPa) tire pressure. However, if the granular material was placed as part of an undercut to stabilize an unstable subgrade, then use the weight appropriate for the original subgrade materials (35 or 50 tons).

The goal of proof rolling is to maximize the load to locate unstable subgrade. These unstable soils could be 3 to 5 feet (1 to 2 m) deep. In rare cases, the unstable soil may be deeper than 5 feet (2 m).

Close inspection throughout proof rolling is necessary to observe the rolling effects of the tires and to mark unstable subgrade locations for correction or investigation. Inadequate stability is indicated by deflection, cracking, or rutting of the surface of the subgrade.

Failure Criteria

When is rutting from the proof roller an indication of unstable subgrade? Technically, the maximum allowable rutting or elastic movement of the subgrade is the amount that allows the subgrade soil to maintain the specified density throughout the construction process. For example, if subgrade density can be maintained with 6-inch ruts, then this would be the allowable maximum. In practice, when the ruts from the proof roller are deeper than 1 inch, then there is usually cause for concern. Additionally, if the subgrade deflects more than 1 inch with substantial cracking or lateral movement of the soil, then

this is also cause for concern. Elastic deflection is when the subgrade moves down under the weight of the proof roller and then comes backup (rebounds) after the proof roller passes.

When rutting and deflections are less than 1 inch, there is no assurance that overlying pavement construction will not damage the subgrade compaction. Although subgrade density and stability can be maintained during proof rolling, the repetitive loading, the hauling of materials, and the base and pavement construction can still destroy the subgrade compaction. This may be an issue on some reconstruction projects. On reconstruction projects, the following complications can create or worsen subgrade problems.

1. Water accumulates under the pavement because of poor drainage or clogged underdrain outlets.
2. Construction time frames are more limited.
3. Space limits the ability to dry the material in place.
4. Once the pavement is removed, all the drainage is toward the subgrade. This compounds an already poor drainage situation.
5. Alternate haul routes are limited or not available on reconstruction projects.

The failure criteria are used in this section to determine the locations from which to perform a detailed analysis. This detailed analysis consists of methods discussed later in this section, such as rut depth, soil borings, and test pits. If the subgrade deflects beyond the failure limits given in this section, and the soil borings and test pits determine that the subgrade does not need to be undercut, then the subgrade should be considered satisfactory. One additional area to evaluate is the moisture content of the soil. Some soils are more prone to rut at moisture contents greater than 3 percent below the optimum moisture content. In fill locations, the moisture content can be reduced to minimize this problem. If all of the above criteria are met, there is no reason the subgrade should not perform as anticipated. If there is any debate between the Department and the Contractor, especially if a warranty is involved, then further nondestructive or destructive testing can be used to resolve the issue.

In Figure 204.D, the soil has been compacted in the top foot of the subgrade and the conditions are good for the top 3 feet (1.0 m). However, there is a soft layer at a lower elevation. The soft layer has no detrimental effect on the subgrade density during the subgrade compaction.

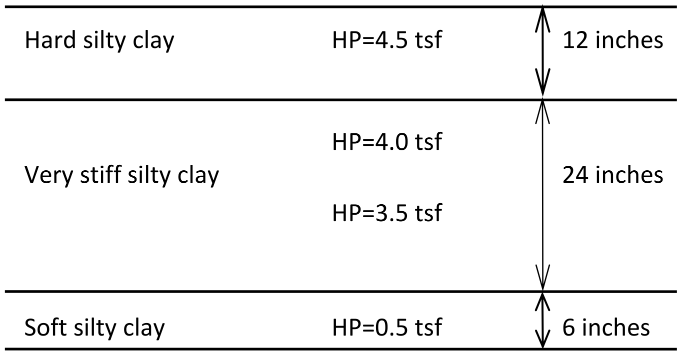


Figure 204.D – Stage 1 compaction of subgrade

In Figure 204.E the proof roller deflects because of the soft soils. The subgrade density may or may not be affected by the proof rolling. The loss of subgrade density is proportional to the amount of rutting or elasticity during proof rolling and subsequent construction operations. The severity of the overall subgrade condition can be measured by the amount of the deflection and elasticity on the surface.

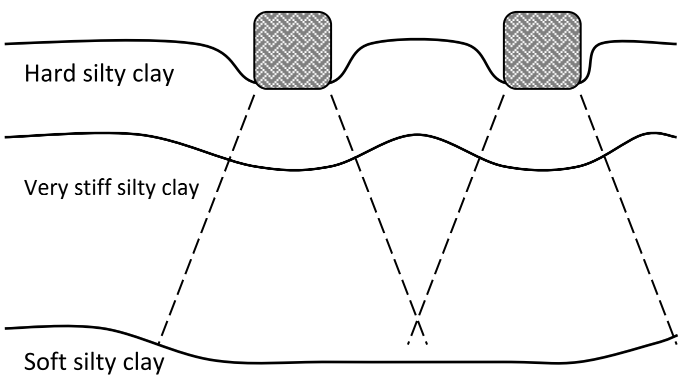


Figure 204.E – Stage 2 proof rolling

When the proof rolling deflections exceed the failure criteria; the proof rolling, repetitive loading, and pavement construction can destroy the top layers of the aggregate base and subgrade.

In actual field conditions, this soft layer can be just a few inches thick and at any elevation from the top 1 foot (0.3 m) to as deep as 5 feet (2 m). In addition, it may be an indication of an overall soil condition that is just over optimum moisture for the entire 5 foot (2 m) depth of the subgrade. The test pit excavation is used to identify the layer, or layers, causing the surface distress. This is further detailed in the section, Investigation, of this Item. It is imperative that these conditions are correctly identified.

Crusting is a condition when the subgrade surface appears to be dry and there is substantial cracking on the surface with or without rutting. This indicates a need for further investigation and usually indicates soft or wet underlying soil at depth with the top foot or so of the subgrade being very dry.

Variations in the Proof Rolling Results

You should not be too concerned with occasional or nominal deflections in excess of the above failure criteria. If the density is checked, and the investigation shows that good soil extends throughout the top 5 feet of the subgrade, then the design intent will be fulfilled and the project can be constructed. All soils will occasionally deflect under these loads.

The pavement design is based on an average CBR. The CBR value was directly correlated to soil density many years ago. By using the average CBR value, the pavement design accounts for a 30 percent, or one standard deviation variation, in the subgrade strength from the design CBR. Fifteen percent is expected to exceed this value and 15 percent is expected to be less than this value. Some variation in the subgrade condition is already accounted for in the pavement design.

Another consideration is the fact that these proof rolling loads and tire pressures are about 10 times the final in-place stresses once the pavement is constructed. The proof rolling tire pressure is 120 psi (820 kPa) and the stresses, once the pavement is constructed, are about 8 psi (55 kPa) for a thin asphalt pavement and 4 psi (27 kPa) for a thick concrete pavement. These proof rolling loads are the largest loads that the subgrade will encounter.

If the project can be constructed while maintaining subgrade density, the subgrade design intent will be fulfilled.

The project should not be concerned with the “Pavement Warranty” issues that Contractors often bring up. If the project follows these guidelines, and properly documents the subgrade work, Central Office can defend the warranty issue.

Once a failure is established based on the proof rolling results, the responsibility for the unstable subgrade and the correction of the failure should be determined.

Responsibility for the Unstable Subgrade

If unstable subgrade locations are found, take compaction tests to determine if the specifications are met in the top 12 inches (300 mm). The Engineer should instruct the Contractor to correct any deficiencies found in these locations.

The Department is responsible when the unstable subgrade is encountered:

1. In cuts.
2. On reconstruction projects.
3. In shallow fill locations where the unstable material is found under the contract fill.
4. When the unstable material is found at lower elevations than the project contract work.

Subgrade stability may not be possible by compacting the upper 12 inches (0.3 m) because of conditions at these lower elevations.

It is the Contractor's responsibility to correct all unstable locations in fills. If the Contractor built the fill correctly, the proof rolling will do nothing but verify specification work. If the fill fails then the proof rolling will determine the location of the deficient specification work.

If the Contractor fails to maintain the subgrade, the Engineer should instruct the Contractor to repair the failed areas. See C&MS 203.04.A for the Contractor's responsibility to drain and maintain the subgrade.

The Contractor must be afforded reasonable use of the subgrade for hauling and for constructing the base material. If subgrade density cannot be maintained through reasonable use of the subgrade, then the allowable proof rolling rutting is too much. If the project conditions allows, areas other than the subgrade should be used as haul roads. For a Contractor 'to bid' to haul loaded trucks or scrappers endlessly across the subgrade throughout the life of the project is not reasonable. At a minimum, the Contractor should be allowed the use of the subgrade to place the base material with vehicles of legal weight.

Investigation

Investigate the causes of failed locations quickly to expedite the corrective treatment. Three pieces of information are needed to make the most economical subgrade treatment:

1. Rut depth.
2. Soil boring information.
3. Test pit data.

At this point, the rut depth has already been determined.

Soil Boring Information

For reconstruction projects or cut sections, the soil borings can be examined to determine an estimated undercut depth or stabilization methods.

Evaluate Standard Penetration Test (SPT) results from soil borings in the failed subgrade locations. The SPT is an indicator of soil consistency or strength and measures the number of blows per foot (N-values)) required to drive the soil sampler through the soil. Due to variability of drilling and testing equipment, the N-values are corrected to a standard equivalent energy of 60 percent and are demoted as "N_{60}" on the boring logs and soils information plan sheets. {Note: The soil data on the boring logs from projects prior to about 2007 were presented as the number of blows required to drive each 6-inch (150 mm) increment. The first 6 inches (150 mm) of the run is ignored because the sampler may not be seated in the borehole or may be driven through cuttings. For example, standard penetration data shown as 1/2/3 has an N-value of five blows per foot.}

When investigating the need for undercutting or stabilization in failed locations, look at the borings in those locations in the upper 5 feet (1.5 m) of the subgrade. At each location, pick the lowest N_{60} value when multiple N_{60} values are taken in the top 5 feet (1.5 m) of subgrade.

Average the N_{60} values along the failed locations. This value provides one part of the information needed to determine the undercut depth or stabilization methods.

Test Pits

Once the soil borings have been evaluated, construct test pits by excavating 3 to 5 feet (0.6 to 1.5 meter) into the subgrade using the Contractor's excavation equipment. Excavate at least two test pits that represent the failed area. Use judgment for long areas, usually about two to four test pits per mile is sufficient. Construct the test pits across the width of the subgrade in the failed locations. Pick locations with the highest deflections to evaluate the most severe locations.

Warning: These trenches may collapse on the construction personnel. The Department offers an 8-Hour Construction Safety Class to evaluate the trench collapse risk. In addition, there is a trench safety class offered by the Bureau of Workers Compensation, Division of Safety and Hygiene. These classes are given statewide, all year around. (800-644-6292)

An examination of the soil and moisture conditions in these test pits provides valuable information to make the appropriate correction. Once the pits are excavated, the Engineer must examine the trench sidewalls and the bottom of the cut.

Record the test pit information on the "Subgrade Test Pit Investigation Form" shown in Figure 204.G. The soil conditions vary with depth and must be quantified. By examining the sidewalls, the Engineer can determine the soil type, layer thickness, soil condition, and soil strength by using a hand penetrometer.

Project No. ____________ Co-Rt-Sec ____________ Date ____________

Proof Rolling Results

Station to Station	Lane Lt/Rt	Rut Depth	Cracking	Elastic or Plastic Movement

Test Pit Location

Station ____________ Offset ____________ Subgrade Elevation ____________

Depth from	Depth to	Hand Penetrometer ton/ft²	Layer Description
		HP1 =	Material type:
		HP2 =	Layer thickness (ft):
		HP3 =	Soil / rock conditions:
		Avg =	Comments:
		HP1 =	Material type:
		HP2 =	Layer thickness (ft):
		HP3 =	Soil / rock conditions:
		Avg =	Comments:
		HP1 =	Material type:
		HP2 =	Layer thickness (ft):
		HP3 =	Soil / rock conditions:
		Avg =	Comments:
		HP1 =	Material type:
		HP2 =	Layer thickness (ft):
		HP3 =	Soil / rock conditions:
		Avg =	Comments:

Material Types - clay, silt, sand, gravel, shale, rock (see Construction Inspection MOP 203.02)
Soil conditions - wet, dry, organic, roots, water seepage, soup, jello, hard or soft peanut butter

Take photographs of test pit.
Draw diagram of test pit and
relevant features on back.

Inspector Date

Figure 204.F –Subgrade test pit investigation form

The Engineer must field classify the soil. See 203.02 Materials, Identifying Soil and Granular Materials in the Field, for help in the classification.

Added soil conditions are described on the bottom of the test pit form. These conditions are stated in commonly-known consistencies, so that the non-geotechnical reader can relate to the soil conditions. They are listed on the bottom of the form. No explanation is needed for these terms.

Hand Penetrometer Readings

A hand penetrometer can be used to further classify the soil and to estimate its strength. A hand penetrometer can be obtained from a test lab supply company for less than $100. Hand penetrometers (a.k.a, pocket or soil penetrometers) can be obtained from the following companies:

Gilson Company, Inc.	Model # HM-500
ELE International	Model # 29-3729
Humboldt Manufacturing	Model H-4200 or H-4195
Geotest Instrument Corp	Model E-280

The exact instructions come with the hand penetrometer. In summary:

1. Push the hand penetrometer slowly into the soil perpendicular to the surface.
2. Record the reading when the hand penetrometer penetrates the soil to the 1/4-inch groove mark.
3. Record the readings to the nearest 0.25 tons per square foot (tsf).
4. Take at least three different readings in each soil layer.

Use the "Subgrade Test Pit Investigation Form" to record the readings. Average the readings once three readings are taken for the soil layer. Also, evaluate the bottom of the test pit; this is extremely valuable information. Average the hand penetrometer readings (HP) of all the test pits in the failed locations. Use this number to further evaluate the undercut depth or stabilization methods.

Consider the following when evaluating the sidewalls of a trench:

1. Different layers of a natural formation or cut are more noticeable than fill materials.
2. High hand penetrometer readings may be obtained with high deflections or rolling at the surface. This is an indication of soft soil at a lower elevation than 5 feet (2 m) or a subgrade soil that is just too wet.

Undercut Depth and Stabilization Determination

Once the proof rolling rut depth (in inches), soil boring information (N_{60}), and hand penetrometer readings from the test pits (HP) are obtained, use the Subgrade Treatment Chart in Figure 204.G to determine the recommended depth of undercut or chemical stabilization. The input values (rut depth, N_{60} and HP) are on the horizontal axis. The two curves show the undercut depth with a geotextile and with a geogrid. The chart also shows the chemical stabilization depth required in inches along the bottom. Note that the results from this chart are guidelines. The subgrade conditions might require undercuts that are less than or greater than those shown, because subgrade conditions can be highly variable.

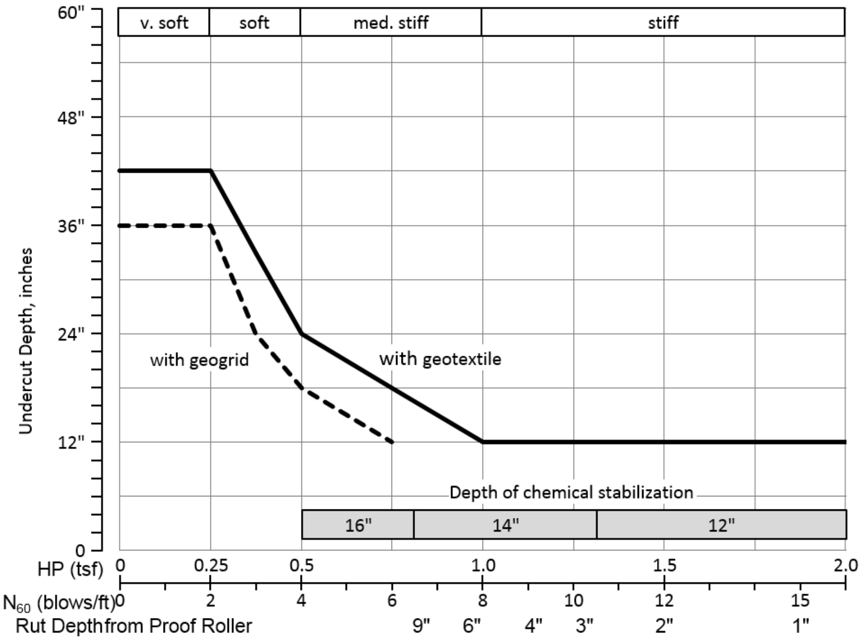


Figure 204.G – Subgrade treatment chart

The subgrade treatment chart takes into account some variation in test results, the anticipated loading from the proof roller, and typical truck loading during construction.

Use the rut depth, N_{60} values, and hand penetrometer readings (HP) to draw a vertical line to the curve. The recommended depth of the undercut is where the vertical line intersects the curve. For soft and very soft soils, it may be economical to use a geogrid to reduce the depth of the undercut. The geogrid restrains the granular material from lateral movement and makes it more effective. Refer to Supplemental Specification 861 for using geogrids for subgrade stabilization.

The chart does not recommend chemical stabilization for soft and very soft soil. This is primarily because of constructability problems. Although chemical stabilization does improve the stability of soft and very soft soils, these soils usually cannot support the equipment used to perform the chemical stabilization.

It would be rare to see a perfect alignment in the results from all three inputs. In some cases, one or two of these inputs may not be available. In other cases, some judgment is needed to redesign the most economical undercut that will work. In order of hierarchy, use the test pit data, then the N_{60} values, and then the rut depth. The rut depth is the least reliable indicator of undercut need because it cannot determine which soil layer is causing the deflection.

There will be cases where the N_{60} values and unconfined strength values are all high, but the subgrade is rolling and cracking, and rut depth is greater than allowable. In this case, use the rut depth as a guide to redesign the undercut. See the last example in the example section.

There is an example in Figure 204.H.

Given: Average N_{60} = 10.
Average HP = 1.1 tsf.
Average Rut Depth was 4 to 8 inches.

Answer: Use an undercut depth of 12 to 18 inches with a geotextile or chemically stabilize with 14 inches of cement or lime. For very large areas, give serious consideration to the stabilization method. It will be more cost effective.

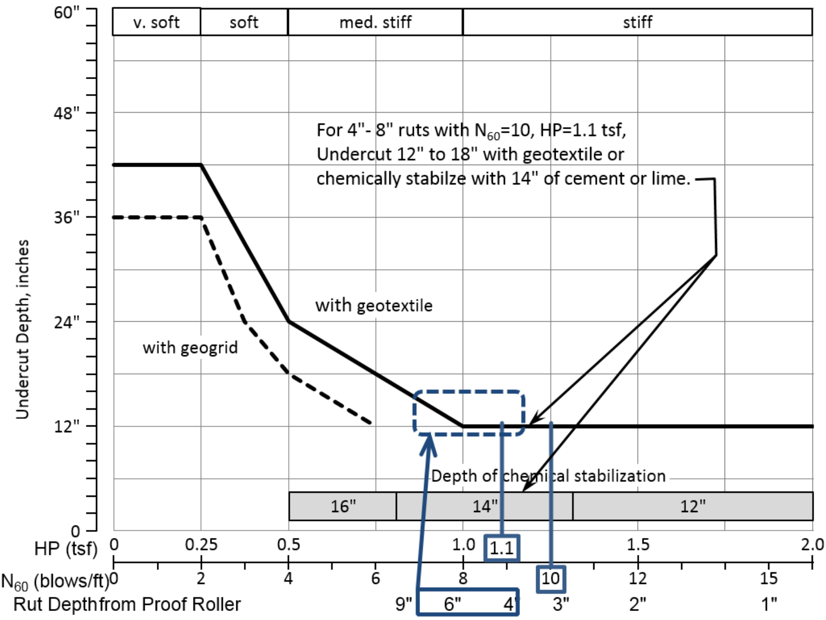


Figure 204.H – Example using the subgrade treatment chart

After making the undercut, this depth may need to be adjusted to meet the actual conditions. See the section, “Implementation During Construction,” of this manual.

General Rules

On new construction projects, if all of the unstable material can be removed, and the bottom of the test pits or cuts are stable, then soil may be used as replacement material. For reconstruction projects, soil is usually not available in large quantities. Therefore, soil undercuts are less effective solutions on reconstruction projects.

If the bottom of the test pit is unstable when conditions are highly variable or for reconstruction projects, use granular material, rock, geotextile, geogrid, or chemical stabilization rather than soil.

Undercuts should be used in small locations or in areas where spot locations are identified. Consider chemical stabilization for long areas greater than one mile.

Only the most unusual cases require removal to depths greater than 3 feet (1 meter). Seventy five to 90 percent of subgrade problems can be solved with a 1-foot treatment of granular material and geotextile or chemical stabilization.

If a project or section of a project undercut locations are more than 30 percent of the total area, undercut or chemically stabilize the entire area. If you do not undercut the entire area, these locations will grow, and the construction will be inefficient as the construction proceeds. The Department pays a higher cost at a reduced, final quality by undercutting a high percentage of the subgrade throughout the project. ODOT would not repair a bridge deck or pavement with this high a percentage of repairs.

Chemical stabilization methods speed construction because of the ability to work immediately after a rain. Estimates indicate that the construction production is increased by at least 50 percent by using stabilization methods.

Examples:

The following table shows some example solutions. The types of material refer to 703.16.C and Item 206.

Given	**Solution**
Project with Deep, weak, and wet A-4a with N = 12 or HP=1.4 tsf. Rut Depth = 2"	12 inches of Granular Material Type B, C, or D, with geotextile or 12 inches of stabilization with cement. (A-4a: PI $\leq$ 10)
Project with Deep, weak & wet A-4a, A-6 or A-7-6 combination with N = 10 or HP=1.0tsf. Rut Depth = 4"	12 inches of Granular Material Type B, C, or D with geotextile or 14 inches of stabilization with lime or cement (Check the PI of the soils to select the stabilization chemical).
New Construction, Jell-O like consistency of soil with N = 5 or HP=0.5 tsf. Rut depth > 6"	24 inches of Granular Material Type B, C, or D, with geotextile, or 18 inches of granular material with geogrid and geotextile, or 16 inches of chemical stabilization (Check the PI of the soil).
Project with soup like consistency of soil with N = 2 or HP=0.25 tsf. Rut Depth = Buried equipment	3.5 feet of Granular Material Type B, C, or D with geotextile, or 3 feet of granular material with geogrid and geotextile. (Use Type D material if available)
Reconstruction Project with Sandy, A-4a, A-6a soils PI < 20, N = 8 or HP=1.0 tsf Rut Depth = 6". (Long Project)	Cement Stabilized Subgrade 14" deep at 6%
New Construction A-7-6 clay soil, PI > 20 N = 11 or HP=1.2 tsf Rut Depth =3". (Long Project)	Lime Stabilized Subgrade 14" deep at 5%
Reconstruction Project A-6a silty clay PI < 20, N=30 and HP>4.5 tsf. Rut depth > 2" and rolling The key here is the rolling. Probably caused by high moisture content of the soil at a depth. If the subgrade is rolling with one pass of a proof roller then the subgrade condition can rapidly deteriorate during construction.	16" of Cement at 6% or 24-inch undercut with Granular Material Type B, C, or D, with geogrid and geotextile. Use Type D material if available.

Type of Undercut Materials

Use Granular Material Types B, C, D, E, and F. They are generally cheaper than 304.

Type B is a well-graded aggregate with the gradations of Items 304, 411, or 617, but can have more fines. Type C has a top size of 3 inches and Type D has a top size of 8 inches. Both C and D are well-graded materials. The larger top size material will bridge the unstable material better than the smaller size material.

Use Granular Material Type E when water levels are high or cannot be drained. The Type E materials are very porous. Always choke the Granular Material Type E with Granular Material Type B or geotextile fabric.

There is a potential for piping of soil into the Granular Material Type E as shown in Figure 204.I. In the figure on the left, when the open graded material is placed on wet, fine-grained soil, the soil is carried into the open graded material during construction (pipes). In the figure on the right, the geotextile fabric blocks the fine-grained soil from entering the open graded material. Geogrids will not perform this separation function.

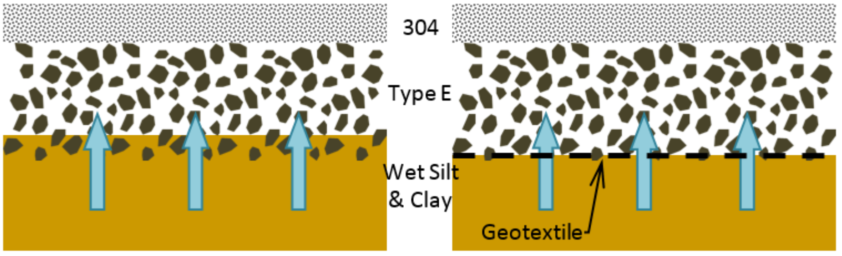


Figure 204.I – Soil piping in open material

Underdrains cannot be placed through Granular Material Types D, E, or F. Use Granular Material Type B in the locations of underdrains. Underdrains can be trenched through geotextile and geogrid if there is enough material above the geotextile or geogrid to confine it. Always drain the undercut to an underdrain, catch basin, or pipe.

The use of 712.09 Geotextile Fabric Type D is recommended in most cases. The cost is around $1.00 per square yard, and it serves to keep the granular material and underlying soil separated. This results in better performance of the undercut. When the depth of the undercut is 24 inches or greater, consider using a geogrid to reduce the depth of the undercut. For undercuts 12 to 16 inches deep, place a geotextile in the bottom, then the geogrid, and then the granular material. For undercuts 16 inches deep and greater, place the geotextile in the bottom, then half the granular material, the geogrid, and then the rest of the granular material. For severe situations, you can use multiple layers of geotextile and geogrids. Consult with the Office of Geotechnical Engineering in these cases.

Chemical Stabilization of the Subgrade

Item 206 Chemically Stabilized Subgrade can be used to treat unstable subgrades. Lime or cement is typically used.

Lime is used for A-6b (silty/clay) or A-7-6 (clay) soils which have a plasticity index of 20 or greater. As a general guideline, use 5 percent lime by dry weight of the soil, assuming a dry weight of 110 pounds per cubic foot.

Cement can be used to treat unstable subgrades consisting of A-3's (fine sand, coarse and fine sand), A-2-4 through A-2-7 (sandy and silty gravels), A-4a (sand silt), A-6a (silt and clay), A-6b (silty clay), or A-7-6 (clay) which have a plasticity index less than 20. As a general guideline, use 6 percent cement by dry weight of the soil assuming a dry weight of 110 pounds per cubic foot.

See Item 206, Chemically Stabilized Subgrade, of this manual.

Implementation During Construction

Once the type of stabilization treatment has been chosen, constant monitoring of the construction is required to adjust the treatment to meet the field conditions. Soil conditions always vary; they vary the most on reconstruction projects or in cuts.

If the undercut option is chosen, the project should monitor the bottom of the cut and evaluate the condition. Take hand penetrometer readings at the bottom of the cuts and compare them to the initial test pit or soil boring information. If the condition changes from the earlier evaluation of the test pits or the soil borings, then adjustments to the undercut depth are required.

For undercuts that are 2 feet deep or greater, give consideration to using geogrid in addition to the geotextile fabric. The need for geogrid can be determined by: 1) Placing fill to approximately half of the undercut depth. 2) Load the undercut with a fully loaded truck. 3) If the area is still unstable, place the geogrid and continue to fill the undercut.

Once the undercut or stabilization is complete, proof roll the area to ensure that the final subgrade meets the rut depth and density requirements as detailed earlier in section "Failure Criteria."

Constant vigilance is needed in order to make the most economical correction. It is easy to over-excavate unnecessarily and waste money. It is more difficult to make the right economical choice to stabilize the subgrade and to meet the design and construction needs.

205 Chemically Stabilized Embankment

Uses of Chemically Stabilized Embankment

Chemically stabilized embankment is generally used to repair landslides, as shown in the following figure. This situation involves the removal of wet soil, treating it with cement or lime, and then using the treated soil to rebuild the embankment. Notice the addition of drainage to the slide repair.

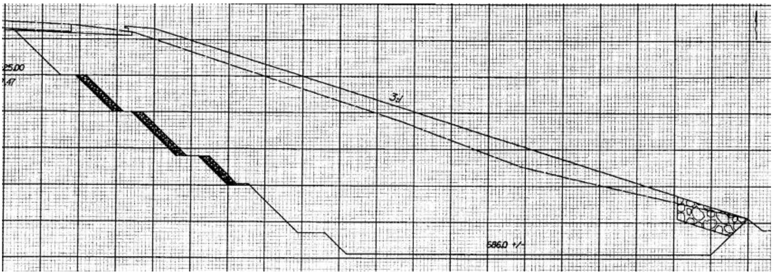


Figure 205.A – Typical use of chemically stabilized embankment to repair landslide

Cement is most effective in treating soils with a Plasticity Index (PI) less than 20, such as sandy and silty soils like A-3a, A-4a, A-4b, A-6a, and some A-6b soils. Use cement stabilized embankment to treat areas with N values (SPT blow counts) as low as 5 and unconfined strengths (hand penetrometer) as low as 0.5 tsf.

Lime is most effective in treating soils with a PI greater than 20, such as A-7-6 and A-6b soils. Use lime stabilized embankment to treat areas with N values (SPT blow counts) as low as 10 and unconfined strengths (hand penetrometer) as low as 1.0 tsf.

Lime kiln dust (LKD) has been used to stabilize unstable soils. But, it is currently limited to being used by the Contractor as a drying agent for wet embankment material.

Materials (205.02)

If using cement, use Type 1 cement according to 701.04. If using lime, use quick lime conforming to 712.04.B. Quick lime must pass through the No. 4 (4.75 mm) sieve. Lime must come from a certified supplier.

Construction (205.04)

Limitations

Chemical stabilization should not be performed when the temperature is below 40 ºF (5 ºC), when the ground is frozen, or when it is raining. In order to stabilize the soil, the chemical needs to react with the water in the soil. It cannot do that if the water is frozen. If it is raining, the rain water will react with the lime or cement instead of the water in the soil.

Spreading lime or cement creates some dust; therefore, chemical stabilization should not be performed when it is windy, as this will spread the dust outside of the project area.

Spreading (205.04.A)

The amount of chemical applied to each lift is based on a percentage of the dry weight of the soil that will be treated. The percentage is typically 4 to 7 percent for cement and 4 to 8 percent for lime. If the Mixture Design for Chemically Stabilized Soils pay item is included in the plans, the Contractor will determine the appropriate percentage of chemical based on a testing program. If the pay item for the mixture design is not included in the plans, use the percentage given in the plans or the percentage given in 205.04.A.

To calculate the spreading rate (number of pounds of chemical per square yard), use the following equation:

$$C = 0.75 \times T \times D \times P$$

Where:

C = Spreading rate for chemical (pounds per square yard).

T = Thickness of embankment lift (inches).

D = Average dry density of soil (if not known, assume 110 lb/ft^3).

P = Percentage of chemical, expressed as a decimal

(e.g., 5% = 0.05)

0.75 is a unit conversion factor (9 ft^2 / 1 yd^2 × 1 ft / 12 in).

For example, if using 4 percent of a chemical and an 8-inch embankment lift:

$$C = 0.75 \times 8 \text{ in} \times 110 \text{ lb/ft}^3 \times 0.04 = 26.4 \text{ lb/yd}^2 \text{ of chemical}$$

The Contractor must submit a spreading plan or report two days before the work and indicate how the Contractor will achieve the required spreading rate. After the spreading operation, check the Contractor's spreading rate by taking the total weight of chemical spread and dividing it by the area that was treated.

For slide repair work, a loader is sometimes used to spread the chemicals. The exact amount of chemical in each lift of soil is not as critical as it is in subgrade stabilization work (Item 206).

When a mechanical spreader is used, dusting is minimized by using a shroud around the spreader bar that extends to the surface. A distribution bar with a maximum height of 3 feet (1 m) above the subgrade should be used. The chemical should not be spread if wind conditions are such that blowing dust exceeds the limits in 107.19.

Figure 205.B – Spreading cement with a shroud around the spreader bar

Mixing (205.04.B)

The Contractor should mix the chemical into the soil immediately after spreading the chemical. The Contractor may use a spring tooth harrow, a disk harrow, or a power driven rotary mixer which looks like a big rotary tiller. However, if the area is beneath a pavement or paved shoulder, the Contractor must use the power driven rotary mixer.

Figure 205.C – Rotary mixer for chemical stabilization

If using a power driven rotary mixer, mix the soil and chemical until all the soil clods are reduced to a maximum size of 2 inches (50 mm). Add water, if necessary, to bring the mixture to at least the optimum moisture content if using cement, or to bring the mixture to at least 3 percent above optimum moisture content if using lime. Quick lime reacts more strongly with water and the additional water prevents future expansion problems. Determine the optimum moisture content from the moisture-density curves developed in

the test program from the mixture design or by using the Ohio Typical Moisture Density Curves and the one-point Proctor method in Supplement 1015.

Figure 205.D – Disk harrow

If using a spring tooth or disk harrow, break-up the soil with the harrow before spreading the chemical. Mix the chemical into the soil and add water as described above. During mixing, use at least 20 passes of the harrow: 10 in one direction and 10 in a direction which will be perpendicular to the first 10. Reduce all the soil clods to a maximum size of 1 inch (25 mm). The harrows do not mix the chemical as well as the rotary mixer; therefore, more effort is required with the harrow to mix the chemical and soil.

Note that for Chemically Stabilized Embankment, the mixing is the same for all the chemicals. This is different from Chemically Stabilized Subgrade.

Compacting (205.04.C)

Compact to 98 percent of the maximum dry density and use the one-point Proctor method in Supplement 1015 to determine the maximum dry density. In some cases, the test section method or the moisture-density curves developed by the Contractor may be used to determine the maximum dry density.

Mixture Design for Chemically Stabilized Soils (205.05)

If a pay item for Mixture Design for Chemically Stabilized Soils is included in the plans, then the Contractor uses the testing program described in Supplement 1120 to determine the spreading rate for the chemical. Different mixtures of the soil and chemical are tested for unconfined compressive strength. The results are used to determine the percentage of chemical used in the field. The common increase in strength ranges from 20 psi to 100 psi with lime and from 50 psi to 200 psi with cement.

Method of Measurement (205.06)

The mixture design pay item also includes verification testing of the stabilized embankment. For this reason, the Department pays for only two-thirds of the lump sum

item for mixture design testing after the mixture design is complete. The other one-third is paid after the chemically stabilized embankment is completed, and all field verification test results have been provided.

206 Chemically Stabilized Subgrade

Uses and Application for Chemically Stabilized Subgrade

Use chemically stabilized subgrade for improving long sections of subgrade, generally more than a mile. It is not cost-effective for short spot locations. If the chemical stabilization is not in the plans, and is being added to the project in order to address a subgrade problem, use the Subgrade Treatment Chart in Figure 204.H to determine the appropriate depth of chemical stabilization. If the chemical stabilization is in the plans, the designer used Geotechnical Bulletin 1, *Plan Subgrades*, from the Office of Geotechnical Engineering to design the chemical stabilization.

There are primarily two chemicals used to treat soil: cement and lime. The Department discontinued using lime kiln dust for subgrade stabilization. It is currently limited to being used by the Contractor as a drying agent for wet embankment material.

Cement is most effective in treating soils with a plasticity index (PI) less than 20, such as sandy and silty soils like A-3a, A-4a, A-4b, A-6a, and some A-6b soils. Use cement stabilized subgrade to treat areas with N values (SPT blow counts) as low as 5, unconfined strengths (hand penetrometer) as low as 0.5 tsf, and to remove ruts up to 12 inches (300 mm) deep.

Lime is most effective in treating soils with a PI greater than 20, such as A-7-6 and A-6b soils. Use lime stabilized subgrade to treat areas with N values (SPT blow counts) as low as 10, unconfined strengths (hand penetrometer) as low as 1.0 tsf, and to remove ruts up to 6 inches (150 mm) deep.

Materials (206.02)

If using cement, use Type 1 cement conforming to 701.04. If using lime, use quick lime conforming to 712.04.B. Quick lime must pass through the No. 4 (4.75 mm) sieve. Lime must come from a certified supplier.

The curing coat consists of a rapid setting emulsified asphalt conforming to 702.04 (e.g., RS-1, RS-2, HFRS-2, CRS-1, CRS-2). The Department has discontinued using prime coat and concrete curing compounds for the curing coat on chemically stabilized subgrade.

Test Rolling (206.04)

If chemical stabilization is specified in spot locations, use test rolling with a proof roller to locate areas that require the chemical stabilization. If rutting is significant (greater than 6 inches for cement, greater than 4 inches for lime), investigate the subgrade by digging test pits. After the chemical stabilization is complete, proof roll the stabilized areas.

If chemical stabilization is specified throughout the project, do not test roll before stabilization, but do perform proof rolling after the chemical stabilization work is complete.

Construction (206.05)

Limitation

Chemical stabilization should not be performed: when the temperature is below 40 ºF (5 ºC) or forecasted to be below 40 ºF (5 ºC) during the curing period; when the ground is frozen; or when it is raining. In order to stabilize the soil, the chemical needs to react with the water in the soil. It cannot do that if the water is frozen. If it is raining, the rain water will react with the lime or cement instead of the water in the soil.

Spreading lime or cement creates some dust; therefore, chemical stabilization should not be performed when it is windy, as this will spread the dust outside of the project area.

Spreading (206.05.A)

The amount of chemical applied to the subgrade is based on a percentage of the dry weight of the soil that will be treated. The percentage is typically 4 to 7 percent for cement and 4 to 8 percent for lime. If the Mixture Design for Chemically Stabilized Soils pay item is included in the plans, the Contractor will determine the appropriate percentage of chemical based on a testing program. If the pay item for the mixture design is not included in the plans, use the percentage given in the plans or the percentage given in 206.05.

To calculate the spreading rate (number of pounds of chemical per square yard), use the following equation:

$$C = 0.75 \times T \times D \times P$$

Where:

C = Spreading rate for chemical (pounds per square yard).

T = Thickness (or depth) of stabilization (inches).

D = Average dry density of soil (if not known, assume 110 lb/ft^3).

P = Percentage of chemical, expressed as a decimal.
(e.g., 5% = 0.05)

0.75 is a unit conversion factor (9 ft^2 / 1 yd^2 × 1 ft / 12 in).

For example, if using 5 percent of a chemical and a 12-inch depth of treatment:

$$C = 0.75 \times 12 \text{ in} \times 110 \text{ lb/ft}^3 \times 0.05 = 49.5 \text{ lb/yd}^2 \text{ of chemical.}$$

The Contractor must submit a spreading plan or report 2 days before the work and indicate how the Contractor will achieve the required spreading rate. After the spreading operation, check the Contractor's spreading rate by taking the total weight of chemical spread and dividing it by the area that was treated. To check the spreading rate during the work, take a pan and place it on the prepared surface in front of the spreading truck (the pan will have to be placed in a small depression to keep the shroud from knocking it over). Once the spreader has passed and filled the pan with the chemical, weigh the filled pan. Determine the weight of the chemical by subtracting the weight of the pan. Calculate the spreading rate by dividing the weight of the chemical by the area of the pan (remember to convert the area of the pan to square yards).

Example: Weight of pan and chemical = 7.3 lb

Weight of pan = 2.8 lb

Pan is 9 in × 13 in

$$\frac{7.3\text{ lb} - 2.8\text{ lb}}{9\text{ in} \times 13\text{ in}} \times \frac{1296\text{ in}^2}{1\text{ yd}^2} = 49.8\,{}^{\text{lb}}\!/_{\text{yd}^2}$$

When a mechanical spreader is used, dusting is minimized by using a shroud around the spreader bar that extends to the surface. A distribution bar with a maximum height of 3 feet (1 m) above the subgrade can be used. The chemical should not be spread if wind conditions are such that blowing dust exceeds the limits in 107.19.

Figure 206.A – Spreading cement with a shroud around the spreader bar

Mixing (206.05.B)

The Contractor should mix the chemical into the soil immediately after spreading the chemical. The specifications require a power driven rotary mixer which looks like a big rotary tiller.

Mixing Cement

The specification describes a two-step process for mixing cement into the soil, but a single mixing is allowed if the Contractor can add water through the mixer and obtain the required gradation with the single mixing. For cement, at least 80 percent of the mixed soil must be smaller than the openings in a No. 4 sieve, and all of the soil clods must be smaller than 1 inch (25 mm). Any stones in the soil that would be retained on the No. 4 sieve are not considered when calculating the percentage. If necessary, add water until the soil-chemical mixture is at optimum moisture content. Determine the optimum moisture content from the moisture-density curves developed in the test program from the mixture design or by using the Ohio Typical Moisture Density Curves and the one-point Proctor method in Supplement 1015. To ensure thorough mixing, check the mixture for uniform color.

Figure 206.B – Rotary mixer adding water from tanker truck

Mixing Lime

Lime stabilization requires two separate mixings with a mellowing period in between the mixings. During the initial mixing, all the soil clods are reduced to a maximum size of 2 inches (50 mm) and water is added, if necessary, to bring the mixture to at least 3 percent above optimum moisture content. Quick lime reacts more strongly with water and the additional water prevents future expansion problems. Determine the optimum moisture content from the moisture-density curves developed in the test program from the mixture design or by using the Ohio Typical Moisture Density Curves and the one-point Proctor method in Supplement 1015.

After the initial mixing, lime stabilized subgrade is allowed to sit undisturbed (mellowed) for at least 24 hours, but not more than 7 days. During the mellowing period, the clumps of lime breakdown and the lime reacts with the soil, breaking up the soil clods. After the second mixing, at least 60 percent of the mixed soil must be smaller than the openings in a No. 4 sieve and all of the soil clods must be smaller than 1 inch (25 mm). Any stones in the soil that would be retained on the No. 4 sieve are not considered when calculating the percentage. To ensure thorough mixing, check the mixture for uniform color.

Compacting (206.05.C)

Chemically stabilized subgrade should be compacted immediately after the shaping and final mixing. For cement, the compaction needs to be completed within 2 hours of adding water. Compaction is performed with a vibratory, footed roller weighing at least 10 tons (9 metric tons). However, the final rolling is performed with a smooth drum roller without any vibration.

For the compaction testing criteria, use 98 percent of the maximum dry density and use the one-point Proctor method in Supplement 1015 to determine the maximum dry density. In some cases, the test section method or the moisture-density curves developed by the Contractor may be used to determine the maximum dry density.

Check the depth of the stabilization by digging a hole. Apply phenolphthalein or dilute hydrochloric acid to the side of the hole to check for the presence of lime or cement. If the chemicals are present, the phenolphthalein will turn purple and dilute hydrochloric acid will fizz.

Figure 206.C – Checking depth of soil stabilization with phenolphthalein

Curing (206.05.D)

The chemically stabilized subgrade must cure for at least 5 days. The surface of the chemically stabilized subgrade is covered with a rapid setting emulsified asphalt to retain moisture in the subgrade during the curing period. Before the curing coat is applied, the surface must be wet. If the surface has dried out (turns white) before the curing coat is applied, the Contractor needs to add more water to the surface.

The curing coat must uniformly cover the surface of the chemically stabilized subgrade. The following photos show an example of good coverage and poor coverage using a curing compound.

Figure 206.D – Example of good coverage with curing compound

Figure 206.E – Example of poor coverage with curing compound

Curing coats can leach off the subgrade if not cured completely prior to a rain event. During the curing period, all equipment should stay off the subgrade.

Proof Rolling (206.05.E)

Proof roll the chemically stabilized subgrade after the cure period. If the stabilization was performed properly, and the planned depth of stabilization was adequate, there should be no deflection or rutting.

Mixture Design for Chemically Stabilized Soils (206.06)

If a pay item for Mixture Design for Chemically Stabilized Soils is included in the plans, then the Contractor uses the testing program described in Supplement 1120 to determine the spreading rate for the chemical. Different mixtures of the soil and chemical are tested for unconfined compressive strength. The results are used to determine the percentage of chemical used in the field. The common increase in strength ranges from 20 psi to 100 psi with lime and from 50 psi to 200 psi with cement.

Method of Measurement (206.07)

The mixture design pay item also includes verification testing of the stabilized subgrade. For this reason, the Department pays for only two-thirds of the lump sum item for mixture design testing after the mixture design is complete. The other one-third is paid after the chemically stabilized subgrade is completed, and all field verification test results have been provided.

208 Rock Blasting

General Information

This section only covers the basic concepts of rock blasting. The topic is covered in more detail in the FHWA manual, *Rock Blasting and Overbreak Control*, FHWA-HI-92-001. Many of the figures and specification concepts originated from this manual. The manual is available on the FHWA website:

www.fhwa.dot.gov/engineering/geotech/library_listing.cfm

There used to be a training course from NHI for Rock Blasting and Overbreak Control, but unfortunately this course is no longer available from NHI.

Rock Blasting Basics

Rock blasting consists of drilling holes in the rock at depths, in diameters, and at spacing so that the explosive can fracture the rock in a controlled manner. The rock must fracture enough to displace it and break it down to the size of the intended use. The primary explosive used for rock blasting is ANFO, which is a mixture of Ammonium Nitrate (fertilizer) and Fuel Oil (diesel fuel).

The specifications limit the way blasting contractors can blast to ensure that rock or blast vibrations do not harm people or adjacent property.

Blasting Free Body Diagram

The basic geometry for rock blasting is shown in Figure 208.A.

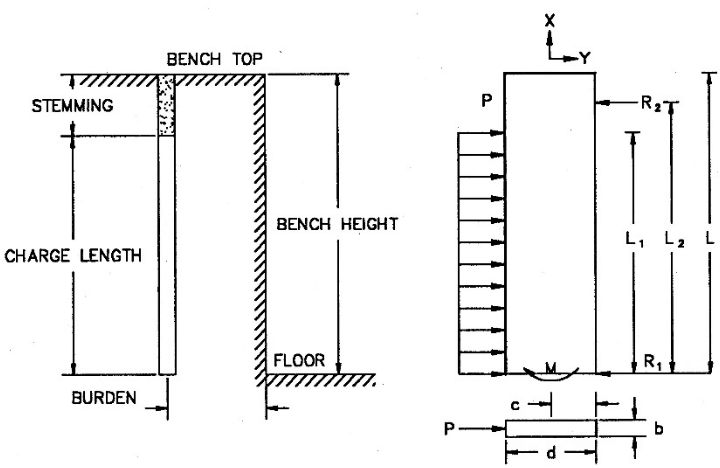


Figure 208.A – Rock blasting free body diagram

Holes are drilled to the required depth in order to remove the rock and then filled with ANFO (the charge length). The charge is topped off with stemming, which helps to hold

the blast down. The free body diagram on the right-hand side of Figure 208.A shows the explosive pressure (P) and moment (M) from the blast.

The blaster and blasting consultant can arrange the geometry of the blast for optimal breakage. This is done so that P and M do not exceed the amount needed to break the rock. Excessive P and M causes flyrock and excessive air blast and vibrations, which can cause damage and injury.

Blasting Geometry and Symbols

Figure 208.B further defines the rock blasting geometry.

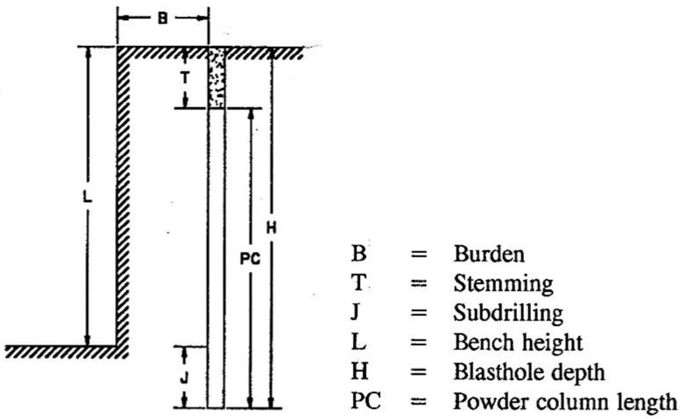


Figure 208.B – Rock blasting geometry and symbols

Figure 208.B illustrates the following blast geometry parameters:

- B (Burden) is the distance between the free face and the first hole.
- T is the stemming (the inert material in the hole).
- L is the length of the bench height.
- H is the blasthole depth.
- PC is the powder column length (ANFO).
- J is the subdrill depth or the depth the hole extends below the planned cut.

Two main parameters to remember here are the slenderness ration (L/B)and the stemming height (T).

Hole Spacing and Timing

The top view of the rock blasting geometry is shown in Figure 208.C. Notice the distance B is still the distance to the free face. The distance S, or spacing of the holes, is a function of the burden.

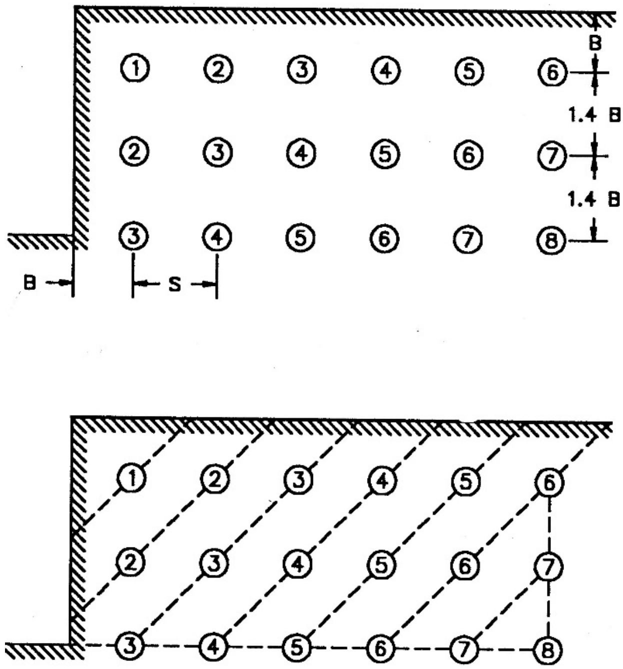


Figure 208.C – Rock blasting (top view)

The spacing of the holes and the timing (or delay) of the holes are part of the blasting design. The bottom illustration in Figure 208.C shows how the blast is delayed by the sequencing numbers. Each hole may be blasted milliseconds apart to control the blast. The row-to-row shots are certainly time delayed.

An initiation system transfers the detonation signal from hole-to-hole at precise times. Plastic shock tubes or electric caps using a timing system are generally employed. A shock tube is non-electric, instantaneous, and has a thin reactive powder that propagates the shock wave signal.

The timing or delay minimizes the pounds of explosive per delay period. This can significantly control noise and vibration effects. It would be a disaster if all the holes went off at the same time.

The design variables of burden, stemming, subdrill length, spacing, and timing are selected to maximize fragmentation and to minimize excessive vibration, air blast, and flyrock.

Effects of L/B Ratio

Figure 208.D shows what happens when the ratio between the distance L (bench height) and B (burden) is changed. Potential blasting problems are decreased as the ratio is increased. As this ratio is decreased, these problems are increased.

Stiffness Ratio (L/B)	1	2	3	4
Fragmentation	Poor	Fair	Good	Excellent
Air Blast	Severe	Fair	Good	Excellent
Flyrock	Severe	Fair	Good	Excellent
Ground Vibration	Severe	Fair	Good	Excellent
Comments	Severe backbreak and toe problems. Do not shoot. REDESIGN!	Redesign if possible.	Good control and fragmentation	No increased benefit by increasing stiffness ratio above 4.

Figure 208.D – Potential problems as it relates to stiffness ratio L/B

The specifications in 208.06.C require that this ratio be greater than one. The blasting contractor designs the correct timing, hole spacing, and stemming. Historically, blasters in Ohio have not had problems with designs having an L/B ratio near one. Local blasters are very familiar with local geology as well.

Generally, a ratio near one maximizes the rock blasting production. The main problem with designing a ratio near one is that the rock generally fractures in large chunks. This can pose problems for the Contractors when trying to use the material for fill. When the ratio is increased, it can decrease the particle size of the rock. This allows the material to easily be used as fill.

Proper Burden

In order to ensure that the blaster is using the proper burden, follow this rule of thumb: the burden is usually 24 to 30 times the production hole diameter. For example:

If the production holes have a diameter of 6 inches (0.5 feet), then the burden should be:

$$24 \times 0.5 \text{ ft} = 12 \text{ ft} \quad \text{to} \quad 30 \times 0.5 \text{ ft} = 15 \text{ ft}$$

The burden for the shot should be between 12 and 15 feet.

Effects of Stemming

The specifications in 208.06.E require that the stemming depth (T) of inert material be at least 0.7 times the burden (B). This helps control the air blast.

Figure 208.E depicts the effects of stemming. If effective, the blast direction is lateral. If the stemming is ineffective, the blast can blow upward and cause excessive air blast. Notice in the poor example, the blast cuts back into the cut slope. This is an obvious problem.

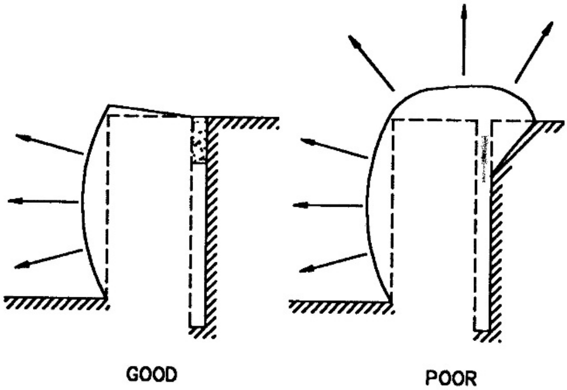


Figure 208.E – Stemming effects

Drill cuttings are normally used for stemming. However, when blasting in water-filled production holes or when blasting within 200 feet of a structure, the stemming material is changed to prevent problems. For holes less than 4 inches in diameter, crushed No. 8 stone is required. For holes 4 inches in diameter or larger, No. 57 stone is required. This helps to hold the blast down better.

Effects of Timing

Timing of the blast is another important parameter. Figure 208.F depicts the effects of poor and good timing.

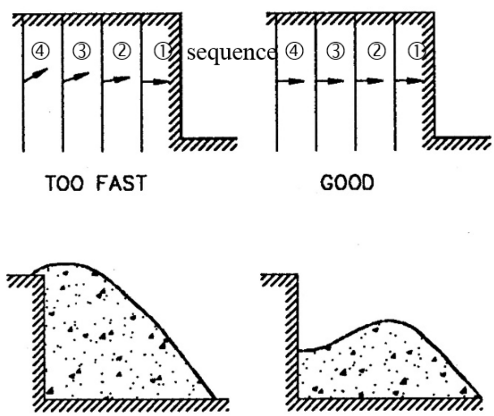


Figure 208.F – Timing effects

With correct timing, the blast has a distinct lateral movement. With poor timing, the movement is more upright and has potential problems.

Vibration and Air Blast Monitoring (208.15 and 208.16)

The blaster is required to design the burden, stemming, subdrill length, spacing, and timing to minimize excessive vibration, air blast, and flyrock. The blaster must monitor the air blast and vibration for every shot at the nearest structure. Seismographs are used to monitor the vibration.

Specialized equipment is used to monitor the air blast. The maximum air blast, in 208.16.A, is required to be under 134 dB. The air blast limit may need to be lower in order to prevent damage.

The specification does not give vibration limits for blasting. Since each site is different, and the blasting contractor is responsible for all damage caused by the blast, the blaster hires a vibration specialist to determine the safe vibration limits. A typical vibration criterion is given in Figure 208.G. This is from the US Bureau of Mines.

To lower the air blast, check the stemming height and type of material used for the stemming. Thin or thick areas of the burden may create excess air blast and flyrock. Measure the burden to the free face to ensure a uniform burden.

To lower the vibration everything needs to be checked. This includes the blast design and layout of the blast holes.

APPENDIX B.—ALTERNATIVE BLASTING LEVEL CRITERIA

Safe blasting vibration criteria were developed for residential structures, having two frequency ranges and a sharp discontinuity at 40 Hz (table 13). There are blasts that represent an intermediate frequency case, being higher than the structure resonances (4 to 12 Hz) and lower than 40 Hz. The criteria of table 13 apply equally to a 35-Hz and a 10-Hz ground vibration, although the responses and damage potentials are very much different.

Using both the measured structure amplifications (fig. 39) and damage summaries (figs. 52 and 54), a smoother set of criteria was developed. These criteria have more severe measuring requirements, involving both displacement and velocity (fig. B–1).

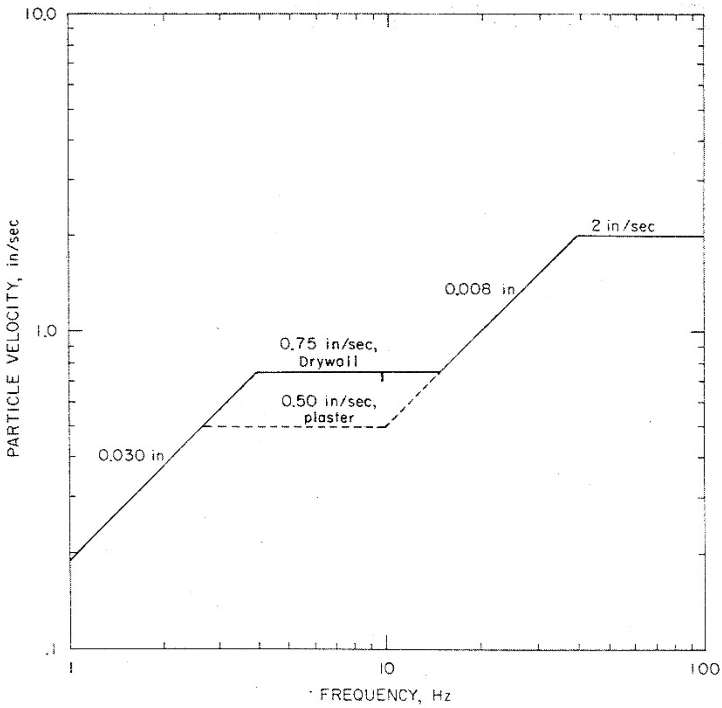


Figure B–1.—Safe levels of blasting vibration for houses using a combination of velocity and displacement.

Figure 208.G – Typical vibration blasting criteria

Each blast has a particle velocity and frequency. The project can plot these values on the chart in Figure 208.G. If the point is lower than the plotted line, the blast is within limits that are generally considered to be safe.

Presplitting (208.09)

Presplitting is a very effective method of controlling the final appearance of steep slopes; it can result in a clean sheared face. Presplitting is required when the slope is steeper than 1H:1V and deeper than 5 feet.

Specialized presplit blasting explosives are used. Hole diameters are approximately 3 inches, and the presplit holes are blasted prior to the production blast. The presplit hole spacing starts at 36 inches. This is adjusted to obtain a good, shear face of the rock.

209 Linear Grading

Linear grading consists of grading along the edge of pavement. This item also includes a pay item for cleaning drainage ditches. Because of the simplicity of this item of work, no further detailed explanation of the item is required in this manual.

250 Pavement Repairs

251 Partial Depth Repair

Description (251.01)

This work consists of partial depth removal of existing pavement in areas exhibiting surface deterioration, applying tack coat, and placing and compacting asphalt concrete.

Removal of Existing Pavement (251.02)

Mark the areas in rectangular shapes. Unless specified, the pavement should be removed to the full width of the traffic lane at transverse joints and along the longitudinal joint. Ensure pavement is removed to the depth shown in the plans and that adjacent pavement is not damaged. If the adjacent pavement is damaged, remove all loose pavement to the depth specified in the plans. Trim the limits of the repair to form a vertical face 1.5 inches (38 mm) deep from the surface unless the repair is covered with an overlay within 60 days.

Removed pavement shall be disposed of in accordance with 202.02. The Inspector shall determine and document where and how pavement is to be disposed by the Contractor.

Placement of Asphalt Concrete (251.03)

The exposed surfaces must be thoroughly cleaned and coated with 407.02 material to fill all cracks and joint openings. The approved asphalt concrete must be placed and compacted in as many lifts as necessary to finish flush with the adjacent pavement surface.

The final lift must be compacted using a Type I pneumatic tire roller that conforms to 401.13. At least 18 passes should be made over all points on the entire surface of the repair area. A pass is defined as one movement of the roller over the surface of the patch. As the rolling progresses, additional patching material may need to be added in order to produce a smooth surface, flush with the existing pavement surface. Use of the proper rolling equipment is necessary to allow for proper compaction of the repair materials. Use of vibratory rollers is not permitted per this specification. Use of improper rollers has resulted in poorly compacted patches that consolidate under traffic and result in a poor riding surface.

Each lift shall be continuously compacted while the material is in a workable condition throughout the depth of the lift. The Inspector must enforce the compaction requirements to ensure that the asphalt has sufficient density to avoid further compaction under traffic. There have been several instances where poorly compacted repairs have consolidated under traffic, after placement of the surface course, leaving a poor quality patch and poor riding surface.

Unless the repair area is scheduled to be covered with an asphalt overlay within 60 days, trim the limits of the repair area to form a vertical face 1-1/2 inches (38 mm) deep from

the surface before placing the final asphalt concrete layer adjacent to the existing pavement.

If the Contract does not include resurfacing, seal the perimeter surface of the repaired areas with a 2 to 4-inch (100 mm) wide strip of approved 705.04 material or 702.01 approved PG binder.

252 Full Depth Rigid Pavement Removal and Flexible Replacement

Description (252.01)

This work consists of the full-depth removal of existing rigid pavement in areas exhibiting deterioration, correcting the subgrade, placing and compacting asphalt concrete, and restoring the shoulders.

Removal of Existing Pavement (252.02)

Pavement Sawing

The Engineer marks the limits of the areas to be repaired. The minimum longitudinal length of a repair is 6 feet (1.8 meters). All pavement repairs are the full lane width, unless otherwise detailed by the plan.

The existing pavement is sawed full-depth, at the limits established by the Engineer, with a diamond saw blade. All diamond saw cuts shall be perpendicular to the surface of the pavement. Normally, the existing concrete pavement thickness is given in the plan. There may be older projects where the existing pavement was built thicker than specified in the new repair plan. Concrete sawing and removal depths may be as much as 1 inch (25 mm) greater than indicated on the repair plan without additional compensation to the Contractor.

If there is an existing asphalt overlay on the concrete pavement, the Contractor may elect to saw full-depth through the asphalt concrete and the Portland cement concrete. Depending on the thickness of each material, the Contractor may not be capable of sawing through both courses and may elect to make an offset saw cut through the asphalt course. The Contractor would then remove enough asphalt to allow room for a diamond saw that would saw full-depth through the concrete pavement. If the Contractor elects to make offset cuts to facilitate the removal, the offset cut will not be measured for payment; only full-depth saw cuts that are made at the limits of the removal are measured for payment. Intermediate saw cuts made by the Contractor to facilitate removal by the lift-out method are not measured for payment.

During hot weather, it may be necessary for the Contractor to saw only at night or in the morning when cooler temperatures prevail. Concrete pavement heats up and expands as temperatures rise during hot summer days. Diamond saw blades could be pinched and locked up while sawing the expanding pavement slabs. Some contractors use a carbide-tipped saw to cut through pavement within the repair area. This is permitted provided

that the Contractor does not damage the base under the pavement that is to be removed. All perimeter saw cuts must be made with diamond saws.

Pavement Removal

Removal of the concrete follows the full-depth sawing operation. The lift-out method is required in order to not disturb the base under the pavement and to minimize the damage to the adjacent pavement that is to remain. Holes are drilled within the removal area and lift pins are inserted. The slab, or portion of the slab, is then removed by lifting the slab vertically with a crane or large backhoe. After lifting, loose debris left behind is removed by hand methods.

Removed pavement shall be disposed of in accordance with 202.02. The Inspector shall determine and document where and how pavement is to be disposed of by the Contractor.

The use of a pavement breaker and backhoe for removal is not permitted unless the Engineer determines that the lift-out method is not practical due to extensively deteriorated pavement, the existence of asphalt concrete full-depth repairs, or old concrete pavement repairs, which are extensively cracked and deteriorated. There will be no additional compensation for the removal of existing pavement with a pavement breaker and backhoe.

Correction of Subgrade (252.03)

Prior to placing asphalt concrete in the removal area, any base or subgrade that is disturbed below the level of clean out is removed. The repair area must be compacted to the satisfaction of the Engineer. All vertical faces shall be cleaned and coated with asphalt material according to 401.14.

Placement of Asphalt Concrete (252.04)

The pavement replacement is constructed by placing and compacting Item 301 or 1 Type 2 material, or 442 19.0 mm material in two or more lifts according to 401.16. Note: The plans for the project may specify the use of another material. The first lift, and all intermediate lifts, must be thoroughly and uniformly compacted using suitable, mechanical, compaction equipment operated over the entire replacement area.

The final lift must be compacted using a pneumatic tire roller that conforms to 401.13. At least 18 passes should be made over all points on the entire surface of the repair area. A pass is defined as one movement of the roller over the surface of the patch. As the rolling progresses, additional patching material may need to be added in order to produce a smooth surface, flush with the existing pavement surface.

Each lift shall be continuously compacted while the material is in a workable condition throughout the depth of the lift. The Inspector must enforce the compaction requirements to ensure that the asphalt has sufficient density to avoid further compaction under traffic. There have been several instances where poorly compacted repairs have consolidated under traffic, after placement of the surface course, leaving a poor quality patch and poor riding surface.

If an overlay is not scheduled to be placed within 60 days of the repair, the perimeter of the repair shall be trimmed vertically 1-1/2 inches deep from the surface before placing the final lift of asphalt concrete.

If the Contract does not include resurfacing, seal the perimeter surface of the repaired areas with a 2 to 4-inch (100 mm) wide strip of approved 705.04 material or 702.01 approved PG binder. After completing repairs, the existing shoulders must be repaired to the condition that existed prior to the repair work.

253 Pavement Repair

Description (253.01)

This work consists of removing existing asphalt concrete, brick, Portland cement concrete, or aggregate pavement courses; shaping and compacting the exposed material; and placing new asphalt concrete pavement or aggregate and asphalt concrete pavement courses.

The plans show details about the repairs and replacement material.

Removal of Existing Pavement (253.02)

The Engineer shall mark all areas for removal. The pavement shall be cut at the limits marked and removed. Ensure that the pavement is removed to full-depth or to the depth shown in the plans, and ensure adjacent pavement is not damaged during removal. If the adjacent pavement is damaged, remove all loose pavement to full-depth or to the depth specified in the plans.

Removed pavement shall be disposed of in accordance with 202.02. The Inspector shall determine and document where and how pavement is being disposed by the Contractor.

Placement of Asphalt Concrete (253.03)

The exposed underlying material must be shaped and compacted. The asphalt material shall be as specified in the plans. Before placing asphalt concrete, all vertical faces of the existing pavement must be cleaned and coated with asphalt material according to 401.14. The replacement material must be placed in appropriate lifts. Each lift must be thoroughly and uniformly compacted using suitable compaction equipment. The final lift must be flush with the existing pavement surface.

Compact the final lift using a pneumatic tire roller that conforms to 401.13. The final lift should be compacted with at least 18 passes over all points on the entire surface of the repair area. A pass is defined as one movement of the roller over the surface of the patch. As the rolling progresses, add additional patching material in order to produce a smooth surface, flush with the existing pavement surface.

Continuously compact each lift while the material is in a workable condition throughout the depth of the lift. The Inspector must enforce the compaction requirements to ensure

that the asphalt has sufficient density to avoid further compaction under traffic. There have been several instances where poorly compacted repairs have consolidated under traffic, after placement of the surface course, leaving a poor quality patch and poor riding surface.

If an overlay is not scheduled to be placed within 60 days of the repair, the perimeter of the repair shall be trimmed vertically 1-1/2 inches deep from the surface before placing the final lift of asphalt concrete.

If the Contract does not include resurfacing, seal the perimeter surface of the repaired areas with a 2 to 4-inch (100 mm) wide strip of approved 705.04 material or 702.01 approved PG binder. After completing repairs, the existing shoulders must be repaired to the condition that existed prior to the repair work.

254 Pavement Planing

Description (254.01)

This work consists of planing the existing pavement and disposing of the cuttings, and if specified in the Contract, patching the planed surface. The pay description indicates the predominant type of pavement.

Equipment (254.02)

The equipment used must be self-propelled and have sufficient power and stability to consistently and efficiently meet the requirements of 254.05 and the plans. Equipment can have grinding, sawing, or milling type cutters. The cutters must be mounted rigidly to the carrier and must be adjustable to control the depth of cut and cross-slope. Use equipment with a suitable carrier wheelbase or with an automatic control system having an external reference. Ensure that cross-slope adjustments or automatic controls are capable of producing a variable and a constant cross-slope, as required.

For small or confined areas, the Contractor may use suitable supplemental equipment or methods approved by the Engineer.

Planing (254.03)

The Engineer should mark the locations of signal loop detectors and notify the maintaining agency before the start of a planing operation.

The Contractor may make one or more planing passes, as necessary, over the designated area to obtain the depth specified in the plans. Where establishing new pavement surface elevation or cross-slope, remove irregularities such as bumps, corrugations, and wheel ruts. Ensure that all cuttings are removed from the surface following each pass.

The Engineer must monitor the milled surface for excessive scabbing or thin layers of asphalt material that can be left due to milling too close to the layer interface. The depth of milling may need to be adjusted to correct the issue. Leaving areas of scabbed material

may affect the bond of the asphalt layers placed on top of the milled surface and lead to premature failure of the roadway.

Before opening the completed area to traffic, the surface shall be thoroughly cleaned of all loose material that would create a hazard or nuisance or would redeposit into the surface texture.

Cuttings shall be disposed of in accordance with 202.02. The Inspector shall determine and document where and how cuttings are to be disposed of by the Contractor.

Monitor and control dust, pavement contamination, and the scattering of loose particles to acceptable levels during planing and cleaning operations.

If damage occurs to the adjacent pavement by planing operations, repair the damaged area by matching the adjacent pavement with the planed area in terms of smoothness and mix type.

Surface Patching (254.04)

After planning, mark areas of spalled or dislodged unsound pavement. Before patching, the areas shall be cleaned of loose materials and coated with 407.02 asphalt material. The area shall be patched with Item 441, Type 1 or 9.5 mm or 12.5 mm asphalt. Patched areas shall be compacted to be flush and level with adjacent pavement.

Surface Tolerances (254.05)

The surface shall be planed free from grooves, ridges, gouges, or other irregularities detrimental to the safe operation of vehicles on the planed surface.

If the Contract specifies planing without resurfacing, the surface shall be planed to a smoothness of 1/8 inch in 10 feet (3 mm in 3 m). If the Contract specifies resurfacing after planing, the surface shall be planed to a smoothness of 1/4 inch in 10 feet (6 mm in 3 m). The surfaces shall be matched at the edges of adjacent passes within 1/8 inch (3 mm). Ensure that the cross-slope of the planed surface is within 3/8 inch in 10 feet (10 mm in 3 m) of the specified cross-slope.

Method of Measurement and Basis of Payment (254.06, 254.07)

Measure the quantity of planing and patching, and convert to square yards for payment.

Payment will not be made for repairs due to damage caused by the planing operation.

If the depth of the planed surface is increased by more than 3/8 inch (9.5 mm), the Department will recalculate the surface area for payment by multiplying the surface area measurement by a factor that equals the new depth, divided by the plan depth. Additional depth will only be paid for with prior approval.

255 Full Depth Pavement Removal and Rigid Replacement

General

During the life of concrete pavement, it is sometimes necessary to make repairs to stop progressive deterioration and to maintain serviceability. Timely repairs restore quality and provide the rideability and life expectancy for which the pavement was designed.

Problems may occur at various stages of the pavement life; it is important that these problems are corrected as they arise. Corrections are often necessary during construction, and these repairs must be of the highest standard in order to achieve the anticipated pavement life. This section establishes a standard repair procedure and provides uniform application for repairs. These standards are applicable at any time throughout the pavement life.

Concrete pavement repairs are classified as full-depth pavement replacement and thin-bonded patching. Full-depth replacement applies when the damage is more extensive than surface scaling or spalling and requires removal and replacement for the full depth of the slab. Thin-bonded patching applies to surface scaling and spalling, spalling at edges and joints, and other surface deterioration that does not extend below the pavement mesh. Compliance with all the provisions of the following standards is necessary to assure durable repairs and to permanently restore the quality of the pavement.

Description (255.01)

When Standard Construction Drawing BP-2.5 is called for, rigid replacement applies to the work. The basic process of full-depth repairs includes the following:

1. Full-depth diamond blade sawing.
2. Removing the existing pavement full-depth.
3. Removing base material, if specified.
4. Compaction of base material.
5. Drilling dowel bar or tie bar holes.
6. Furnishing and grouting dowel bars and tiebars.
7. Installing mesh when required.
8. Placing, consolidating, finishing, and curing concrete.
9. Sealing of repaired surface perimeter.
10. Restoring affected shoulders.

Materials (255.02)

Concrete

The concrete to be used must be 499 Class QC 1, QC FS, or QC MS and will be called out in the pay item description. Additionally, Rapid Repair Concrete Mix (RRCM) may be called out in the pay item description. The RRCM mix will require the Contractor to develop and submit a mix design to the Engineer. The RRCM mix design must develop 400 psi flexural strength in no less than 4 hours and no more than 6 hours using a 6-inch

x 6-inch (150 mm x 150 mm) beam sample conforming to ASTM C293. The Engineer has 10 days to review and accept or reject the RRCM design.

Curing Materials

The curing material to be furnished and used must be white-pigmented, liquid membrane forming compounds meeting 705.07. The shipping containers must be equipped with mechanical agitators to agitate the material prior to use.

Non-shrink, Non-metallic Grout

The dowels and tiebars must be anchored with non-shrink, non-metallic grout material and must set within 30 minutes. Item 705.20 provides the requirements for grout. The Inspector should check to ensure the proposed grout is on ODOT's Qualified Products List.

Reinforcing Steel 709.00

Reinforcing steel for dowel bars, basket assemblies, deformed bars, tiebars, hook bolts, wiggle bolts, and couplings must be epoxy coated steel.

Welded Steel Wire Fabric

Welded steel wire fabric, also called steel mesh, must comply with Item 709.00.

Dowel Bars and Basket Assemblies

Dowel bars may be epoxy coated steel 709.13 or Fiber Reinforced Polymer (FRP) bars 705.01. Basket assemblies must be epoxy coated steel.

Removal of Existing Pavement (255.03)

The Engineer must mark the limits of the areas to be repaired. The minimum longitudinal length of a repair is 6 feet (1.8 meters). All pavement repairs must be the full lane width, unless otherwise detailed by the plans.

The existing pavement is sawed full-depth at the limits established by the Engineer with a diamond saw blade. Normally, the existing concrete pavement thickness is given in the plans; however, there may be projects where the existing pavement was built thicker than shown in the repair plan.

Figure 255.A – Full depth diamond blade saws

Concrete sawing and removal depths may be as much as 1 inch (25 mm) greater than indicated on the repair plan without additional compensation to the Contractor.

If there is an existing asphalt overlay on the concrete pavement, the Contractor may elect to saw full-depth through the asphalt concrete and the Portland cement concrete. Depending on the thickness of each material, the Contractor may not be capable of sawing through both courses and may make an offset saw cut through the asphalt course, remove enough asphalt to allow room for a diamond saw, then make a full-depth saw cut through the concrete pavement. If the Contractor elects to make offset cuts to facilitate removal, the offset cut will not be measured for payment. Only full-depth saw cuts that are made at the limits of the removal are measured for payment. Any intermediate saw cuts made by the Contractor to facilitate removal by the lift out method are not measured for payment.

During hot weather, it may be necessary for the Contractor to saw only at night or in the morning when cooler temperatures prevail. Concrete pavement heats up and expands as temperatures rise during hot summer days. Diamond saw blades could be pinched and lock up when sawing due to slab expansion. Some contractors use a carbide-tipped saw to cut through the pavement within the repair area. This is permitted provided that the Contractor does not damage the base under the pavement to be removed. All perimeter saw cuts must be made with diamond saws.

Figure 255.B – Pavement removal by the lift-out method

Removal of the concrete follows the full-depth sawing operation. The lift-out method is required in order to not disturb the base material under the pavement and to minimize damage to the adjacent pavement that is to remain. Holes are drilled within the removal area and lift pins are inserted. The slab, or portion of the slab, is then removed by lifting the slab vertically with a crane or large backhoe. After lifting, loose debris left behind is removed by hand. The removed pavement is disposed of in accordance with Item 202.02.

The use of a pavement breaker and backhoe for removal is not permitted unless the Engineer determines that the lift-out method is not practical due to extensively deteriorated pavement, the existence of asphalt concrete full-depth repairs, or old concrete pavement repairs, which are extensively cracked and deteriorated. There will be no additional compensation for removal of the existing pavement with a pavement breaker and backhoe.

Regardless of the method used to remove the pavement, if the face of the pavement to remain is damaged by sawing or removal operations, an additional full-depth saw cut is required for the full width of the lane or lanes at a distance from the first cut, which includes the damaged pavement. The additional pavement repair area and the additional saw cut is not measured for payment.

After pavement is removed from the area to be repaired, an additional saw cut must be made if the face of the remaining pavement or shoulder is deteriorated on the bottom to a height greater than 1/4 of the pavement thickness. The additional saw cut should encompass the deteriorated areas. The additional saw cut and repair area is measured for payment.

Removed pavement shall be disposed of in accordance with 202.02. The Inspector shall determine and document where and how pavement is being disposed by the Contractor.

Correction of Subgrade (255.04)

Prior to placing the concrete in the removal area, and before installing dowels or tiebars, shape and compact the base or subgrade material. Any area that has been over-excavated must be filled with concrete.

Figure 255.C – Debris remaining after removal by the lift out method is removed by hand methods

Figure 255.D – Compaction of base

If undercut joints at the limits of the repair areas are specified, the Contractor must be careful when removing the base material to create the undercut section. The undercut section is the void created by removing the base material from underneath the existing, remaining pavement. This undercut will be filled with concrete when placing the new pavement repair. Refer to Standard Construction Drawing BP-2.5 for undercut joint details. Damage to the bottom of the slab that is to remain cannot be tolerated. Any damage caused by the Contractor's operations requires additional removal and replacement at no additional cost. If a backhoe bucket plate is used, exercise care, or use

hand methods to excavate under the existing slab. Undercut work is incidental and included in the pay item.

Placing Dowels and Tiebars (255.05)

Dowels could be smooth or deformed steel bars depending on the type of joint (transverse contraction or transverse tied). Smooth dowels are 1-1/2 inch (38 mm) in diameter by 14 inches (355 mm) in length. Fiber-reinforced polymer dowel bars may be used in lieu of smooth steel dowels. Deformed bars are No. 11 (No. 35M) by 14 inches (355 mm) in length. Refer to Standard Construction Drawing BP-2.5 for details on tied and contraction joint requirements.

Holes for dowels and tie bars are drilled in the existing concrete slab by using hydraulic or electric drills. Drilling is to be done in a manner that will not spall or damage the existing concrete. Damage such as cracking between dowels will result in poor load transfer and is contrary to point of performing the repair. Pneumatic drills are not to be used. Holes must be drilled with a device that allows independent adjustment of all drill shafts in the horizontal and vertical direction. The device must be capable of drilling a minimum of three holes at one time.

Holes for dowel and tie bars are to be centered at mid-slab within a tolerance of ±1/2 inch (13 mm). Dowels are spaced starting 12 inches (300 mm) from the outside edge of pavement, are spaced at 12 inches (305 mm), and stop 24 inches (600 mm) from the adjacent lane to avoid hitting existing tiebars at the longitudinal joint. This will result in 10 bars in each 12 foot lane. The Contractor must drill dowel holes parallel to the pavement surface and the centerline, otherwise the smooth dowels will not perform properly when the pavement expands and contracts.

Figure 255.E – Hole drilling equipment

Holes for dowels or tiebars must be 1-5/8 inches (41 mm) in diameter and a minimum of 7 inches (178 mm) deep into the concrete.

Longitudinal Joints

Full-depth repairs that are greater than 10 feet (3.0 meters) in length will require a tied longitudinal joint using No. 5 x 24-inch (No. 16M x 600) tiebars or hook bolts spaced at no more than 30 inches (760 mm) and not less than 24 inches (610 mm). Refer to Standard Construction Drawings BP-2.1 and BP-2.5 for more details. Holes for longitudinal tiebars must be 3/4 inches (19 mm) in diameter and a minimum of 12 inches (300 mm) deep into the concrete.

Grouting Dowels or Tiebars

This section details the requirements for transverse dowels and tiebars. The requirements for tied longitudinal joints are the same; however, the bar dimensions differ. All dowels and tiebars must be grouted into place with a non-shrink, non-metallic grout material. Prior to injecting grout, the holes must be blown clean with oil-free compressed air. The hole must be dry and frost free before grouting dowels or tiebars.

The grout must be injected pneumatically into the back of the hole and the dowel or tiebar inserted 7 inches (178 mm) into the hole. A nylon or plastic washer (called a grout retention disc) is then pushed flush against the saw cut after the bar is installed to keep the grout in the hole. Grout retention discs must be clear or opaque white in color. Sufficient grout must be used to completely fill all voids around the bar, including any spalling at the face of the saw cut. Grout should extrude through the slot in the grout retention disc after filling and inserting the dowel or tiebar. Other methods of installing dowels or tiebars are not permitted.

Figure 255.F – Typical grout injection equipment

Figure 255.G – Pneumatic injection of grout into hole prior to installing dowel Bar with grout retention disc

Most contractors pump the resin and hardener from separate pressure pots. The two materials are mixed immediately before being injected into the hole through a baffled mixing tube. In cooler temperatures, it may be necessary to heat the grout materials to promote flow and to allow set up in the required 30 minute time period. Dowels or tiebars must be held in proper alignment until the grout has hardened.

Figure 255.H – Insert steel rods with grout discs in place

Figure 255.I – Using a spud bar to push steel rod into place

Placement of Portland Cement Concrete (255.06)

Placement of the concrete can begin when the grout around dowels or tiebars has hardened. Smooth dowels must be coated with new, light form oil before concrete is placed. Rigid forms are required at the outside edge of the full-depth repair. The concrete must be placed in a continuous operation and consolidated with internal vibration.

Figure 255.J – Rigid forms installed at shoulders

Full-depth repairs that are greater than 10 feet (3.0 meters) in length, or will be opened to traffic within 24 hours of placement, require W8.5 or D8.5 wire fabric reinforcement. The clearance from the end of the wire fabric to the edge of the pavement or new transverse joint is 4 ± 2 inches (100 mm ± 50 mm). Refer to Standard Construction Drawing BP-2.5 for details.

When using RRCM concrete the Contractor is required to install maturity sensors to measure the maturity of each day's placement. At least two sensors should be installed for each work day. Install the first sensor where maturity gain is expected to be the slowest. Maturity gain is typically slowest in the thinnest section of pavement or volumetrically smallest patch or repair. If all sections, patches, or repairs have the same dimensions and no concrete is expected to gain maturity slower than another, install the first sensor randomly in concrete from any load, except the last load. Install the other sensor in concrete from the last load mixed and placed that day. See Supplement 1098 for additional details on maturity curve development and use during construction.

Figure 255.K – Screeding of repair area

Figure 255.L – Bull floating the repair area

Specifications require that repairs less than 12 feet (3.7 meters) in length be screeded parallel with the centerline. If the repair is 12 feet (3.7 meters) or longer in length, the screed must be perpendicular to the centerline. After screeding and floating is complete, the surface must be tested with a 10 foot (3.0 meter) straightedge before the concrete hardens to ensure that the transition on and off the repair meets a tolerance of 1/8 inch in 10 feet (3 mm in 3.0 m). Any high or low areas must be corrected and the surface rechecked to assure compliance.

The surface finish of the concrete repair must match the adjacent concrete. If the adjacent pavement is smoothed with a burlap drag, the patch should have the same finish. If the patch texture is different, it may be very noticeable when traveling over the patch at normal traffic speed.

After finishing and straightedge checking is complete, the concrete must be cured with white pigmented curing membrane as per 705.07, Type 2. A uniform coverage of membrane is required at an application rate of 150 square feet per gallon (1 liter per 3.7 square meters).

Wearing Course Replacement (255.07)

If asphalt was removed from the top of the existing pavement, it must be replaced with either 301 or 448 Type II material as shown in the plans. Compact these mixtures as approved by the Engineer using any of the roller types specified in 401.13. Prior to placing the hot mix asphalt concrete, apply a tack coat on the repaired surface per 407.

Vertically trim all transverse joints to a 1-1/2 inch (38 mm) minimum before placing the final asphalt concrete layer adjacent to the existing pavement.

Seal the perimeter surface of the repaired areas with a 2 to 4-inch (100 mm) wide strip of approved 705.04 material or 702.01 approved PG binder.

Shoulders must be restored to the original line and grade with aggregate or asphalt concrete as directed by the Engineer or as shown in the plans. Fill low areas and compact them flush with the surrounding shoulder.

Opening to Traffic (255.08)

Full-depth repairs can be opened to traffic when the concrete attains a modulus of rupture of 400 psi (2.8 Mpa). For RCCM mixes, do not open the rigid replacement to traffic until the RCCM attains a modulus of rupture of 400 pounds per square inch (2.8 MPa) based on maturity testing. The time to obtain this strength will vary depending on the class of concrete used and the atmospheric conditions.

When traffic is maintained adjacent to the lane being repaired, the Contractor must schedule his work so that slab replacements are completed within 48 hours after removing the existing pavement. At the end of a daily work shift, unfilled repairs, 10 feet (3.0 meters) and less in length must be covered with steel plates.

The Contractor must plan work so that no repairs are left unfilled when work is suspended for holidays or weekends. If the Contractor has removed pavement and is unable to complete the repairs in the above time, he must fill or cover the areas less than 4 feet (1.2 m) from the traveled lane. Fill using a temporary patch material suitable to the Engineer or cover unfilled repair areas 10 feet (3 m) or less in length with a steel plate. These areas must be maintained by the Contractor.

Method of Measurement (255.09)

The Department will measure the quantity of full-depth pavement removal and rigid replacement by the number of square yards (square meters) repaired in the completed and accepted work.

Full-depth pavement sawing is measured by the number of feet (meters) of perimeter full-depth saw cuts made in the completed and accepted work. The Department will not measure any offset cuts, pressure relief cuts, or other saw cuts made to facilitate pavement removal.

Basis of Payment (255.10)

Payment is full compensation for all work specified in this item. Payment for accepted quantities of the full-depth pavement removal and rigid replacement item is at the contract price per square yard (square meter).

Payment for the full-depth pavement sawing item is at the Contract price per linear foot (meter). The Department will not pay for additional concrete sawing and removal depths within 1 inch (25 mm) greater than those shown on the plans.

The Department will not pay for additional work to repair damage caused by pavement sawing or pavement removal.

The Department will include tack coat in the cost of the asphalt concrete. The Department will pay for asphalt concrete according to Item 301, 441 or 442.

256 Bonded Patching of Portland Cement Concrete Pavement

General

The success of a thin-bonded patch depends on complete removal of all unsound or damaged material, adequate bond between old and new concrete, use of "low slump" air-entrained concrete, and proper curing. Successful patching depends on strict adherence to all requirements.

Description (256.01)

This work involves bonded patching of Portland cement concrete pavements in areas designated by the Engineer and includes:

1. Marking repair areas using aerosol spray paint; minimum payment is 2 square feet (0.2 m^2) for each area.
2. Saw cutting the perimeter of all areas marked for repair.
3. Removing loose and unsound concrete and asphalt patching materials from within the repair area.
4. Removing sound concrete to obtain a minimum depth of 1-1/2 inch (38 mm).

5. Preparing the surface by cleaning bonding surfaces using abrasive blasting.
6. Applying a bonding grout for Type A, B, or C patches.
7. Mixing, placing, finishing, and curing Type A, B, or C patch material.
8. Checking surface for trueness using 10 foot (3 m) straightedge.

Materials (256.02)

Portland Cement

Type A patches require high early strength cement, 701.05. Type B patches require quick setting concrete mortar, 705.21 Type I or II. Type C patches require quick setting concrete mortar, Type II.

Fine Aggregate

Fine aggregate must meet the requirements for concrete aggregate specified in 703.02.

Coarse Aggregate, No. 8 Size

Coarse aggregate must meet the requirements for concrete aggregate specified in 703.02 and be No. 8 size.

Curing Compound

Curing compound must meet the requirements of 705.07.

Air-entraining Admixture

Air entraining admixtures must conform to 705.10.

Quick Setting Concrete Mortar

Prepackaged mortar material must conform to the requirements of 705.21.

Equipment (256.03)

Equipment must be milling machines, concrete saws, jackhammers, or other approved equipment that is capable of removing the existing surface material. Chipping hammers may not be heavier than 35 pound (16 kg) class.

Oil and moisture free compressed air is required to clean and abrasive blast prepared areas.

An on-site concrete mixer with a minimum capacity of 2 cubic feet (0.06 cubic meters) is required to mix the patching material.

Removal of Unsound Concrete (256.04)

Figure 256.A – Areas to be repaired are marked by the Engineer

Figure 256.B – Perimeter of the repair is saw cut a minimum of 1 inch deep

The limits of the damaged area must first be determined and the repair area be established beyond the deteriorated area and into sound concrete. A steel rod or steel chain may be used to "sound" the surface to determine hollow and deteriorated concrete. The Engineer marks the limits of all bonded patches with spray paint provided by the Contractor.

Figure 256.C – Pavement removal with jackhammer

Figure 256.D – Pavement Removal by Milling Machine

The repair area should be square or rectangular. The perimeter should be outlined by sawing to a vertical depth of approximately 1 inch (25 mm) to avoid feathered edges that usually spall. Additional saw cuts within the outlined area aid the breakup and removal operation. The Contractor must remove all unsound concrete materials and all loose or disintegrated concrete within the marked area. Sound concrete must be removed to the minimum required depth within the patch area. Concrete may be removed by jack hammering or milling. The minimum depth of a repair is 1-1/2 inches (38 mm) except for the perimeter saw cuts which require a 1 inch (25 mm) minimum. During removal operations, remove any reinforcing steel within the patch area by cutting or with a torch.

Figure 256.E – Abrasive blasting of repair areas

Preparation of Patch Area (256.05)

After removal of pavement within the repair area, the area must be cleaned of all loose material, dirt, dust, asphalt, etc. by abrasive blasting and blowing out with oil- and moisture-free compressed air. If water is used for cleaning, it must be mopped out thoroughly before abrasive blasting. Abrasive blasting of the bonding surfaces must be done after the area has dried. The Contractor must comply with all state, regional, and local government agency requirements regarding control of dust generated by the abrasive blasting operation.

Type B and C patching materials that do not use water as an activator may require additional surface preparation. Check the manufacturer's instructions to ensure surface preparation is done correctly.

If a bonded patch area is adjacent to a transverse or longitudinal joint, or crack through the patch, the joint must be reestablished by using a joint board or form that extends below the level of the patch and is as wide as the joint. This board is to be removed about an hour after placing the patching material. Care must be taken when placing material so that the joint is established or pavement movement will cause damage to the patch.

Figure 256.F – Adjacent joints are formed prior to placing the patching material

Bonding Grout Installation (256.06)

For Type A patches, prepare a grout of equal parts by volume of Portland cement, sand, and water to a consistency of a thick paint or slurry. The grout should be brushed and scrubbed into the dry and clean bonding surfaces of the exposed concrete. Grout should be placed immediately prior to placing the patching material. Excess grout should not be allowed to collect in low spots. Ideally, the grout should have a uniform thickness of 1/16 to 1/8 inch.

For Type B and C patches, the bonding grout should be mixed and applied per the manufacturer's requirements.

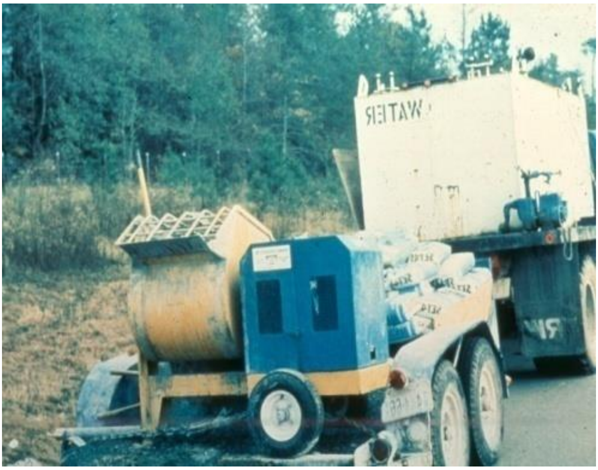


Figure 256.G – Portable mortar mixer used to mix bonding grout and patching material

Figure 256.H – Bonding grout is brushed into the dry patch area

Placing Patching Material (256.07)

The plans will specify the type of patching material to be used. In all cases, after placing the patching material, screed patches 12 feet and less in length, parallel with the centerline and patches longer than 12 feet, perpendicular to the centerline.

While the patch material is still plastic, the surface of the patch should be checked with a 10 foot straightedge to ensure the final surface is flush with the edges of the adjacent pavement. The straightedge is to be placed parallel to the centerline and drawn across the patch while checking for any high or low areas. High or low spots that exceed 1/8 inch in 10 feet are to be immediately corrected. After making any corrections, recheck the surface to ensure that there are no variations more than 1/8 inch high or low in 10 feet.

The surface of the completed patch is to be textured in the same manner as the adjacent pavement.

Type A Patch

Type A patching material is to be mixed in the field using 701.05 high-early-strength cement (Type III). Ready mixed concrete is not permitted. Use only enough water to make it cohesive and cause sufficient air entrainment. One part of cement is combined with 1-1/2 parts of sand and 1-1/2 parts of No. 8 sized coarse aggregate and enough water to obtain a slump practical to place in the patch area. Only the minimum amount of water is to be used and the slump must not exceed 4 inches. A low slump mix will reduce shrinkage of the patch and ensure a good bond to the surrounding concrete. An air entraining admixture is used to obtain 8 ± 2 percent air content.

Place the patching material while the grout is still wet, and vibrate the concrete in place after the patch area is slightly overfilled. Strike off the concrete to the elevation of the adjacent concrete.

Type B Patch

This type of patching material is a quick-setting mortar that comes prepackaged. The patching material must be pre-approved and must comply with 705.21 as Type I or II material.

Mix and place the material according to the manufacturer’s directions. Add coarse aggregate, as needed, according to the manufacturer’s instructions. Place the mortar mixture in the patch area. If the manufacturer’s requirements specify using bonding grout, place the mixture while the bonding grout is still wet. Slightly overfill, vibrate, and strike off the concrete.

Figure 256.I – Patching material placed and consolidating with an internal vibrator

Figure 256.J – Patching material screeded off flush with surrounding pavement

Type C Patch

This type of patching material is also a quick-setting mortar that comes prepackaged. The patching material must be pre-approved and must comply with 705.21 as Type II material. Mix and place the material according to the manufacturer's directions. Add coarse aggregate, as needed, according to the manufacturer's instructions. Place the mortar mixture in the patch area. If the manufacturer's requirements specify using bonding grout, place the mixture while the bonding grout is still wet. Slightly overfill, vibrate, and strike off the concrete.

Figure 256.K – Application of curing compound to new bonded concrete patch

Figure 256.L – Completed bonded patches

Curing and Loading (256.08)

Type A patches must be cured with a white-pigmented, liquid membrane-forming compound conforming to 705.07 and applied at a rate of 150 square feet per gallon (1 Liter per 3.7 square meters). The amount of curing required and used is to be documented. A modulus of rupture of 400 psi (2.8 Mpa) must be obtained prior to opening to traffic. Record the times and results of all beam breaks.

Cure Type B and Type C materials according to manufacturer's directions.

Method of Measurement (256.09)

Project personnel must measure the repair areas and calculate the area in square feet (square meters) of completed and accepted work. If a measured area is less than 2 square feet (0.2 square meters), the Engineer will increase pay to 2 square feet (0.2 square meters).

Basis of Payment (256.10)

Pay the contract price for accepted quantities per square feet (square meters) of Item 256, Bonded Patching of Portland Cement Concrete Pavements, Type A, B, or C.

257 Diamond Grinding Portland Cement Concrete Pavement

Description (257.01)

This work consists of diamond grinding a rigid concrete pavement, normally the full width of the lane, in order to eliminate transverse cracking and transverse joint faulting. The work results in a longitudinal, corduroy-type texture. If done properly, the ride of the finished pavement surface will be improved and the skid resistance enhanced.

Final acceptance of a diamond ground pavement is done by surface measuring equipment, which is passed over the completed pavement and measures the surface profile. This equipment is called a non-contact profilometer or a profiler.

Equipment (257.02)

Figure 257.A – Types of diamond grinding equipment

Figure 257.B – Types of diamond grinding equipment

Equipment requirements for diamond grinding:

- Must be a power driven, self-propelled machine, specifically designed to smooth and texture Portland cement concrete pavement with diamond blades or diamond impregnated cylinder rings.
- Diamond blades or diamond impregnated cylinder rings must be mounted on an arbor head that is a minimum of 3 feet long.
- Must be capable of grinding the surface in the longitudinal direction without causing spalling or other damage at cracks, joints, and other locations.
- Must be capable of correcting the pavement profile and providing proper transverse cross-slope.
- The effective wheelbase must be at least 12 feet (3.6 m): a set of pivoting tandem bogey wheels at the front of the machine and at the rear. Wheels that travel and track in the fresh cut pavement must be provided.
- The center of the grinding head must not be further than 3 feet (0.9 m) forward from the center of the back wheels.
- Must be configured such that it does not encroach on traffic movement outside of the work area in adjacent lanes
- Must be designed to remove all grinding residue. Grinding residue is not permitted to flow across lanes being used by the traveling public.

Requirements for surface measuring equipment (profiler):

- A non-contact, surface measuring device, conforming to Supplement 1058, along with ProVAL software, must be used to measure an IRI.
- All necessary supplies must be provided to fully operate and graph the smoothness test results on the diamond ground pavement.

Contractors doing diamond grinding work must use water trucks to provide water to the grinding heads of each grinder in order to cool the diamond blades.

Construction (257.03)

The plans will designate the areas to be diamond ground. Bridge decks, bridge approach slabs, and roadway shoulders are typically not diamond ground unless indicated on the plans or required to provide drainage. Diamond grinding must eliminate crack or joint faults while providing positive, lateral drainage by maintaining a constant cross-slope between grinding limits in each lane. Adjacent ramp lane grinding must be transitioned as required from the mainline edge to provide positive drainage and an acceptable riding surface.

The diamond grinding operation must result in pavement that conforms to the typical cross-section and the requirements specified for the final surface finish. Faulting at joints and cracks must be eliminated and the overall riding characteristics be restored within the limits specified. To accomplish the smoothness required, diamond grinding may not be required on 100 percent of the existing pavement surface.

In faulted pavement, the rear slab will be lower than the forward slab (in the direction of traffic), thus creating a step or bump. Contractors will grind the pavement in the opposite direction of normal traffic flow so the step is cut first and the remainder of the slab can be feathered out. During initial grinding operations, the profiler must test the pavement surface as soon as the concrete has been ground full-lane width. This initial testing is to aid the Contractor in evaluating the grinding methods and equipment being used. Subsequent to the initial testing, the Contractor must run daily profiles of each day's grinding the following work day.

All dust and residue generated as a result of grinding must be immediately removed. Dust cannot be allowed to blow across traffic lanes, into gutters, or into drainage structures.

Final Surface Finish (257.04)

The final surface finish produced should be a longitudinal corduroy-type texture. The peaks of the ridges of this corduroy-type texture are to be approximately 1/16 inch (1.5 mm) higher than the grooves. There must be 53 to 57 evenly spaced grooves per foot (174 to 187 per meter).

Figure 257.C – Surface texture left by diamond grinding

The pavement surface must be tested by the Contractor with an approved profiler device that provides electronic copies of the pavement profiles which are compatible with

ProVAL software. The Contractor must produce a riding surface that does not exceed an IRI of 95 inches per mile or any localized surface deviations in excess of 0.4 inches in 25 feet.

The Engineer is to witness testing of the pavement's wheel paths. Wheel paths are to be located every 3 feet (0.9 m); measured transversely, inside all lane edges; and parallel to the centerline. The profiler is to be maintained at the wheel path at all times when testing the pavement.

Figure 257.D – Profile measuring device

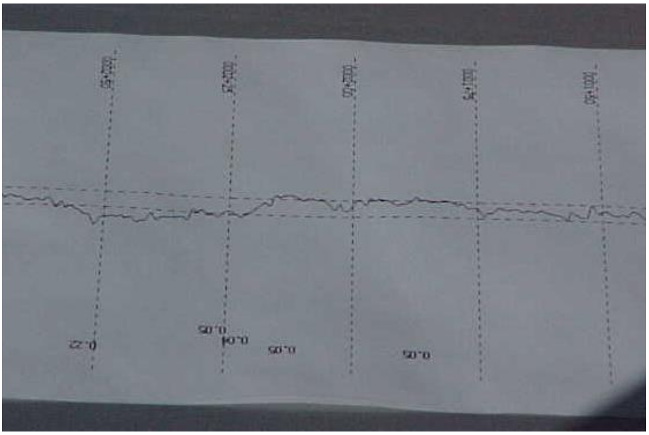


Figure 257.E – Typical profile trace

The Contractor must regrind any 0.10 mile section of pavement with an IRI greater than 95 inches per mile.

The Contractor must provide traffic control and survey stationing necessary for all profiling. Profile measuring equipment is to stop within 1 foot (0.3m) of any existing pavement not ground, any pressure relief joint or any approach slab to a bridge.

Inspection should include spot testing the pavement to verify that transverse joints and cracks are flush with the adjacent pavement. If opposite sides of a joint or crack are within 1/16 inch of each other, it is considered flush. The cross-slope should be checked with a 12 foot straightedge for deviations greater than 1/4 inch. Straightedge requirements do not apply to areas that have not been ground.

Method of Measurement (257.05)

Measure pavement grinding by the square yard (square meter) of pavement ground and accepted. The quantity of pavement grinding will be determined by multiplying the width specified on the plan by the total length of finished pavement surface measured in the field. This excludes bridge decks, approach slabs, and other areas designated by the Engineer.

Basis of Payment (257.06)

Payment is full compensation for the furnishing of labor, materials, tools, equipment, and incidentals and for doing all work involved in grinding the existing surface, removing residue, cleaning the pavement, and testing with a profiler that conforms to the plans and specifications.

258 Load Transfer Retrofit

General

This is a rehabilitation technique that is normally specified to restore load transfer at faulted transverse cracks in older concrete pavements. It has also been used in new construction when dowel bar installing equipment on a concrete paving machine inadvertently fails to install dowels at contraction joints. Standard Construction Drawing BP-2.6, Dowel Bar Retrofit, is to be followed when constructing this item of work.

Description (258.01)

The work involves the following:

1. Sawing the proper size slots across transverse cracks.
2. Cleaning the slots.
3. Injecting a silicone, caulking filler to seal the crack and filler board.
4. Placing a smooth dowel or deformed bar 1-1/2 inch in diameter with appropriate dowel chairs, expansion caps, and 1/2 inch thick filler board in each slot.
5. Filling the slot with one of the specified cementitious patching materials.
6. Consolidating, finishing, and curing the cementitious patching material.
7. Establishing a joint by sawing.

Equipment (258.03)

Equipment for sawing slots in the pavement must be power driven gang type assemblies with diamond saw blades that are capable of sawing a minimum of three slots at a time. Saws must not damage the existing pavement.

Figure 258.A – Slot sawing equipment

Figure 258.B – Slot sawing equipment

Jack hammers used to remove concrete from the sawed slots must be less than a 30 pound (13.6 kg) class.

Abrasive blast equipment used to clean debris from the slots must be capable of removing the saw slurry and other foreign material from the exposed surfaces of the sawed slot. A clean, newly exposed concrete surface free of spalls, laitance, and all contaminants detrimental to achieving an adequate bond will be left. If wet blasting is used, ensure water blasting pressure with abrasives in the water is 10,000 psi (690 bar) or less.

Construction (258.04)

The Engineer must mark the transverse cracks to be retrofitted with dowels. The Contractor will provide the spray paint. The Contractor must position the slots as shown in Standard Construction Drawing BP-2.6, Dowel Bar Retrofit.

The sawing must be done to the specified width of 2-1/2 inches (65 mm) and to a length, as needed, to allow the centering of the dowel at the transverse crack. The slot must be sawed deep enough to ensure that the dowel, when installed with a 1/2-inch tall prefabricated chair, is level and located at mid-depth in the concrete slab. The slots must be parallel to the centerline of the pavement. The Contractor may make multiple parallel saw cuts within the 2-1/2 inch width to facilitate removal of concrete and to provide a level surface for the feet of dowel bar chairs. Six slots are to be cut in each lane at each crack, three slots at 1 foot (0.3 m) centers in each wheel path, as shown in BP-2.6.

Figure 258.C – Saw cuts for three slots

Figure 258.D – Concrete removal by light weight jack hammer

Once sawing is complete, the concrete is carefully removed from the 2-1/2 inch slot using lightweight jack hammers (30 pounds [13.6 Kg] or less). Jackhammers should be operated from each end of the cuts so that they do not damage the sides of the new saw cut in the pavement to remain. Improper operation of hammers has led to immediate spalling and micro-cracking that resulted in spalling of the pavement around the spall after a few freeze thaw cycles. Once concrete is removed, traffic must be kept off of the slots until patching material is placed and cured.

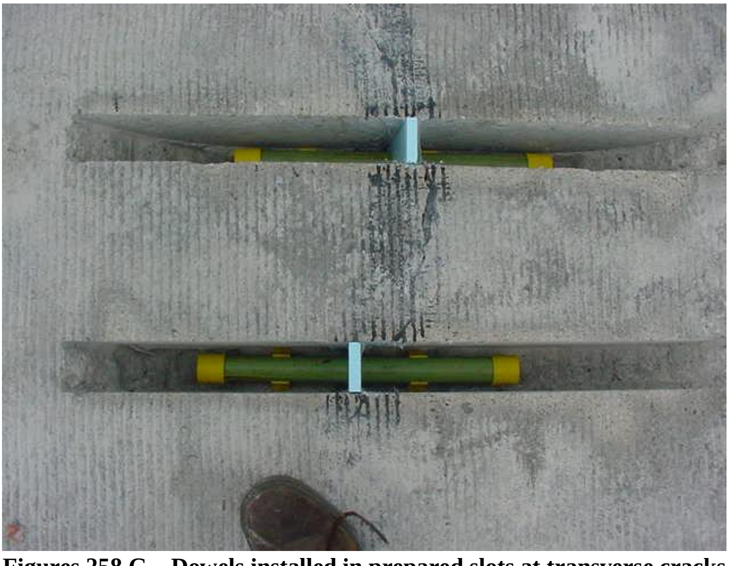
It is permissible to do all of the sawing within an area and open the pavement for a period of time, but once the concrete is removed traffic must be prohibited from using the pavement.

Once concrete is removed from the sawed slots to the proper depth, cleaning of the slots can begin. Inspection should include checking the slot depth to ensure the bottom of the slot is level and to the proper depth. Cleaning must be done by approved abrasive blasting (wet or dry) which will produce a rough surface on the sawed faces of the slots. The Contractor’s abrasive blasting operation must not damage the surrounding pavement. Do not allow the Contractor to begin abrasive blasting operations unless reasonably available engineering controls are implemented to limit fugitive dust. The Contractor must conform to state, regional, and local government agency requirements regarding the control of dust generated by blasting operations.

Figure 258.E – Dry abrasive blasting

Figure 258.F – Blowing out slots - air blast

After cleaning the slots, caulk cracks at the bottom and sides of the slot with silicone material. The purpose of caulking is to keep the patching material from entering the crack when placed in the slot. The caulking material must be forced into the crack under pressure. Care must be taken to be neat and not contaminate the cleaned slot face in adjacent areas.



Figures 258.G – Dowels installed in prepared slots at transverse cracks

Next, dowel or deformed bars are placed into the prepared slots as specified in the plans. Inspectors must ensure the Contractor follows these dowel placing requirements:

Deformed bars must be #11bar, 18 inches (460 mm) and long epoxy coated steel. The bar is to be centered on the crack. No oil or caps are required with deformed bars as they are intended to bond to the patch material and prevent movement at the crack.

Dowels must be 1-1/2 inches (13 mm) in diameter and 18 inches (460 mm) long. The dowel is to be centered on the crack. Dowels must be epoxy coated steel or fiber reinforced polymer.

Coat each dowel with a thin coating of new light form oil just prior to installation in the slot.

Place an expansion cap on each end of the dowel prior to placing it in the slot.

Two chairs are required for each bar. The chair is to be placed parallel to the pavement surface. Normally the two chairs are attached to each bar prior to installation into the slot. These chairs must firmly hold the bar centered in the slot at the proper elevation of 1/2 inch (13 mm) from the slot bottom. Inspectors must reject any chair design that allows movement of the dowel bar during placement of the patching material.

The dowel must have the 1/2-inch (13 mm) thick preformed filler board centered on the dowel to maintain the crack across the slot, as shown in BP-2.6. This filler board must fit tight around the dowel and extend to the bottom and to the edges of the slot. The filler board must be maintained in a vertical position and be tight to all edges during placement of the patching material. Use the silicone caulking material on the bottom of the preformed filler to keep the patching material from flowing under it. The filler board must extend from the bottom of the slot to the surface of the pavement. If the filler board shifts during placement of the patching material, the Contractor must redo the installation at no additional cost.

Once the bars are in place at the proper location, the Contractor must make several passes of an air blast throughout each slot to provide a dust free slot for adequate bonding of the patch material.

Next, the patching material is mixed, placed, and cured per the material manufacturer’s directions. The patching materials specified are prepackaged, proprietary, cementitious materials which may allow the use of a certain amount of aggregate of a certain grading to be blended with each bag. The Contractor must provide one of the approved patching materials listed on the Department’s Qualified Products List (QPL).

Figure 258.H – Portable mortar mixer

Figure 258.I – Filling slots with patching mix

The patching materials are mixed in the field with a portable mixer. When the material is placed into the prepared slot, it must be consolidated with an internal vibrator approved by the Engineer. The excess patching material is screeded off flush with the adjacent pavement. The surface is cured per the manufacturer's directions; however, a minimum cure time of 4 hours (or as directed by the Engineer) is required before placing any vehicle loads on the repair.

Figure 258.J – Internally vibrating patch

Figure 258.K – Patches cured with spray cure

Method of Measurement (258.05)

The Department will measure the quantity of Retrofit Dowel Bars by the actual number in the complete and accepted work.

Basis of Payment (258.06)

Payment is full compensation for furnishing all materials including paint; sawing and cleaning the slots; installing dowel chairs, dowels, bond breaker material, dowel bar end caps, sealant/caulking material, filler material, and patching material.

300 Bases

301 Asphalt Concrete Base

Description (301.01)

This work consists of constructing a base course of aggregate and asphalt binder, mixed in a central plant, and spread and compacted on a prepared surface.

The requirements of Item 401 apply, except as modified by this specification.

Composition (301.02)

The Contractor shall furnish aggregate for the mix that conforms to the following gradation:

Sieve Size	Total Percent Passing
2 inch (50 mm)	100
1 inch (25.0 mm)	75 to 100
1/2 inch (12.5 mm)	50 to 85
No. 4 (4.75 mm)	25 to 60
No. 8 (2.36 mm)	15 to 45
No. 16 (1.18 mm)	10 to 35
No. 50 (300 µm)	3 to 18
No. 200 (75 µm)	1 to 7

The Contractor may use reclaimed asphalt concrete pavement (RAP) or reclaimed asphalt shingles (RAS) as per 401.04. The Laboratory will establish the JMF according to 401.02.

Asphalt concrete is sampled and tested by the Contractor at the asphalt plant. The Contractor quality control tests should be based on the random number procedure found in the Contractor's QCP. Random number along with sample tonnage location and time should be recorded on the TE-199. Contractor tests are used for pay if they are verified by District testing. See 403.06 for sampling details.

Spreading and Finishing (301.04)

The Contractor must notify the Engineer at least 24 hours before the start of paving. Spreading equipment must conform to 401.12 specifications. The maximum compacted thickness of any one lift is 6 inches. The uncompacted lift thickness will be greater than 6 inches by approximately 1/4 inch per inch of compacted thickness.

The minimum air temperature required for paving 301 base on aggregate base is 40 °F (5 °C) and 36 °F (2 °C) when paving on any asphalt course. The minimum mixture temperature when delivered to the paver is 250 °F (120 °C). The mixture temperature

should be checked at a minimum of four times per day or more if necessary. The temperature should be documented in the project records.

Asphalt base courses are very prone to segregation of course and fine aggregates. These segregated areas (course spots) severely reduce the performance of the pavement section and must be addressed by the contractor. Failure to correct these segregated areas and covering them with the successive asphalt course will result in a reduced pavement life and future repairs for the Department.

Hauling

Hauling must conform to specification 401.11.

The Contractor must use trucks for hauling asphalt concrete that have tight, clean, smooth metal beds from which the entire quantity of mixture is discharged smoothly into the spreading equipment.

If transporting hot asphalt concrete at prevailing air temperatures below 50 °F (10 °C), or if the length of haul exceeds 20 miles (32 km), ensure that all truck beds are insulated to maintain workable mix temperature and ensure that all covers are fastened to exclude the wind. Do not exceed a distance of 50 miles (80 km) from the asphalt concrete plant to the paving site, unless specified by the Department.

Proper tarping, insulation, and reasonable haul lengths are important to minimize cooling of the mixture which will result in higher density variability and reduced performance.

Haul trucks should also be monitored for segregation. The contractor's approved Quality Control Plan (403.03) is required to address the steps that will be taken to ensure that material is not segregated. This should include actions such as: monitoring at the plant, loading in three drops, and properly breaking loads to discharge into the hopper. Loads of severely segregated material should be rejected. Loads with moderate segregation should be noted, brought to the attention of the Contractor's FQCS, and modifications made to address the issue. Loads with moderate levels of segregation may be placed, so long as there is not visual segregation noted behind the paver.

Compaction

Compaction must conform to specification 401.16.

Performance of asphalt bases rely on adequate placement and compaction. 301 mixes are not measured for in place density like many of the other asphalt courses. The successful compaction of these mixes relies on strict adherence to the placement temperature, roller train capacity/coverage, and spread rate requirements. Compact the mixture uniformly using a combination of both steel and Type I pneumatic tire rollers which conform to 401.13. Do not use a spreading rate that exceeds the total of the specified capacities of the rollers in use. A pneumatic tire roller is required for compaction of base mixes. The type and number of rollers must be documented in the project records.

Ensure that the maximum compacted depth of any one layer is 6 inches (150 mm) and the temperature of the mixture, when delivered to the paver (not to the job site), is a minimum of 250 °F (120 °C).

<u>Example: Roller capacity and placement rate.</u>

A contractor is using one 3-wheel roller, one vibratory roller with 66-inch drums (both vibrating), and one Type I pneumatic tire roller to compact a 5-inch thick mat using material with a Laboratory conversion factor of 2.0 tons per cubic yard.

From Table 401.13-1, the following is the capacity of the rollers the Contractor will use:

- Three-wheel = 700 *sq yd/hr*
- Vibratory r oller = 2 *drums* x 66 *in* x (15 *sq yd/in* of width) = 1,980 *sq yd/hr*
- Type I pneumatic roller = 1,000 *sq yd/hr*
- Maximum roller capacity = 700 + 1,980 + 1,000 = 3,680 *sq yd/hr*

[(3,680 *sq yd/hr)* X (9 ft^2/*sq yd*) X (5 *in*) X (1 *ft*/12 *in*)] X (1 $yd^3/27\ ft^3$) = 511.11 yd^3/hr.

511.11 yd^3 X 2.0 *tons/*Yd^3 = 1,022.22 *tons per hour* maximum placement rate.

Spreading and Surface Tolerances (301.05)

Spread the mixture at the rate calculated using the specified thickness, the compacted width of the pavement course being placed, and the weight-to-volume conversion factor established in 401.21. Maintain the actual rate of spreading the mixture within a tolerance of ±5 percent.

Do not exceed 3/8 inch (10 mm) in surface variation from the edge of a 10-foot (3 m) straightedge. Surface variations include bumps and depressions. If using Item 301, Asphalt Concrete Base, as a subbase for a rigid pavement or base, do not exceed a variation of 1/4 inch in 10 feet (6 mm).

<u>Example: Determining the required placing rate per station (RPRS).</u>

A contractor is placing a 5-inch uniform mat of asphalt concrete pavement whose Laboratory conversion factor is 2.0 tons/cubic yard. The required placing rate (RPRS) in tons of material per station for a 12-foot wide mat is:

RPRS = [Volume of asphalt in cubic yards] x [Lab Conversion Factor]

= [{100 *ft per station* X 12 *ft* X (5 *in* ÷ 12 *in/ft*)} ÷ 27 ft^3/yd^3] X 2.0 *tons/*yd^3

= 37.04 tons/station

302 Asphalt Concrete Base

Description (302.01)

This work consists of constructing a base course of aggregate and asphalt binder, which is mixed in a central plant, and spread and compacted on a prepared surface. This item is similar to 301 and requires the same level of field inspection and documentation.

The requirements of Item 401 apply, except as modified by this specification.

Composition (302.02)

The Contractor shall furnish aggregate for the mix that conforms to the following gradation:

Sieve Size	Total Percent Passing
2 inch (50 mm)	100
1-1/2 inch (37.5 mm)	85 to 100
1 inch (25.0 mm)[1]	68 to 88
3/4 inch (19.0 mm)[1]	56 to 80
1/2 inch (12.5 mm)[1]	44 to 68
3/8 inch (9.5 mm)[1]	37 to 60
No. 4 (4.75 mm)	22 to 45
No. 8 (2.36 mm)	14 to 35
No. 16 (1.18 mm)	8 to 25
No. 30 (600 µm)	6 to 18
No. 50 (300 µm)	4 to 13
No. 200 (75 µm)	2 to 6
[1] Provide aggregate to retain a minimum of 7 percent of the material on each of these sieves. This requirement applies to the gradation of the JMF and the mix production according to Item 403.	

The Contractor may use reclaimed asphalt concrete pavement (RAP) or reclaimed asphalt shingles (RAS) as per 401.04. Asphalt concrete is sampled and tested by the Contractor at the asphalt plant. Contractor tests are used for pay if they are verified by District testing. See 403.06 for sampling details.

Spreading and Finishing (302.04)

The Contractor must notify the Engineer at least 24 hours before the start of paving. Spreading equipment must conform to 401.12 specifications. The Contractor must submit, in writing, the model of asphalt spreader to be used, provide a certification statement that all required modifications have been made, and provide a signature. The compacted thickness should be a minimum of 4 inches and a maximum of 7-3/4 inches.

The minimum air temperature required for paving 301 base on aggregate base is 40 °F (5 °C) and 36 °F (2 °C) when paving on any asphalt course. The minimum mixture temperature, when delivered to the paver, is 250 °F (120 °C). The mixture temperature should be checked a minimum of four times per day or more if necessary. The temperature should be documented in the project records.

Asphalt base courses are very prone to segregation of course and fine aggregates. These segregated areas (course spots) severely reduce the performance of the pavement section and must be addressed by the contractor. Failure to correct these segregated areas and covering them with the successive asphalt course will result in a reduced pavement life and future repairs for the Department.

Hauling

Hauling must conform to specification 401.11.

The Contractor must use trucks for hauling asphalt concrete that have tight, clean, smooth metal beds from which the entire quantity of mixture is discharged smoothly into the spreading equipment.

If transporting hot asphalt concrete at prevailing air temperatures below 50 °F (10 °C), or if the length of haul exceeds 20 miles (32 km), ensure that all truck beds are insulated to maintain a workable mix temperature and ensure that all covers are fastened to exclude the wind. Do not exceed a distance of 50 miles (80 km) from the asphalt concrete plant to the paving site, unless specified by the Department.

Proper tarping, insulation, and reasonable haul lengths are important to minimize cooling of the mixture which will result in higher density variability and reduced performance.

Haul trucks should also be monitored for segregation. The contractor's approved Quality Control Plan (403.03) is required to address the steps that will be taken to ensure that material is not segregated. This should include actions such as: monitoring at the plant, loading in three drops, and properly breaking loads to discharge into the hopper. Loads of severely segregated material should be rejected. Loads with moderate segregation should be noted, brought to the attention of the Contractor's FQCS, and modifications made to address the issue.

Compaction

Compaction must conform to specification 401.16.

Performance of asphalt bases rely on adequate placement and compaction. 301 mixes are not measured for in place density like many of the other asphalt courses. The successful compaction of these mixes relies on strict adherence to the placement temperature, roller train capacity/coverage, and spread rate requirements.

Compact the mixture uniformly using a combination of both steel and Type I pneumatic tire rollers which conform to 401.13. Do not use a spreading rate that exceeds the total of the specified capacities of the rollers in use.

Ensure that the compacted depth of any one layer is between 4 and 7-3/4 inches and the temperature of the mixture, when delivered to the paver (not to the job site), is a minimum of 250 °F (120 °C).

<u>Example: Roller Capacity and Placement Rate</u>

A contractor is using one 3-wheel roller, one vibratory roller with 66-inch drums (both vibrating), and one Type I pneumatic tire roller to compact a 5-inch thick mat using material with a Laboratory conversion factor of 2.0 tons per cubic yard.

From Table 401.13-1, the following is the capacity of the rollers the Contractor will use:

- Three wheel = 700 *sq yd/hr*
- Vibratory roller = 2 *drums* x 66 *in* x (15 *sq yd/in* of width) = 1,980 *sq yd/hr*
- Type I Pneumatic Roller = 1,000 *sq yd/hr*
- Maximum roller capacity = 700 + 1,980 + 1,000 = 3,680 *sq yd/hr*

[(3,680 *sq yd/hr)* X (9 ft^2*/sq yd*) X (5 *in*) X (1 *ft*/12 *in*)] X (1 yd^3*/27* ft^3*)* = 511.11 yd^3*/hr*.

511.11 yd^3 X 2.0 *tons/*Yd^3 = 1,022.22 *tons per hour* maximum placement rate.

Spreading and Surface Tolerances (302.05)

Spread the mixture at a rate calculated using the specified thickness and the compacted width of the pavement course being placed, and the weight-to-volume conversion factors established in 401.21. Maintain the actual rate of spreading the mixture within a tolerance of ±5 percent.

Do not exceed 3/8 inch (10mm) in surface variation from the edge of a 10-foot (3 m) straightedge. Surface variations include bumps and depressions. If using Item 302 Asphalt Concrete Base as a subbase for a rigid pavement or base, do not exceed a variation of 1/4 inch in 10 feet (6 mm).

<u>Example: Determining the Required Placing Rate per Station (RPRS)</u>

A contractor is placing a 5-inch uniform mat of asphalt concrete pavement whose Lab conversion factor is 2.0 tons/cubic yard. The required placing rate (RPRS), in tons of material per station, for a 12-foot wide mat is:

RPRS = [Volume of asphalt in cubic yards] x [Lab Conversion Factor]

= [{100 *ft per station* X 12 *ft* X (5 *in* ÷ 12 *in/ft*)} ÷ 27 ft^3/ yd^3] X 2.0 *tons/*yd^3

= 37.04 tons/station

304 Aggregate Base

Materials (304.02)

All of the material requirements for 304 are located in section 703.17. This section allows for the use of the following four material types:

1. Crushed Carbonate Stone (CCS).
2. Crushed gravel.
3. Crushed Air-Cooled Blast Furnace slag (ACBFS).
4. Open Hearth slag (OH).

Crushed Carbonate Stone (Limestone) Used for 304

If Crushed Carbonate Stone (CCS) is used, the material must meet the gradation and physical requirements in 703.17. In rare cases these materials become soft after a rain event or over the winter.

Crushed Gravel Used for 304

If crushed gravel is selected for use as aggregate base, it must be manufactured from material retained on the 1/2-inch (12.5 mm) sieve. It must meet the gradation and physical requirements shown in 703.17. At times this material lacks some fine material and becomes unstable.

Crushed Air-Cooled Blast Furnace Slag Used as 304

If Air-Cooled Blast Furnace slag is selected for use, ensure that the material meets the requirements of Supplement 1027. This material can cause environmental concerns. The gradation and physical requirements are detailed in 703.17.

Open Hearth Slag Used as 304

If Open Hearth slag is selected for use, ensure that the material meets the gradation and physical requirements of 703.17 and the requirements of 703.14 which include:

1. Deleterious Substances.
2. Identification of OH slag.
3. Verification of Tufa performance.
4. Aging and stockpiling requirements.
5. Expansion testing.

Before Spreading (304.03)

1. Sample the material to be used.
    a. Develop a moisture density curve per Supplement 1015.
    b. The curve provides the optimum moisture content for the test section.
    c. Note: The test section maximum dry density is used for compaction acceptance, not the density from the curve.
2. Material Moisture.
    a. The material must have reasonably uniform moisture content.
    b. Prior to spreading, moisture content must be no less than 2 percent below optimum moisture.
    c. Add water to the stockpile, if required.
3. Minimize segregation.
    a. If segregation occurs in stockpile, mix or re-grade the stockpile.

Spreading (304.04)

1. Do not spread on frozen surfaces.
2. Do not use frozen material.
3. Do not exceed a compacted lift thickness of:
    a. Eight inches (200 mm) when using vibratory rollers with effective weights greater than 12 tons (11 metric tons).
    b. Six inches (150 mm) when using vibratory rollers with effective weights between 10 and 12 tons (9 to 11 metric tons).
    c. Four inches (100 mm) with no vibratory roller. If the Contractor is compacting with a vibrating plate compactor, the maximum lift

thickness is 4 inches. If the Contractor is compacting with a roller without any vibration, the maximum lift thickness is 4 inches.

d. Effective weight of a roller is the roller weight plus the centrifugal force.

e. Centrifugal force is the additional force from the roller vibrations.

f. Contractor needs to document that the roller effective weight requirements are met.

4. Place in equal lifts when the specified thickness exceeds 8 inches (200 mm).
    a. Example: if a 12-inch lift is specified, place in two 6-inch lifts.
5. Use self-propelled spreading machines.
    a. Capable of placing the 304 material true to line and grade.
    b. Use a dozer with a spreader box or an asphalt paver.
        i. This operation prevents segregation.
        ii. If an area appears to be segregated, take in-place gradation tests according to Supplement 1090.
        iii. Contractor is only allowed to use dozers without spreader boxes, graders, or hand-placing methods when the total area of the aggregate base is 2,000 square yards or less or in small areas. Do not take in-place gradation tests in small areas.

Figure 304.A – Spreading 304 with a dozer and spreader box

Figure 304.B – Spreading 304 with an asphalt paver

Figure 304.C – Spreading 304 with a dozer may result in segregation

Figure 304.D – Spreading 304 with a grader may result in segregation

Compaction (304.05)

1. Add water or dry out the material.
    a. To bring material to within 2 percent of the optimum moisture content.
    b. Add water or dry the 304 prior to compaction.
        i. Material is too dense to add water after compaction.
    c. Maintain moisture during compaction.
    d. Uniformly apply water throughout the lift.
    e. Reduce when unstable.
2. Compact immediately after spreading.

Figure 304.E – Adding water to 304 prior to compaction

Figure 304.F – Compacting 304 with vibratory roller

3. Prior to 304 production, construct a short test section to determine maximum dry density and minimum number of roller passes.
    a. Construct the test section according to Supplement 1015.
    b. Use a minimum of eight passes in the test section.
        i. Minimizes getting a false maximum.
    c. Adjust the vibration to maximize density and stability.

d. Maximum vibration can make any material unstable.

4. Construct a new test section when:
   a. Material changes.
   b. Supporting materials change (e.g., change from natural soil to cement stabilized subgrade).

Figure 304.G – Construct a test section

5. Use at least the same number of passes and compactive effort used to obtain the test section maximum density for the production material.
   a. Increases passing results in the production area.
6. At a minimum, use eight passes in the production area.
   a. Increases passing results.
7. Reduce minimum passes if detrimental.
   a. Do not over roll, it may cause cracking.

Figure 304.H – Perform the compaction tests

8. Perform compaction testing according to Supplement 1015.
9. Use 98 percent for the acceptance in the production area.
    a. Take three tests in the lot for acceptance.
    b. Use the average of the results.
10. Check production material density.
    a. Before or after the finishing operations.
11. Maintain the surface so the texture is:
    a. Reasonably uniform.
    b. Aggregate firmly keyed.
    c. Hauling on the 304 will “Un-key” the material.
12. Scheduling 304 operations.
    a. Cover the aggregate base with the next pavement layer prior to the end of construction season.
    b. If the Contractor doesn’t pave before the end of construction season, then the Contractor is responsible for contamination, damage, and instability of the base, subgrade, and underdrains.
13. Provide drainage and maintain the material according to 203.04.A.
    a. Maintain the cross-slope.
    b. If it rains or material sits over the winter.
        i. Dry the 304 and subgrade.
        ii. Obtain and maintain stability and density.

Finished Surface (304.06)

1. Finished surface should not vary:
    a. More than 3/8 inch (10 mm).
        i. From a 10-foot (3 m) straightedge parallel to the centerline.
    b. Or more than 1/2 inch (13 mm).
        i. From a template conforming to the required cross-section.

2. Contractor to furnish straightedges, templates, or other devices.

Checking the Depth

1. At the beginning of the spreading operation.
    a. Contractor must adjust the spreader.
        i. Produce sufficient loose depth to meet plan compacted thickness.
            1. Determined after compaction.
        ii. Make occasional checks.
            1. During the spreading to ensure uniform depth after compaction.
    b. Purpose is to control spreading.
        i. Need not be recorded.
2. After fine grading.
    a. Make depth checks.
        i. At 500-foot (150 m) intervals.
        ii. Extended to 1,000 feet (300 m) if depth is consistent and meets plan depth.
    b. Some variation in depth is expected.
        i. Tolerance of 3/4 inch (19 mm) between individual measurements.
    c. If consistently less by any amount.
        i. Requirements have not been met.
        ii. Take corrective action.
    d. If individual measurement less than 3/4 inch (19 mm) of plan depth.
        i. Make measurement within 100 feet (30 m).
        ii. If greater than plan thickness.
            1. Satisfactory.
        iii. If less than plan thickness.
            1. Make checks at additional locations.
            2. Define deficient area.
            3. Require correction.
    e. Record all depth measurements.
        i. With station locations.
        ii. Place in the project records.

Checking the Width

1. Measurements of the width of base.
    a. Need not be made prior to placement of overlying courses because the width of base can readily be verified.
2. After the overlying pavement is placed, make a visual verification of the base width.
    a. If it conforms to or exceeds the plan width, file a statement in the project records.

305 Portland Cement Concrete Base

Construction (305.02)

When constructing this item, the requirements of 451 apply with the following exceptions:

1. Reinforcing mesh required by 451.08 is not required in concrete base.
2. Provide dowels at transverse contraction joints in mainline pavement, ramps, acceleration/deceleration lanes, or collector/distributor lanes. Dowels are not required in shoulders for mainline pavement, ramps, acceleration/deceleration lanes, or collector/distributor lanes unless the transverse contraction joint is located within 500 feet of a pressure relief joint.
3. Construction joints are not to be placed within 6 feet of another parallel joint.
4. The curing application rate for the membrane forming, curing compound for concrete base is 200 square feet per gallon (5 square meters per liter) instead of what is specified for 451 and 452 pavement described in 451.11.
5. The surface finish for concrete base is broom dragged in either the longitudinal or the transverse direction to provide a uniform, gritty surface texture to the satisfaction of the Engineer. Tining per 451.10 is not required.
6. Surface smoothness variations for concrete base are not to exceed 1/4 inch in 10 feet (6 mm in 3 m).
7. Station numbers as required in 451.10 are not required for concrete base.

Method of Measurement (305.03)

The concrete base must be field measured and the area of pavement placed be calculated for payment in square yards (square meters). The area is determined the same as 451 or 452 pavement.

The pavement width for payment will be based on the plan typical cross-section, plus any additional widening that has been directed by the Engineer. The length will be field measured along the centerline of the roadway or ramp.

Determine thickness of the base conforming to 451.18.A.

Basis of Payment (305.04)

Pay a reduced price for base found deficient in thickness according to 451.19.A. There is no additional payment for a concrete base thicker than that shown in the plans. Pay for accepted quantities at the Contract price per square yard (square meter).

320 Rubblize and Roll

Description (320.01)

This work consists of breaking up existing, rigid, concrete pavement using a rubblize and roll method to provide a base material for the placement of new asphalt concrete pavement.

Materials (320.03)

Filler material may be needed to correct grade after the concrete pavement has been rubblized. The Contractor must furnish materials conforming to Item 304 in order to fill depressions 1 inch (25 mm) or greater in depth.

Equipment (320.03)

The Contractor must use a self-contained, self-propelled unit of either the resonant frequency type or the multiple head breaker type for rubblizing the exposed concrete pavement. There are specific equipment requirements for each type of breaker. The Contractor must provide documentation showing that the proposed equipment meets those requirements. Refer to C&MS 320.03 for specific details.

A vibratory roller is required and must have a total weight of at least 10 tons. The Contractor must provide documentation for the roller, if needed by the project, to verify total weight.

Construction Details (320.04)

Saw Cutting

The Contractor must make a full-depth saw cut to cut load transfer devices at existing joints on ramps or on the mainline pavement where the rubblizing abuts concrete pavement or approach slabs that are to remain in place permanently, or temporarily, for maintenance of traffic.

Test Section

The Contractor is required to rubblize a test section before beginning full-scale operations. The Engineer will designate the test section area. The Contractor will rubblize the test section per the specification requirements. At the direction of the Engineer, the Contractor will excavate a test pit to check the particle sizes of the rubblized concrete throughout the depth of the slab. Based on the Engineer's determination, the rubblizing operation may proceed or additional test sections and test pits may be required in order to obtain the required particle sizes.

The test pit can be refilled using the excavated material and additional 304 aggregate to bring the final surface to the required grade. The test pit can be rolled at the completion of the test section, or later, during full operation.

Excavate at least one test pit, at the location designated by the Engineer, for each production day or every 7,040 square yards (5,886 m2), whichever is greater. Throughout the rubblizing, the Engineer may require additional test pits, as necessary.

Control and Operating Speed

The Contractor is required to adjust the speed of the rubblizing operation in order to maintain the correct particle sizes. If the Contractor does not consistently obtain the specified particle sizes, the Engineer may require another test section, test pit, or additional passes to ensure compliance. The correct particle size is of critical importance to obtaining a suitable base material, details of the particle size requirements can be found in 320.04.

Filling and Compacting

Leave steel reinforcement in place in the rubblized pavement. Reinforcing steel may rise to the surface during the rubblizing or rolling operations. However, cut off any exposed steel reinforcement to below the surface and remove it from the site.

The rubblized pavement must be compacted with two passes of the vibratory roller operated in the vibratory mode at a speed not to exceed 6 feet (1.8 m) per second.

Depressions 1 inch (25 mm) or more in depth, below the immediate surrounding surface that form as a result of rubblizing, compaction, or steel reinforcement removal, must be filled with filler aggregate conforming to Item 304 or other Department accepted well graded aggregate that will compact.

Excess filler material must be leveled off so that it is level with the surrounding area. Compact filled depressions with the same roller and compactive effort as previously described.

Restrictions

Traffic is not allowed on the rubblized pavement before the initial asphalt concrete base and intermediate courses are in place.

The Contractor must structure operations so that no more than 48 hours elapse between rubblizing the pavement and placing the initial asphalt concrete course. In the event of rain during the 48-hour period, the Engineer may waive this time limitation to allow sufficient time for the rubblized pavement to dry to the Engineer's satisfaction.

If the Engineer waives the time limitation, cease rubblizing the pavement until the Engineer allows paving to resume.

Method of Measurement (320.05)

The Engineer will measure rubblize and roll by the number of square yards (square meters).

The Engineer will use the actual width of the existing concrete pavement and will measure the length along the centerline of each roadway or ramp.

The Engineer will measure the filler aggregate by the number of cubic yards (cubic meters) furnished, placed, and compacted.

321 Cracking and Seating Existing Plain Concrete Pavement

Description (321.01)

This work consists of breaking up an existing, non-reinforced concrete pavement using a cracking and seating method to provide a stable base for the placement of new asphalt concrete pavement.

Equipment (321.02)

The Contractor must use equipment that is capable of producing the desired crack pattern without extensive spalling or excessive shattering. Extensive spalling is considered at depths greater than 1-1/4 inches.

Whip hammers cannot be used.

The Contractor must use a 50-ton pneumatic tire roller that conforms to the requirements of 204.06 (Proof Rolling) to seat the cracked concrete slabs. Pneumatic tire towing equipment is required to move the roller forward and backward along predetermined lines. The Contractor shall provide information to verify the roller meets the specification requirements.

Construction Details (321.03)

The Contractor should provide positive provisions, in addition to 107.07, to contain any flying debris during cracking operation.

The Contractor must demonstrate to the Engineer the ability of the selected equipment and procedure to produce the desired crack pattern by cracking at least three, but no more than 5 existing concrete slabs. The Contractor shall furnish and apply water to dampen the cracked concrete to enhance visual determination of the crack pattern during the test section process. The Contractor must make adjustments to the energy or striking pattern to maintain the desired crack pattern.

The Contractor must provide a crack pattern of 4-foot by 4-foot (1.2 m X 1.02 m) segments.

There may be instances where the existing slab is already cracked into segments by age and traffic. In these cases, the Contractor must further crack the slabs to obtain a maximum 5-foot and minimum 3-foot dimensions, both transversely and longitudinally.

The breaking equipment shall not be allowed to affect slabs within 1 foot of another break line, a joint, or the edge of the concrete slab.

At least once a day, the Contractor must apply water to a check section to allow verification of a satisfactory crack pattern. When the crack pattern differs from required, the Contractor must make adjustments to the operation in order to bring the crack pattern into compliance.

The Contractor must roll the cracked pavement until the all of the concrete pieces are seated with at least two roller coverages. The seated pieces cannot rock or move after seating.

The Engineer will determine the maximum number of coverages of the roller on the test section to ensure proper seating of segments without damage to the concrete.

Before placing asphalt concrete, the Contractor must remove all loose pieces of concrete that are not fully seated. All voids must be repaired by applying 407 Tack Coat, filling with asphalt concrete, and compacting as directed by the Engineer.

Traffic is not allowed on the cracked concrete before the initial asphalt concrete base and the intermediate courses are in place.

400 Flexible Pavement

401 Asphalt Concrete Pavements

General Description

General requirements for mix production and construction of asphalt concrete pavement courses are included in Item 401. The Contractor responsibilities in supplying and placing a quality asphalt pavement are summarized in C&MS 401.01 paragraph 3.

Other specific requirements for flexible pavement production, quality control, and mix design are included in Item 402 Asphalt Concrete Mixing Plants, Item 403 Asphalt Concrete Quality Control and Acceptance, and Item 441 Contractor Mix Design and Quality Control - General. Requirements for the specific pavement courses are found in the specifications under the contract item designation (301, 442, 446, 448 etc.).

The quarterly posting of Supplemental Specification (SS) 800 on ODOT's website is used to update the C&MS. Plan sets list the SS800 that is in effect for every project. Check the plan set to ensure you are using the correct SS800 posting since specifications change over time.

Asphalt concrete is a mixture of aggregate and asphalt material. The asphalt material used in these mixtures has a relatively high viscosity at normal temperatures. It is necessary to heat the aggregate and asphalt material to permit mixing, placing, and compacting.

Asphalt concrete may be used in new construction as the entire pavement structure or it may be used with other materials in a layered pavement structure. Extensive use of asphalt concrete is made for rehabilitating existing pavements by resurfacing or widening and resurfacing. Asphalt concrete is particularly adaptable to this type of work, where disruption of normal traffic flow must be kept to a minimum. Although written with reference to new construction, the instructions contained herein also apply to rehabilitation construction.

Asphalt concrete mixtures are produced in a central proportioning and mixing plant. At the plant, aggregate is dried and heated to the mixing temperature and combined with the specified asphalt material. On completion of mixing, the asphalt mixture is discharged directly into trucks, or conveyed to surge bins or silos, from which trucks are loaded for transport to the project.

Asphalt concrete is placed by mechanical pavers. After it is placed, the mixture must be compacted using the proper compaction equipment before it cools and becomes unworkable.

The term flexible pavement, used throughout this manual, includes pavement or surfacing material construction composed of asphalt material and aggregate mixtures or various combinations of layers of these mixtures on layers of aggregate base or subbase. Although designs may vary in the combination of these materials, flexible pavement functions in a definite manner under traffic loads. It is the intent of the design that deflection of the pavement, in reaction to wheel loads, will not stress the materials to the point of fracture within the reasonable life expectancy of the pavement.

Except for chip seals and other surface treatments, the strength of all flexible pavement layers, including subgrade, is dependent upon the density of the material and the gradation of the particle sizes. In addition, the strength of the subgrade and granular base material is dependent on moisture content, and the strength of asphalt mixtures is partially dependent on the quantity and viscosity of the asphalt material. While the strength of granular base materials is less affected by moisture content than soil subgrade material, adequate drainage of this material is necessary to prevent saturation of soil subgrade material and loss of subgrade strength.

All flexible pavement courses, except microsurfacing, etc., are placed loose by means of spreading and leveling equipment and then compacted with compaction equipment. The typical sections or other plan details specify the width and thickness of the individual courses. For granular subbase and base courses, the thickness shown in the plans is the actual compacted thickness to which the course is to be constructed. Normally, the thickness specified for all other courses is to be used to calculate a weight of material to be placed per unit of area.

Aggregate

Aggregate may be hauled to the paving site from approved stockpiles located at the source, on the project, or at some intermediate storage point. In any case, it is necessary to maintain sufficient surveillance to ensure that loading is from approved stock and that identity of the stockpile is not altered by addition of material or other cause. It also is necessary to inspect the aggregate for uniformity as it is being loaded or placed. When such observations are made, they should be recorded for the project record.

Aggregate Stockpiling

Two fundamental requirements are included in 703.01 for aggregate stockpiles: separate identity and freedom from contamination. In addition to these considerations, knowledge of the method used in constructing the stockpile is necessary to have an understanding of the characteristics of the material as it is drawn from the pile for use.

The characteristic of an aggregate most affected by the method of stockpiling is its gradation. The larger size aggregate particles have a tendency to separate from the smaller size particles in parts of the stockpile; this is called segregation. A reduction in aggregate particle size can occur due to breakage or wear; this is called degradation.

Segregation is more likely to occur in an aggregate having a relatively large particle size range from coarse to fine. The amount of segregation of aggregate particle sizes usually depends on the degree of freedom the aggregate has to flow from one place to another during stockpiling or handling. Usually, segregation is minimized when the stockpiles are formed by placing the aggregate in successive small mounds or layers. Small pockets of segregated aggregate are not objectionable in the stockpile, when re-mixing occurs in the loading and spreading operations, resulting in a uniform appearance. However, when these pockets are sufficiently large that non-uniform areas can be observed in the material placed on the grade, the results are unsatisfactory, and corrective measures ensuring uniform material in place are required.

Degradation of an aggregate may occur during stockpiling due to the action of hauling and spreading equipment operating on the stockpile. Aggregate particles may be broken into smaller sizes by heavy compressive forces exerted by such equipment. Also, excess

fine particles may be produced by interparticle abrasion caused by repeated application of these forces. Normally, however, degradation is severe only in the case of very brittle or very soft aggregate particles.

Liquid Asphalt Materials

The Laboratory maintains a certification program throughout the year with all participating liquid asphalt material producers. Reference should be made to Supplement 1032 regarding forms used for identification of loads from approved stock. Loads arriving without proper identification are not to be used until specification compliance can be determined.

Since liquid asphalt materials may become contaminated and errors in shipment may occur, it is necessary to observe the delivered materials. Where there is a question concerning the quality of the material, the Contractor should be notified and a check sample should be taken.

Quality Control of Asphalt Concrete

The quality control of an asphalt concrete mix is performed by the Contractor in accordance with 401.02, 441, and/or 442.

Field Quality Control Supervisor (FQCS)

Item 403.03 requires the Contractor to provide a FQCS, who is a company employee who is at the paving site and is responsible for the quality of the asphalt being placed. The FQCS is responsible for identifying problems (see C&MS 401.01 paragraph 3) with the placement and immediately works to make corrections. Address all field quality issues with the FQCS and document all problems and all corrections. When the FQCS is not responsive, refer the problem to the Engineer for resolution. An FQCS can have their approval removed for failure to perform their duties. A list of approved FQCS personnel, by contractor, can be found on ODOT's website.

Field Inspection

The Inspector assigned to the placing of asphalt concrete should closely observe the placing of each type of mixture for indications of deficiencies in the mixture composition. If the mixture appears to be deficient in any of the following respects, notify the District plant monitor and the FQCS immediately, and note on the Inspector's Daily Report. The Engineer should be consulted when there is mix deficiencies that need addressed. In some cases, production should cease immediately.

Requirements for Mix Design, Materials, Rap, Mixing Plants (401.02 through 401.05)

A Job Mix Formula (JMF) is submitted by the Contractor using the contract mix specifications for the contract asphalt concrete (446, 448, etc.). The Laboratory must provide conditional approval of all JMFs before production of any asphalt concrete. A JMF is not considered "approved" until it has been used successfully in the field. The JMF provides the proportions of the aggregates and Reclaimed Asphalt Pavement (RAP), Reclaimed Asphalt Shingles (RAS), and binder content, along with the optimal

compaction temperature for the asphalt mix. This information is used in quality control for production and in field inspection. The Contractor quality control requirements for asphalt concrete are provided in Item 403.

Laboratory personnel must inspect and approve the mixing plant that will be used by the Contractor prior to the production of any asphalt concrete. Specification Item 402 and Supplement 1101 provides detailed requirements for asphalt mixing plants.

Weather Limitations (401.06)

There are specific requirements for air and surface temperatures in Item 401.06 that must be met before paving can start. In all cases, the existing surface to be paved must be dry and with weather conditions that allow proper handling placement and compaction. Table 401.06-1 provides minimum surface temperature requirements based on the thickness of the course being placed.

The air temperature must be 40 °F for all surface courses. For any surface course using a polymer modified asphalt binder the surface and air temperature must be at least 50 °F.

TABLE 401.06-1

Course Thickness	Minimum Surface Temperature	
3.0 inches (75 mm) and over	36 °F[1]	(2 °C[1])
1.5 to 2.9 inches (38 to 74 mm)	40 °F	(5 °C)
1.0 to 1.4 inches (25 to 37 mm)	50 °F	(10 °C)
Less than 1.0 inch (25 mm)	60 °F	(16 °C)
Variable Intermediate, 0 to 3.0 inches (0 to 75 mm)	40 °F	(5 °C)
[1] Instead of 36 °F (2 °C), use a minimum air temperature of 40 °F (5 °C) if paving on an aggregate base or subgrade.		

This specification prohibits Contractors from scheduling placement of a surface course with a polymer modified asphalt binder after November 1, regardless of the pavement or air temperature. Although the Department, in certain circumstances, may allow the placement of a polymer modified surface course after November 1, this practice should be avoided if at all possible. Additional measures such as delayed start time, elevated temperature, WMA as a compaction aid, additional roller capacity, remixing devices, ect. will likely need to be performed to ensure adequate placement of the mixture. Contact Central Office pavement specialists for concurrence prior to allowing placement. Where the Engineer does allow paving after November 1, ensure the Contractor is taking all precautions to ensure uniform temperature at the time of placement and to complete all roller coverage before the mix cools below the minimum compaction temperature of approximately 175°F.

Surface temperature measurements should be taken using the following procedures:

- When taking a reading in the sun, place the thermometer on the pavement and then shade that area with a clipboard, cardboard, or other available shading material. Take the temperature reading after approximately 3 minutes. The intent is not to shade the area to allow it to cool, but to protect the thermometer from obtaining a false reading due to direct exposure to the sun.

- The surface temperature should not be taken under the only shade tree or at the only sunny (unshaded) spot on the project. The surface temperature should be taken at a representative area.
- The surface temperature should be taken in the lane to be paved and not the adjacent berm.
- On Portland cement concrete pavements where flexible repairs have been performed, the surface temperature of the Portland cement concrete will be the governing temperature.
- A new surface temperature should be taken when the existing pavement surface material changes (asphalt concrete to Portland cement concrete or vice versa) to ensure that the new surface meets the minimum temperature specification. If this specification is not met, paving operations must be discontinued until the surface reaches specification temperature. Paving operations may be moved to a different area of the project where the surface meets minimum specification temperature.

Placing thin, surface courses at temperatures near the applicable temperature limits may require the Contractor to employ special precautions to produce a satisfactory surface. These precautions include avoiding paver stops, keeping the rollers close to the paver, adding additional rollers, and providing proper insulation for the trucks hauling the material.

It is the Department's responsibility to instruct the Contractor to stop paving operations in the event of rain. It is the Contractor's responsibility to stop plant production. If the Contractor will not stop placement, notify the Engineer.

During a rain event, a load of material in the process of being dumped into the paver may be placed with the requirement that the rollers follow closely behind the paver and a construction joint is formed at the end of the run. Do not allow waiting trucks to be dumped and placed. The material in the waiting trucks will retain sufficient heat for proper placing and compacting for an hour or more depending on the ambient temperature. Water can be kept from accumulating on the covers of the trucks and draining into the asphalt mixture by raising the truck beds slightly. These loads may be placed when conditions improve if the asphalt temperature is acceptable and the surface being paved is in a reasonably dry condition.

Notification (401.07)

The Contractor is required to notify the Engineer at least 24 hours before starting paving on a project. It is a recommended practice for the Engineer to call for a meeting to discuss the material and equipment to be used.

Hauling (401.11)

Included in the specifications (401.11) are the requirements concerning the condition of the vehicles used to haul asphalt concrete mixtures and the distance the mixture may be transported.

Check the trucks for compliance with the specifications as they arrive at the paving site. In particular, look for the following:

- The bed tarp is in good condition and covers the bed. Contact the testing office if any concerns.
- Small portions of the load are not isolated from the mass on projections such as extensions over cabs.
- The load is not segregated in the truck and the truck is loaded in multiple drops per the approved QCP.
- The load is discharged evenly, without surging in the paver hopper, and without jogging the vehicle when it is in contact with the paver.
- As the bed is raised, it does not come in contact with the paver.
- Uniform contact between the truck and the paver is maintained as the paver pushes the truck during unloading.
- Excess release agent is not being used on the truck bed.
- Diesel fuel is not being used as a release agent. If diesel is smelled in a load notify your testing office.
- Insulation is required when the air temperatures are below 50 °F or haul length exceeds 20 miles, check to see that all trucks are properly insulated and permit only approved trucks to be loaded.

Notify the Contractor when deficiencies are found. When corrections are not satisfactory and difficulties persist, the vehicle in question should be removed from the project. Contact the testing office with any issues.

The Contractor is to provide a place off the roadway for cleaning trucks. If the sticking to the truck bed is determined to be from excessive cooling of the mix, the Engineer will require an insulated bed.

Each load of asphalt is delivered to the project accompanied by a plant ticket with the load tonnage. The plant ticket must contain the date; project number; load gross, tare, and net weight; the JMF and material identification; producer name; producer location or plant number; and the time the truck left the plant. When the load is accepted at the paving site, the Inspector records the placement location and initials the ticket.

Spreading Equipment (401.12)

Asphalt pavers shall be self-propelled, mechanical spreading and finishing equipment, provided with a screed assembly capable of distributing the material to the full width of the lane being paved. The type of equipment suitable for spreading asphalt concrete depends on the particular paving operation to be performed: mainline, widening, berm, intersections, and whether the pavement course to be placed is base, intermediate, or surface. Spreading equipment requirements are stated in 401.12.

The Contractor should use means and methods approved by the asphalt spreader manufacturer consisting of, but not limited to, any combination of chain curtains, deflector plates, or other such devices that will eliminate segregation. Spreading equipment that does not produce a uniform texture must be corrected or replaced prior to proceeding with placement.

Pavers that leave ridges, indentations, or other marks in the surface shall not be used. The Engineer shall determine whether a paver is providing an acceptable asphalt mat that is ready for compaction. See C&MS 401.01 Paragraph 3.

The basic types of pavers found in current practice are described in the following paragraphs.

Floating Screed Asphalt Paver

A standard asphalt paver consists of a tractor with a receiving hopper, a conveying and distributing system, and a floating screed. The screed is essentially a rectangular trowel which floats on the surface of the asphalt mixture. The tractor pulls the screed by means of two shafts, or arms, hinged to each side of the tractor. The thickness of placed material is regulated by adjusting the angle of the screed with respect to the arms. This adjustment causes the screed to rise or fall until a condition of equilibrium is reached. Vibrating or tamping devices on the screed maintain a uniform flow of mixture under the screed. A heating system is provided to bring the screed to operating temperature at the beginning of work and to maintain proper screed temperature in cool weather.

The paver must have an automatic control system that maintains the screed in a constant position relative to grade, profile, and cross-slope references. These references must be capable of controlling the screed position independent of irregularities in the underlying surface and the paver operation.

When paving in excess of the nominal paver width, only a screed extension with full auger and tunnel extensions and the ability to heat should be used. Strike-off plates may only be used on adjacent berm areas.

Look for the following items when considering approval:

- Equipment must have sufficient size, power, and stability to receive the asphalt concrete material without erratic operation.
- Equipment must be capable of placing the material accurately in regard to line and grade.
- Asphalt concrete must be fed uniformly across the width of the screed without surges (which produce corresponding roughness in the finished surface).
- Asphalt concrete mixture behind the screed must have a uniform appearance across the full width of the course.

It is the Contractor's responsibility to make any necessary adjustments in the paver operation. The Inspector, however, should be familiar with the working of the paver, the effect of wear on paver operation, and the effect of various paver adjustments on the placing operation.

Offset Blade Strike-Off Paver

Where the use of a standard paver cannot be used due to irregular areas or size, special paver types can be approved by the Engineer. One type is the offset blade strike-off paver. This type of paver has a receiving hopper that feeds asphalt to a side-mounted strike-off blade. The tractor to which the hopper is attached operates on the surface adjacent to the area being paved. The blade is attached to the tractor and can be adjusted for width, elevation, and cross-slope. These pavers are used to place asphalt concrete for pavement widening, berm paving, pavement repairs, and other applications where a relatively narrow width is to be placed.

Anti-Segregation Equipment

Segregation of the asphalt mixture will reduce the longevity of the pavement. Segregation of the mixture can be classified as physical, thermal or both. Segregated areas of any type generally will have variable density based on the degree to which the mixture is segregated. Research has shown that equipment that remixes the mixture tends to produce a more uniform texture and temperature. It should be noted that equipment is not a cure-all for reducing segregation. While remixing equipment can be effective, the lack of following proper mix design, handling, loading, and placement best practices can still result in a mixture with unacceptable levels of segregation.

When anti-segregation equipment is specified, the contractor has the choice of what equipment they use to meet the specification requirements. The equipment must be evaluated to ensure the mat placement is acceptable. On the first day or night of paving any JMF on the project the Engineer must evaluate the first 1000 ft. of paving as a test strip. Visual inspection of the mat should have uniform texture with no areas or coarse or fine material. Pay special attention for texture differences between the main screed and extensions as well as areas following truck changes. If the material passes visual inspection, it should then be evaluated for temperature uniformity. Five (5) representative locations should be chosen during placement of the test strip and measured transversely for temperature uniformity. Measure and record temperature readings in approximately 2ft increments transversely across the mat after placement and prior to rolling. Temperature reading should begin and end approximately 1ft from the edge of the mat. Temperature readings should not be taken on the outer edges of the mat due to measurement area influences that could alter results. The range of all temperature readings at each transverse location must be 35°F or less. Document results of the test strip on Department Form CA-FP-5. The Contractor must produce an acceptable test strip in no more than two attempts per JMF. If a successful test strip is not achieved the operation should not continue until the contractor evaluates the operation and provides a written plan of action to correct the deficiency that is approved by the DCA.

Upon successful completion of a test strip the Engineer should monitor for continued compliance by performing random visual and thermal checks daily in the same manner as described above. If random checks yield an area with excessive temperature differential, the Engineer may allow paving to continue if additional measurements determine the area to be isolated and random. The Engineer may require additional evaluation (density, gradation, AC content, ect.) to determine the acceptability of the material

Rollers (401.13)

Compaction of asphalt concrete is governed by 401.16, 446.05, or 448.03 depending on the contract item designation. Item 446 is accepted by density testing and the roller selection is at the discretion of the Contractor, not governed by 401.13. This is also the case for 448, when it is accepted by field density testing using Supplement 1055. Acceptance by density testing allows the Contractor to select the type and number of rollers needed to obtain proper compaction, and thus, receive full compensation. When compliance with 401.13 is not required, rollers must be inspected for general working condition, leaks, and suitability. The Department retains the right to reject the use of rollers which are not in good repair or are not designed to do the required work fully and satisfactorily.

Where Item 448 is not accepted by density testing, and for Items 301 and 302 Asphalt Concrete Base, the requirements of 401.13 apply.

For asphalt concrete items requiring compliance with item 401.13, all rollers must be inspected for conformance with the specifications before paving begins.

Steel drums and rubber tires used for compaction should have the necessary accessories to prevent adhesion to the mixture. They should be kept moistened with water, water containing a detergent, or water containing an approved release agent. Excessive use of liquid should be prohibited.

Pneumatic tire rollers must be self-propelled, reversible units with vertical oscillation on all wheels, on at least one axle. The Contractor should determine the tire inflation pressure necessary to meet the specified minimum contact area and contact pressure requirements. The Contractor should furnish the tire manufacturer's charts or tabulations to the Engineer for verification of the required inflation pressure. Tire inflation pressure should be maintained within 5 pounds per square inch (35 kPa) of the required pressure.

Approval of specialized equipment proposed for compaction, in areas inaccessible to the specified rollers, should be based on obtaining equal results.

Tables 401.13-1 through 401.13-3 list the specific requirements for rollers.

TABLE 401.13-1 ROLLER CAPACITY

Roller Type	Maximum Capacity Square Yards per Hour (m^2/hr)
Tandem	700 (600)
Three-Wheel	700 (600)
Trench	15 per inch width (13 per 25 mm width)
Pneumatic Tire, Type 1	1000 (850)
Pneumatic Tire, Type 2	700 (600)
Vibratory, Vibrating Roll	15 per inch width (13 per 25 mm width)
Vibratory, Static Roll (not vibrating)	3 per inch width (3 per 25 mm width)

TABLE 401.13-2 STEEL WHEEL ROLLERS

Roller Type	Three-Wheel	Tandem	Vibratory Static	Trench
Total weight, tons (metric tons)	10 (9)	8 to 12 (7 to 11)	8 to 12 (7 to 11)	-
Compression rolls, pounds per inch width (kN/m), minimum	300 (53)	200 (35)	120 (21)	300 (53)

TABLE 401.13-3 PNEUMATIC TIRE ROLLERS

Type I	
Tire size, minimum	9.00 × 20 in (229 × 508 mm)
Wheel load, minimum	5000 lb (2250 kg)
Average tire contact pressure, minimum	85 psi (590 kPa)
Type II	
Tire size, minimum	7.50 × 15 in (191 × 381 mm)
Wheel load, minimum	2000 lb (900 kg)
Average tire contact pressure, minimum	55 psi (380 kPa)

Conditioning Existing Surface (401.14)

Cleaning the Surface

The surface on which an asphalt concrete course is to be placed must be free from material accumulations that would contaminate the mixture, prevent bonding, or interfere with placing operations. This includes loose or bony material that may accumulate along the unconfined joint edge. The surface of the existing pavement should be inspected before the paving operation begins, and should be cleaned of all foreign material, particularly dust, in accordance with 401.14. The surface should be checked a short distance in front of the paver to ensure that the surface has not become contaminated during the construction operation. A dirty or very dusty surface reduces the ability of the tack coat to bond, resulting in a potential slippage plane between the existing surface and the asphalt overlay.

Maintenance of Previously Constructed Surfaces

Prior to placing asphalt concrete on a pavement course constructed under the same contract, the condition of this previously approved work should be inspected. Where the approved subgrade or pavement course has become loosened, rutted, or otherwise defective, the deficiency must be corrected before the placing of a subsequent course is permitted. Hauling of materials over an asphalt concrete base course, for example, may cause cracking when there is not sufficient pavement thickness to carry heavy loads or where excessive deflection occurs over soft areas developed in the subgrade. Where cracking of the pavement occurs in such a case, the strength due to slab action is destroyed, and the affected material must be removed and replaced after correcting the cause of the failure.

Tack Coat

A tack coat is applied to the surface in preparation for the next course. Tack materials are asphalt emulsions conforming to C&MS Item 702. The following types are allowed 702.04 RS-1, SS-1, SS-1h, CRS-1, CSS-1 or CSS-1h, 702.12 or 702.13. The plans will indicate where tack is to be placed. Tack coats provide bond strength between pavement layers so they act as one monolithic section. Tack coats should not be diluted, minimized or non-performed.

Coating Vertical Faces

The specification requires all vertical faces that will be in contact with an asphalt course to be coated with asphalt material of a type specified in 401.03 in order to improve the bond to the new asphalt concrete course. This includes gutters, curbs, catch basin castings, etc., and the vertical face of an existing pavement. Due to the small quantity of material involved, approval of the asphalt material for this purpose may be based on field inspection. The results of this inspection are recorded, with the material identified as to type, grade, manufacturer, and quantity used.

Correcting Existing Surface Irregularities

In some resurfacing contracts, a quantity of asphalt concrete may be specified in the plans for making spot corrections, or for placing a continuous intermediate course to correct the cross-slope and profile of the existing pavement, as directed by the Engineer. This operation should be controlled closely to ensure that the best possible riding quality is obtained in the completed pavement.

Spot corrections, when provided for in the plans, are made to correct irregularities such as cross-slope or profile problems. Spot corrections can include a leveling or “scratch” course. These corrections are made prior to placing the intermediate or surface course. Unless specifically detailed on the plans, the Engineer will locate deficiencies in the existing surface requiring spot correction and notify the Contractor of the required corrective measures. Interior edges of spot patching may be irregular, but outside edges must conform to the specified edge alignment. All spot corrective work must be completed to the satisfaction of the Engineer before the intermediate or surface course is placed.

Intermediate course of asphalt concrete can be specified to correct minor irregularities in the existing pavement surface. Spot correction may be needed prior to placing the intermediate course. The intermediate course should not be used to correct major deficiencies. Inspect the placing of the intermediate course to assure that all deficiencies have been corrected satisfactorily. For intermediate courses where the profile or cross-slope is not specified on the plans, the profile of the new course should provide for a smooth riding surface, and the cross-slope should be uniform on all tangent sections and should vary uniformly in transition sections into superelevated sections. For an intermediate course where the profile or cross-slope is specified, the new course should conform to the required profile and cross-slope, within the specified limits. The procedure for checking the profile and cross-slope is given in Section 401.19.

Spreading, Finishing, and Night Work (401.15)

Field Inspection

During asphalt paving, careful observation of the mat behind the paver and the rollers is required to ensure a quality and durable finished pavement. The Contractor’s FQCS is responsible for the entire paving operation from surface preparation to paving. The Contractor is required to control and take prompt corrective action when the mat being placed is not free of any defect. Any deficiency in the mat should be brought to the attention of the FQCS. Record the deficiency and the action taken by the FQCS. If the FQCS does not make changes to remedy the defects, notify the Engineer. An FQCS can

have his approval removed for failure to perform his duties. The following examples are defects or problems during pavement preparation or paving that should be observed and corrected.

Tack Coat

Tack coats are used to bond asphalt layers together to create a monolithic pavement structure. All of the pavement layers need to act as one in order to effectively resist the shear and tensile stresses induced by traffic. The tack coat keeps the pavement layers from sliding over one another and prevents layer delamination. If the tack coat is insufficient, the pavement life will be reduced. The proper application of tack coat is often overlooked in the field.

Tack must be applied in a fine, even spray that covers the entire pavement. Tack application that appears “stringy,” spider-webbed,” streaked, or ridged is unacceptable and should not be included for pay. Refer to Item 407 in the MOP.

Pavements to be tacked must be properly cleaned using power brooming or street sweeping. Where surfaces have been milled, residual dust is a major problem, thus, creating a bond breaker between the existing asphalt and the tack coat. This leads to excessive truck tire pick-up. Additionally, the tack coat must be given time to “cure” so tire pick-up is minimized.

Picture 401.15.A&B – Improper tack application

Picture 401.15.C – Uniform tack coverage

Segregation

Segregation can be caused by asphalt plant processes, improper truck loading, hand placing and raking, and paver operation. Segregated areas will have variable density and are susceptible to raveling and rapid pavement deterioration. Only a dense, uniform surface texture is acceptable.

When an asphalt mat is segregated, the coated coarse and fine aggregate particles physically separate from each other. Segregation can appear in a cyclical pattern or randomly across the mat. The aggregate in the mat should appear to be uniformly graded in size from coarse to fine, behind the paver, in the finished mat.

End-of-load segregation occurs as cyclical V-shaped or chevron type patches in the mat. In finer surface mixes end onof load segregation may not be immediately visible but temperature measurements can identify coldrepeating cooler spots that become visible as mix loss within a few years after placement. This type of segregation is a result of improper truck loading operation at the plant that results in the large aggregate separating from the fine aggregate in the truck bed and or improper management of the paver hopper level and wings. This generally can be controlled by changing loading operations at the plant to multiple drops, keeping the hopper level above the tunnels, and eliminating folding the paver wings.

Segregation must be controlled by the Contractor. The FQCS is responsible for making changes to eliminate segregation in the mat. If the FQCS does not make changes that remedy the defect, the Engineer should stop the paving operation until the causecauses of the defect are identified and corrected. While the project staff should work with the contractor to obtain an acceptable mat, continuous or repeating areas of segregation cannot be tolerated. Isolated areas of segregation should also be evaluated and removed if necessary. An FQCS can have his approval removed for failure to perform his duties.

Picture 401.15.D&E – Examples of segregated mats

Picture 401.15.F&G – End of load segregation

Mixture Consistency and Mat Texture and Uniformity

The asphalt mixture should have sufficient cohesion to remain mounded in the vehicle during hauling, but should flow freely from the vehicle when the load is dumped. Bumping or stopping the paver between loads, as well as uneven flow of material into the paver hopper, will likely leave bumps in the finished mat. Trucks backing up to the paver hopper should never bump the paver; the paver should move to the truck and make contact with the rear tires. During paving, asphalt should flow uniformly from the truck into the hopper with the quantity in the hopper being maintained at a constant level. Sudden surges cause surface irregularities.

The mat should have a uniform appearance across the width placed. Streaks of differing texture and pulling or tearing of the mixture generally indicate the need for adjustments to the paver screed and extensions. Worn screed plates can also cause streaking behind the paver. Other causes can include low mix temperatures and mix problems. In all cases, the FQCS is required to make changes to correct deficiencies. If the FQCS does not make changes to remedy the defects, the Engineer should direct the contractor to cease paving and correct the cause of the defect. The contractor should demonstrate that material can be placed free of defect before continuous paving continues. This may

require the plant to limit production until correction is proven. An FQCS can have his approval removed for failure to perform his duties.

Picture 401.15.H&I – Lack of mat uniformity and texture problems

Picture 401.15.J&K – Screed mark from stopped paver (left) and pulling and tearing of mat (right)

Stability

The mixture should have sufficient stability under the rollers without excessive displacement and movement. A bow wave in front of a roller drum is indication that the material is not stable. Resultant small, transverse cracks after rolling are also indication that the material is tender. Roller marks may also be an indication of an unstable mix.

Picture 401.15.L&M - Roller "Checking" caused by unstable material

Picture 401.15.N&O - Roller marks remaining in an unstable material

PG (Asphalt) Binder Content

Asphalt binder is used to bind the aggregate particles together. The mixture should contain enough PG (asphalt) binder without producing a glazed or flushed appearance under the action of roller compaction. A flushed asphalt pavement may contain too much asphalt binder.

Another cause of a flushed or glazed surface can be a result of opening to traffic too soon, particularly on hot summer days. The action of traffic tires on the hot surface can draw the liquid asphalt binder to the surface causing a shiny, glazed appearance. Traffic should not be permitted on a completed surface course until the mixture has cooled sufficiently.

Picture 401.15.P&Q - Glazing or flushing

Mixture Temperature

All asphalt paving compaction must be completed before the mixture cools below a workable temperature, generally 175 °F to 225 °F. During inspection, the temperature of the asphalt delivered to the paver, and immediately behind the paver, must be close to the optimal compaction temperature to ensure the mix is workable. The breakdown roller (first roller) must compact the mat at, or near, this temperature. Complete coverage of the breakdown roller across the mat is required to obtain uniform density. Lower compaction temperatures are directly related to lower in place densities, which increase the permeability of the pavement. A high permeability pavement will fail prematurely unless specifically designed to be permeable. Even with a perfect mix design, if the mix is not properly compacted in the field, the final product will not last for its intended length of time.

Thin lift asphalt is susceptible to rapid loss of heat, and its temperature must be monitored very closely, particularly during cool weather paving.

Any mixture that cools before it can be compacted properly should be removed and replaced.

Monitor and record the mix temperature on a regular basis throughout the paving operation.

Truck Cleanout

Asphalt delivery trucks are not allowed to clean out truck beds on the pavement that will be paved. The material that remains in truck beds is cold and will not compact correctly, often causing a bump in the pavement, and likely, a future pot hole. Spreading or broadcasting the cold material across the pavement prior to paving does not solve the problem. Always have the Contractor designate a cleanout area and ensure truck drivers are using it. If truck drivers continue to clean out on the road to be paved, have the FQCS address the issue.


Picture 401.15.R&S – Trucks improperly cleaning out in front of the paver

Release Agents

Truck drivers use release agents to keep asphalt from sticking to truck beds. Diesel fuel is prohibited to be used as a release agent in truck beds, but its use still occurs on ODOT projects. ODOT allows the use of special asphalt release agents and maintains a list of approved products on its website. Diesel fuel dissolves the asphalt binder and causes a soft spot in the asphalt mat, which eventually becomes a pot hole. Any truck driver using

diesel fuel must be removed from the project. Contact the testing office for assistance if needed. The FQCS is required to take action to prevent diesel fuel used as a release agent. Pavement areas affected by diesel fuel should be corrected by removing the contaminated material and replacing it with acceptable material. Note: the overuse of approved release agents can damage new pavement. Observe truck loading at the asphalt plant to ensure there is no free liquid draining from truck beds as a result of over application of any approved release agent.

Picture 401.15.T&U - Soft spots in the mat as a result of diesel fuel used as a release agent

Moisture

Variations in the moisture content of the aggregate fed to the plant, or an erratic production rate, may result in an excess of moisture in the asphalt concrete mixture. This can cause slumped or flattened loads accompanied by considerable bubbling or steaming of the mixture. In extreme cases, the PG binder material may separate from the aggregate and collect in a film over the surface of the load. This condition is unacceptable and is sufficient cause for rejection of the load. Excess moisture may cause streaks of excess PG binder material to appear as the mixture is spread. Report moisture problems to the Plant Monitor and the FQCS.

Contamination

An asphalt concrete mixture can become unsatisfactory due to contamination of the PG binder material, the aggregate, or the mixture itself. Contamination of the PG binder material, either in shipment or in storage at the plant, has the most serious effects. Contamination of the PG binder material may remain undetected until a quantity of mix is produced, at which time a marked change in the odor, consistency, or appearance of the mixture in the truck or in the paver hopper indicates that contamination has occurred. When these changes are noted, observe the mixture carefully as it is being placed and compacted. Report changes in the mixture to the FQCS and ensure there is follow-up.

Night Paving

Luminance

When nighttime paving is required, no work can proceed without an approved and operating lighting system. This work consists of furnishing, installing, operating, maintaining, moving, and removing nighttime lighting to illuminate construction work areas for night work. Night work is defined as work performed from 30 minutes before sunset to 30 minutes after sunrise.

An illuminated zone of at least 5-foot-candles is required in the immediate vicinity of all paving equipment and at least 1-foot-candle at 25 feet. Item 401.15 provides these specific requirements. The Engineer must approve the lighting system based on measured luminance readings. The Contractor must provide a photometer that can measure the luminance levels at the specified foot-candles with measurements taken 20 inches above the roadway.

Luminance measurements can be required by the Contractor at any time as requested by the Engineer. The Contractor must provide luminance readings at any change in the approved lighting configuration. Any corrections and deficiencies must be made within 1 hour or the Engineer is required to shut down the construction.

Light sources shall be positioned so they do not interfere with, impede, or cause glare for motorists. Light cannot be pointed at adjacent properties. Luminaires must be kept clean and bulbs replaced immediately. Asphalt pavement placed during nighttime operations should be reviewed and inspected in the daylight for mat problems like segregation, smoothness, etc. The results and observations of daylight reviews should be used to make corrections and adjustments to the paving procedures in order to correct and prevent substandard operations and unacceptable asphalt pavement.

Picture 401.15.V - Night paving lighting

Anti-Segregation Equipment for Night Work

Many jobs require paving during night hours to avoid lane restrictions during peak traffic hours. The Department maintains a website that details those roadways that cannot have lane closures during daylight hours. It can be difficult to see mat deficiencies (e.g., segregation) during night paving due to limited lighting and shadowing. Undetected

segregation has been known to be a problem; therefore, the Department requires the use of an MTV/MTD with paver hopper insert or remixing paver for night paving under the following conditions:

The project plans include more than 1 mile of continuous paving (measured through the bridges) and the surface course is being paved.

An MTV, MTD, or remixing paver must be a machine specifically made to eliminate segregation of asphalt mats. There are MTVs and MTDs that merely transfer material from the truck to the paver and do not mechanically remix the material prior to discharge to the paver hopper. These machines are not allowed. The Contractor must provide manufacturer's information to prove that the MTV/MTD proposed for use on the project has a mixer/agitator mechanism that consists of either segmented, anti-segregation, re-mixing augers, or two full-length longitudinal paddle mixers specifically designed for the purpose of re-mixing. Longitudinal paddle mixers shall be located in the paver hopper insert.

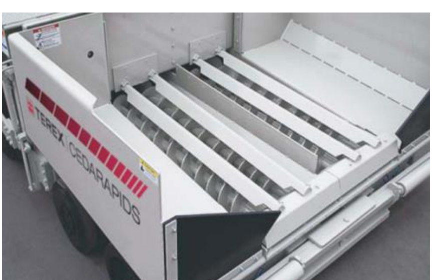
Remixing pavers specifically made to eliminate asphalt segregation are acceptable alternatives to an MTV/MTD.

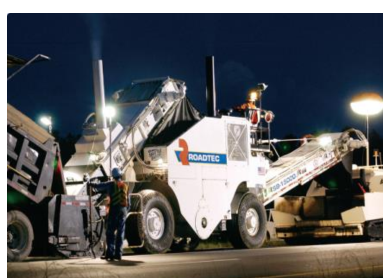
In all cases, the selected equipment must provide a uniform mat texture and temperature throughout the mixture, and limit temperature differentials to less than 35 °F (20 °C) across the mat. Use the same evaluation procedures from 401.12 to evaluate the anti-segregation equipment.

Before the start of paving, the Contractor shall provide a method for measuring the mat temperature differentials, and a method of inspection for segregation, that will be used during paving operations. Measuring mat temperatures can be performed using an infrared thermometer or special equipment specifically designed for this purpose, such as the Pave IR system. There should be a regular daylight inspection of the mat placed the previous night to ensure there are no areas of segregation that could not be seen during night paving operations.

Equipment that that does not consistently eliminate physical segregation and/or does not meet the temperature differential requirement should not be used on the project. Notify the FQCS of deficiencies of the equipment and ensure a remedy is put in place.

In many cases anti-segregation equipment may be specified directly and will be paid according to the specified line item for both surface and intermediate courses. In some cases the Department may not include a pay item for the route but the contractor chooses to pave at night. In this scenario the equipment cost is incidental to the work and will not be paid separately.





Picture 401.15.W - Remixing paver (left) and material transfer vehicle (right)

Possible Corrective Actions

Specification Item 401.15 requires the Contractor to, "Remove and replace, or otherwise correct, any portion of the pavement course found to be defective in surface texture or composition before or after compaction in a manner satisfactory to the Engineer." The Engineer will make a determination about whether a defective pavement must be removed or can remain in place with some repairs. The following methods may produce satisfactory results when the work is properly performed by sufficiently skilled workers. All corrective methods must be approved by the Engineer.

Where removal of material is required or to correct a low area, saw the patch area to neat lines. Generally removal should be for the entire lane width on surface courses. Remove the asphalt to the full-depth of the defective course and coat the surface of the of the patch area and butt joints with approved tack coat material. Place the new mixture in the prepared patch area to the proper elevations and compact as required.

When material must be removed to correct high areas in the surface, use a diamond grinder. Removal and replacement of the surface course and a portion of the underlying material may be necessary in extreme cases.

Compaction (401.16)

The compaction of asphalt concrete mixes is currently governed by one of two types of specifications. A method specification is used for some asphalt concrete (301, 302, and 448), while most mix types (446 and 448) are governed by a density requirement (446.05 and 448.03). Supplement 1055 details the requirements of density testing for 448 mixtures.

The Job Mix Formula (JMF) provides the optimal compaction temperature for the design. This temperature may be used as a starting point for the appropriate laydown temperature in the field. Temperature may need to be adjusted based on mix type, liquid AC type, haul distance, and weather conditions to ensure the mixture is workable and has ample compaction time. Once the target temperature is set, the mixture should be checked frequently to ensure the asphalt is being compacted at or near that temperature. For foamed Warm Mix Asphalt this the compaction temperature may be able to be reduced up to 30 °F. Warm Mix technology may also be used as a compaction aid for some mixtures to aid in coating and compactability. For asphalt concrete base pavements, refer to Items 301 and 302 for minimum allowed mix temperature. In all cases, the mixture should not be allowed to cool below a workable temperature for adequate compaction (175 °F to 275 °F) and the majority of compaction should be accomplished before the temperature reaches 225 °F.

Compaction (Method Specification)

This section applies to all mixes without a density specification. Compaction of an asphalt concrete mixture using the method specification is performed by using the rollers and methods specified in 401.13 and 401.16.

The number and type of rollers proposed for use by the Contractor should be checked for compliance with 401.13. The calculation for the roller capacity (tons per hour) should be made by the project personnel. Documentation of the calculations and the tire manufacturer's charts or tabulations furnished by the Contractor should be kept in the

project files. As the work progresses, the placement rate should be checked to ensure that it does not exceed the combined capacity of the rollers in use. If the placement rate does exceed the roller capacity, the Contractor must either reduce the rate or use additional rollers.

For compacting base mixtures, the specifications require at least one steel wheel and one Type 1 pneumatic tire roller. This requirement must be met even though the placing rate may indicate the need for only one roller. The intent is to ensure that each layer of base mixture will be subjected to the traffic conditioning effects of pneumatic tire rolling while the mixture has sufficient retained heat to respond without fracturing.

For compacting intermediate or surface courses, the specifications require the use of a three-wheel roller in the breakdown position. Ensure this requirement is met when using a method specification.

Example:

Roller capacity and placement rate.

A contractor is using one 3-wheel roller, one vibratory roller with 66-inch drums (both vibrating), and one Type 2 pneumatic tire roller to compact a 3-inch thick mat using material with a Laboratory conversion factor of 2.0 tons per cubic yard (*tons/yd*^{3}).

From Table 401.13-1 the following is the maximum capacity of the rollers the Contractor will use:

Three wheel = 700 *yd*^{2}*/hr*
Vibratory roller = 2 drums x 66 *in.* x (15 *yd*^{2}*/hr/in. of width*) = 1,980 *yd*^{2}*/hr*
Type II pneumatic roller = 700 *yd*^{2}*/hr*

Maximum roller capacity = 700 + 1,980 + 700 = 3,380 yd^2/hr

3,380 *yd*^{2}*/hr* x (3 in ÷ 36 *yd*^{3}*/in.*^{3}) = 281.67 *yd*^{3}*/hr*

281.67 yd^3 x 2.0 tons/yd^3 = 563.34 tons per hour maximum placement rate.

Therefore, the Contractor is limited to placing a maximum of 563.34 tons per hour using the rollers brought to the job.

Compaction (Density Acceptance)

This section applies to mixes accepted based on a density specification. The Contractor is responsible for determining the correct roller train to ensure compaction.

For 446 and 448 asphalt accepted by density testing, only the last four paragraphs of 401.16 are applicable.

Item 446 mixtures require the Contractor to meet a specified density target. To determine the density, ten 4-inch cores are cut from the pavement for each day of paving. The District Test Lab determines the field density from the cores. The Contractor can receive a bonus or deduction to the pay item based on the field densities. Refer to Item 446 for detailed information on this process.

Supplement 1055 provides the procedure for density testing using a gauge for 448 mixtures. This process requires the cutting of cores only to establish the correlation

between core density and gauge density. Refer to Item 448 and S1055 for details on determining density of 448 asphalt concrete.

Picture 401.16.A – Standard steel wheel vibratory roller

General Compaction Inspection

This section pertains to the compaction of asphalt concrete mixes using either the method specification or the density acceptance specification (described above). The Inspector should refer to the last four paragraphs of 401.16 to review the common part of both compaction specifications.

The optimum compaction conditions are present immediately behind the paver, and the greatest increase in density per roller pass occurs in this area. It is important that the breakdown roller follows the paver as closely as possible and obtains full-coverage across the entire mat width being placed. In general, roller coverage should begin at the edge and move toward the centerline, moving longitudinally, and overlapping each roller pass by one-half of the prior pass. When a longitudinal joint is being made (i.e., matching a previous course), this joint should be rolled first and then preceded with the normal rolling pattern. The specified roller pattern should be repeated uniformly, without abrupt stops or changes in direction, and the reversing points at the end of the roller runs should be staggered to reduce the possibility of forming transverse bumps. Final rolling should remove all tire marks.

Asphalt pavement joints can be confined or unconfined. Confined joints occur when the asphalt mixture is placed directly against a previously placed asphalt pavement or an existing pavement. Unconfined joints are considered loose since they are not placed against any confining edge or structure. Unconfined edges of the mat should be rolled using a steel drum roller with the roller drum hanging out over the edge approximately 6 inches.

Longitudinal joints occur where two lanes are, or will be, joined together. For an unconfined or confined longitudinal joint, best results are obtained by using a drum vibratory roller operated in the vibratory mode with the frequency set at maximum. Pneumatic tire rollers should not be used to do the first pass of an unconfined longitudinal joint.

Picture 401.16.B – Rolling the unconfined edge

Picture 401.16.C – Rolling the longitudinal joint first

Joints (401.17)

Longitudinal Joints

Longitudinal joints in the surface layer shall correspond with the edges of proposed traffic lanes. Longitudinal joints in lower layers shall be offset, as per Standard Construction Drawing BP-3.1, alternating each side of the edges of traffic lanes no less than 6 inches (150 mm).

Proper longitudinal joint construction requires the loose asphalt mixture to be placed at an extra 25 percent thickness above the confined joint material to allow for roll down and with a 1-inch to 1-1/2-inch overlap to permit proper compaction. If the joint is being made against a sawed or milled vertical edge, the overlap can be around 1/2 inch.

The height of the new asphalt mixture over the joint must be sufficient to permit full compaction of the material being placed before the weight of the roller begins to be carried on the adjacent construction. This pre-compaction height must be maintained uniformly, particularly on surface courses where raveling of an unsound joint is likely to occur. Height uniformity is achieved by continuous, automatic control of the strike off height.

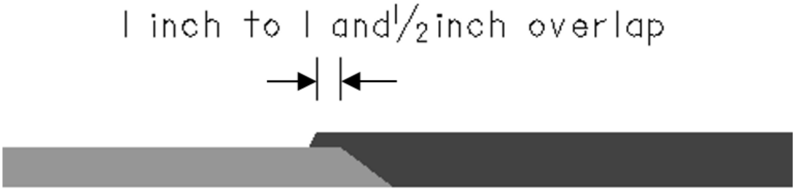


Figure 401.17.A – Joint overlap

The paver should be operated in a straight line to provide a mat with a straight edge that can be consistently overlapped. The crew must use string lines, skip paint or other appropriate controls to give the paver operator something to reference. Excessive deviations of the edge line from a straight line are unacceptable and require trimming the edge before the adjacent material is placed. With a good edge and proper control of the placing operation, little or no hand work is needed to form a good longitudinal joint. The Contractor should not continuously rake the joint. On surface courses, the Inspector must be sure that when hand raking does occur, it does not produce an irregular surface texture.

On projects where traffic is maintained, the longitudinal joints between adjacent lanes of surface course pavement must be completed within 24 hours. Where this time limit is exceeded, the joint should be inspected, and if the joint appears to be excessively rounded or displaced, trim the face to vertical according to 401.17.

All cold longitudinal joints are required to be sealed, as specified in 401.17, using a certified PG binder or SS875.02 Hot Applied Asphaltic Joint Adhesive to provide 100 percent coverage of the joint. Ensure the correct material is being used. Often tack is used instead of the required material; this is not acceptable.

Picture 401.17.A – Sealing the cold longitudinal joint

Transverse Joints

Transverse joints occur at any time the paving operation is stopped for the day (or night). When placing the last load of asphalt for the day, the paver should move forward until all material is spread. This leaves an irregular end that should be squared off by hand to form the joint. This joint edge should be compacted thoroughly, with the rollers passing over the edge, even though this may cause some rounding or even displacement of the material in the process.

Note that transverse joints at the beginning or completion of a project require joint construction, as detailed in the plan sheets, or in accordance with Standard Construction Drawing BP-3.1.

When the paving operation resumes, locate the point where the rounding or other departure from the profile begins, and continue the paving operation from that location in order to assure a smooth transition from one section to the other. In some cases, trimming the joint face may be necessary. The transverse construction joint is required to be formed or cut to vertical. All cold, transverse, longitudinal joints are required to be sealed as specified in 401.17 using a certified PG binder, SS875.02 Hot Applied Asphaltic Joint Adhesive, SBR Asphalt Emulsion to provide 100 percent coverage of the joint, or with a certified 702.04 asphalt material at a rate of 0.25 gallon per square yard (1 L/m^2).

The Contractor must have workers and hot material available during construction of the transverse joint. Utilize alternate rolling, a 10-foot straightedge, and the addition or removal of material to produce a uniform profile. Paving operations should not be permitted to continue until a satisfactory joint has been obtained.

Spreading and Surface Tolerances (401.19)

The specifications require the Contractor to maintain the rate of spreading of a uniform asphalt course to within ± 5 percent of what is required by the plan. For a given uniform course, the Required Placement Rate per Station (RPRS) is calculated in tons per station and checked against the Actual Placement Rate (APR). Determine the APR using the plant weight tickets, which accompany each load of material, and the area covered by a given number of loads. The area to be used for the check should not be greater than 500 feet (150 m) in length and should be measured from the start of a full load of asphalt concrete to the end of a full load. The results of these checks should be recorded on Form CA-FP-4, Bituminous Concrete Inspection.

To establish the RPRS, the laboratory conversion factor (tons/yd^3) is multiplied by the required volume of the asphalt pavement per station. One station is equal to 100 feet. The placement rate, in tons per station, is given by the following equations:

Calculate Required Placement Rate per Station, RPRS:

RPRS = [Volume of asphalt in cubic yards (*yd^3*)] x [Lab Conversion Factor, CF (*ton/yd^3*)]

= [{100 *ft. per Station*) x Lane Width (*ft.*) x Mat Thickness (*ft.*)} ÷ 27 *ft^3/yd^3*] x C.F. (*tons/yd^3*)

= tons/station

Calculate the Actual Placement Rate (APR):

APR = [Material Used (*Tons*) ÷ (Test section length (*ft.*) ÷ 100 per Station)]

= tons/station

Calculate the % Difference between the RPRS and the APR:

% = [1 - (RPRS / APR)] x 100

Where:

RPRS is the required placement rate per station.

APR is the actual placement rate per station.

C.F. is the lab conversion factor (*tons/yd*^{3}*)*.

Example:

Determine the Required Placing Rate per Station (RPRS):

A contractor is placing a 5-inch uniform mat of asphalt concrete pavement 12 feet wide, with a Laboratory conversion factor of 2.0 tons/cubic yard (*tons/yd*^{3}). In 500 feet the Contractor used 188 tons of material (from the truck weight tickets). Is the APR within ± 5 percent of the RPRS?

The required placing rate (RPRS) in tons of material per station:

RPRS = [Volume of asphalt in cubic yards] x [Lab Conversion Factor]

= [{100 *ft./station* x 12 *ft.* x (5 *in.* ÷ 12 *in./ft.*)} ÷ 27 *ft*^{3}*/yd*^{3}] x 2.0 *tons/yd*^{3}

= 37.04 tons/station

This rate should be rounded off to two digits after the decimal for control purposes.

The APR in tons per station:

APR = 188 *tons* ÷ (500 *ft* ÷ 100 *ft/station*) = 37.6 *tons/station*

% Difference in Spreading Rate Tolerance:

% Difference = [1 - (RPRS / APR)] x 100 = [1 – (37.04 ÷ 37.6)] x 100 = 1.49%

The Contractor's actual spreading rate is within ± 5 percent of the required spreading rate.

Note: This calculation can also be made on a tonnage basis instead of the "per station basis." Simply determine the required tons for the 500 feet and compare it to the actual tons placed.

Tons required = [500 *ft* x 12 *ft* x (5 *in* ÷ 12 *in/ft*) ÷ 27 *ft*^{3}*/yd*^{3}] x 2.0 *tons/yd*^{3} = 185.19 *tons*

Tons used = 188

% Difference = [1 - (185.19 ÷ 188)] x 100 = 1.49%

When variations greater than ± 5 percent of the required rate are calculated, the Inspector should address the variance with the FQCS to determine a cause. The Contractor should adjust the paver operation accordingly to bring an unwarranted variation back into tolerance. The Inspector should immediately check the actual spreading rate when changes are made to the paving operation. All variations in tolerance should be recorded in the Inspector's daily report.

Depending on the nature of the material being placed, and quality of the placing operation, one to four placement rate checks per day normally will represent the material placed with a given paver. When the work involves a series of small areas, the use of partial loads at each location makes the check impractical. In such cases, the Inspector should determine plan thickness is being obtained.

The placing of asphalt concrete should be closely controlled and kept as near as possible at the specified rate. Even for a well-controlled operation, both positive and negative variations will occur. The Contractor should not place the material at a rate greater than required since this would result in an overrun of plan quantity for which the Contractor would not be paid. As stated in 401.21, "Method of Measurement," the pay quantity is limited to the total weight of the item placed, converted to cubic yards (cubic meters), with no payment made for the quantity of material placed which exceeds that calculated from plan lines and dimensions.

Checking Longitudinal Profile

For all new construction, and some rehabilitation construction, the required profile grade and pavement elevations are given in the plans. Where a profile grade is not specified for rehabilitation construction, the profile of the finished pavement surface depends upon the profile of the existing pavement surface. The plans may require profile correction prior to placing an overlay pavement; however, profile elevations may or may not be specified.

For construction where a profile grade is specified, the Contractor is required to set grade stakes in order to provide a reference for controlling the elevation at which the asphalt concrete is placed. These grade stakes should be set at intervals of no more than 50 feet (15 m) on tangents and no more than 25 feet (7.5 m) on vertical curves and transition lengths of superelevated curves. The stakes should be placed on both sides of the pavement to permit easy checking of the grade; intermediate stakes should be provided in areas of greater than normal width.

The specifications require the completed pavement longitudinal profile does not deviate more than 1/2 inch from the plan elevation at any point. The difference in pavement elevation may be obtained by methods such as profile levels or differences in rod readings. Prior to placing the surface course, the Contractor must check the profile of the preceding course at 50-foot intervals and submit a tabulation of the results to the Engineer for approval. The results should be tabulated in a convenient form, which list the following:

- Station
- Pavement elevation
- Plan elevation
- Difference

The Engineer will evaluate the Contractor's profile check. Approval of the profile and permission to place the surface course should be based on satisfactory completion of any corrective work needed for compliance with the profile requirement. The approved profile check will be part of the project record.

Checking Cross-slope (Transverse Slope)

For all new construction, and some rehabilitation construction, the required cross- or transverse slope of the asphalt concrete pavement is given either as crown or as superelevation in the plans. Where a cross-slope is not specified for rehabilitation construction, the cross-slope of the finished pavement depends on the cross-slope of the existing pavement surface.

For construction where the cross-slope is specified, the pavement cannot vary more than 3/8 inch in 10 feet from the required slope. The Contractor should check the cross-slope of the pavement course being placed during the spreading operation with a 10-foot straightedge. The Inspector should observe this operation regularly to ensure that the pavement course is being constructed substantially within the specified cross-slope limits.

Particular attention should be given to the checking of the cross-slope on the asphalt concrete course preceding the surface course. Where observation of the Contractor's checking or additional checking by the Inspector reveals substantial deviations from the specified limits, corrections must be made to bring the asphalt concrete course within the specified cross-slope limits before the surface course can be placed.

Example of cross-slope check:

The plan specified the cross-slope as 0.016 foot per foot of pavement width (0.016 ft./ft.). For a 12-foot wide lane, the pavement drops from the crown to the edge based on the rate of slope. This vertical drop (in inches) is calculated:

0.016 *ft./ft.* x 12 *in./ft.* x 12 *ft.* pavement width = 2.3 *inches*

Therefore, if the Contractor checks the slope with a 10-foot straightedge, the vertical measurement from the pavement surface to the level straightedge is calculated:

0.016 ft./ft. x 12 in./ft. x 10 ft. straightedge = 1.92 inches

The spec requires a tolerance of ±3/8 inches (0.375 in.) on the cross-slope, so the vertical measurement from the pavement surface to the level straightedge can be:

1.92 *in.* + 0.375 *in.* = 2.30 *inches*

1.92 *in.* – 0.375 *in.* = 1.54 *inches*

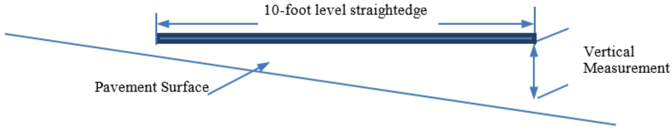


Figure 401.19.A – Cross slope

Checking Surface Smoothness

The required smoothness of asphalt intermediate and surface course cannot exceed 1/4 inch from the testing edge of a 10-foot (3.0 m) straightedge. The Contractor is required to provide a straightedge that is satisfactory to the Engineer. The Contractor should check the course being placed while the Inspector observes. The frequency of checking depends on the nature of the work being done. The surface smoothness should be checked closely when a transverse joint is being made, when erratic paver operation occurs, or when hand placing is required in the construction of a transverse joint. This check is often done at the end of a paving project since many Contractors elect to use a non-contact profiler and software per ODOT Supplement 1058.

When PN 420 or PN 470 is included, the Contractor is required to check smoothness using approved profilers and provide an analysis using ProVAL software according to S1058.

The project Inspector should determine at the beginning of the project which method the Contractor will use to check smoothness when PN 420 or PN 470 do not apply. In the case neither of these proposal notes apply, ensure that the Contractor is regularly checking the surface behind the paver with the 10-foot straightedge.

Method of Measurement (401.21) and Basis of Payment (401.22)

Asphalt mixture is delivered to the project based on weight in tons for each load. Payment is made in cubic yards for the specific item of work (e.g., 301, 448, or 446). A conversion from tons to cubic yards is required. The Laboratory provides a conversion factor (unit weight/volume) for the specific JMF being used in tons/cubic yard (tons/yd^3).

The number of tons placed and accepted is converted to cubic yards and compared to the quantity calculated from the plan lines and dimensions. The Department will not pay for additional quantities over the plan calculated cubic yards.

Converting Tons to Cubic Yards (Cubic Meters)

After the total tonnage of material used in a pavement section has been determined, convert it to cubic yards (cubic meters) using the applicable conversion factor established in 401.21. The conversion factor of a mix is included on the JMF and can be obtained from the District test lab. The tonnage of material used in a pavement section is converted to cubic yards (cubic meters) as follows:

Cubic Yards = [TW ÷ CF]

Where:

TW = Total weight of asphalt placed (*tons*)

CF = Conversion factor ($tons/yd^3$) or ($tons/m^3$)

This volume should be rounded off to the nearest cubic yard (cubic meter).

Summarizing Quantities

Keep a daily summary that includes Reference Number (Pay Item), Item Number, paving location, tons used (along with the conversion to cubic yards), and the calculated pay quantity. Add the asphalt plant tickets and keep with the daily summary. Use an adding machine with a paper printout. On the printout write the project number, date, Reference and Item Number, Participation Code, paving location (route, station to station, lane, etc.), and show the conversion to cubic yards. Initial the printout and keep with the daily summary sheet.

Complete a final summary of the total quantity placed for each Reference Number. The final summary should provide details for all separate pavement areas. In general, separate pavement areas include different contract parts, different participation codes, physically separate roadways, and pavement areas having differing design sections (e.g., ramps).

Pay Quantity for Uniform Course

The pay quantity of asphalt concrete with a uniform plan depth is calculated using the plan width and measured distance along the centerline. Paving in excess of the plan width or plan length is not eligible for pay. Excess quantity can only be paid if approved by the Engineer.

Pay Quantity for Variable (Leveling) Course

Where one to two courses of asphalt concrete is placed on an existing pavement for the correction of the profile and cross-section, the depth is variable and the pay quantity is the quantity placed as directed by the Engineer in accordance with the intent of the plans. Placement rate checks, as described in Section 401.21, should be used to verify that the Contractor is meeting the intent of the plans.

407 Tack Coat

Description (407.01)

Tack coat is an application of liquid asphalt material on an existing pavement surface that provides a bond with a new asphalt pavement. The bonding of pavement courses together creates a monolithic structure. The entire pavement structure is needed to resist shear and tensile stresses caused by traffic. The tack coat keeps the new pavement layers from sliding over the old layer (delamination). Insufficient or poor application of tack coat reduces pavement life. Proper application of tack coat is a key factor in producing a quality asphalt paving project.

Materials (407.02)

The specification requires tack coat to be an asphalt emulsion conforming to 702.04, which includes types RS-1, SS-1, SS-1h, CRS-1, CSS-1, and CSS-1h; 702.12 Non-

Tracking Asphalt Emulsion; or 702.13, which includes SBR Asphalt Emulsions. The most commonly used tack in Ohio is SS-1h.

Emulsions are classified as rapid setting (RS or CRS), medium setting (MS or CMS), or slow setting (SS or CSS). The letter "C" in front of an emulsion type (CRS, CMS, or CSS), denotes a cationic (positively charged) emulsion. If the emulsion type is followed by an "h" (SS-1h) it means the emulsion was made from harder base asphalt cement.

SBR asphalt emulsions are required for use on concrete pavements. This replaces the older specification that required rubberized asphalt emulsion.

Tack is not to be diluted with water. The color of diluted tack will appear browner on application than does undiluted tack.

In some cases, Non-Tracking Tack may be specified by the project plans. Non-Tracking Tacks are products that are applied like ordinary tack coats, but cure and set up very quickly, generally within 10 to 15 minutes, thus helping to eliminate tracking onto adjacent pavements. Note: Pick up and tracking due to the application of tack on dirty pavements is not solved merely by using Non-Tracking Tack; pavement cleaning is still required as well as proper application. The non-tracking characteristic makes them very suitable where construction zones are short, for example, urban paving conditions. If the Non-Tracking Tack provided does not perform in the field, the Contractor shall discontinue its use. Examples of non-performance would include long cure times and tracking of the material.

Equipment (407.03)

Distributor trucks are used to apply tack coat using a tank and spray bar system. The distributor is required to have a tachometer, thermometer, pressure gauges, and an accurate volume measuring device or a calibrated tank. A calibrated tank means there is a dedicated measuring stick for the tank and a chart that correlates the stick reading to the volume in the tank. The spray bar system must be fully circulating and the spray bar must be adjustable both laterally (to apply coverage to the correct width) and vertically (to adjust the spray fans). The spray bar must also maintain a constant height above the pavement surface as the load in the tank changes.

Many distributor trucks are now computerized and automatically adjust the pump pressure/discharge (gpm) to obtain the required application rate. However, there are many older distributor trucks still in use that require synchronization of the truck speed/RPM, the asphalt pump pressure/discharge (gpm), and the bar height to obtain the required application rate. Where these trucks are used, the Contractor must provide charts or other information that shows truck and pump speeds that are required to obtain the application rate.

In general, the faster the distributor truck goes, the faster the asphalt pump has to turn in order to get the same application rate that one would get at a slower speed.

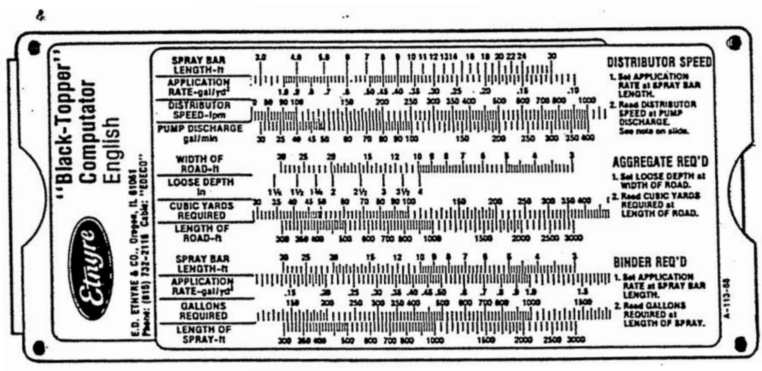


Figure 407.A – Example application chart for Etnyre distributor

Spray nozzles must be matched to the material and desired application rate. Often the standard nozzles that are installed by the manufacturer are not correct and have to be changed out. If the Contractor cannot get complete coverage at the specified application rate, he may be using the wrong nozzles.

All nozzles have to be adjusted to 15 degrees to 30 degrees with the axis of the spray bar in order to get complete coverage. Ensure all nozzles are adjusted to the same angle and are open. Clogged nozzles have to be cleaned or replaced.

Figure 407.B – Misaligned spray nozzles

The spray bar height must be adjusted to allow spray fan overlap, either single overlap or double overlap (if complete coverage is needed). Item 407 does not specify the required overlap and it may not be required to obtain complete coverage when the specified application rate is very light. In some cases, with light application rates, the Contractor may need to turn off one nozzle per every foot of spray bar and raise the spray bar height to get uniform coverage.

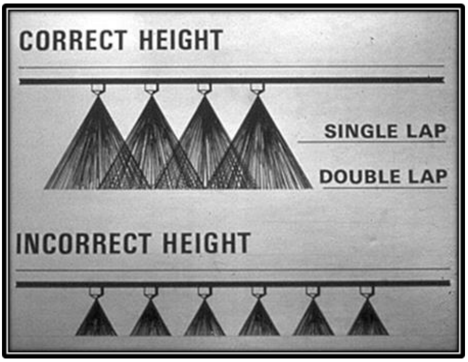


Figure 407.C – Spray bar height and fan overlap

Distributors that cannot apply tack uniformly and at the required application rate shall be removed from the project.

Mechanical sweepers, power brooms, street sweepers, and other related equipment may be of any type that will adequately clean the existing surface prior to tack coat application.

Weather Limitations (407.04)

Apply tack in accordance with the temperature surface requirements for the pavement course being placed. The minimum surface temperatures are provided in 401.06. Record the surface temperature.

Preparation of Surface (407.05)

The pavement surface must be dry and free of any foreign material accumulations that interfere with the bonding of the tack to the pavement. This includes dust and mud, including dust from milling operations. Excessive use of tack coat should never be a substitute for proper cleaning of pavement. Excessive tack coat can act as lubricant, creating a slip plane between pavement layers.

Remove all dust, loose aggregate, soil, leaves, and pieces or lumps of other foreign material using power brooms and street sweepers. Blades and hand work may be required for heavy accumulations. Make sure the full width of pavement to be paved is cleaned.

Although emulsified tack coat could be applied to a damp pavement, this practice is discouraged and should only be considered in certain critical circumstances where paving cannot be delayed. Damp pavement will require additional cure time and the tack bond may not be as strong. In the cases where paving on a damp surface is allowed by the Engineer, there should be no standing or flowing water on the surface of the pavement to be tacked. The time to cure should be closely monitored to ensure the tack application has completely set before paving begins.

Application of Asphalt Material (407.06)

Protection and Control of Traffic

When the Contract requires traffic to be maintained, tack coat application should not be allowed to start until the provisions of the traffic maintenance plan have been met. Alternate movement of one-way traffic (flagger operation) must be in place before the distributor is brought into the starting position.

Application of Asphalt Material

Only asphalt material meeting the requirements of 407.02 can be used. Tack is shipped under ODOT's Asphalt Materials Certification Requirements as detailed in Supplement 1032. Weight tickets will be provided for the loads of asphalt material delivered to the project. A weigh-back ticket must be provided after the application to accurately determine the quantity of tack used. The weigh-back ticket provides the weight of the material left over and not used. The weight used will have to be converted to gallons based on the appropriate conversion factor for the tack. Although the distributor is required to have an accurate volume measuring device, payment must be made using the weight tickets.

Inspect the distributor for compliance with the specifications. The Contractor must demonstrate the use of the required volume measuring device, thermometer, and application controls. Work should not be permitted to start if this equipment is unsatisfactory. In addition, the approval of the distributor is based on observation of the operation and check measurements of the actual application rate, performed, as described, in the following paragraphs.

For large areas, the application rate is determined by the placement of a given quantity of an asphalt material over a known area. The rate is calculated using the gallons (liters) indicated by the volume indicating device on the distributor, the known length of the distributor run, and the measured width that is covered. The required rate should be set by the Engineer to obtain full coverage within the range specified in Table 407.06-1. The rate of application is considered acceptable when the measured application rate is within ±10 percent of the required rate and the tack is uniformly applied. The application rate for small areas, where volume measurement is not practical, may be judged visually. Note that for payment, the quantity used is based on weight tickets, not the volume measuring device on the distributor.

TABLE 407.06-1

TYPICAL TACK COAT APPLICATION RATES

Existing Pavement	**Application Rate** gal/yd^2 (L/m^2)
New Asphalt	0.05 to 0.06 (0.23 to 0.27)
Oxidized Asphalt	0.08 to 0.09 (0.36 to 0.41)
Milled Asphalt Surface	0.08 to 0.09 (0.36 to 0.41)
Milled PCC Surface	0.06 to 0.08 (0.27 to 0.36)
PCC Surface	0.06 to 0.08 (0.27 to 0.36)

All of the nozzles should be angled 15 degrees to 30 degrees (depending on the manufacturer) from the axis of the spray bar, and the elevation of the spray bar should be maintained at a height that produces fully developed fans of bituminous material.

The operation of the distributor is judged by visual observation. The quantity of material flowing from each nozzle should be uniform. The angle of each "fan" of material with the spray bar should appear to be at the same angle as specified by the manufacturer. The material should be applied uniformly across the width of the spray bar, with no visible streaks, and with no apparent variations in the width of spray, from the beginning to the end of the run.

The results of the foregoing observations and checks are recorded for each distributor used on the job, together with a means of identification (license plate or equipment number) and indication of approval or non-approval. This information is entered in the project record. The asphalt material should be sprayed uniformly on the pavement surface. The application must be uniform, without streaking, thin lines, or dribbles. Streaking is caused by faulty distributor adjustment or operation. Applications with streaking, thin lines, ridges, etc. are not acceptable. The Contractor must be notified to make corrections by adjusting the distributor and the operation to obtain a uniform and consistent application of material across the entire width of the area to be paved. After distributor corrections or repairs, a test strip must be prepared to demonstrate proper application. Do not allow the continued use of equipment that cannot obtain a uniform application.

Pick-up and tracking of tack by paving equipment and trucks is to be controlled by the Contractor. Pick-up occurs due to dirty pavement and/or insufficient cure times. The Contractor is required to take steps to eliminate pick-up and tracking. The only way to avoid pick-up of a tack coat is to apply the approved material on a clean pavement and allow the material to set up or cure prior to allowing any asphalt delivery trucks or traffic on the tacked lane. This may require the Contractor to lengthen the traffic control zone to allow adequate cure time and to perform more thorough pavement cleaning. Pick-up and tracking is a serious deficiency and can result in a poor bond. The tracked material ends up on the roadway and can be a safety hazard.

When tack coverage is not uniform and not corrected or there is pick-up and tracking, the Engineer should require a proper correction to the operation before continuing paving. The entire area of non-uniform coverage is considered non-specification and will be deducted from payment.

Figure 407.D – Examples of good tack applications

Figure 407.E – Examples of bad tack applications

Figure 407.F – Good application with tracking (left)/ poor application with tracking (right)

There may be rare occasions where traffic has to be maintained on a tacked pavement. In such a case, the Contractor must place a cover aggregate to maintain a safe construction zone. Cover aggregate is required to be sufficiently dry to permit adhesion of liquid asphalt. When the cover aggregate is placed on an asphalt emulsion tack coat, the aggregate may be moist, but not to the extent that free water drains from the truck bed.

The Contractor is required to apply only the quantity of cover aggregate needed to prevent pick-up of the tack by traffic. A typical rate for applying cover aggregate is 4 to 8 lbs/yd^2.

Method of Measurement (407.07) and Basis of Payment (407.08)

Determine gallons (liters) to be paid from weight tickets and weighed partial loads using Supplement 1060 and ODOT Form CA-FP-6.

Where tack application is determined to be inadequate and non-specification, determine the number of gallons (liters) for non-payment by using the approved rate of application times the total square yards (square meters) of non-uniform application.

Cover aggregate is included in the bid price for the tack coat.

408 Prime Coat

Description (408.01)

Construction requirements for prime coats are included in 408. An asphalt material having low viscosity is required for a prime coat. This material is intended to penetrate a prepared granular surface prior to the placement of an asphalt concrete mixture. The purpose is to bind the granular particles together for some depth below the surface to provide additional stability.

Asphalt Material (408.02)

One of the following types of asphalt material can be used: 702.02 MC-30, MC-70, or MC-250 or 702.03 Primer 20.

Cover Aggregate (408.03)

Cover aggregate must conform to No. 9 size or gradation requirements of 703.05 or 703.06.

Weather Limitations (408.04)

Prime coat cannot be used on a wet surface.

Do not apply prime coat for asphalt concrete paving or surface treatment work when the air temperature is below 50 °F or when the air temperature in the last 24 hours has been 40 °F or lower.

Do not apply prime coat on stabilized or granular base courses when the air temperature is below 40 °F.

Equipment (408.05)

Equipment requirements for the application of tack coat are the same as detailed in 407. These requirements include the use of tachometer, pressure gauges, and an accurate volume measuring device or a calibrated tank. A thermometer is required to monitor temperature of the tack. The spray system must by fully circulating and the spray bar must be adjustable both laterally and vertically. The Contractor must provide charts or other information that shows truck and pump speeds required to obtain the application rate.

The spreading of the cover aggregate, when required, can be accomplished by any approved method depending upon the specific job conditions. When sweeping is required, the brooms approved for use should produce a uniform surface without causing damage.

Preparation of Surface (408.06)

The surface to be primed should meet all requirements for the particular specification item (e.g., subgrade, aggregate base, stabilized subgrade, etc.). Irregularities in the subgrade, subbase, or base material in excess of specified tolerances must be repaired prior to priming. These include, but are not limited to, ruts, corrugations, and high and low areas. Mud, clumps of dirt, and other foreign material must be cleaned from the surface to be primed.

Application of Asphalt Material (408.07)

The specified application rate for the asphalt material is an estimated rate suitable for average conditions. Open textured surfaces may permit an increase, while dense surfaces may require a reduction in the estimated rate. The application rate should be such that the prime will be absorbed by the material within 24 hours.

The asphalt material must be applied uniformly over the entire width of the area to be primed. The distributor must meet the same requirements of 407.03. If excess material is applied, the Contractor should squeegee the excess from the surface. Any deficient or skipped areas must be coated.

Prime is shipped under ODOT’s Asphalt Materials Certification Requirements as detailed in Supplement 1032. Weight tickets will be provided for the loads of asphalt material delivered to the project. A weigh-back ticket must be provided to accurately determine the quantity of tack used based upon weight. This weight will have to be converted to gallons based on the appropriate conversion factor for the tack. Although the distributor is required to have an accurate volume measuring device, payment must be made using the weight tickets.

Application of Cover Aggregate (408.08)

When traffic must use the primed area where the material has not penetrated completely, cover aggregate must be applied to absorb any excess material.

Method of Measurement (408.09)

Determine gallons (liters) from weight tickets or weighed partial loads (weigh-back). For weights or volumes that are questionable or unknown, a volume-measuring device is required before accepting the material. Cover aggregate is included in the bid price for the prime coat.

409 Sawing and Sealing Asphalt Concrete Pavement Joints

Materials (409.02)

Be sure approved materials are used per 409.02 requirements. These include joint sealant and backer rod.

Construction Details (409.03)

Check that the following operations are proceeding properly per 409.03:

- Saw cut the intermediate course if the surface course is not placed within 5 days. Saw cut is 1/8 inch wide by 1/4 the depth of the intermediate course over contractor joints. At expansion joints the saw cut is 1/2 inch wide by 1/4 the depth of the intermediate course.
- Saw cut the surface course no later than 48 hours after paving.
- Accurately locate saw cuts over joints with pins or stakes before paving. The Engineer shall approve the method of joint marking before any resurfacing operations begins. Poorly located saw cuts will result in cracking adjacent to the cut and poor performance of the joint.
- Final saw cuts shall be 2 inches deep with a sealant reservoir that is 3/8 inch wide by 3/4 inch and is recessed 1/8 below the surface.
- Dry cut joints shall be cleaned using compressed air by way of an air compressor with a minimum rated capacity of 100 psi. Wet cut joints require water blast cleaning followed by drying with a propane torch or lance unit (409.03 has details on lance unit requirements).
- The saw cut shall extend over the full pavement width including paved shoulders.
- The joint is to be kept clean until sealing; traffic is not permitted to damage the joint before sealing. Damaged saw cuts must be repaired prior to sealing
- The sealer is to be heated per the manufacturer's directions.
- The first gallon of material that flows out of the applicator wand at the start of the day is to be discarded and not used.

Prior to sealing, a backer rod must be placed in the clean joint and the liquid sealant immediately placed in the joint using a nozzle that is inserted into the joint and reservoir completing filling the joint. The sealant level after cooling should be not more than 1/8 inch below the pavement surface.

410 Traffic Compacted Surface

Because of the simplicity this item of work, no detailed explanation of the item is required in this manual.

411 Stabilized Crushed Aggregate

Because of the simplicity this item of work, no detailed explanation of the item is required in this manual.

421 Microsurfacing

Description (421.01)

This item of work is used to provide a cold laid polymer modified emulsified asphalt pavement course to fill ruts, depressions, and to provide a leveling course. It can also be used as a surface course over existing pavements. The mixture includes the use of crushed aggregate, mineral filler, water, polymer modified emulsified asphalt binder, and other additives.

Materials (421.02)

Materials used in the mixture and the completed mix are approved by the Laboratory prior to beginning work. The Contractor must provide a certificate of analysis and statement of compliance from the manufacturer with each load of binder.

Proportioning (421.03)

Verify job mix formula (JMF) approval by the Laboratory.

Weather Limitations (421.04)

The mixture cannot be placed when it is raining.

Allow microsurfacing placement if:

1. Air/Surface temperature is a minimum of 45 °F (5 °C) and rising.
2. Air temperature within 24 hours of placement is NOT forecasted to be below 32 °F (0 °C).
3. Between September 30 and May 1, minimum surface temperature is 50 °F (10 °C) or above.

Mixing Equipment (421.05)

Mixing equipment must conform to the specifications. Equipment must be self-propelled, front feed, with a continuous loading conveyor system. A gear pump must accurately proportion aggregate and asphalt emulsion.

Mineral filler must be dropped into the aggregate before reaching the pug mill. A spray bar must pre-wet the aggregate with water and additive before the addition of asphalt emulsion and before it drops into the pub mill.

The pug mill must be continuous flow type and a minimum of 49 inches long.

The equipment must have driving stations on both sides. The back mixing station must have forward speed control to allow the mixing operator to control speed and the level of mixture in the paver.

A water pressure system with spray nozzles that can spray water ahead of the spreader box may be required.

The Contractor can use truck-mounted machines with a conveyor belt delivery system on projects or routes of less than 15,500 square yards or use it for spot repairs.

Figure 421.A – Self-propelled front feed, continuous loading and mixing machine (left) Truck mounted machine (right)

Equipment Calibration (421.06)

Before mix production, calibrate the mixing equipment in the presence of the Engineer. Perform a new calibration if there is any change in the mix design. Obtain documentation of individual calibrations of each material from the equipment calibrator. After the initial calibration, no further changes or adjustments to the mixing equipment can be made without the Engineer's approval.

Spreading Equipment (421.07)

The spreading equipment must apply the mixture uniformly. A standard spreader box is allowed when placing a leveling course or surface course. For surface courses, a secondary strike-off must be attached to the spreader.

If a rut fill course is required, the Contractor must use a V-shaped rut filling spreader box equipped with a steel strike-off.

Either spreader box must be attached to the mixer and must be equipped with adjustable paddles that continuously agitate and mix the materials throughout the box. Check for excessive buildup and settling in the spreader box and have the Contractor correct the issue.

Burlap or other drags are allowed for use to provide the desired surface finish.

Surface Preparation (421.08)

Remove raised pavement markers according to 621.08. Fill depressions with the same material being used for the microsurfacing.

Pavement markings and all other paint must be removed using an abrasion method per 641.10.

Seal visible joints and cracks longer than 2ft in length in accordance with 423. The type of approved material used is the Contractor's discretion to ensure compatibility with the microsurfacing materials.

Be sure the surface is thoroughly cleaned before application. Apply a tack coat consisting of 1 part asphalt emulsion and 3 parts water and apply at a rate of 0.06 to 0.12 gallons per square yard. Apply tack in accordance with 407.

Test Strip (421.09)

A 1,000-foot test strip must be constructed for evaluation by the Engineer. The test must include all courses specified and must be constructed at the same time of day as the scheduled, full-scale production. For example, if the Contractor plans night work, the test strip must also be done at night.

The Engineer will evaluate the test strip after 24 hours of traffic to determine if the mix design is acceptable. Full-scale operations can only begin after the Engineer accepts the test strip.

If work is scheduled after May 1 and before September 30 and the Contractor has constructed a test strip with the same JMF and materials in the same construction season, the test strip may be waived.

Application (421.10)

During application the following items should be closely checked and monitored:

1. Uniform and complete coverage that fills cracks, potholes, and surface irregularities.
2. No skips, lumps, or tears are allowed in the material placed.
3. No unmixed aggregate is allowed.
4. In a rut, fill material must fully fill ruts without excess overfilling that creates a crown of 1/8 inch after 24 hours of traffic compaction.

5. Rut fill must be applied in 5- to 6-foot passes in each wheel path.
6. Restore the design profile of the pavement cross-section.
7. Leveling course must be applied at 14 ± 2 pounds per square yard (7.6 kg/m2).
8. Surface course must be at 16 ±1 pounds per square yard (8.7 kg/m^2) when placed on another microsurfacing course.
9. Surface course must be placed at 21-24 pounds per square yard (9.8 kg/m^2) when not placed on another microsurfacing course.
10. Surface courses must be wide enough to cover rut fill and leveling courses.
11. Straight lines must be maintained along curbs, shoulders, and intersections. Do not allow material to runoff in these areas.
12. All seams in the material should be smooth and neat with 1-3 inches of overlap where the two passes meet.
13. Stop placement if excessive streaking or other problems develop.
14. Contractor must use a rubber tire roller if the material is not exposed to traffic within 48 hours.
15. The pneumatic roller must meet 401.13 and have a tire pressure of 40 to 60 psi (275 to 400 kPa).
16. Squeegees are required where hand spreading and finishing is needed. Ensure that all handwork provides the same uniform appearance of the surface.

Acceptance (421.11),

Accept microsurfacing based on the Engineer's summary of quantities for each day provided the proportion of binder to dry aggregate is maintained within 2 gallons per ton (8.5 L/metric ton). Ensure all other control requirements for proportioning and spread rate are in conformance with the specifications.

The final pavement surface must be free from excessive scratch marks, tears, rippling, streaks, and other surface discontinuities. Longitudinal joints and transverse joints must be neat and straight.

Performance Review (421.12),

The contractor is required to warrant the work for a period of two years from the date of substantial work complete on Form C-85. Warranty by the Contractor does not alleviate the requirements in the specification for acceptance. The District will review the work prior to the end of the warranty period and notify the contractor of any defects exceeding the thresholds in Table 421.12-1, regardless of whether the contractor schedules the review or not. The review should be based on 1000ft lane segments. The beginning of the segment is the beginning of the distress type in that lane. The District will measure and document the quantity of distress in each lane segment. The District will notify the contractor in writing of the results of the Performance Review. The contractor is then required to contact the District to schedule and perform the remedial actions prior to September 30th of the review year.

If the District determines that immediate repairs are necessary, due to a potential hazard to the traveling public, the District will notify the Contractor and establish a date that all repairs are to be finished.

Prior to performing a Remedial Action, the contractor must submit a Remedial Action plan to the DCA for approval. The plan must state when and how the Remedial Action will be performed; what material will be used; and how traffic will be controlled.

The Contractor is not responsible for pavement damage beyond the Contractor's control (i.e., car fire, oil spill, structural issues etc.).

Method of Measurement (421.12), Payment (421.13)

Microsurfacing (surface and leveling course) is measured and paid by the square yards completed and accepted. The pavement width is as shown on the plans, specified in these specifications, or as directed by the Engineer. Length is measured along the centerline of the roadway.

Rut fill course will be measured and paid by the number of tons of dry aggregate used and accepted based on ticket weights.

The test strip will be paid based on the acceptance at the individual bid prices for each course placed. For example, if the plans require a leveling and surface course, the test strip must be constructed using these courses and would be paid on the measured quantities for both of these items.

Item 407 Tack coat and Item 423 Crack Sealing are not paid separately and considered incidental to the work.

Removal of existing pavement markings is not incidental and should be paid for under Items 643, 644, 645, 646, 647, or 648 as specified. Removal of RPMs should be paid for under Item 621 Raised Pavement Markers Removed.

Figure 421.B – Unacceptable streaking (left); unacceptable surface prep (right)

Figure 421.C – Unacceptable transverse joint and "skip"

Figure 421.D – Uniform coverage

422 Chip Seal

Description (422.01)

Chip seal consists of the application of polymer modified asphalt emulsion covered by an aggregate course. It is applied as a single or double chip seal for use as a surface course on all types of pavements and on paved berms. Chip seal can also be used as an intermediate course for a hot mix asphalt surface course.

The purpose of a chip seal is to seal and protect the underlying course from weathering and from wear by traffic. A coating of asphalt material helps seal existing pavement cracks and joints; the cover aggregate provides a skid-resistant surface.

When applied on berms, the cover aggregate provides delineation of the traffic lanes from the berms by a change in surface color and texture.

Figure 422.A – Chip seal operation

Materials (422.02)

Chip seals require the use of an emulsified polymer emulsified binder CRS-2P. Only asphalt binder materials meeting the requirements of 706.16 Type A are permitted. Asphalt binder is shipped under ODOTs Asphalt Materials Certification Requirements as detailed in Supplement 1032. Ensure that the material used on the project is from a certified source.

Cover aggregate must be washed limestone or dolomite meeting 703.05. Aggregates with a source designated as “SR” cannot be used. The Laboratory maintains The Aggregate Source Group list that designates aggregate sources that do not provide acceptable friction characteristics and may become polished or slippery with wear. These aggregates are designated as “SR” or “SRH.”

Cover aggregate for chip seals must be sampled and approved prior to use. Sampling occurs at the source stockpile and at a staging stockpile location. For example, at the job site. If there is doubt as to whether any stockpile continues to meet the required aggregate gradations, the District can sample and test at any time.

The Contractor must submit a mix design for the chip seal and a Job Mix Formula (JMF) to District Testing for approval. District testing should review the JMF for compliance with the specification for materials and perform testing to validate compliance for the gradation of the aggregate.

Equipment (422.03)

Distributors

The Inspector must make a general examination of the distributor to ensure compliance with the requirements of this specification and 407.03. The equipment used for the application of a tack coat is the same as used for the application of the polymer binder for chip seal, but must include a computerized rate control that automatically adjusts the binder pump to the unit ground speed. This control must have a gauge or meter (in gallons) that is easily read. The spray nozzles must be appropriate for the material and rate specified. In addition, the approval of the distributor is based on observation of the operation and check measurements of the actual application rate, performed as described in the following paragraphs. The Inspector should have the Contractor demonstrate the use of the required volume measuring device, thermometer, and application controls. Work should not be permitted to start if this equipment is unsatisfactory.

Figure 422.B – Distributor trucks applying binder

The operation of the distributor is judged by visual observation. The quantity of material flowing from each nozzle should appear uniform. The angle of each "fan" of material with the spray bar should appear to be the same; the angle is specified by the manufacturer. The material should be applied uniformly across the width of the pavement, with no visible streaks and with no apparent variations in thickness, from the beginning to the end of the run.

Figure 422.C – Distributor with improperly aligned nozzles (at different angles)

Streaking or ridging will not be tolerated when applying polymer binder for chip seal work. This type of defect is generally caused by nozzles that are not all at the same angle in respect to the spray bar. The Inspector must approve or prohibit use of a particular distributor accordingly.

Figure 422.D – Unacceptable application of "ridged" binder

The results of the foregoing observations and the results of the test section are recorded for each distributor proposed for use, together with a means of identification (license plate or equipment number), and indication of approval or non-approval.

After the initial inspection, continued approved status of a given distributor depends on continued satisfactory results determined visually or by additional checks when deemed advisable.

Rollers

Only Type II pneumatic rollers conforming to 401.13 are permitted for embedding the cover aggregate; however, the maximum capacity shall not apply.

Figure 422.E – Type II pneumatic tire rollers

Aggregate Spreaders

The aggregate spreader must be self-propelled with a variable width aggregate hopper (8 to 16 feet) and shall conform to specification 422.03. The spreader must produce a uniform application of aggregate without gaps or ridges at the rate specified. Spreaders must have pneumatic tires, a screen to prevent oversized material from passing through to the roadway, revolving cylinders, and adjustments.

Figure 422.F – Aggregate spreader

Brooms

Rotary brooms are used for the initial surface preparation to sweep the roadway prior to the application of the polymer binder. After the cover aggregate application, a rotary broom or sweeper is required to sweep excess aggregate from the completed surface without dislodging the embedded aggregate. Be sure that aggregate is not being swept onto adjacent lawns. Pickup sweepers or other measures will be needed in these areas.

Figure 422.G – Rotary brooms

Weather Limitations (422.04)

For chip seals, the weather limitations are specified in 422.04. This section requires a minimum pavement and air temperature of 60 °F (16 ºC). Work should not begin if temperatures are forecasted to be below 50 °F (10 ºC) within 24 hours from the start of work. Do not place the chip seal if the existing pavement temperature is 140 °F (60 °C) or above. This work is not to be performed before May 1 or after September 1. These requirements are meant to produce quality chip seals; cool temperatures and cloudy days make application of chip seal more difficult, as is takes longer for the binder to cure out than in the heat of summer. Ideally chip seal work should be performed as early as possible in the construction season to allow traffic to work the aggregate into the surface throughout the summer.

Test Strip (422.05)

The Contractor is required to provide a test strip to demonstrate that the equipment and operations can meet the requirements of the specifications. Traffic control must be provided per the specification for the test section. Do not allow traffic to exceed 25 mph on the un-swept chip seal surface.

The test strip must be 1000 feet long by 1 lane width wide. The test strip must be continuous. The test strip is used to determine the binder application rate, the aggregate application rate, and the aggregate gradation.

During the test strip, the aggregate spreader will be calibrated by applying aggregate to a piece of cardboard of a known size (generally 1 square yard). The material is collected from the cardboard and weighed to determine the application rate (pounds/square yard). Based on acceptance of the test strip, this will be the rate of cover aggregate application.

The proper binder application rate will be determined. Initially the binder should be applied at the target rate specified for the first 200-300ft of the test section. The depth of embedment of the aggregate will be checked visually. A good rate of application will provide an average of 2/3 embedment of the chip in the binder after rolling. Several chips will need to be pulled to evaluate embedment and care needs to be taken to select stones that are representative of what will remain after sweeping. The Engineer will require adjustments to the rate as needed to obtain the proper embedment and apply binder to another 200-300ft of the test section. The embedment check and binder rate

adjustment process should be repeated until satisfactory results are achieved. (A good rule of thumb would be that the binder rate can be increased until pickup is observed by the truck tires and then decreased by ~ 0.02 Gal/SY.) The rate will be calculated using the test strip dimensions and the number of gallons used as measured by the distributor gauge or meter (gallons/square yard).

The Engineer will review the test strip the following day. The acceptance criteria of 422.11 will be used to determine acceptance of the test strip. These criteria include proper chip embedment, binder streaking, ridging, flushing, loss of cover aggregate, and joint construction. The Engineer may require another test strip if there are problems with the application.

The test strip cannot be waived and is required on every project. If the roadway condition or route changes within a project, an additional test strip should be performed to ensure the proper rate of application.

Surface Preparation (422.06)

Before a chip seal is applied to an existing surface, all material accumulations, debris, foreign objects, dust, leaves, soil, etc. that would interfere with the adhesion of the asphalt material must be removed. Proper cleaning of the surface requires power brooming and may necessitate hand scraping and power blading of heavy accumulations, such as mud. Hand brooming may be necessary. Special attention should be given to the edges of the roadway to ensure proper coverage of the width intended.

All existing polyester, thermoplastic, and epoxy pavement markings must be removed using an abrasion method prior to placement of the chip seal. Acceptable removal methods include sand, shot, or water blast. Grinding is not allowed.

For single chip seals, raised pavement markers (RPMs) must be removed or covered/protected during the chip seal operation. Any removed RPMs must be replaced unless otherwise shown on the plans.

For double chip seals RPMs must be removed. Removed RPMs must be replaced unless otherwise shown on the plans.

Binder Application (422.07)

A uniform application in the transverse and in the longitudinal direction is important. Continued application should not be permitted when visible defects occur. Where distributor results are erratic, discontinue use of the equipment until the problem is corrected.

The binder must be maintained at 150 °F to 185 °F (65 °C to 85 °C) during application and at the beginning of the day. Binder is not to be reheated at a rate faster than 25 °F (14 °C) per hour when it has been allowed to cool to below 150 °F (65 °C).

With all other conditions being equal, the application rate of asphalt material depends on the average size of the cover aggregate particles. In a good chip seal, the average size aggregate will be embedded for approximately 2/3 of its height after thorough seating by rolling. This can be checked by pulling out chips by hand and visually inspecting how much of the chip is coated. When the binder application rate is too heavy, the particles may become totally embedded, resulting in a flushed or bleeding surface. When the

application rate is too light, the particles may not be held with sufficient firmness to resist dislodging by traffic, and a loss of cover aggregate will result.

Figure 422.H – Aggregate embedment after rolling

The binder application rate required to produce proper embedment for a given particle size may depend upon the porosity, absorption, and firmness of the surface to be sealed. The target rate determined by the test strip may need field adjustment depending upon the actual nature of the surface. Considerable judgment is required to determine the proper application rate and to avoid undesirable effects of bleeding or raveling. If proper stone embedment is not obtained, the Engineer must be notified, and the application rate adjusted and documented.

The binder application must be started and stopped on a removable protective cover of paper, cardboard, metal or other material that protects the adjacent pavement or previous chip seal from being coated. The use of the protective cover allows the binder to be applied at the full rate at each ending and beginning point, but does not allow the binder to be applied to existing pavement, or over applied on a previously constructed chip seal. The binder application must not be lapped, such as where one day's production meets the next. The protective cover must be removed immediately after use.

Cover Aggregate Application (422.08)

Only aggregate that has been approved is permitted for use. Collect the weight tickets when the material is received at the paving site.

The previously established spreading rate of aggregate must be verified using a 1 square yard of cardboard, weighing and determining pounds per square yard. The Contractor must make adjustments to the spreader to meet the test section calibrated rate.

The aggregate must be sufficiently free from dust and moisture to permit immediate adhesion of the asphalt material. Material delivered to the site with water running from the bed of the truck must be rejected.

Excessive application of cover aggregate and amounts of aggregates considered to be a nuisance to the public will require the work to be stopped. It is unacceptable to rely on brooming or vacuuming to remove excess aggregate. The spreading operation requires recalibration in these cases.

Construction Operation (422.09)

General Considerations

The Contractor must establish stations for the project at 1,000 foot intervals before placing any material. The stationing must be clearly marked and be maintained throughout the project. Stationing is typically provided using wooden lath along the roadway and the markings should be easy to read.

The binder distributor, aggregate spreader, and rollers must be as close to each other as possible. The binder distributor cannot be more than 150 feet ahead of the aggregate spreader.

Figure 422.I – Keep the distributor, spreader, and rollers close together

The longitudinal joint must be placed on a lane line or as the Engineer directs. For double chip seals, the longitudinal joint for the first course is to be placed 6 inches off the centerline, and the second course is to be placed on the centerline.

Where a double chip seal is required by the plans, the first course must be cured, swept, and capable of withstanding construction traffic. Any deficiencies or damage must be corrected before placing the second course of chip seal.

Rolling

Rolling of the chip seal cover aggregate is required to begin immediately behind the aggregate spreader. Three rollers minimum are required. Do not allow the aggregate to go unrolled for more than 5 minutes. This is to ensure that the aggregate particles will be embedded in the asphalt binder before the binder sets up. If the binder sets before the

aggregate is rolled, the result will be loose stone that must be removed. That section of roadway would be unacceptable and would require rework.

The specifications require a minimum of two complete roller passes of the cover aggregate. A single complete pass is forward and back over the same area. Each new pass must be overlapped by one-half of the roller width. While making these passes, the speed of the roller must be slow enough, not greater than 5 miles per hour (8 km/h), to avoid displacing or dislodging the aggregate particles from the asphalt. If stone is being picked up by the rollers, have the Contractor adjust the speed.

Sweeping and Opening to Traffic

Sweep the chip seal within 4 hours of placement of the cover aggregate using a power broom to remove loose aggregate. The Contractor cannot reuse this aggregate in the double chip seal course. There may be issues that do not allow the Contractor to sweep within the 4 hour timeframe, such as stone moisture, high humidity, slow binder cure rate, rain, etc. In this case, the Engineer may suspend the operation until the problem is resolved or more favorable conditions prevail which allow for sweeping within 4 hours.

Make sure sweeping extends 1 foot beyond the edge of the roadway to remove any loose aggregate that could migrate back to the roadway.

Before opening the road to traffic, the contractor must place "Loose Stone" and "35 MPH" signs on the same post spaced at 0.5 mile intervals. Signs must conform to Item 614.

Figure 422.J – "Loose Stone" sign and pilot vehicle

On two-lane roads where traffic is being maintained on a chip seal, the Contractor must provide a pilot vehicle at 25 mph to guide traffic through the work zone.

The Contractor is responsible for all damage claims that result from his operations, and the chip seal surface, until the application of the final pavement markings or the application of a fog seal if required.

Quality Control (422.10)

The Contractor is required to provide quality control of the chip seal process and must stop placement and notify the Engineer and DET if any of the parameter tolerances are exceeded. The Contractor must identify and correct problems and receive permission

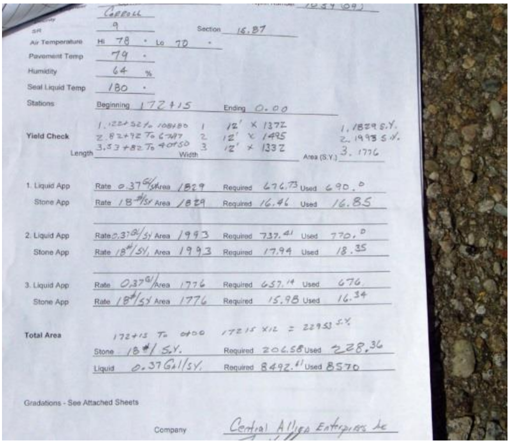
from the Engineer to restart the chip seal operation. Additionally, the Department can obtain samples at any time. Aggregate samples can be taken from the stockpile or from the spreader to test for conformance. If Department testing shows out of compliance material, work can be stopped.

The Contractor is to provide an asphalt binder sample on a daily basis for the Department. The sample is to be collected within 1 hour of the start of production from the distributor truck. The sample must be collected in a plastic container with a plastic screw lid. After sample collection, the Contractor must give the sample to the Engineer the same day it is collected. Additional samples may be requested by the Engineer at any time.

The binder application rate cannot exceed ±0.02 gallons per square yard from the established application rate.

The Contractor is to provide an aggregate split sample from the spreader box on a daily basis for the Department. Aggregate must meet a specific moisture content and gradation as provided in 422.10. The Contractor is required to reject material that does not meet these requirements. If water is seen running from the truck bed when aggregate is brought to the job, it must be rejected.

The Contractor must provide a daily quality control report to the Engineer that includes the specific information as listed in 422.10.



Carroll
SR 9 Section 16.87
Air Temperature Hi 78 ° Lo 70 °
Pavement Temp 79 °
Humidity 64 %
Seal Liquid Temp 180 °
Stations Beginning 172+15 Ending 0.00
Yield Check
1. 122+52 To 108+80 1 12' × 1372 1. 1829 S.Y.
2. 82+92 To 67+97 2 12' × 1495 2. 1993 S.Y.
3. 53+82 To 40+50 3 12' × 1332 3. 1776
Length Width Area (S.Y.)

1. Liquid App Rate 0.37 Gl/SY Area 1829 Required 676.73 Used 690.0
Stone App Rate 18#/SY Area 1829 Required 16.46 Used 16.85

2. Liquid App Rate 0.37 Gl/SY Area 1993 Required 737.41 Used 770.0
Stone App Rate 18#/SY Area 1993 Required 17.94 Used 18.35

3. Liquid App Rate 0.37 Gl/ Area 1776 Required 657.14 Used 676
Stone App Rate 18#/SY Area 1776 Required 15.98 Used 16.34

Total Area 172+15 To 0+00 17215 × 12 = 22953 S.Y.
Stone 18#/S.Y. Required 206.58 Used 228.36
Liquid 0.37 Gal/SY Required 8492.41 Used 8570

Gradations - See Attached Sheets

Company Central Allied Enterprises Inc

Figure 422.K – Example of daily quality control (page 1) report by the Contractor

These items should be on the Contractor's daily quality control report.

- Control section, project number, county, route, and Engineer.
- Date, air and pavement temperature, and humidity.
- Binder temperature.
- Beginning and ending stations.
- Yield check on binder and aggregate (3 times per day).
- Gradation, moisture content, and identifying station of aggregate samples.
- Length, width, and total area chip sealed.
- Condition of signs.
- Contractor's signature.

Acceptance (422.11)

Acceptance of the final product depends on daily inspection of the six items listed in 422.11 and final inspection after 25 to 35 days for the defects listed in 422.11.

Daily Inspection and Acceptance

1. The finished surface shall have no more than four tears or untreated areas greater than 1 inch wide and 4 inches long in any 120 square yard area.
2. Joints are neat and uniform; there is no buildup, uncovered areas, or other unsightly appearance.
3. Longitudinal joints have less than a 2-inch overlap.
4. Transverse joints have no more than 1/4 inch difference in elevation as measured across the joint using a 6-foot straightedge.
5. The edge of the chip seal does not vary more than 2 inches in any 100 feet along a shoulder or edge.
6. Typical stone embedment is two-thirds of a typical chip.

Final Project Acceptance

Deficiencies in chip seal construction often do not show up until the surface has been under traffic for a period of time. The Engineer and Contractor will review the completed chip seal in 25 to 35 days after placement. Surface patterns that show streaking or ridging; bleeding/flushing; and loss of cover aggregate are to be specifically evaluated. The Contractor is required to perform corrective work when any one defect exceeds 20 percent of any 120 square yard area. The following are descriptions of these defects and likely causes.

Surface Patterns (Ridges and Streaking)

Streaking is caused by faulty distributor adjustment or operation, which result in the asphalt being placed in ridges. Contrary to popular belief, these ridges will not "flow" together, particularly when the cover aggregate is applied immediately after the application of asphalt material as required by the specifications. Streaking results in insufficient asphalt material between the ridges to hold the aggregate in place. This aggregate is loose and will be “kicked up” by traffic. This leaves only the aggregate that was embedded in the ridged asphalt, thus producing a streaked appearance.

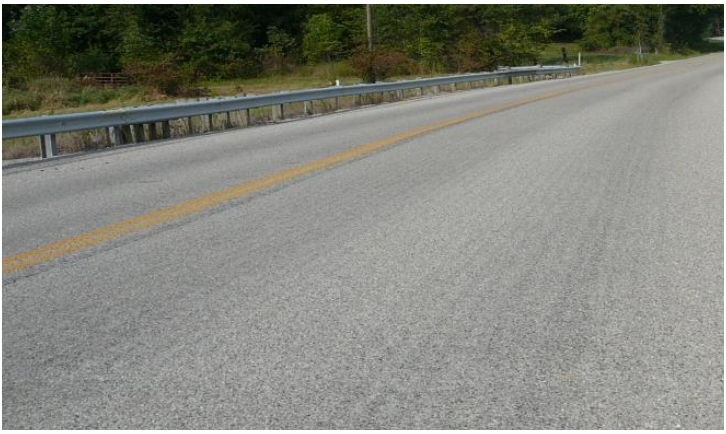


Figure 422.L – Streaking and ridging in completed chip seal

Bleeding/Flushing

Bleeding and flushing is defined as a migration of asphalt material to the surface, completely or almost completely submerging the cover aggregate. Continuous bleeding is likely the result of too high a rate of application. Spotty bleeding usually is the result of variations in the surface of the existing pavement. Bleeding at tie-ins between distributor loads is the result of an overlap of the previous run.

Figure 422.M – "Bleeding" or "Flushing" of a chip seal

Loss of Cover Aggregate

Loss of cover aggregate is the detachment, loosening, or stripping away of the aggregate material from the asphalt binder leaving behind a black shiny surface. This is a serious form of chip seal failure because of the traffic hazard created by the exposure to the

slippery film of uncoated asphalt binder material and loose aggregate particles. It may be caused by one or more of the following:

1. Too light an application of the asphalt material.
2. Penetration of the asphalt material into the underlying surface.
3. Use of an improper grade of asphalt material for existing conditions.
4. Delay in spreading the aggregate on the asphalt emulsion (binder has set-up).
5. Excess aggregate application.
6. Lack of adequate rolling.
7. Use of wet or dirty aggregate.
8. Opening the roadway to traffic before adequate curing has taken place.

Figure 422.N – Loss of cover aggregate

Performance Review (422.12)

The contractor is required to warrant the work performed on the chip seal contract per 433.12 for a period of two years. Any defect exceeding the threshold levels in Table 422.12-1 is required to be remedied by the contractor during the warranty period. The warranty defect thresholds are set based on expected performance of the chip seal at the end of the two year warranty period. The warranty provisions should not be used to prior to acceptance or as reason to accept work that does not meet the specification during construction.

Method of Measurement (422.13) and Basis of Payment (422.14)

Single or double chip seals are measured by the number of square yards in place and accepted. The actual width and length along the centerline of chip is measured for pay.

The cost of the removal of all pavement markings will be paid according to the Item 643, 644, 645, 646, 647, or 648 as specified.

Payment includes any costs to make repairs to deficient chip seals.

Where RPMs are removed for a double chip seal, the department will pay for the removal under Item 621 Raised Pavement Markers Removed. However, the removal of RPMs for a single chip seal is included for pay with the chip seal item.

For single chip seals, the cost of replacing of RPMs that are removed by the Contractor is included in the Chip Seal item unless the plans specifically state that they are not to be replaced.

For double chip seals, the cost of replacing RPMs should be set-up as a separate item unless the plans specifically state that they are not to be replaced.

423 Crack Sealing, Hot Applied

Description (423.01)

This work consists of cleaning and preparing pavement cracks and placing a hot crack joint sealant.

Materials (423.02)

The hot applied crack sealer must be the type specified on the plans and meet the requirements of 423.02. Crack sealants are known as Type I, Type II, Type III, or Type IV.

Type I crack sealant must be approved by the Laboratory before shipping to the project. Type II and III joint sealants are mixed on the project and require the use of PG 62-22 binder and fibers. Binder is accepted based on a certification program while the fiber manufacturer must be on the Qualified Product List. Type II can be a premixed and prepackaged sealant. This type of sealant requires certified test data.

Type IV sealant is a prepackaged and preapproved mixture that requires the fiber manufacturer's representative be present during the application to ensure proper application. The Contractor must submit a 10 pound sample of the base binder and 10 pounds of fiber to the Laboratory for approval.

Equipment (423.03)

All equipment used for crack sealing must meet the Engineer's approval and the requirements of 108.05.

Type I sealant must be heated in a kettle or melter constructed as a double boiler. The space between the kettle and outer shell must be filled with oil or other heat-transfer fluid. The melter must have temperature control of the oil and have a mixing vat,

mechanical agitation, and recirculation pump. Heat cannot be applied directly to the sealant.

Type II, III, and IV sealants must be heated in a double boiler as described above for Type I sealant; there must be separate thermometers for the oil and the mix vat. A full sweep agitator and a minimum 2-inch recirculation pump must be used in the kettle. Heat cannot be applied directly to the sealant.

For all sealant types, a mechanical applicator wand with a flow shutoff valve is required. Nozzles on the wand must be shaped to penetrate the crack.

Air compressors are used to clean out the cracks prior to placing the sealant. Air compressors must be a minimum of 100 psi and have water and oil traps.

Water cleaning equipment must deliver water at 2,000 psi to the crack being cleaned.

A propane lance that produces hot air and operates at 1,000 °F, with a gas velocity of 2,000 feet per second, must be used to dry the crack.

Routing and sawing equipment must be mechanical and power driven and capable of following the path of the crack and widening the crack to a desired dimension without causing spalling or damage to the adjacent pavement. Saw blades must be diamond and 8 inches or less in diameter.

Weather Limitations (423.04)

The pavement surface must be dry (no visible moisture of any kind) and at least 45 °F (7 °C).

Preparation (423.05)

The Engineer determines the cracks to be sealed.

If routing is required for cracks of less than 3/4 inch wide, rout cracks to an opening 3/4 inch wide by 1 inch deep. This is the reservoir for the joint sealant

If sawing is required, saw cracks to 3/4 to 7/8 inch wide by 7/8 to 1 inch deep. The slivers of asphalt concrete left behind that are less than 1 inch wide along the sides of the crack must be removed. The Contractor can use hand tools or a light weight chipping hammer. Before sealing the crack, it must be sandblasted to remove contaminants and to provide a rough face so the sealant adheres to the walls of the crack. If the crack below the saw cut is greater than 3/8 inches, a backer rod has to be pushed into the crack to form a bottom.

All cracks must be cleaned using an approved method, including water blasting and air blasting. All dust, dirt, debris, moisture, and vegetation must be removed from the crack. The prepared crack must be kept clean and dry prior to sealing.

Mixing Type II and Type III (423.06)

Determine the proper proportion of fiber and binder to blend by using weigh tickets. Check for thorough mixing. Check the sealant temperature against the manufacturer's

recommendation and do not let it exceed this temperature. Be sure the temperature of Type III sealant does not exceed 295 °F (146 °C) at any time.

Application of Sealant (423.07)

Fill cracks within 250 feet (76 m) of the cleaning operation.

Seal cracks that are wide enough to allow injection of the sealant. Tight cracks less than 1/4 inch wide are to be sealed only if they are raveling or spalling. Do not seal cracks greater than 1 inch wide. Do not seal spalls and cavities greater than 4 inches wide.

For Type I and IV sealants, fill the entire crack reservoir from the bottom to about 1/16 inch above the pavement surface. The surface must be scraped immediately with a V-shaped or U-shaped squeegee to smooth the sealant at the surface. The band that remains on the surface after smoothing must be less than 2 inches wide. Wider bands must be rejected.

For Type II and Type III sealant, the width of the band should be 2 to 4 inches, but never over 4 inches. Do not accept the work if the band is too wide and/or the thickness of the sealant on the pavement surface is more than 3/16 inches (5mm).

Opening to Traffic (423.08)

Do not allow traffic on fresh sealant until it has cured and will no long pick up and track under traffic. The Engineer may allow the use of an anti-tracking material if traffic must use the roadway.

Method of Measurement (423.09) and Basis of Payment (423.10)

Crack sealing is measured by the number of pounds or square yards of hot applied crack sealant in place and accepted as shown in the plans.

424 Fine Graded Polymer Asphalt Concrete

General

This specification is intended to be used for pavement preventive maintenance, but may have other applications as well. The specification includes two mixture compositions: Type A and Type B. Both mixtures are required to use a polymer binder.

Composition (424.02)

Type A material is a very fine graded mix composed primarily of natural sand and contains a very high polymer binder content (8.5 percent). This is a recipe mix. It is

designed to give a long life, but generally is not for high truck traffic situations. A Type A mix is normally specified as a 5/8-inch (16 mm) mat thickness.

Type B material is a fine graded mix composed of more angular materials and contains less binder content than the Type A mix (minimum of 6.4 percent). This mix is designed by the Marshall Mix Design Method for light, medium, or heavy traffic. The Type B mix is designed to be more rut resistant than Type A. The Type B mix can be placed on medium and high volume roads, including most interstate applications. A Type B mix is normally specified as a 3/4-inch to 1-inch (19 to 25 mm) mat thickness.

Figure 424.A – Item 424 (Type A and Type B) mix compositions

Equipment

The equipment requirements of 401 apply to this work.

Materials (424.03)

Both types of mixtures under this specification use a polymer binder. Either a PG 76-22M asphalt binder or a PG 64-22 asphalt binder modified by the addition of 5.0 ± 0.3 percent Styrene Butadiene Rubber (SBR) can be used.

The use of reclaimed asphalt pavement is not permitted in a Type A mix.

Fine aggregate for use in this specification is required to have at least 50 percent silicon dioxide by weight. This special requirement ensures proper skid resistance for both mix types.

Coarse aggregate used in the Type B mix is required to have 10 percent two-faced crushed aggregate by weight for medium traffic applications and 100 percent two-faced crushed aggregate for heavy traffic applications.

Mixing (424.04)

When these mixtures are discharged from the plant, the mix temperature must be between 335 ºF and 370 ºF (168 ºC to 188 ºC).

Figure 424.B – Mix texture for Type A, Item 424

Figure 424.C – Mix texture for Type B, Item 424

Weather Limitations (424.05)

The placement of either Type A or B material cannot be placed if the exiting pavement temperature is less than 60 °F or the ambient air temperature is less than 60 ºF (16 ºC).

Spreading Compacting and Finishing (424.06)

Either mixture is to be placed and compacted per the requirements of 401; a three-wheel roller is required in the breakdown position behind the paver. Do not use vibratory rollers when the mat thickness is less than 1-1/2 inches. Vibratory rollers are not necessary and many times can hinder densification of these mixtures. Proper mix design, temperature and placement methods will generally have more effect on densification than the vibratory roller. Laydown temperatures may need to be higher than typically seen with other mixtures to obtain good compaction numbers.

Traffic is not allowed on the compacted surface until it has cooled enough to prevent damage.

Surface tolerances are to be checked and must be in conformance with 401.19 for transverse slope and surface smoothness. The transverse slope cannot vary more than 3/8 inch in 10 feet. The surface smoothness cannot vary more than 1/4 inch in 10 feet. Ensure that the finished surface is within these tolerances as the paving progresses.

Acceptance (424.08)

Type A mixtures are to be accepted using Item 301 procedures (see Item 403) and Type II materials are to be accepted according to Item 448 procedures.

441 Asphalt Concrete

Description (441.01)

This item is a mix design specification utilizing a marshall method to produce an asphalt concrete that is used for an intermediate or surface course. This asphalt concrete is used for medium to low traffic routes and can be either a 446 or 448 acceptance method. 441 asphalt concrete requires inspection and documentation as per the requirements of 401 and 446 or 448.

Acceptance (441.13)

These items are accepted per 448 or 446 requirements. See those items for details.

442 Superpave Asphalt Concrete

Description (442.01)

This item is a mix design specification utilizing a gyratory compactor to produce an asphalt concrete that is used for an intermediate or surface course. Known as Superpave, this asphalt concrete is used for higher traffic routes and can be either a 446 or 448 acceptance method. Superpave mix design requires the use of special equipment, material properties, and design procedures. Superpave asphalt concrete requires inspection and documentation as per the requirements of 401 and 446 or 448.

Acceptance (442.07)

Superpave items are accepted per 448 or 446 requirements. See those items for details.

443 Stone Matrix Asphalt Concrete

Description (443.01)

This work consists of constructing a stone matrix asphalt concrete (SMA) course consisting of aggregate, asphalt binder, and additives. Stone matrix asphalt (SMA) is a gap-graded HMA that is designed to maximize deformation (rutting) resistance and durability by using a structural basis of stone-on-stone contact. SMA is generally more expensive than a typical dense-graded HMA because it requires more durable aggregates, higher asphalt content, a modified asphalt binder and fibers.

Construction (443.07)

443 SMA is accepted 446 requirements. The requirements of 401 will apply to this item. See those items for details.

Approved test strips and JMF evaluation are required before the contractor can move to full production. Do not begin full production of the SMA until receiving authorization from District Testing. This authorization will be based on the successful construction of one or more test strips. The test strip will be included in the first lot for determining density for payment.

SMA relies on stone to stone contact and aggregate breakage can occur with over vibration. Vibratory rollers in vibratory mode, set at a high frequency and low amplitude, can be used as the breakdown roller only. Always operate the breakdown roller immediately behind the paver. Do not compact SMA that is below 230 °F (110 °C).

Because SMA mixes have a high asphalt binder content as the mix sits in the HMA storage silos, transport trucks, and after it is placed, the asphalt binder has a tendency to drain off the aggregate and down to the bottom – a phenomenon known as “mix draindown”. If draindown is observed in the truck beds prior to placement, those loads must be rejected and changes made to resolve the issue. If isolated, small fat spots

develop, apply sand immediately during compaction. If continuous and/or large fat spots develop, cease production until resolved.

Acceptance (442.07)

After accepting the test strips, the Department will accept SMA according to 446.04.

446 Asphalt Concrete

Description (446.01)

This item includes placing a surface or intermediate course asphalt concrete that is accepted based on the level of density obtained. The specification requires the Contractor to obtain a minimum level of density that is measured based on cores taken from the completed pavement course. In the event the minimum required density is not obtained, there is a deduction to the Contractor's pay for the item. This type of specification is known as a performance specification. Performance specifications tell the Contractor what is to be achieved, but not necessarily how to perform the work. This differs from standard method specifications that detail exactly how the work shall be performed. For this item, while material and equipment requirements are standard, the method of compaction is not defined; therefore, the Contractor selects the rollers for the course being placed, not ODOT. Under this specification, a Contractor can be rewarded for providing a better product than required by the minimum specification, but as noted above, can be penalized for not meeting the minimum requirements. The requirements of 401 apply unless noted.

Density Acceptance (446.04)

Item 446 is accepted by density testing and the roller selection is at the discretion of the Contractor and not governed by 401.13. The requirements of 401.16 that detail compaction operations are waived except the last four paragraphs. These last four paragraphs describe general rolling pattern requirements such as compacting the longitudinal joint first, removal of roller marks, and complete coverage. The Inspector should observe the rolling pattern for conformance.

Density of the asphalt concrete is based on cores that are cut from the completed pavement course. ODOT does the density testing of these cores at the District Test Lab. Random core locations are determined by the Engineer as detailed in 446.05. Ten, 4 inch cores are required to be cut per lot. A lot is one day (or night) of production with provisions for combining a small production day (<400 tons) with the next day's lot. Each lot is divided into five equal sublots and two cores are cut from each sublot. Core locations are determined at random by using a random number selection process. That process will be used for all lots and is detailed below.

Core Procedure

Cores are required to be cut within 48 hours of placement. To allow the Contractor to core the same day, determine core locations prior to the end of work by estimating

production based on production rate and Contractor expectations. The Engineer should only mark the core locations for each sublot after the paving operation (including the finish roller) has completely finished rolling the sublot. The core drill operation can begin cutting cores when the newly placed pavement surface temperature is less than 140 °F. The Department does not intend to bias the Contractor's operations by specifying where the cores will be taken. In cases where paving is being done under a flagger closure of one lane of a two-lane highway using Standard Construction Drawing MT-97.11 or MT-97.12, some allowance can be made for allowing the paving operation to proceed concurrently with the marking and cutting of cores required for 446 density acceptance. See, Two-Lane Flagger Closure, below for this exception.

If a cold longitudinal joint is made between the mainline and shoulder, include the shoulder area in the lot for coring. If a hot joint is made between the mainline and shoulder, the shoulder is not included in the area to be cored, but the Contractor must use the same equipment and rolling pattern on the shoulder as on the mainline. In this case, it is very important to monitor the rolling pattern on the shoulder. If the Contractor does not adhere to this requirement, include the shoulder in the lot for coring. A hot joint means the Contractor is using two pavers concurrently: one paving the mainline and one paving the adjacent shoulder. Asphalt delivery trucks are alternated between the pavers to maintain a close distance of about one truck load of material.

There are additional, specific requirements for cold longitudinal joint cores. In each lot, three cores are taken from the cold longitudinal joint. One core should be taken in the first and last sublots and randomly one core from one of the middle three sublots. Joint cores are to be 3, 4, or 6 inches from the cold joint depending on its construction type. All other cores are to be located at least 12 inches from the edge of pavement.

Form TE-217 provides a standardized method for sublot layout and random selection of core locations (transversely and longitudinally). The form is located on ODOT's Construction website and is available as either an Excel spreadsheet that automatically calculates core sample locations or as a manual-use (non-electronic) form.

If using the Electronic TE-217 form, enter all required information as indicated by the yellow highlighting. After entering the beginning and ending stations for the lot, press key F9 and the computer automatically generates the random numbers. The form automatically calculates the core sample locations as shown in the orange highlighted boxes. Use these locations to lay out the cores on the completed asphalt mat. Note that both forms are set-up for continuous mainline paving and may have to be modified when the paving operation does not continue in a straight line.

TE-217 Electronic Version — **Bituminous Concrete Density Determination - 446 Cores**

Sample ID:		Personnel ID:		Type of Inspection:	
Producer Code:		Material Code:		Date Sampled:	
Quantity:	1000				
Project:		Item:	Reference	JMF:	
Lane Paved:				Lot:	
Beginning Station*:	1+50	*Press F9 after entering beginning and ending stations to generate random numbers in the spreadsheet below		Day:	
Ending Station*:	20+55			Date Placed:	
Does sublot include shoulder? Y or N	N				
Width of Sublot (feet):	12.0				

* Enter station without "+" sign (Ex., 1+00 = 100)

Sublot Number	Core Number	Beginning Station	Length of Sublot (feet)	Ending Station	Longitudinal Random Number* - 2 per sublot	Station - Location of Core	Width of Sublot Lane (feet)	Transverse Random Number* - 2 per sublot	Distance in feet Left or Right of Centerline (for joint cores see joint core instructions)	Joint Core? Y or N	Confined or Unconfined Joint? Y or N	Remarks/Notes
1	1	1+50	381.00	5+31	0.40	3+04	12.0	0.37	4.4			
	2				0.79	4+50	12.0	0.76	9.1			
2	3	5+31	381.00	9+12	0.44	6+99	12.0	0.21	2.6			
	4				0.35	6+65	12.0	0.89	10.6			
3	5	9+12	381.00	12+93	0.53	11+15	12.0	0.26	3.1			
	6				0.28	10+18	12.0	0.16	1.9			
4	7	12+93	381.00	16+74	0.87	16+26	12.0	0.52	6.2			
	8				0.29	14+02	12.0	0.60	7.2			
5	9	16+74	381.00	20+55	0.51	18+67	12.0	0.41	4.9			
	10				0.85	20+00	12.0	0.08	1.0			

Information to be entered by project
Calculation by spreadsheet

Figure 446.A – Electronic TE-217 form

For the Non-electronic TE-217 form, all calculations are done manually. The selection of random numbers must come from a table. This table is included with the non-electronic TE-217 on the ODOT website as well as instructions for selecting random numbers. The same random number selection method should be used consistently on the project. When this form is completed, use the calculated locations to lay out the cores on the completed asphalt mat.

The Engineer will physically mark the core locations on the mat using aerosol paint. Be sure coring takes place where marked. This can be ensured by observing each coring operation and by painting the core location with a small diameter circle with an "X" or other marking. The Contractor must be instructed to cut the core within this circle. The cut core should be examined to verify there is paint on the surface which indicates the core was cut at the selected location. If the Contractor takes "sister" cores, make sure they are cut within 4 inches longitudinally of the Department's cores. Sister cores are tested by the Contractor for comparison to ODOT test results. For joint cores, use a different paint color than for the mainline cores. This provides assurance that joint cores are cut from the locations selected by the project.

There have been incidents where cut cores have been switched out with other cores that presumably would provide better density test values. Project personnel must witness the coring operation and take immediate possession of the core from the contractor upon removal, to ensure the cores being tested for payment are from the locations selected by the project through the random selection process. Substitution of cores by cutting in other locations or by replacing cut cores with others is absolutely prohibited and will not be tolerated. No cores for acceptance testing can be taken by the contractor without project personnel present. Project personnel should immediately take possession and maintain custody of all lot samples until shipped to the District lab for testing.

Core holes are required to be filled by the next work day using the same asphalt mixture used to place the mat. The holes must be dry and coated with tack meeting the requirements of 707.02. The asphalt must be compacted adequately and finished flush

with the completed asphalt mat. It is important that the core holes are dry and clean prior to tacking and filling. Compaction must be done with a suitable tamper. The sole of a worker's boot is not a suitable tamper.

After core samples are obtained, package and identify in accordance with current District or Laboratory policy. The District test lab may have specific requirements for labeling the core samples. The samples should be shipped to the District lab as soon as possible. Care should be taken not to damage the core by dropping, throwing, or exposing it to excessive heat. Cores should not be stacked in any way.

Two-Lane Flagger Closure

In cases where paving is being done under a flagger, closure of one lane of a two-lane highway using Standard Construction Drawing MT-97.11 or MT-97.12, some allowance can be made for allowing the paving operation to proceed concurrently with the marking and cutting of cores required for 446 density acceptance.

In all cases, the Contractor should lengthen their lane closures to the maximum permissible length detailed in the above referenced Standard Construction Drawings to allow the Engineer adequate time to mark the required core locations and for core cutting operations. The Contractor will provide to the Engineer the planned quantity that will be placed for the day's production.

Follow the requirements above for, "Core Procedures," with the following changes.

Determine the planned quantity of asphalt that will be placed for that day and determine the core random locations. The Engineer will mark the core locations after the paving operation (including the finish roller) has completely passed the selected core location. The core drill operation can begin cutting cores when the newly placed pavement surface temperature is less than 140 °F. It is the Contractor's responsibility to maintain the lane closure during all paving, marking, and coring operations per the requirements of the Standard Construction Drawing used for the paving operation.

Joints (446.05)

The contractor is instructed to place a hot longitudinal joint between the mainline pavement and the adjoining shoulder, unless a hot joint is specified elsewhere between lanes. The contractor does not have the option to place cold longitudinal joints between the mainline and shoulder unless the hot joint is relocated by plan or agreement on the project. Properly constructed hot longitudinal joints will have the nearly the same density as the surrounding mat and perform better than cold longitudinal joints. When possible, it would be best practice to construct hot joints in as many locations as practical.

448 Asphalt Concrete

Description (448.01)

This item includes placing a surface or intermediate course asphalt concrete that is accepted based on plant testing and verification or plant testing and verification with field density testing. The requirements of 401 and 441 apply to this item except as noted.

Density (448.03)

Supplement 1055 details the requirements for performing density testing using either a nuclear gauge in the backscatter mode or an electronic density gauge, Pavement Quality Indicator (PQI) Model 300/301/380, manufactured by TransTech Systems. Each gauge requires a specific method of operation as detailed in Appendices A and B of S1055.

Figure 448.A – PQI electronic density gauge

Startup

The Contractor is required to establish a “minimum density target” during the first production day or when there are subsequent mix changes that require reestablishing the minimum density target. The minimum density target is determined by rolling the newly placed mat until there is no change in the unit weight (pounds per cubic foot = PCF) as recorded by the test gauge. At that time, a core is cut and tested to correlate the gauge unit weight to density. This is done in three separate locations when using a nuclear gauge and in five separate locations when using an electronic gauge. Readings and calculations are recorded on Form TE – Min Density Target, Nuclear, in S1055 Appendix C or Form TE – Min Density Target Elec Gauge, in S1055 Appendix D. The cores are sent to the District Lab and tested for density. Using the average of the gauge readings and the average of the laboratory density results, a minimum target density unit weight (PCF) is calculated that corresponds to 93 percent density. This means the gauge reading in the field has to be at least that minimum unit weight (PCF) in order to have 93percent density of the asphalt mat.

Example:

The following information was recorded on Form TE – Min Density Target, Nuclear.

Average of nuclear gauge readings = 142.0 PCF

Average of core density test results = 95.0%

Minimum density target for 93 percent field density = [93 x (142.0/95.0)] = 139.0 PCF (unit weight)

Therefore, in the field, the gauge has to read 139.0 PCF in order to have a minimum 93 percent mat density.

Nuclear and Electric density gauges are not capable of accurately measuring density values without correlation to cores. These gauges are made to offset the reading to the actual core unit weights to obtain accurate results. While this feature is useful, it also allows the gauge operator to manipulate the output and provide false readings. S1055 procedures require the gauge offset to be zero during the core calibration and QC/QA readings to ensure the gauge baseline is left unaltered. The Form TE – Min Density Target mathematically calculates the offset value for the gauge to avoid manipulation. Thorough oversight of the startup operation is necessary to ensure accurate results. The gauge must be verified to ensure that a zero offset is entered. Gauge readings should be taken after each roller pass until the maximum unit weight is found and this number of passes is then recorded. Random locations should then be chosen for coring. Once core results are determined and the Minimum Density Target is established if the all of the results exceed the minimum 93.0% density. If core results do not exceed 93.0%, changes must be made to the mix to improve density. Generally this will involve mix changes at the plant or different roller types as the current roller train has already achieved its maximum density. QC/QA testing should begin using the initial core results as correlation to establish pay for the day's material.

Note: There is a time lag between when the cores are cut and tested, and the project will not know what unit weight (as recorded by the gauge) corresponds to 93% field density. During this period, the Contractor will calculate a required unit weight based on the JMF Maximum Theoretical Specific Gravity. The testing technician will use this unit weight in the gauge until the lab unit weight is determined from the actual cores.

Quality Control Testing

During paving, after startup, the Contractor uses the minimum target density unit weight to maintain mat density above 93.0% but less than 96.5%. Quality control (QC) tests are required to be taken at 1,000 feet intervals, but the Contractor is expected to perform more than the minimum required. Alternate the transverse location of each 1,000 foot test; start at the left side of the mat, move to the middle of the mat, then the right side of the mat, and repeat. Tests at the edge of the mat should be taken one foot from the edge. The Contractor will mark the test location on the pavement.

The minimum required QC tests must be recorded; interim tests do not have to be recorded. Use Form TE – Mat Density QCQA to record the required tests.

The Contractor is expected to make changes to the rolling pattern or mix as required to keep the density above 93.0 percent.

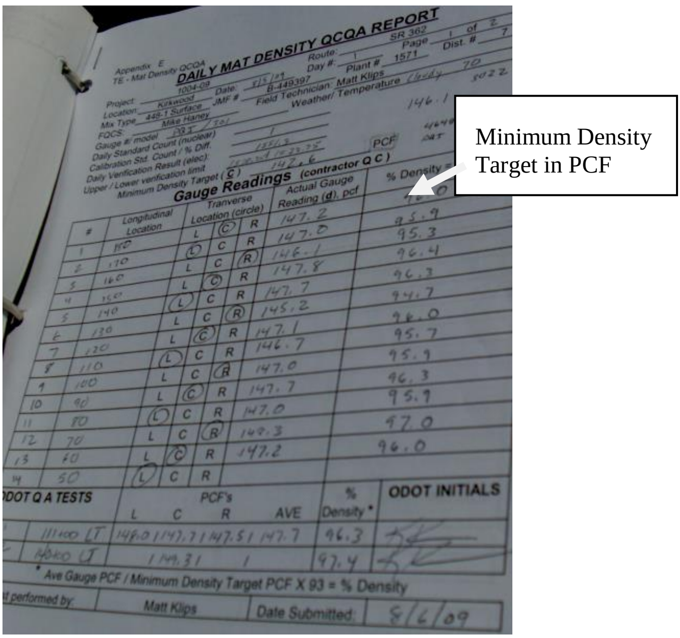
Quality Assurance Testing

The project Inspector will randomly select two locations during each production day for Quality Assurance Testing (QA). Each test should represent one-half of the day's

production. The first location will be at a Contractor QC test area where tests were performed that day. The second location will be anywhere on the mat, but at least 500 feet from the start of the day's paving. QA tests must be located inside the closed lane. The project Inspector must witness and initial the QA tests. Inspector's should closely monitor QC testing and ensure that the offset is set to zero in the gauge before each QA test is observed.

QA tests are completed using three gauge readings across the mat, left, center, and right, and averaging the density results. The results are recorded on Form TE – Mat Density QCQA.

When one of the daily QA test density results is less than 91.0 percent, a deduction is applied to the Contractor's payment for that half day's production as detailed in Table 1055.04-1 in S1055. If both daily QA test densities are below 92.0 percent, the payment deduction is based on Table 1055.04-2 in S1055 and is applied to each half day's production.



Appendix E
TE - Mat Density QCQA

DAILY MAT DENSITY QCQA REPORT

Project: 1004-09 Date: 8/5/09 Route: SR 362 Page 1 of 2
Location: Kirkwood JMF #: B-449397 Day #: 1 Plant #: 1571 Dist. #: 7
Mix Type: 448-1 Surface Field Technician: Matt Klips
FQCS: Mike Haney Weather/ Temperature: Cloudy 70
Gauge #/ model
Daily Standard Count (nuclear)
Calibration Std. Count / % Diff.
Daily Verification Result (elec):
Upper / Lower verification limit
Minimum Density Target (C) 146.1 PCF

Gauge Readings (contractor Q C)

#	Longitudinal Location	Tranverse Location (circle)	Actual Gauge Reading (d), pcf	% Density =
1	180	L C R	147.2	95.9
2	170	L C R	147.0	95.3
3	160	L C R	146.1	96.4
4	150	L C R	147.8	96.3
5	140	L C R	147.7	94.7
6	130	L C R	145.2	96.0
7	120	L C R	147.1	95.7
8	110	L C R	146.7	95.9
9	100	L C R	147.0	96.3
10	90	L C R	147.7	95.9
11	80	L C R	147.0	97.0
12	70	L C R	149.3	96.0
13	60	L C R	147.2	
14	50	L C R		

ODOT Q A TESTS		PCF's L	C	R	AVE	% Density *	ODOT INITIALS
1	111+00 LT	148.0	147.7	147.5	147.7	96.3	
2	140+00 LT		149.3			97.4	

* Ave Gauge PCF / Minimum Density Target PCF X 93 = % Density

Test performed by: Matt Klips Date Submitted: 8/6/09

Figure 448.B – Example of completed QC/QA report

Acceptance (448.05)

Acceptance of the asphalt mix is based the Contractor's quality control testing at the asphalt plant and the District Lab Monitoring Team's verification of the Contractor's testing. Sampling is typically not required at the project site, but in the event there are workmanship problems during placement, or quality control problems at the plant, the Monitoring Team may require a sample taken from the road in accordance with Supplement 1035. If the pavement mat is less than 1-1/4 inches, the sample would be taken from the paver hopper. After a plate or hopper sample is obtained, it should be packaged and identified in accordance with current District or Laboratory policy. The

sample must be shipped to the District Lab as soon as possible or as directed by the Engineer or DET. Samples obtained by plate sampling are tested to determine the gradation and binder content of the asphalt concrete mix.

In addition to plant sampling and verification for acceptance, the specifications require density gauge testing according to Supplement 1055 when placing a uniform course 1 inch or thicker. When field density testing is required, the roller selection is at the discretion of the Contractor and not governed by 401.13. The requirements of 401.16 are waived except the last four paragraphs. These applicable paragraphs detail the compaction operation and sequence.

Field density testing is used to determine compaction and whether a deduction to the Contractor's pay will be made for inadequate compaction.

Refer to Supplement 1055 for the details of density testing requirements. The Inspector should understand and monitor the testing for compliance.

450 Rigid Pavement

451 Reinforced Portland Cement Concrete Pavement

General

Portland cement concrete pavement must be constructed so that it provides a smooth-riding surface satisfactory to the traveling public. It must be durable when subjected to natural weathering, traffic abrasion, and chemicals used for snow and ice control. It must be capable of sustaining the traffic that it is intended to carry and be of sufficient skid resistance to eliminate slippery conditions when wet.

While the quality of the riding surface is the chief construction element by which the public either approves or condemns a pavement, this element is no more important than durability and structural strength. All desirable elements of a good pavement are a product of the Contractor's workmanship and the engineering and inspection personnel assigned to the work.

Every step of construction, from the preparation of the subgrade and base, through concrete curing and opening to traffic, has a definite effect on the rideability, durability, and structural integrity of the finished pavement.

Description (451.01)

This item includes the construction of a Portland cement concrete pavement that contains reinforcing steel.

Materials (451.02)

Concrete

The concrete specified for use in reinforced Portland cement concrete pavement is defined in Item 499.

The coarse and fine aggregates used in the Contractor's JMF to produce a well graded aggregate in the Class QC 1 concrete for exposed concrete pavements (Items 451 and 452) have additional requirements found in 703.02. The fine aggregate used in the concrete must be natural sand; manufactured sand is not permitted. Coarse aggregate must be provided in accordance with 703.13, in addition to the requirements of 703.02.

Coarse Aggregate

In addition to the requirements of 703.02, the following aggregate requirements apply per 703.13.

Where gravel, crushed ACBFS, or limestone is selected, and the total combined quantity of the plan items (451, 452 or 305) is greater than 10,000 square yards (8,000 m^2), the coarse aggregate must be No. 57 or 67 size.

If the total combined quantity of the plan items (451, 452, or 305) is less than 10,000 square yards (8,000 m^2), the coarse aggregate can be one of the following sizes: No. 7, 78, 8, 57, or 67.

Freeze-thaw resistance testing is required for all No. 57 or No. 67 gravel or limestone coarse aggregate used in 451 (or 452 or 305) to help eliminate the concrete pavement's potential for D-cracking in accordance with ODOT Supplement 1024. Testing is performed by the Department. Contact the Aggregate laboratory to validate if your coarse aggregate sources are approved.

D-cracking is cracking caused by freeze-thaw deterioration of the aggregate within the concrete. This type of cracking can be observed in about 7 to 10 years after construction of concrete pavement. D-cracks are closely spaced cracks parallel to transverse and longitudinal joints which multiply outward from the joints toward the center of the pavement panel. D-cracking is a function of the pore properties of certain types of aggregate particles and the environment in which the pavement is placed. Due to the natural accumulation of water under pavements in the base and subbase layers, the aggregate may eventually become saturated. With freezing and thawing cycles, cracking of the concrete starts in the saturated aggregate at the bottom of the slab and progresses upward until it reaches the wearing surface. This problem can be reduced by either selecting aggregates that perform better in freeze-thaw cycles or where marginal aggregates must be used by reducing the maximum particle size. Also, installation of effective drainage systems for carrying free water out from under the pavement may be helpful.

Figure 451.A – D-cracking in concrete pavement

Joint Sealer

Expansion joint sealer must be a 705.04 hot-applied joint sealer conforming to ASTM D 6690, Type II.

Curing Materials 705.05, 705.06, 705.07 Type 2

These curing materials are burlap cloth, sheet-curing materials, and liquid membrane-forming compounds. The liquid membrane-forming compounds used on the project must be on the Department's QPL.

Tie Bar Steel, Epoxy Coated

Tie bar steel used in the longitudinal joints in concrete pavement must meet the epoxy coated reinforcing steel requirements of 709.00.

Reinforcing Steel

The reinforcing steel must comply with 709.09, 709.10, and 709.12

Dowel Bars and Basket Assemblies

Dowel bars and dowel bar assemblies (dowel baskets used to support the dowels at the proper position) must be coated with a fusion-bonded epoxy coating, which conforms to AASHTO M 254, with the exceptions listed in 709.13, Requirements for all Dowel Bars

Dowels should be inspected to ensure the epoxy coating is continuous on the lateral surface of the dowel and that the coating is not perforated, cracked, or otherwise damaged, in which case it must be rejected. The coating must be free from holes, voids, contamination, cracks, and there shall be no more than two holes (pinholes not visually discernable) in any 12 inch (305 mm) length of the coated dowel. The free ends of the dowels must be free of burrs or projections in addition to being completely coated.

Pavement Quality Control (451.03)

Where project pavement has a bid item ending in "with QC/QA," the Contractor will provide a quality control plan (QCP), quality control (QC) testing, and quality control inspection. The Engineer initially accepts the QCP. All requirements for the QCP submittal, what is required in the Contractor's QCP, minimum QC testing, and the Engineer's quality assurance (QA) responsibilities are in Item 455.

Equipment (451.04)

Reinforced Portland cement concrete pavement is placed by a series of equipment called a paving train. A paving train normally consists of a concrete spreading machine, a mesh cart, a mesh depressor, a finish paving machine, a work bridge and a cure/texture machine.

The riding qualities of a pavement depend largely on the proper operation of mechanical finishing equipment. The equipment must be in correct adjustment. It is almost impossible to use hand finishing to correct a poor surface left by the equipment. Frequent checking, and minor adjustments to compensate for changing conditions, will help to eliminate surface irregularities.

The Contractor is responsible for equipment adjustments. Department personnel are not expected to adjust or advise the Contractor on how to adjust and maintain mechanical equipment, but they are expected to observe the checking of all equipment. The Inspector

should be able to recognize when such equipment is out of adjustment or is not coordinated with the balance of the paving train. The following information on spreaders and finishing equipment is given to provide some knowledge on the operation of the equipment.

General Equipment Requirements

The equipment used must be self-propelled spreading and finishing machines that are capable of consolidating and finishing the concrete and producing a finished surface, which meet the specified requirements. Paving equipment must be operated in a manner that does not result in segregation of the mixture or loss of air entrainment in the mixture.

The specifications give the Contractor the option of using slip form or fixed form pavement construction methods.

Vibrators are used for the full-width and depth of the concrete slabs to provide consolidation of the fresh concrete. They must be internal type, using a tube or multiple spuds. Internal means the vibrators must be immersed in the fresh concrete. External vibration is not allowed. Vibrators may be attached to the spreader or the finishing machine or may be mounted on a separate carriage. They must not come in contact with the load transfer devices, subgrade, reinforcing mesh, or side forms. Multiple spuds should not be spaced further apart than 2-1/2 feet (0.76 m). Therefore, a minimum of 10 spuds is required for a full 24 feet (7.2 meter) width paving.

Internal vibrators must operate at a frequency of 7,000 to 11,000 impulses per minute. The vibrators should be connected to an electronic monitoring device equipped with an automatic recorder. The monitoring device should display the operating frequency of each internal vibrator. The readout display should be located near the paving operator's controls and must operate continuously when paving and display all vibrator frequencies with manual or automatic sequencing between individual vibrators. The automatic recorder must record the following information for every 25 feet (8 m) of paving or at every 5 minute time interval.

- The time of day.
- Station location.
- Paving machine track speed.
- The frequency of each vibrator.

If the monitoring system is not equipped with an automatic recorder, the Contractor must manually record the above information every 30 minutes. The Contractor must provide a record of the data, in electronic format, to the Engineer prior to the next concrete placement.

Vibration is required for all concrete pavements. Small, irregular areas require vibration by hand-held or machine-mounted equipment to ensure that adequate consolidation for the full-depth and width is achieved without segregation.

Vibrators must be connected so they turn off when the machine on which they are mounted stops.

Transit Mix and Mix Equipment

Concrete plants and trucks hauling concrete are inspected annually by the District Laboratories. Concrete plants and hauling units must be checked for proper condition

prior to paving operations and at regular intervals during paving. Water and admixture metering devices will be checked to ensure proper calibration within specified tolerances. The scales will be checked for accuracy (the specifications require that concrete materials be measured by weight).

Central mix plants should be checked to see that the mixer drum is capable of uniformly mixing and discharging the large volume of concrete. During paving, the Contractor, or ready mix supplier, must keep mixer blades free from concrete buildup and excessive wear.

Materials should be placed in the batch plant bins by dumping into the middle of the bin with as short of a drop as possible. Keeping the drop to a minimum reduces the chance for segregation in handling aggregate as well as in handling concrete.

Figure 451.B – Transit mixer truck

Even after the annual inspections, transit mixers should be checked to determine that the counters are functioning properly. After having been mixed for no less than 70 revolutions at mixing speed, the mixer should contain concrete of uniform consistency and be able to discharge the batch without segregation. Since this determines acceptability, mixers that do not perform in this manner should not be used and discontinued if encountered. Sources of trouble are badly-worn mixing blades and leaky valves, which prevent mixers from producing uniform concrete. They should not be used until corrected.

Figure 451.C – Non-agitation concrete dump-crete truck (left), dump truck (right)

When the concrete is transported to the paving site in dump trucks or other non-agitating units, check the bodies to ensure that they are water-tight and free of objectionable corners or internal ribs where concrete may accumulate. Canvas covers that shield concrete from sun and wind shall be provided when required by the Engineer.

Aggregate Stockpiles

Contractors build aggregate stockpiles at locations where concrete will be mixed. In all cases, aggregate stockpiles can be placed on areas which are paved, or they may be placed directly on the ground if the existing ground is firm, cleaned of foreign material, and shaped to provide drainage. No aggregate is to be removed from the stockpile within 1 foot of the ground during production of concrete.

Stockpiles should be built in such a manner that different types or sizes of aggregate do not become mixed, and the aggregate does not become segregated.

Coarse aggregate stockpiles must be constructed to prevent segregation. In building the stockpiles of coarse aggregate, the Contractor is to prevent segregation through proper handling. Methods that allow the aggregate to be deposited close to the surface of the pile helps prevent aggregate from rolling to the bottom of the stockpile and aggregate segregation. As the pile increases in height, each layer of aggregate should be benched back to help limit rolling and segregation.

Rubber tire front-end loaders are often used to construct stockpiles. Rubber tires must be kept clean and the bucket drops kept short. If the front-end loader is on the pile, it should not be moved on and off the stockpile. This can cause contamination of the stockpile. Using a bulldozer to push coarse aggregate is not permitted; this causes segregation and the use of steel treads on the pile crushes the aggregate. Small aggregate does not segregate as easily as large aggregate because the smaller pieces are less likely to roll down the side of the pile.

Any operation which can result in segregation, degradation, or contamination is not permitted. Aggregate stockpiles that appear segregated should be tested for gradation at the lab.

Slag aggregate and any other aggregate with a reported absorption above 3 percent must be managed in stockpiles to ensure uniform moisture content at the time of batching (499.06). A stockpile watering system must be used that raises the aggregate moisture to saturated surface dry (SSD) or above. The Contractor is responsible for collecting samples to confirm the aggregate moisture requirement. Additionally, the Contractor is responsible for maintaining the aggregate stockpile at or above SSD until dewatering prior to batching in the concrete mix. During production of concrete, the Contractor is required to test and maintain the aggregate moisture. Variation in moisture of more than 1 percent requires more frequent testing such that the correct information is used in concrete batching.

Where QC/QA is required, the Contractor is required to test aggregate gradations conforming to Item 455.

Fixed Form Construction (451.04.A)

This construction method requires the Contractor to furnish equipment that will spread, screed, and consolidate concrete using one or more machines operating on previously placed side forms. There must be enough equipment with capacity to perform the work

at a rate equal to the concrete delivery rate. The equipment must be self-propelled and uniformly distribute and consolidate the concrete without segregation. Fixed form construction is used on small or irregular paving jobs because of slower productivity and potential issues with smoothness.

The equipment must either operate on two side forms, on adjacent lanes of pavement and one side form, or on two adjacent lanes as necessary. When operating the equipment on adjacent lanes, the adjacent lanes must be protected from damage from the equipment.

Pavers for fixed form construction must be able to spread, consolidate, and finish the concrete pavement to the cross-section and profile required using one or more machines. The machines must be able to distribute and consolidate the fresh concrete without causing segregation. Consolidation must be for the full-depth of the concrete thickness being placed.

Forms for use on ODOT projects must meet the following requirements:

- Made of steel.
- Straight and must not be less than 10 feet (3 m) in length without horizontal joints in the form.
- Have a depth equal to the pavement thickness specified.
- Base width of at least 3-inches or greater. Older forms will likely have a base width equal to the depth of the forms.
- Built-up and shimmed forms are not allowed.
- Forms that are bent or damaged are not permitted.

Figure 451.D – Sections of steel concrete paving forms (left), forms in place (right)

Forms must be cleaned and oiled each time they are used. If the radius of the pavement edge is 100 feet (30 m) or less, flexible or curved forms may be used as approved by the Engineer.

The Contractor must provide methods and devices that securely set forms and withstand paving equipment operation. Built-up forms must not be used unless constructing less than 2,000 square yards (1,650 square meters) of pavement for the entire project. All forms must have adequate joint locks to tightly join the ends of abutting sections together.

The surface left by the transverse screed must be uniform and satisfactory.

Slip Form Construction (451.04.B)

This method of construction permits pavement placement without the use of fixed side forms. In lieu of forms, a slip form paver spreads concrete uniformly across the paving area with an auger or spreader plow, consolidates the concrete with spud vibrators, and strikes off the top of the concrete and then feeds the concrete under a profile pan that provides the correct elevation and proper cross-section. Many slip form pavers have a tamping bar that tamps larger aggregate into the top of the slab before it enters under the profile pan. When the concrete leaves the mold, the slab should retain its shape and position. Some slip form pavers utilize an oscillating float (auto-float) or tube float after the slab is extruded. These floats are used to smooth and seal the top of the slab; however, in some cases, they can cause the slab to be bumpy. Excessive finishing after the slab is extruded should not be necessary if the slip form paver is set-up correctly.

The base must be constructed as outlined in the specifications. Stability of the base is critical for slip form construction. The base must be graded to the plan elevation by a properly designed machine. The track area for the paving train may be brought to grade using a form grader with a subgrader on crawlers used to grade the area under the pavement. An automatic subgrader operating from a preset grade line is ideal for slip form construction and does not require the use of a form grader. See Fine Grading of Subgrade or Subbase below for more details.

Stabilization in the paving machine track area in order to provide traction is permissible provided the area is scarified after pavement construction to avoid interference with lateral drainage of the subbase. Any method of stabilization proposed by the Contractor must be approved by the Engineer.

An industry-standard, approved slip form paver must be used to spread, consolidate, screed, and finish the concrete in one pass. The machine must consolidate the full-width and depth of pavement being placed to provide a dense homogeneous pavement slab which requires a minimum of hand finishing.

For the placement of steel mesh, two machines may be used with the leading machine, striking off the bottom course for placement of the mesh. The width of the bottom course may be 6 inches (150 mm) narrower than plan width, so it does not interfere with the second paving machine.

Figure 451.E – Slip form paving

Preset grade lines are required for slip form paving equipment to ensure acceptable riding quality of the pavement. Paving equipment must have controls that trace the grade line and automatically adjust the screed. String lines offset from and parallel with the edge of pavement are most often used. Sensors on the paver follow the string line and automatically adjust the screed.

The use of string lines will not ensure riding quality. All lines, grades, and controls should be frequently checked. The electronic controls of a slip form paver utilizing a string line merely follow the ups and downs of the string line; thus, any dips, bumps, and errors in the string line set-up are mirrored on the surface of the new pavement. String line should be supported at intervals that eliminate sagging of the string under its own weight. Supports every 25 feet (8 m) produce the most desirable results. The stringline tension must be taut enough so excessive sag does not occur.

For best results using a slip form paver, the concrete slump should be maintained at about 1-1/2 inches. Too much slump will cause the slab edges to sag and too little slump will result in a torn or open surface. In either case, the slab will require hand finishing to make repairs. Good construction results are achieved by operating the slip form paver with continuous forward motion and a minimum of starting and stopping. When the paving machine stops, all vibrating, tamping, and oscillating elements must stop.

The slip form paver must not be used like a dozer to push large quantities of concrete piles. The Contractor is responsible for placing concrete that requires as little rehandling as possible, including pushing mounds of concrete or using hand vibrators to move concrete. See Placing Concrete below.

Figure 451.F – Improper concrete placement in front of slip form paver

At the end of the day's production, pavement at construction joints may be reduced approximately 2 inches (50 mm) in overall width. This allows the Contractor to use an insert just inside each moving side form so that the slip form paver can be positioned at the joint when production is resumed. The trailing side forms do not bind and spall the slab edges when this leeway is provided on each side.

Inspection of slip form paving should include checking the pavement edges. The pavement's edge should be perpendicular to the pavement's surface. Since no forms are used to screed against or to hold the edge in place, the edge can slump downward or lean outward. Use a straightedge placed perpendicular to the pavement's edge to check transversely and longitudinally for slumping or leaning. Edges must be corrected while the concrete is plastic. The Contractor is required to make changes to the slip form paving process to prevent edge slump.

Where pavement will be placed against an outside edge, the pavement must not vary more than 1/4 inch (6 mm) below the typical section.

Where pavement will not be placed against an outside edge, the pavement must not vary more than 1/2 inch (13 mm) from the typical section.

All pavement edges must be nearly vertical with no projections or keyways exceeding 1/2 inch (13 mm). If edge projections exceed 1/2 inch (13 mm), concrete must be removed by hand methods and the edge should be troweled smooth.

Setting Forms (451.05)

Forms serve as the "tracks" for the paving equipment, in addition to serving as forms for the concrete. Since developments in paving equipment have provided heavier

equipment, the forms play an increasingly important role in the construction of smooth pavements.

Before any forms are set on a project, they must be inspected to see that they comply with specification requirements. They must have sufficient pin pockets for setting securely so that they will withstand the operation of the paving equipment. Forms are to be set so they do not vary more than 1/8 inch in 10 feet (3 mm in 3 m) on the top face or more than 1/4 inch in 10 feet (6 mm in 3 m) on the vertical face. If they cannot be reset or repaired to meet this tolerance, they cannot be used. Forms are reused continuously. Therefore, inspection of forms must be continuous. Any time forms are found out of tolerance, they must be rejected. Forms that are rejected should be marked so they are not incorporated into the work.

Figure 451.G – Forms are set in position and pinned to the base

Forms are to be set true to line and grade on a thoroughly compacted base with uniform bearing throughout their entire length and width. Using loose earth pebbles or other shims to bring forms to the required grade is not permitted. Whenever adequate and uniform form support is not obtained, the forms must be removed, the base corrected and compacted, and the forms reset. At least 3 form pins are to be used in each 10 foot (3 meter) length. These pins must be long enough to hold the form in position during the placing and finishing operations.

Figure 451.H – Built-up and shimmed forms are not allowed

Pin keys must be straight and free-moving in the pockets and capable of holding the forms tight against the pins. The joint locks must not be bent or worn and must be capable of holding the ends of the forms in true alignment. The pins and locks are checked when the forms are set, but should be rechecked prior to placing concrete and tightened if necessary. Make a final visual check at the same time to ensure forms are at proper line and grade. Smooth riding pavement with good surface finish is extremely difficult to obtain with poorly aligned and set forms.

The forms are to be cleaned and oiled prior to the placing of concrete. When hook bolts or wiggle bolts are fastened to the forms, the forms must be oiled prior to placing these units.

Fine Grading of Subgrade or Subbase (451.06)

After the embankment has been placed and compacted, the subgrade is brought to the required grade, cross-section, and density in accordance with 203. Base material is provided by plan for all concrete pavements with only a few exceptions. The typical plan section indicates the depth and width of compacted base materials. Generally, base material is 304 Aggregate Base and must be placed, shaped, and compacted in accordance with that specification. Fine grading of the base material should be done in advance of the concrete paving operation to allow the Engineer to check the established grade for conformance to the plan elevation. After the grade has been checked and accepted, no further disturbance of the base material is allowed.

Fixed Form Construction and Slip Form Construction (451.06.A and 4514.06.B)

For both fixed form and slip form construction, the surface of the base material is left approximately 1 inch (25 mm) above grade after compaction has been completed to the required density. After forms have been set to grade for form paving, or the string line is set for slip form construction, the slight excess is removed with a subgrade planer (subgrader). The fine grading operation should result in a slight removal so that the trimmed surface is compacted thoroughly without low areas. Low areas require the addition of material, compacting, and regarding, which results in a delay in progress of fine grading.

When automatic subgraders are used, they will precede the setting of forms. Grade will be maintained from a preset string line that will be parallel to the grade line. After final trimming, the surface will be treated the same as for conventionally graded base.

Loose base material windrowed along the inside of the forms cannot be removed by machine, so removal of this material by use of a shovel is necessary. This shall be done before re-compacting.

The trimmed surface left by the subgrader should be compacted to restore surface density. This rolling operation also smooths the surface and reduces the friction between the base and the pavement.

For fine grading between forms, the resulting base surface can be checked using a multiple pin template operated on the forms or a stringline stretched between the forms. The template must be operated behind the subgrader and roller. Any high or low spots encountered shall be corrected immediately, then rerolled and rechecked before continuing. Where the subgrader is operated on a string line, the grade will be checked based on the grade stakes for the pavement. The Inspector should record the limiting stations of the area checked and conformance to the specification requirements in project records.

The subgrader is usually one of the heaviest pieces of equipment operating on the forms. Therefore, this is a good time for the Inspector to observe the forms for excess movement or displacement. Areas where movement or displacement is noticed should be rechecked for compliance with requirements before placing concrete.

Moisture is controlled by spraying the base prior to fine grading, preferably in the late afternoon before fine grading. This provides the uniform moisture distribution necessary for density. After removal of excess material during fine grading, moisture is present for the final surface compaction.

It is good practice to recheck the alignment and grade of forms, the form locks, and the pin keys after fine grading. Some Contractors assign employees to this job. The Inspector should check these items regardless of the Contractor’s operation to ensure that any irregularities have been corrected. Since the paving equipment relies on the forms for support, it cannot be expected to produce a quality-riding surface when yielding or improperly set forms are encountered.

Placing Concrete (451.07)

Prior to placing concrete, the subbase must be thoroughly moistened with water. This keeps the subbase material from absorbing water from the plastic concrete, thus affecting its workability and decreasing its set-up time. Different moisture levels throughout the depth of concrete can build in stresses that lead to cracking.

The concrete must be placed as close to the paving and finishing operation as possible to limit rehandling. Excessive handling of plastic concrete can reduce the air entrainment, and therefore, the long term durability of the pavement.

Even distribution of concrete on the base or in each course being placed is the first step toward an acceptable job. The most even distribution in initial placing results in minimum variation in final surface settlement. If concrete is deposited in piles or windrows, unequal consolidation may take place before finishing operations are started. This never will be overcome throughout the finishing procedure and can be the cause of unequal settlement and rough surfaces after finishing has been completed. In the case of transmit mixer or dump truck delivery, use discharging methods that spread each batch as evenly as possible. Better results are obtained when a hopper-type spreader is used with either transit mixer or dump truck delivery.

Concrete must be vibrated using internal vibration for the full-width and depth of the pavement being placed. When using dowel basket assemblies, the Contractor is required to use a separate handheld internal vibrator to consolidate the concrete around the assembly. This requirement is sometimes overlooked and must be required to ensure complete and adequate consolidation at the dowel basket assemblies. Internal vibrators, mounted on a paver, must automatically shut off when the machine stops. Vibrators that continue to run cause segregation of the coarse aggregate from the paste which results in weak areas in the pavement.

Workers should not walk in the concrete unless they are wearing clean boots that do not have dirt, earth, clumps, or other foreign matter on them. Workers should never walk on concrete that has been struck off; these boot tracks can fill with mortar which will develop as low and weak spots on the surface of the slab.

Concrete must not be allowed to displace dowel bar assemblies or expansion joints.

A separate concrete placer/spreader is required when the width of pavement being placed in one operation is 12 feet (3.6 meters) or more and the area of any given width exceeds 10,000 square yards (8,300 square meters). When using a slip form paver with a dowel bar inserter (DBI), the placer/spreader requirement may be waived. When a slip form paver with DBI is used, there are no dowel baskets; therefore, concrete delivery vehicles can deposit concrete directly and evenly in front of the paver.

Placer/spreaders must be industry standard equipment that is self-propelled and receives concrete in a hopper adjacent to the area being paved and delivers the concrete using a conveyor system evenly and uniformly in front of the paver. Placer/spreaders must be adjusted to deposit the proper amount of concrete for the required slab thickness. The amount of concrete deposited is determined by the elevation of a strike-off plate located behind the screw augers, paddle, or hopper that distributes the concrete.

Figure 451.I – Concrete placer / spreader

The elevation of the bottom of the strike-off plate in relation to the top of the forms is shown on an indicator that is visible to the operator. The equipment should be checked to make sure that the indicator shows zero when the bottom of the strike-off is exactly even with the top of the forms.

The initial placing of the concrete should be just enough so that a slight excess is carried ahead of the placer/spreader as it levels the concrete to a uniform surface. Unless this is done, there will be an irregular surge past the strike-off of the spreader or past the finishing screed. This necessitates excessive manipulation of the surface in order to obtain specified smoothness requirements. Excessive manipulation tends to alter the quality, durability, and wear resistance of the finished pavement.

Concrete should not be mixed, placed, or finished after dark without operating an adequate and approved lighting system.

When the air temperature is 35 °F (2 °C) or below, the concrete temperature must be between 50 °F and 80 °F (10 °C and 27 °C) at the point of placement.

When the air temperature is greater than 35 °F (2 °C), the concrete temperature cannot exceed 95 °F (35 °C). When placing higher temperature, concrete setting and finishing can become an issue. Cure and delivery time also becomes critical. Ensure that the cure is immediately being applied and do not allow curing to lag behind the paver. See Hot Weather Construction.

Concrete cannot be placed on any surface that is frozen or has frost.

Two test beams are to be made for each 7,500 square yards of concrete or fraction of 7,500 square yards that is placed each day. Construct and test the beams for modulus of rupture in accordance with Supplement 1023.

Concrete Running Yield Check

The running yield of concrete may be determined at any time during concrete paving and can provide an easy, accurate method to ensure that the proper thickness is being placed. When a constant width and thickness is placed, a yield factor in cubic yards per foot (cubic meters per meter) can be calculated. This factor is determined by calculating the amount of concrete required for 1 foot length (one meter) of finished pavement of the width and depth required. This factor is computed by using Equations 451.2 and 451.3:

$$\text{Yield Factor} = \frac{\text{Width (ft) x Thickness (ft) x 1 ft}}{27\ ft^3 / yd^3}$$

Equation 451.2 – Yield Factor

$$\text{Yield Factor} = \frac{\text{Width (m) x Thickness (mm) x 1 m}}{1000\ mm / m}$$

Equation 451.3 – Yield Factor (metric)

Running Yield = (Yield Factor) x Length Placed

Equation 451.4 - Running Yield

Example:

A Contractor is placing a 24-foot wide slab that is 9 inches thick. Determine the yield factor and running yield for this cross-section when the Contractor placed 4,254 linear feet. Using Equation 451.2, the following calculation results:

$$\text{Yield Factor} = \frac{24\ ft \times (9\ in/12\ in/ft) \times 1\ ft}{27\ ft^3/yd^3} = 0.667\ yd^3 \text{ per foot of length}$$

Once the running yield factor has been calculated, it can be used to determine the concrete volume required for any length of slab of the same dimensions.

For this example: *Running Yield =* $0.667\ yd^3$ *per foot of length x 4,254 ft =* $2{,}830\ yd^3$

This is the volume of concrete that should be used for this length of pavement if it is placed to the plan width and thickness. A comparison to the quantity of concrete used will show whether the Contractor is over or under running on yield.

Example:

Actual quantity used = 2,880 yd^3

Running yield (from above calculation) = 2,830 yd^3

Over/Under run = Actual used – Running Yield = Difference

$2{,}880\ yd^3 - 2{,}830\ yd^3 = +50\ yd^3$ *difference*

$(50\ yd^3 \div 2{,}830\ yd^3) \times 100\ \% = 1.77\%$ *overrun*

A 1 to 3 percent greater than that required is generally due to wasting over the forms, spillage, etc. An overrun of 3 percent or more should be investigated to determine the cause. Overruns may be caused by several factors, including inaccurate weighing, low subgrade/base, excessive waste, line and grade, etc. Similarly, an under run in concrete may be due to inaccurate weighing, high subgrade/base, insufficient width, thickness of slab, settlement of forms, etc.

Hot Weather Construction

When high air temperatures, low humidity, and winds are encountered during concreting operations, the rate at which concrete hydrates (hardens) increases. High temperatures, especially when accompanied by wind and low humidity, tend to cause a rapid loss of moisture from the surface of the plastic concrete resulting in early setting and a reduction in time allowed for finishing.

Lowering the concrete temperature to 75 ºF (24 ºC) or below will help offset the effects of high ambient temperatures. Selection of a cool water supply is the most effective means of lowering the mix temperature. Watering of coarse aggregate stockpiles for moisture control also aids in controlling the mix temperature.

When form paving, it is good practice to maintain the slump of concrete near the top limit during hot weather. Increasing the slump will help delay hydration, thereby making more time available for the finishing operations.

During hot weather operations, there may be a tendency to add water to the surface of the concrete to aid in finishing. This practice cannot be allowed. Using water on the surface during finishing results in an increase in the water-cement ratio and reduces the entrained air content of the concrete at the surface. Both of these changes adversely affect the long-term durability of the pavement's surface. The use of the whitewash brush to sprinkle water has caused the majority of scaling that occurs in concrete surfaces.

Under extreme drying conditions caused by high temperatures, coupled with low humidity and high winds, mixing water may evaporate quickly from the concrete's surface. This water may be restored by applying a fog spray of water on the surface provided the surface has been completely finished and will not be screeded or straight edged after the fog spray. This provision should be carefully controlled and should be the exception rather than the rule.

An approved Type B or D (705.12) set retarding admixture is required when the concrete temperature exceeds 75 °F. Set retarders help slow down the setting time, thereby providing more time for finishing. The use of this admixture will result in less slump loss and result in higher strength concrete.

Protection from Rain

Concrete paving must not be undertaken in rainy conditions; however, in the course of paving, rain can occur and the Contractor must take steps to protect the plastic concrete from damage. If the pavement is adequately protected from rain, extensive corrective work can be avoided.

A roll of polyethylene sheeting on the finishing machine or the curing machine can be quickly unrolled to protect large areas of pavement. When the concrete hasn't been protected and has been damaged by rain, increased attention to corrective measures will be necessary to obtain durable concrete.

Concrete that has been exposed to rain will have some mortar or paste washed from the surface resulting in a sandy appearance along with a speckled or splattered surface pattern. If the surface hasn't been machine finished, it should be screeded with the machine. This screeding will eliminate the sandy texture and force grout to the surface. For a surface which has been machine finished, the machine may be used to make a single pass over the area affected, or the surface may be dragged with the burlap to remove the sand and work grout to the surface. A broom drag may be used for several passes to restore the surface finish. When correcting damage to newly placed concrete surfaces, the excess surface water must first be removed, not worked into the concrete. Cement must not be placed on the surface in an attempt to restore cement paste washed away by the rain. Such a practice is detrimental to the concrete and must not be allowed.

When rain persists for a lengthy period, it will be necessary to remove any protective covering to finish and texture the concrete before it sets. Membrane curing should not be applied when the surface is wet. If polyethylene sheeting is used as a covering, curing may be delayed indefinitely provided the sheeting is maintained in accordance with the specifications. However, membrane curing should eventually be applied.

If rain damages the curing membrane, the surface should be re-sprayed after the excess water has dissipated to restore the impervious covering and retain moisture necessary for curing.

If, for any reason, measures taken by the Contractor to produce a surface that meets specifications are unsuccessful, the affected portions of the pavement must be repaired or replaced to comply with contract requirements.

Cold Weather Construction

During cold weather, provisions must be made to prevent concrete from freezing until it has attained adequate strength. Concrete that has been frozen prior to gaining sufficient strength may be permanently damaged and may never achieve the design strength. Therefore, it is necessary to protect the concrete from freezing temperatures during the cure period.

The temperature of the concrete and the surrounding air directly control the rate of hardening of the concrete. As the ambient temperature decreases, the rate of hardening decreases. The rate of hardening ceases at the freezing point. If the concrete is maintained just above freezing, it will not be damaged. However, it will require a lengthy curing period before it will harden and gain sufficient strength.

The Contractor is responsible for protecting concrete during cold weather. If damage might possibly occur, the surface shall be protected by any means that prevents the concrete from freezing and retains the heat of hydration.

In order to control the rate of hardening and strength gain, it may be necessary to control the temperature of the concrete being placed and to protect the concrete thereafter to retain the heat of hydration during curing. If the air temperature is 35 ºF (2 ºC) or below when concrete is being placed, the concrete must have a temperature from 50 ºF to 80 ºF (10 ºC to 27 ºC) when placed. The Contractor is responsible for ensuring that the concrete temperature is in the required range.

If the concrete temperature is less than 50 °F the mixing water or aggregates may be heated. The heated water and aggregate should be introduced into the mixer before the cement so the temperature is reduced before cement is added to avoid the possibility of

a flash set. One further precaution is to delay the introduction of the air-entraining agent until the temperature has been reduced, because hot water tends to reduce its effectiveness.

The subgrade or base and forms must be free from frost when concrete is placed. Covering these areas usually prevents frost and avoids delays.

Any request to incorporate an accelerating admixture during cold weather construction must be submitted and approved.

Job Control Testing and Sampling

All material being used in the production of concrete shall be sampled, tested and approved, or accepted by certification before being used. Material that has not been sampled before delivery to the project must be sampled and submitted for testing. Such material must not be used until approval has been given by the Laboratory. Sampling must be done in accordance with the specifications and as outlined in Item 499.

Concrete for use in pavements must meet the specified requirements for air, slump and yield. Tests must be conducted to check for compliance with these requirements. The test results must be within the following limits:

AIR	SLUMP	YIELD
7 ± 2%	1 to 3 inches	± 1%

Under QC/QA, the Contractor will perform tests and report this information to the Engineer. If random QA tests find out of tolerance concretes, the Contractor must be notified of out of specification test results and make immediate adjustments to the mix. Production should be stopped and check tests made to confirm non-compliance of the original tests. Concrete that does not meet specification requirements must not be used unless adjustments can be made to correct the deficiency prior to incorporating it into the work. The fact that concrete has been produced and transported to the project does not justify its use unless it conforms to requirements.

Insufficient air may be corrected by the addition of an air-entraining agent and remixing the load to generate additional entrained air. Variations in yield should not be cause for rejection; however, immediate adjustments must be made in the batch weights and must be followed by additional yield tests until conformance is obtained. Slump may be increased by the addition of water provided it remains within the limits of the water-cement ratio. If slump is excessive, the concrete should not be used.

Concrete cylinders are not required for pavement concrete. However, if for some reason cylinders are desired, they should be cast from concrete obtained at the paving site and are to be made in accordance with Item 499. Cylinders are to be shipped to the District Laboratory 48 hours after casting. Notify the Laboratory when the cylinders are to be tested for compressive strength (normally at 28 days of age.)

Results of air, slump, and yield tests must be recorded on the Concrete Inspector's Daily Report and in SiteManager. See either 499 or SiteManager help documents for required entry. Results of flexural tests on beams are to be recorded in the project records. Results of compression tests on cylinders (if made) will be reported by the Laboratory.

Placing Reinforcement (451.08)

Distributed steel or reinforcement used in reinforced pavement (Item 451) is welded wire fabric or mesh. Reinforcing mesh details for pavement are shown on Standard Construction Drawing BP-1.1. The longitudinal wire is designated as a W8.5 or D8.5 (MW55 or MD55) size and has a nominal diameter of 0.329 inch (8.4 mm). The longitudinal wires are to be spaced at 6-inch (150 mm) centers. A W4 or D4 (MW26 or MD26) wire is used transversely and has a nominal diameter of 0.225 inches (5.7 mm). Transverse wires are to be spaced at 12-inch (300 mm) centers.

The mesh holds together the slab after cracks have formed. Adequate load transfer across the crack is ensured, and the infiltration of incompressible material into the crack is prevented or delayed. Mesh does not increase the flexural strength of the slab. Steel mesh is designed to withstand tensile stresses and hold the slab together.

Mesh is usually delivered to the job in advance of paving operations and stored. It should be carefully stacked and kept clean. Before it is used, it should be inspected to see that it has not been damaged in shipment or in storage, and that it is free from dirt, oil, and mud, which will prevent bonding with the concrete. Any mesh that has been bent or has broken welds should be rejected. Mesh with rust, mill scale, or a combination of both will be considered satisfactory provided the minimum dimensions are not less than specified. Research indicates that tight, scaly, and pitted rust does not prevent bond.

Mesh should not be rejected for rusting unless the rust is so severe that the wire dimensions are reduced to less than the minimum specified. If it is suspected that the wire dimensions have been reduced, the District laboratory should be requested to check the wire dimensions with a micrometer.

Figure 451.J – Concrete spreader with mesh cart

If mesh is placed along the rough grade or the shoulder to be easily accessible during paving, it should not be done so far in advance that mud will accumulate on it. Take care to prevent the mesh from becoming bent.

If a mesh cart is used on the forms behind a spreader, the mesh is stacked in cart-sized piles at intervals along the grade. These stacks should be placed on wood blocks or in some manner to keep them from becoming caked with mud or soil.

The specifications allow three methods of installing reinforcing mesh. The allowable methods are:

1. Place one layer of concrete, place the mesh on top of this layer so that it is located at its final location without any further manipulation, and place the second layer of concrete on top of the mesh. If the pavement is being placed in two layers, the concrete for the base layer should be distributed uniformly on the base and then struck off by means of a mechanical spreader to the proper depth. The strike off should leave a plane surface without voids or high or low spots on which to place the mesh
2. The mesh may be supported on chairs at the correct elevation and securely anchored to the base and the concrete placed in one layer.
3. Place and spread one layer of concrete. While the concrete is still plastic, use a mesh depressor that vibrates or mechanically installs the mesh to the proper depth in the slab. This method eliminates the need for placing two courses of concrete and thereby eliminates the possibility of a plane of weakness (a cold joint) between two separately placed courses. Control of the mesh placement within the slab is more accurate than when placed between courses, based on measurements of cores removed for checking thickness requirements. Another advantage of this method is that a bulkhead can be placed readily and quickly in the event of breakdown since the concrete is placed full-depth and not in two separate courses.

Figure 451.K – Placing two layers of concrete (left), mesh supported (right)

Figure 451.L – Using a mesh depressor

Mesh is required to be located in the slab within the range of 2-1/2 inches to T/3 + 1 inch (64 mm to T/3 + 25 mm) below the finished concrete surface (where T is the thickness of the pavement). In its final position, reinforcing mesh must not touch either dowel bars or tie bars. Mesh must also be located so there is 2 inches (50 mm) clearance from a longitudinal joint or pavement edge to the reinforcing wires and 12 ± 2 inches (300 ± 50 mm) from any transverse joint.

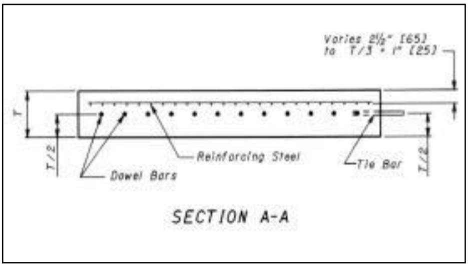


Figure 451.M – Location of mesh in the Slab

If the mesh is bent, it should be straightened before it is placed. If it has a gradual bow, place it so the concave side is down. Workers placing steel must not track mud or dirt into the concrete.

Two types of machines have been approved to vibrate the mesh into position. One type consists of a grid of steel plates approximately 15 feet (4.6 m) in length and extending the full-width of pavement being placed. The self-propelled machine is positioned over the mesh, stopped, the mesh depressed into the freshly placed concrete, and moved ahead to repeat the operation.

The other type is self-propelled and consists of long tapered longitudinal runners across the width being placed. This machine gradually depresses the mesh into position in the fresh concrete using an oscillating tamping motion while continuously moving forward.

Since there is forward movement during placing, the latter type of machine may cause movement of the mesh across transverse contraction joints when not properly adjusted. When using a machine of this type, periodic checks must be made by uncovering the mesh at joint assemblies to ensure that the specified clearance of 12 ± 2 inches (305 ± 51 mm) is being maintained on each side of the center of the transverse joint. If the mesh position is found to be out of tolerance, it should be corrected and the machine adjusted at once or its use immediately discontinued. Production may be continued without the mesh installer by changing to the two-course method.

Both types of machines can be adjusted to control the depth of the mesh. Therefore, depth checks must be made daily to confirm that the machine is placing mesh to the required depth. Standard when mesh depth is out of tolerance, immediate adjustments must be made by the Contractor.

Reinforcing mesh is normally shipped in lengths of 19 feet (5.9 m) by 11 feet 8 inches (3.6 m) wide which will fit the specified joint spacing of 21 feet (6.5 m) for reinforced concrete pavement with an allowance of 12 ± 2 inches (300 ± 50 mm) from the center of each transverse joint. If shorter lengths are provided, transverse laps must be 12 inches (305 mm) and mesh sheets must be fastened at the edge of the lane and two other locations.

Usually mesh is not fabricated for lane widths greater than 12 feet (3.6 m). Therefore, when placing pavement lanes in excess of 12 feet (3.6 m) in width, it will be necessary to tie additional mesh to the standard width sheet. This is done by tying the outer longitudinal wire of adjacent sheets together. A minimum of four ties should be placed along the overlapped longitudinal wires to hold the two sections of mesh in the same plane until the concrete sets.

If the screeding operation has been done properly and the mesh placed in flat sheets and tied properly, there will be no difficulty with the steel working up into the finishing operations.

Joints (451.09)

Joints are classified as transverse and longitudinal. Transverse joints are further classified as contraction, expansion, and construction joints. Detailed instructions for joints are found in the specifications and in the standard construction drawings. See Standard Construction Drawing BP-2.1 for longitudinal joint details and BP-2.2 for transverse joint details. The Inspector should know the requirements of the specifications and the drawings before inspecting joint construction.

All transverse joints are to be constructed normal (perpendicular) to the centerline of the pavement lane unless otherwise noted on the construction plans and are to be coated with a thin, uniform coat of new light form oil. Only new oil should be used. The oil coating should be applied no sooner than 2 hours prior to concrete placement. For example, it is not acceptable for the Contractor to oil the dowels the day before the concrete is placed. For slip form construction which uses mechanical dowel bar inserter, the dowels must be oiled just prior to loading the dowels into the machine.

Joint sawing is required to prevent uncontrolled cracking of concrete pavement and is required for all transverse contraction joints. Joint sawing is also required for all longitudinal joints when concrete pavement has been placed across two or more lanes at the same time.

The timing of the sawing operation is critical. The use of HIPERPAV software is required to determine the sawing time limits to help protect from early, uncontrolled cracking. If the curing compound damage caused by sawing is repaired according to 451.11 and to the satisfaction of the engineer, the Contractor may operate the sawing equipment necessary to saw joints on newly constructed pavement. The software is available as detailed in Supplement 1033 as well as the requirements for analysis. Note: the use of HIPERPAV does not relieve the Contractor of his responsibilities under 451.17 regarding the repair of cracks in the completed pavement.

The HIPERPAV analyses must be run 24 hours prior to placing concrete and for every pour according to S1033. The original HIPERPAV files and printout must be provided to the Engineer. If HIPERPAV predicts early age slab cracking will occur, whether due to standard construction practices, joint sawing methods, mix design or curing, the Contractor cannot start construction until modifications have been made to eliminate HIPERPAVs predicted slab cracking.

If HIPERPAV predicts that joint sawing can exceed 24 hours, ensure that all joints are sawed within 24 hours.

Sawing must be done after the concrete has sufficiently hardened and is able to support the sawing equipment and to avoid spalling and raveling. This operation cannot be tied to normal working shifts. A standby saw is required at the paving site in the event of the breakdown or inability of one machine to maintain necessary progress.

Inspection should include random checking of each day’s sawing to ensure the width and depth specified is achieved. Saw blades will wear with use, so continued checks must

be made. Since the timing of sawing is critical, inspectors assigned to this operation must be aware of the importance and document the actual time of sawing.

Sawing may be done wet or dry and the cut must be cleaned by a jet of water (if sawed wet) or air under pressure (if sawed dry).

Longitudinal Joints (451.09.A)

Joints between adjoining lanes of pavement or shoulders are longitudinal joints. They are necessary to control cracking in the longitudinal direction due to the warping stresses in wide concrete slabs. Joints between separately placed adjoining lanes are longitudinal joints, as well as construction joints, and are often called longitudinal butt joints. Most pavement lanes are 12 feet wide.

Epoxy coated tiebars or hook bolts are required at longitudinal joints to tie the lanes and prevent them from moving apart or from settling unevenly. Since they tie the lanes together by bond, tiebars or hook bolts are not to be oiled.

Longitudinal Joint - (in Simultaneously Placed Lanes)

Both tiebars and hook bolts should be placed in accordance with the requirements of standard construction drawings called out in the plans (BP-2.1). Tiebars are 5/8 inch (16 mm) in diameter, deformed reinforcing bars, 30 inches (760 mm) in length. The spacing of tiebars or hook bolts varies with the joint spacing. The maximum spacing of tiebars is 30 inches. The minimum offset of tie bars to the transverse joint is 15 -21 inches and also varies by joint spacing. Tiebars or hook bolts must be placed approximately at right angles and placed at one-half the thickness of the pavement. For example, if the slab is 10 inches thick, the tiebars are to be placed at 5 inches as measured from the surface of the slab.

Tiebars may be set on chairs prior to concrete placement or inserted in the plastic concrete using a mechanical device on a slip form paver. Chaired tiebars must be adequately anchored to the base material. A mechanical inserter must be able to install the tiebars at mid-depth in the plastic concrete. Tiebars must be inserted after the concrete has been placed to its full-depth and after the reinforcing mesh is placed (mesh is not required for 452 or 305 pavement). Pushing tiebars into the plastic concrete by hand is not acceptable.

Figure 451.N – Mechanical tie bar inserters center tie bar (left), edge tie bar (right)

Figure 451.O – Tie bars can be supported prior to concrete placement

When a standard (water-cooled diamond bladed) concrete saw is used to make the longitudinal joint between simultaneously placed lanes, the following applies:

- Pavement ≤ 10 inches thick: Saw the joint to a minimum depth of one-fourth the specified pavement thickness.
- Pavements > 10 inches (255 mm) thick: Saw the joint to a minimum depth of one-third the specified pavement thickness.
- Saw joints 1/4 ± 1/16 inch (6 ± 1.6 mm) wide as measured at the time of sawing.

When using early-entry (dry cut, light weight) saws, only use saw blades and skid plates as recommended by the manufacturer. Perform the early entry sawing after initial set and before final set as follows:

- Saw the joint 2-1/4 to 2-1/2 inches (56 to 63 mm) deep.
- Saw joints approximately 1/8 inch (3 mm) wide as measured at the time of sawing.

Longitudinal Joint - (between Separately Placed Lanes)

Standard, 30-inch long tiebars can be installed in the slip formed edge of the pavement using a mechanical inserter at longitudinal joints when lanes are placed separately. This is normally done by a mechanical ram which pushes a tiebar 15 inches into the edge of the slab along the joint and at the center of the slab. Tiebars cannot be placed by hand. Bent tiebars are not permitted in longitudinal construction joints.

Figure 451.P – Mechanically inserted tie bars with slip form paver (Left), hook bolts used with forms (right)
(Note that spec now requires epoxy coated hook bolts)

The epoxy coated hook bolt or an epoxy coated hook bolt alternate (wiggle bolt) may be used in longitudinal joints when using fixed form paving. An epoxy coated coupling attached to one-half of the device is bolted to the side-form for the first lane placed. Before placing concrete in the adjoining lane, the other half is coupled to the embedded part after removal of the forms. The hook bolts are to be securely fastened to the forms so they are positioned properly in the slab. The right-angled hooks on each side of the coupling anchor provide the tie. The position of the hooks is not important, that is, they do not have to be turned down, up, or sideways.

The inside and outside edges of the paved lane must be edged to a 1/8-inch (3 mm) radius. The slab should be edged as soon as the concrete becomes stiff enough to remain firm without running back into the groove. The edge should be cut first with a small trowel and then followed by the edger. The edging tool should be held flat with the pavement surface. Tool marks left by the edging tool must be removed. Since the final texturing is to follow edging, this operation must not be permitted to lag.

Figure 451.Q – Radius edger and removal of tooling marks

Longitudinal joints (butt joints) between separately placed lanes require extra care to ensure that a smooth transition from one lane to the other will result. Good workmanship is necessary at these joints to obtain satisfactory results. Hand finishing and straight edging should be performed carefully so that each lane will be at the same elevation. The surface of the pavement in the joint area should not vary more than 1/8 inch (3 mm) from a 10 foot (3.0 meter) straightedge in both longitudinal and transverse directions.

Figure 451.R – Edging and finishing a longitudinal butt joint

Transverse Joints

Transverse joints include contraction joints, expansion joints, or expansion joints. All transverse joints are constructed normal (perpendicular) to the centerline of the pavement lane unless otherwise shown on the plans. All transverse joints require the use of smooth, epoxy coated, round dowels. The size of dowels is dependent on the thickness of the pavement as shown in Table 451.09-1 in the specifications.

Table 451.09-1 Dowel Size

Thickness of Pavement (T)	Diameter of Steel Dowels
Less than 8-1/2 inches (215 mm)	1 inch (25 mm)
8-1/2 to 10 inches (215 to 255 mm)	1-1/4 inches (32 mm)
Over 10 inches (255 mm)	1-1/2 inches (38 mm)

Load Transfer Devices (451.09.B)

Dowels can be placed in concrete pavement using dowel basket assemblies. Dowel basket assembly wires, as well as the dowels, are required to be epoxy coated according to 709.13 of the Specifications. Dowel basket assemblies shall conform to Standard Construction Drawing BP-2.2.

Dowel basket assemblies are not to exceed the maximum spacing for the type of pavement specified (reinforced or non-reinforced) and must be perpendicular to the centerline and edge of proposed pavement or forms. Locating the transverse alignment may be by any method that ensures a right angle to the centerline. On curves, the joints should be approximately on radial lines.

Transverse contraction joints must be continuous across the full-width of pavement placed. Therefore, the joint in a lane already placed must be continued across all other adjoining lanes.

Figure 451.S – Dowel baskets are pinned to the base material

When properly located and placed, dowel basket assemblies are anchored in place with steel pins. At least eight 1/2-inch (13 mm) diameter steel pins, 18 inches (460 mm) in length, are required to hold each 12-foot (3.6 m) basket assembly. The pins are driven at an angle to brace the assembly from lateral movement and to prevent vertical displacement when concrete is placed. Two of the pins are driven opposite each other at each end of the dowel assembly and the remaining four are driven in a staggered pattern

on each side. The assembly should not be hit when driving the anchor pins. If wires of the basket are bent, the dowels may be thrown out of line and require the entire assembly to be rejected unless it can be removed, straightened, and reset properly. Any badly distorted assembly should be rejected. The epoxy coating must not be damaged during the any operation.

If concrete pavement is placed on an existing concrete pavement or stabilized base, the dowel baskets must be held firmly in position by use of power-driven fasteners and appropriate clips or pins driven in predrilled holes of a diameter slightly less than the pin diameter. The Contractor may use either of these methods or a combination of the two in sufficient numbers to adequately anchor the basket assembly. The method used must secure the dowel basket from lateral and vertical displacement during concrete placement.

While the specification allows the use of steel bearing plates when placing basket assemblies on granular material that may distort, this practice is not common and should not be used for standard construction purposes. If there is a base stability problem this must be corrected before pinning basket assemblies.

Shimming of basket assemblies with pebbles, stones, wood, etc. is not permitted. If shimming is necessary, it is obvious either that the base is not prepared properly or the dowel basket assembly is bent or misaligned. In either instance, the base or assembly must be rejected until corrective action has been completed.

Dowel Shipping and Spacer Wires

After dowel assemblies have been set and anchored properly, the shipping and spacer wires used to hold both halves of the dowel basket together during shipping and handling must be removed. The shipping wire is normally cut at two locations and removed immediately prior to placing the concrete. The shipping and spacer wires are usually a small diameter wire parallel to the dowels and hooked or tack welded to the basket assembly wire. Shipping wires run the same direction as the dowels. Dowel basket assemblies must be anchored to the base before the shipping and spacer wires are removed.

Figure 451.T – Shipping wires fully removed (left) and only cut (right)

Checking Dowel Basket Assemblies

Specifications require that dowel basket assemblies be preset prior to the beginning of paving unless the Engineer determines that it is impractical to do so. This allows time to check the baskets to ensure they are parallel to the base and centerline of the pavement.

Checking of the assemblies is to be done after the removal of the shipping and spacer wires. Measurement checks of the distance between the dowel and the forms (made at each end of the dowel) or the proposed edge of pavement provide a check for being parallel to centerline. The distance to each end of the dowel must be equal for the dowel to be parallel to the forms and the centerline. After some experience, this check can be visual when fixed form paving since dowels out of alignment are easy to spot in relation to the forms.

Figure 451.U – Checking dowel level with an A-frame level

An adjustable A-frame level is used to check several dowels in every assembly unit to ensure that all dowels are parallel with the surface of the base. The level is first placed on the base adjacent to a basket assembly and adjusted to read level. The level is then placed on the dowels. The bubble will indicate level if the dowel assembly is set properly and is parallel to the surface of the base. Check as many dowels as possible, but at least three dowels should be checked in each 12-foot (3.6 m) section, one at each end and in the middle. If the dowels are not parallel with the surface when checked, the assembly must be adjusted and rechecked. If proper alignment cannot be obtained, the assembly must be removed and replaced.

Slip Form Paving using a Mechanical Dowel Bar Inserter (DBI)

The Contractor may propose to use a slip form paver with a mechanical device that automatically inserts dowels in the plastic concrete during the paving operation. Dowels placed using a DBI must be placed in the full thickness of the concrete pavement slab and spaced according to the standard construction drawings. A DBI is integral to a slip form paver and is located behind the vibrators and the initial strike-off of the paver. The DBI consists of a rack located above the slab and in the correct transverse locations across the slab. The loose dowels are loaded into the rack, and the dowels drop into place and are pushed into the fresh concrete using metal forks that push (and sometimes vibrate) the dowel to the correct elevation in the slab. The metal forks must insert each dowel so that it is parallel to the base and the pavement centerline and be at the center of the slab thickness. After the dowels are placed at mid-depth, the forks are withdrawn leaving the dowels in position and supported by the concrete. The dowels are to be installed after the concrete is placed to its full depth, and if required, after the mesh is positioned properly. The only operations permitted after positioning the dowels are the machine's final strike-off, mechanical float finishing, and hand finishing the concrete's surface.

The specifications require the Contractor to submit to the Engineer details and specifications of the proposed slip form paver with DBI at least 14 calendar days prior to bringing the equipment to the project. The use of the slip form paver with DBI must

be demonstrated using a test section and specialized scanning equipment to verify the location of dowels in the completed pavement.

Verification of dowel placement is done using MIT Scan-2 equipment and software. The MIT Scan-2 uses magnetic tomography to locate the dowels in three dimensions. The equipment provides an immediate print out in the field and a detailed report of each dowel in the joint including all measurements and a color depiction of the dowels in the joint.

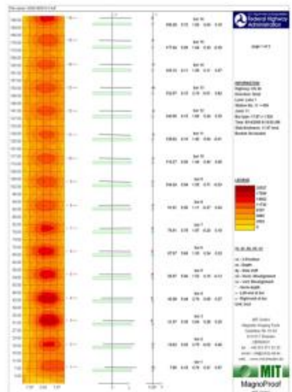


Figure 451.V – Checking dowel alignment using a MIT Scan-2 after placement with DBI

Dowels placed using a slip form paver with DBI have a required placement tolerance as shown in the Table 451.09-2. Note: dowel basket assemblies have tolerances as shown on Standard Construction Drawing BP-2.1. These are the manufacturing tolerances for the basket and dowels in the basket. As noted above, the dowel basket assemblies require checking for level and perpendicular placement with the joint.

Dowel misalignment can result in poor load transfer and joint locking which is detrimental to the performance of the pavement. 451.09-2 states the allowable tolerances for each of the following misalignment parameters:

Table 451.09-2

Individual Dowel Bar Alignment Tolerances

Alignment Parameter	**Acceptance Tolerance (inches)**	**Rejection Criteria (inches)**
Horizontal Translation [a]	±2.0	±3.0
Longitudinal Translation [b]	±2.0	±4.0
Vertical Translation [c]	±1.0	± T/6
Horizontal Skew [d]	±0.60	±1.0
Vertical Tilt [e]	±0.60	±1.0
Cover [f]	-	2.5 minimum

a. Horizontal Translation - the total difference, measured horizontally, between the actual dowel bar location and the plan required dowel bar location along the transverse contraction joint.

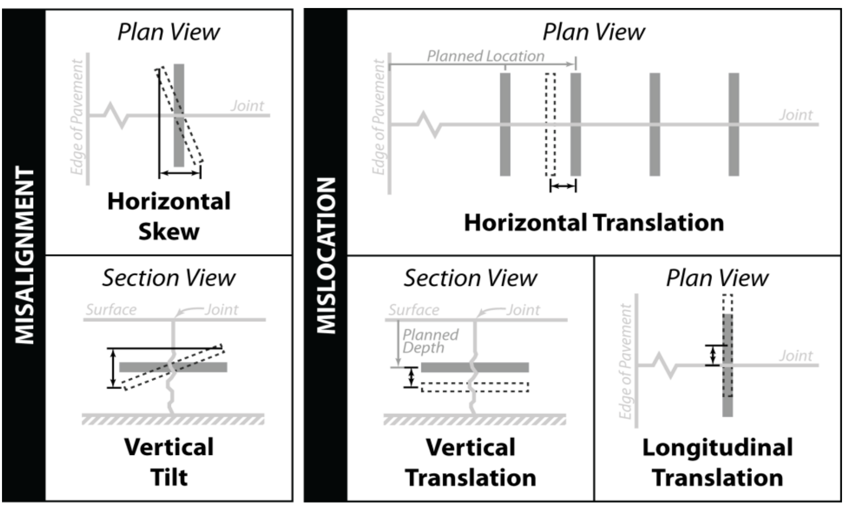
b. Longitudinal Translation - the total difference, measured in the longitudinal direction, from the center of the transverse contraction joint to the actual dowel bar center. Also termed as "side shift".

c. Vertical Translation - the total difference, measured vertically, between the centerline of the actual dowel bar location and the mid-depth of the slab. (T = Pavement Thickness in inches)

d. Horizontal Skew - the total difference, measured from end to end of a dowel bar, of the dowel in the horizontal plane.

e. Vertical Tilt - the total difference, measured from end to end of a dowel bar, of the dowel bar in the vertical plane.

f. Cover - the least distance between the surface of embedded reinforcement and the outer surface of the concrete.



Rotational misalignments (horizontal skew and vertical tilt) must be evaluated using a Joint Score Analysis per an FHWA publication called *Best Practices for Dowel Placement Tolerances* (CPTP Tech Brief, FHWA-HIF-07-021). The Joint Score is a measure of the combined effects of rotational misalignment.

The Joint Score (JS) is calculated using a weighting system that assigns a number to each dowel bar in a joint depending on the amount of deviation. The deviation is referred to as Single Dowel Misalignment (SDM), and is the resultant misalignment of a dowel. SDM is calculated as the square root of the sum of squares of horizontal skew and vertical tilt.

$$Single\ Dowel\ Misalignment\ (SDM) = \sqrt{(Horizontal\ Skew)^2 + (Vertical\ Tilt)^2}$$

Horizontal and vertical misalignments are the skew and tilt measurements determined using the MIT Scan 2. Once the SDM is calculated for each dowel in the joint; determine

the weighing factor (W) for each bar from Table 451.09-3; sum the W values for every dowel in the joint and add one (1) to calculate the Joint Score (JS).

Table 451.09-3

Weighting Factors in Joint Score (JS) Determination

Single Dowel Misalignment (SDM)	W, Weighting Factor
SDM ≤ 0.6 in. (15 mm)	0
0.6 in. (15 mm) < SDM ≤ 0.8 in. (20 mm)	2
0.8 in. (20 mm) < SDM ≤ 1 in. (25 mm)	4
1 in. (25 mm) < SDM ≤ 1.5 in. (38 mm)	5
1.5 in. (38 mm) < SDM	10

Joint Score (JS) – Evaluated for a single transverse joint between adjacent longitudinal joint(s) and/or pavement edge(s) (i.e., a typical 12 ft [3.6 m] standard lane or up to 14 ft [4.3 m] widened lane), and calculated as:

$$Joint\ Score\ (JS) = 1 + \sum_{i=1}^{n} W_i$$

where:

n = number of dowels in the single joint

W_i = weighting factor (Table 451.09-3) for dowel i

The Joint Score threshold for a locked joint of 10 (JS=10), was developed for a nominal pavement width of 12ft and must be adjusted to account for differing pavement widths. This adjustment is made using the Joint Score Trigger (JST).

Joint Score Trigger (JST) – A scaling of the Joint Score risk value to account for the actual number of dowels required in a single joint for pavement width other than 12 ft (3.6 m), calculated as:

$$Joint\ Score\ Trigger\ (JST) = 10 * \frac{\#\ of\ Dowel\ Bars\ in\ Single\ Joint}{12}$$

Include the Joint Score and Joint Score Trigger for every joint scanned in the report to the Engineer. Any joint with a Joint Score equal to or greater than the Joint Score Trigger is considered locked and rejectable.

Joint Score Example

- Excel spreadsheet from MIT Scan-2 software for Joint No. 24
- Horizontal and vertical misalignments shown on the spreadsheet as “sh” and “sv.”
- Calculate the resultant misalignment (deviation) as the square root of the squares of horizontal and vertical misalignments.

- Assign a weight for each dowel based on the resultant misalignment.
- Multiply the number of bars in each weight category times the weight.
- Total products of number of bars x weight and add 1.
- In this example, the Joint Score = 14.

Horizontal and Vertical (misalignments)

Resultant misalignment
= √(sh^2+sv^2)

Joint	Lane	Bar No.	X-Position	Depth	Depth Deviation	Side Shift	Misalignment	Horiz. Misal.	Vert. Misal.	Minimal Cover	Deviation	WEIGHT				Joint Score
Jo	La	BNo	xs	zs	dz	dy	s	sh	sv	c		0	2	4	5	
-	-	-	inch	inch	inch	inch	inch	inch	inch	inch						
24	La. 1	1.00	6.91	**6.09**	0.11	**2.89**	0.78	0.43	0.65	5.07	0.78		1			
24	La. 1	2.00	19.22	**6.09**	0.11	1.29	0.50	0.50	0.07	5.33	0.50	1				
24	La. 1	3.00	31.29	**6.07**	0.09	0.99	0.15	0.09	0.12	5.31	0.15	1				
24	La. 1	4.00	43.56	**6.14**	0.15	0.98	0.20	0.01	-0.20	5.34	0.20	1				
24	La. 1	5.00	55.39	**5.95**	-0.04	1.01	0.31	0.21	-0.22	5.14	0.31	1				
24	La. 1	6.00	67.48	**6.01**	0.02	0.56	0.35	0.05	0.35	5.14	0.35	1				
24	La. 1	7.00	79.45	5.87	-0.11	0.15	0.42	0.35	-0.24	5.06	0.42	1				
24	La. 1	8.00	91.72	**6.06**	0.08	0.18	0.34	0.34	0.05	5.31	0.34	1				
24	La. 1	9.00	103.86	**5.90**	-0.09	0.56	0.27	0.27	-0.02	5.14	0.27	1				
24	La. 1	10.00	115.92	**5.95**	-0.03	0.63	0.17	0.17	0.01	5.19	0.17	1				
24	La. 1	11.00	128.04	5.98	-0.01	-0.91	0.19	0.11	-0.16	5.20	0.19	1				
24	La. 1	12.00	140.09	5.51	-0.47	-1.27	0.42	0.14	-0.39	4.62	0.42	1				
24	La. 1	13.00	151.56	5.85	-0.13	-1.27	0.66	0.27	-0.60	4.85	0.66		1			
24	La. 1	14.00	163.66	6.06	0.07	-0.55	0.58	0.47	0.34	5.19	0.58	1				
24	La. 1	15.00	175.71	6.11	0.13	-0.97	0.32	0.19	0.26	5.28	0.32	1				
24	La. 1	16.00	188.00	6.16	0.18	-0.70	0.46	0.39	-0.24	5.34	0.46	1				
24	La. 1	17.00	200.28	6.09	0.11	-0.54	0.42	0.41	-0.08	5.33	0.42	1				
24	La. 1	18.00	212.14	6.24	0.26	-0.36	0.20	0.20	-0.03	5.48	0.20	1				
24	La. 1	19.00	224.11	6.46	0.47	-1.03	0.23	0.23	-0.01	5.70	0.23	1				
24	La. 1	20.00	236.20	6.77	0.79	-1.43	0.49	0.37	0.32	5.92	0.49	1				
24	La. 1	21.00	248.16	6.40	0.42	-1.15	0.16	0.14	0.07	5.64	0.16	1				
24	La. 1	22.00	260.33	6.59	0.60	-1.79	**0.96**	0.45	-0.85	5.46	0.96			1		
24	La. 1	23.00	272.43	6.48	0.50	-1.14	0.18	-0.17	-0.08	5.73	0.18	1				
24	La. 1	24.00	284.72	**6.48**	0.49	**2.41**	**1.95**	-0.39	1.91	4.82	1.95				1	
												0	4	4	5	14

Multiply the number of dowels in each Weight category times the Weight, (i.e., in Weight category "2" there are 2 bars ∴ 2 x 2 = 4)

Add all the products together and add "1" to get the Joint Score.

In this example the joint being measured is 24 feet wide so the number of dowels required is 24. The JST should then be calculated as follows:

$$JST = 10 * \frac{24}{12} = 20$$

We now check to ensure that the JS < JST and (14 < 20) so the joint has an acceptable joint score. Keep in mind that the JS is <u>not</u> the only a measure for a compliant joint. All other parameters of Table 451.09-2 must be met as well.

Test Section

Prior to using a slip form paver with DBI on a project, the Contractor is required to perform a test section of at least 500 feet. Every joint in the test section must be verified for accuracy of dowel bar placement using the MIT Scan-2 equipment. The slip form paver and DBI can be accepted for production paving if the following acceptance criteria are met:

1. Each Joint Score (JS) is less than Joint Score Trigger (JST);
2. Ninety percent (90%) of the dowel bars meet the Acceptance Tolerances of Table 451.09-2;

3. None of the dowels exceed the Rejection Tolerances of 451.09-2.

When the test strip does not pass the stated requirements, the Contractor must make adjustments to the paver, mix or other parameters and retest. In some cases, the Contractor may have to remove and replace the test section pavement.

New test strips are required at the beginning of every construction season, after any major paver repair or maintenance, at every mobilization and remobilization to a project, and after any major concrete mix design change. A paver that is approved for use on one project must still pass the test section requirement on every other project it is used on.

Any ferrous metal, namely tie bars, that is too close to the dowels being measured can reduce the accuracy of the MIT Scan-2 device. Determine during the test section if embedded tiebars or other project conditions are affecting the Rejection Tolerances and JS's. If the test section demonstration shows interference, exclude from the JS and JST calculations any dowel bar(s) closer than 12 in. (300 mm) in any direction to tiebars in the longitudinal joint(s). At the Engineer's discretion, establish the location of excluded dowels by another equivalent non-destructive method or by probing.

Paving Quality Control Testing (QCT) for Dowel Bar Inserters

After completion and acceptance of the test section, the Contractor can begin using the approved slip form paver and DBI. During production paving, perform quality control scans with the MIT-Scan 2 equipment at the following minimum:

Measure the alignments and location for every 10^{th} joint and calculate the JS and JST for each of those joints. QCT is acceptable when all of the measurements are within the tolerances of Table 4514.09-2, and JS is less than JCT.

1. When the daily Quality Control Testing (QCT) finds more than 10 percent of the joints scanned have dowels exceeding the acceptance tolerances of Table 451.09-2 but the JS is less than the JST, increase the scanning frequency to every 5th joint. Evaluate the paving process to reduce/eliminate misalignments and mislocations and continue to pave. The QCT frequency will revert back to every 10th joint when two consecutive days of scanning every 5th joint show no dowels exceeding the acceptance tolerances of Table 451.09-2 and all JSs are less than the JST.

   a) When QCT finds any individual dowel bars exceeding the rejection criteria of Table 451.09-2 or the JS is found to exceed the JST, the joint is considered to be locked and immediate investigation needs to be made as follows:

      i) Scan joints in front and behind the locked joint location until five (5) consecutive joints in both directions are found with no dowel bars exceeding the rejection criteria of Table 451.09-2 and no JS is found to exceed the JST.
      ii) If the additional scanned joints show no additional dowel bars exceeding the rejection criteria of Table 451.09-2 and no JS exceeding the JST, evaluate equipment to determine what caused the original problem. Before continuing paving increase the frequency of QCT to conform to 4.a.i.

      iii) If the additional scanned joints show additional dowel bars exceeding rejection criteria of Table 451.09-2 or joints with a JS exceeding the JST,

stop paving. Investigate to determine the cause of the dowel bar rejection issues and provide the causes and alternative corrections to the Engineer.

The Engineer will determine if the corrections will correct the problem and may allow paving to temporarily continue to validate if the corrections work. During any evaluation, scan all joints to determine if the corrections were successful. If successful, continue QCT scanning at the frequency of 4.a.i. If not successful, discontinue paving, repair or replace the slip form paver and DBI, and repeat the Test Section.

All dowel bars found beyond rejection criteria of Table 451.09-2 or joints with a JS exceeding the JST require a corrective action proposal conforming to 451.09.B.5, Corrective Action.

Corrective Action
The contractor must submit a proposal for corrective action to the Engineer for any dowel that exceeds the rejection criteria in Table 451.09-2 or any joint that has a JS greater than the JST. The Engineer should evaluate the proposal and approve of any corrective actions prior to them being performed by the contractor. The following in the corrective action proposal includes the following:

1. Locations of all rejectable dowels along with identification information.
2. Locked joint identification information.

Proposed method of remediation for each identified location, including documentation supporting the effectiveness of this proposed remediation.

Corrective action for all JS exceeding the JST may not be required, if they are random in nature. Up to two (2) consecutive joints with a JS exceeding the JST may be accepted, provided that the adjacent three (3) joints before or after do not have dowels exceeding Table 451.09-2 rejection limits and have JS's less than the JST. Corrective action is required where there are more than two (2) consecutive joints with a JS exceeding the JST.

No corrective action shall take place prior to the approval of the proposal by the engineer.

Expansion Joints (451.09.C)

Relief for compressive forces that are caused by movement in the pavement (typically in hot weather) is provided at bridges, structures, and intersections in the form of expansion joints. Expansion joints permit contraction and expansion of the concrete pavement.

The first two regularly spaced joints in the concrete pavement adjacent to a bridge approach slab must be expansion joints (when a pressure relief joint is not included in the plans). Other expansion joints may be detailed in the plans at locations at other structures and intersections. Standard Construction Drawing, BP-2.2 provides additional information on the installation of expansion joints. All expansion joints are doweled and allow the pavement to expand or grow due to temperature variations. A standard expansion joint allows for 1 inch (25 mm) of expansion.

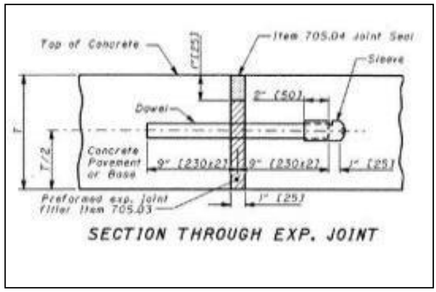


Figure 451.W – Typical expansion joint (left), SCD BP-2.2 detail of expansion joint section

If the pavement consists of two or more separately placed lanes, the expansion joints must be a continuous straight line for the full-width of the concrete pavement, including concrete shoulders. All expansion joints are perpendicular to the centerline adjacent to a skewed approach slab.

Preformed compressible material, 1 inch (25 mm) thick, is installed in the dowel assembly at the location of the expansion joint. It must be set perpendicular to the dowel as well as perpendicular to the line of forms and the pavement centerline. The material must extend down to the base and to the side forms to allow free movement throughout the entire joint. The top of the expansion material is held 1 inch (25 mm) below the pavement surface. It is permissible to place the expansion material closer to the pavement surface to facilitate sawing of this joint, provided all material is removed to a depth of 1 inch (25 mm). The 1 inch by 1 inch area at the top of the expansion joint shall be sealed using a hot applied joint sealer which meet the requirements of 705.04.

Standard 18 inch (460 mm) long epoxy coated dowels are required for load transfer in all expansion joints.

Inspectors must ensure that the 1 inch (25 mm) thick, preformed expansion joint filler is held rigidly in position and extends the full-width of all lanes. The preformed expansion joint filler must be the required height and must extend to the top of the base, or bottom of the new pavement, so that no concrete is permitted to flow under it. Holes in the expansion joint filler must be neatly punched or drilled, and the dowels must fit tightly through the holes with no gaps in which concrete could flow through.

The dowels are oiled within 2 hours of placing the concrete with new form oil as is required for contraction joints. After oiling, an expansion cap, also called a sleeve, is placed on the opposite ends of adjacent dowels (each dowel will have one cap, but on alternate ends) to create a void in the concrete to permit expansion movement. The cap contains a crimp or stop that provides for the 1-inch (25 mm) void. These caps must not be forced beyond the crimp; otherwise, the space for expansion will be compromised and the joint will not function properly.

The Contractor must provide adequate consolidation throughout the slab depth, adjacent to the preformed expansion joint filler, and around dowels by use of hand-held internal vibrators. The top of the joint must be formed to a 1-inch (25 mm) wide and 1-inch (25 mm) deep opening, carefully edged using an edger having a 1/8-inch (3 mm) radius on top of the preformed expansion joint filler, and sealed with 705.04 joint sealer.

Contraction Joints (451.09.D)

Contraction joints in concrete pavement are constructed at right angles across a pavement lane unless otherwise specified by the plans. These joints control cracking of concrete pavement that result from stresses from volume changes during curing of the concrete. These joints are designed to transfer the loading from traffic from one slab to the next and require the use of dowel bars to accomplish this function. These dowel bars are called load transfer devices. Dowel bars can be pre-installed using dowel bar assemblies (basket assemblies) or can be installed using dowel bar inserters during slip form paving.

Dowels must be spaced at 12-inch (300 mm) centers beginning 6 inches (150 mm) from the longitudinal joint. The spacing between the end dowel and the outside edge of the lane may be increased up to 12 inches (300 mm). A dowel must be placed 6 inches (150 mm) from the outer edge of the pavement when the spacing between the end dowel of the basket and the outside edge exceeds 12 inches (300 mm). Contraction joints are required to be spaced in the pavement at intervals not to exceed the maximum spacing indicated in Standard Construction Drawing BP-2.2 or the plan construction drawings. The maximum contraction joint spacing for reinforced concrete pavement (Item 451) is 21 feet (6.5 m). For non-reinforced concrete pavement (Item 452) and concrete base (Item 305), the maximum spacing is 15 feet (4.6 m).

To function properly, dowels must be placed parallel to the surface and parallel to the centerline of the pavement since expansion and contraction movements occur in this direction.

Saw Cutting Contraction Joints

When a standard (water cooled diamond bladed) concrete saw is used to cut the contraction joint, the following applies:

- Pavement ≤ 10 inches thick: Saw the joint to a minimum depth of one-fourth the specified pavement thickness.
- Pavements > 10 inches (255 mm) thick: Saw the joint to a minimum depth of one-third the specified pavement thickness.
- Saw joints 1/4 ± 1/16 inch (6 ± 1.6 mm) wide as measured at the time of sawing.

When using early-entry (dry cut, lightweight) saws, only use saw blades and skid plates as recommended by the manufacturer. Perform the early entry sawing after initial set and before final set as follows:

- Saw the joint 2-1/4 to 2-1/2 inches (56 to 63 mm) deep.
- Saw joints approximately 1/8 inch (3 mm) wide as measured at the time of sawing.

Joints should be spot checked to make sure that the Contractor is sawing the pavement to the required depth.

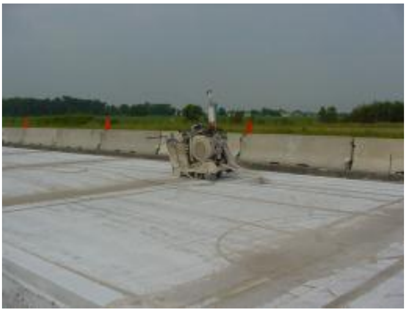


Figure 451.X – Standard water cooled saw (left), early entry saw (right)

If a crack appears ahead of the machine during pavement sawing, it is an indication that sawing is late. When such cracking is noted, stop sawing that joint immediately and move the saw ahead several joints. Saw a joint, move ahead several more joints, and saw another joint. Continue skipping three or four joints and sawing every fourth or fifth joint until sawing is back on schedule. The presence of slight raveling indicates proper timing of sawing. Saw every joint in order when sawing is back on schedule. After sawing has been completed for the day's production, the saw can be returned to saw the skipped joints. The standby saw may be put into service to saw the skipped joints if an experienced operator is available.

This procedure of skipping ahead and sawing every fourth or fifth joint relieves the stresses that occur when the concrete hardens and shrinks during curing. Once these stresses are relieved, the sawing of the in-between joints is not as critical, but should be done as soon as possible.

The following day, the pavement is normally subjected to expansive forces when the temperature rises. When temperatures drop during the evening of the following day, the pavement experiences shrinkage stresses and all joints originally bypassed must be sawed before these stresses result in random cracking.

A HIPERPAV analysis for each day's paving is required to be completed by the Contractor. HIPERPAV software is used to help determine the correct time for sawing and potential for early age cracking based on mix design, pavement configuration, and environmental factors. HIPERPAV generates the critical stress-to-strength of the pavement for the first 72 hours after placement. Supplement 1033 provides HIPERPAV details. HIPERPAV files must be provided to the Engineer prior to paving. If the critical stress-to-strength ratio is 98 percent or greater, the Contractor is required to modify the paving operation and rerun the HIPERPAV analysis.

Generally pavement should be sawed the same day, usually 6 to 8 hours after placing. Concrete placed late in the day may not harden to permit sawing until the next day, but sawing should be completed before the following late afternoon temperature change, as shrinkage will occur as temperatures drop. The Contractor is responsible for determining the optimal sawing time to prevent uncontrolled cracking.

Joints in lanes adjacent to previously placed lanes that are tied together must be sawed as soon as possible to prevent uncontrolled cracking. If a new lane is tied to an existing concrete pavement, which is expanding and contracting with changes in temperature, stresses will be transmitted to the new slab unless joints are sawed as quickly as possible. The following provisions are important to obtain quality sawed joints in these areas:

- All contraction joints in the previously placed lane of pavement must be in-line with those in the newly placed lane.
- The joint sawing must be done as soon as the saw can be operated on the newly placed pavement lane without damaging or excessive raveling of the joint.
- Full-depth joint cracking in the previously placed lane indicate movement. Therefore, joints in the newly placed lane, which are in line with the cracked joints, must be sawed first.
- The cut is to be made from the old slab to the outside or open edge of the new slab being sawed.

A sudden drop in temperature, wide variations in day and night temperatures, or a cold rain cause thermal changes and add stress, thus making the timing of sawing especially critical. When these conditions occur or are anticipated, increased attention to the sawing operation to assure control of cracking is needed.

Construction Joints (451.09.E)

Construction joints are transverse joints placed at the conclusion of each day's paving or when production is interrupted for more than 30 minutes. These joints are formed by using an adequate bulkhead that provides a straight joint. Construction joints in all concrete pavements are to be doweled and perpendicular to the centerline. Construction joints may be located at a contraction joint or between contraction joints. The bulkhead must have openings provided for individual dowels or a dowel basket assembly. The bulkhead must be shaped to conform to the typical section of the pavement.

Locate construction joints at or between contraction joints. If located between contraction joints, construct the construction joint no closer than 10 feet (3 m) to the last contraction joint.

In non-reinforced concrete base (305), construction joints must not be closer than 6 feet (1.8 m) to another transverse joint.

At skewed joints between approach slabs and approach pavement, exercise care to position the dowels parallel to the centerline. Recent experience indicates movement occurs at such joints. Make provisions for this movement by placing dowels the same as for contraction joints.

The joint may be hand-formed or sawed to the same dimensions required for transverse joints in adjoining pavement.

Figure 451.Y – Transverse construction joints are doweled

Smooth epoxy-coated dowels must be used in construction joints placed parallel to the surface of the base. The free half of all dowels must be coated with a thin, uniform coat of new light form oil within two hours of concrete placement. The dowel size and spacing is the same as required for standard contraction joints. See 451.09.B for those details.

Finishing (451.10)

Finishing behind the concrete paving operation can be done by a variety of methods. In all cases, a 10-foot straightedge must be used to continually check the pavement surface for smoothness.

Paving operations may include floats of different configurations behind the paver. Some slip form pavers include oscillating longitudinal floats or other types of "automatic" floats attached to the paver. Regardless of the type of machine floating, a straightedge should be used to check the pavement surface.

The Contractor is required to round the edges of the pavement slab to the radius specified before the concrete sets. For an inside slab edge, the radius is to be 1/8 inch (3 mm), and for an outside slab edge, the radius is typically 1/2 inch (13 mm). Any tool marks left by the edging tool must be eliminated.

Some slip form paving machines trail several sections of forms while others have no trailing forms. When trailing forms are used, they provide protection to the edges while the surface is straight edged. However, straight edging should not be confined to the area of the trailing forms.

Final finishing is perhaps the most important step in the paving operation, at least from the public viewpoint, because it determines whether the final surface meets the necessary tolerance for a smooth riding surface. Projects using high-strength, quality concrete and the best of modern paving equipment often end up with substandard surfaces, simply because of careless work and lack of attention to details during final finishing.

The work of the hand finishers will be simplified if forms or string lines are set accurately. The finishing machines must also be adjusted and operated properly. If finishing machines are not operated properly, additional work is required for the hand finishers to correct surface irregularities and to produce an acceptable surface that complies with the specifications. The preferred method is to keep the machines in proper adjustment and limit the amount of handwork that is required. In any case, it is up to the Inspector to insist that the finishers produce a pavement with the required smoothness and an acceptable uniform final surface texture.

The Inspector should ensure that the finishers check their hand tools before paving operations begin to make sure that they comply with specifications. Straightedges should be tested with a string or a master straightedge to make sure they are straight. Inspection of tools should be done daily to correct for wear. Tools should be restored to the desired accurate form. They must be rigid enough to remain straight with no bending while in use.

After mechanical finishing, while the concrete is still plastic, minor irregularities and surface marks should be removed with a scraping straightedge. When necessary, remove excess water and laitance from the surface transversely by means of a scraping straightedge. Any such excess should be wasted over the forms or removed from the pavement edge if slip forming.

A number of different types of straightedges have been used satisfactorily. They must be strong enough to maintain a true straightedge and yet light enough to handle. In some cases, they must be heavy enough to cut or scrape off any high spots left by the machine finishing operations. They must be a minimum of 10 feet (3.0 meters) long to comply with the specifications.

Figure 451.Z – Highway straightedges/bump cutters behind the automatic float

The straightedge is operated from the side of the pavement transversely and should be advanced along the pavement in successive stages. By proper manipulation, it can be used as a float to smooth the surface or as a cutter to remove high spots. Long-handled floats may be used to smooth and fill in open textured areas in the surface, but this must be done before straightedge finishing. The use of such floats should be held to a minimum. If open textured areas persist, the aggregate grading, mix design, and the method of placing the concrete must be evaluated and corrected. A properly proportioned mix along with correct paver operation should not require excessive hand floating.

No water is to be added to the surface during this or any other operation. This includes sprinkling of water on the surface using a brush, spraying, or otherwise introducing additional water into the finishing process. Adding water reduces the air entrainment in the surface causing a mortar layer that will not be resistant to freezing and thawing. This thin weak surface layer will pop off over time.

Texturing

The final surface texture should be applied when most of the water sheen has disappeared, but before concrete becomes non-plastic. Finishing methods used must produce the texture as described in the appropriate specification item.

Unless otherwise specified, concrete pavement (451 and 452) must be textured by the use of a broom drag in the longitudinal or transverse direction immediately followed by an approved device which produces a random pattern of grooves in the longitudinal direction. The broom drag must produce a uniform, gritty texture. Brooms suspended from a machine or truss and dragged over the pavement surface have provided satisfactory longitudinal texture. The broom should be lifted clear of the surface when not being used.

Figure 451.AA – Machine brooming in longitudinal direction (left), transverse direction (right)

Concrete base pavement (Item 305) must have a final surface finish that is a uniform, gritty texture as obtained with a broom drag in the longitudinal or transverse direction. No grooves are put in base pavement because it is normally covered with asphalt concrete prior to opening it to traffic.

The broom drag provides a more skid resistant pavement. The Department has found that new concrete pavement would lose skid resistance after one year of service with merely a light burlap drag prior to tine grooving. Broom dragging roughens the area of concrete between grooves that results in a longer lasting skid resistance.

Immediately after brooming, the pavement is longitudinally tined using a uniform tine spacing of 3/4 inches, 1/8 inch wide, and 1/8 inch deep. Longitudinal tining must be applied using a machine specifically made for this application and must be controlled from a stringline that controls the line and grade of the tining operation. Longitudinal tining shall be kept 3 inches from the edge of pavement and any longitudinal joint.

Small areas may be longitudinal tined with non-machine operations. This may be done only with the approval of the engineer. The finished longitudinal tining will be straight to within 3/4-inch in 20 feet (20 mm in 6.4 m).

Figure 451.BB – Longitudinal tining

Station Numbers

The Contractor is required by specification to stencil complete station numbers into the plastic concrete pavement (Item 451 and 452) each 100 feet (50 meters) before the concrete sets. The dies used to form the station numbers must be 3 to 4 inches (75 to 100 mm) high and 1/4 inch (6 mm) in depth. The numbers are placed parallel to the pavement edge, centered 12 inches (0.30 m) from, and facing the right edge of the pavement. For

the purposes of placing station numbers, the right edge is the edge to the right of the normal direction of travel.

The numbers should be impressed into the plastic concrete following the texturing of the surface and before curing is applied. If the impression is made too early, the number will tend to close up and not be as distinct as desired.

For divided highways, station numbers must be provided for each pavement direction.

If concrete shoulders are placed with a traveled lane, the station numbers should be placed 12 inches (0.3 m) in from the outside edge of the shoulder and facing the pavement.

Station numbers are not required on concrete base (Item 305).

Curing (451.11)

Curing is the treatment or protection provided to concrete during the curing period. Proper curing consists of keeping the concrete moist and preventing rapid evaporation of the mix water to ensure adequate hydration of the cement. Curing protects concrete from early shrinkage due to changes in temperature and/or loss of moisture before it has developed sufficient strength to resist the resulting tensile stresses.

It is extremely important to provide adequate curing during the first few days, with the first few hours being most important to obtain a strong durable pavement. Strength loss due to lack of moisture during this period is difficult to regain even with subsequent curing.

During windy, hot, dry weather, it is very important that finishing is completed rapidly and the curing be placed before the surface dries out to the extent that plastic shrinkage cracks develop. These cracks can never be sealed, and they are an indication that the surface may have been depleted of the necessary water to properly complete the chemical reaction of cement hydration. Water curing may halt this shrinkage cracking, but the addition of more water will not correct the cracking once it occurs.

In cold weather, the concrete may continue to bleed after finishing. Take care in placing any type of curing under these conditions so that the surface will not be marked.

Prior to the application of any curing material, ensure that it meets the requirements of 705.05, 705.06, or 705.07 Type 2. This also applies to any equipment used in the application.

Liquid Membrane Curing

For concrete pavement, an approved curing membrane must be sprayed on all exposed surfaces using a self-propelled mechanical sprayer with adequate shielding to prevent overspray to adjacent areas from wind. The curing membrane must be applied at a minimum rate of 1 gallon per 150 square feet (1 liter per 3.6 square meters) as soon as the free water has dissipated from the surface. Approved liquid membrane curing compounds are white in color so that coverage can be readily observed. They are sprayed over the exposed concrete faces while the concrete is still plastic. Hand spraying can be used on pavement with integral curb, for small irregular areas, sections of variable width, and on pavement edges after form removal.

Project inspection should include a daily check of the Contractor's curing compound application rate to ensure that the correct amount of curing membrane was applied to the pavement. To do this check, determine the amount of curing compound required for the day's placement and compare it to the amount of curing compound actually used by the Contractor.

To calculate the amount of curing compound required, the area in square feet (square meters) of pavement that is to be cured must be determined. This area includes the top surface of the pavement plus the area of any pavement edges that are to be cured if the Contractor is slip form paving. Once the area has been calculated, it is divided by the specified application rate in gallons per square yard (liters per square meter). The formula below is used to calculate the required amount of curing compound in gallons (liters):

$$\textit{Required Gallons} = \frac{\textit{Area (square feet)}}{\textit{Rate (gallons/ square feet)}}$$

$$\textit{Required Liters} = \frac{\textit{Area (square meters)}}{\textit{Rate (liters/square meter)}}$$

The above equations give the amount of curing compound required in gallons (liters). The amount of gallons (liters) required is compared to the amount that was actually used during the day's work. The amount of gallons (liters) of curing actually used must be equal to or greater than the required amount of gallons (liters).

If properly applied, these membrane-forming compounds prevent evaporation and the retained water provides excellent curing. Therefore, make sure that the specified rate of application is adhered to and the curing compound is applied evenly. This ensures that a uniform thickness of membrane coating is obtained. If this is not done, the quality of the concrete pavement will be affected. It should be noted that concrete with a grooved (tined) surface may require more curing compound to obtain complete coverage than a base pavement without tining. The specified application rate is a minimum and the Contractor must use more if the visual coverage is lacking.

White pigmented compound is the only membrane curing compound acceptable on paving projects. This has an advantage over clear type compounds in summer construction in that it provides a coating that reflects heat from the surface. This decreases heat absorption in the pavement and the tendency for transverse cracks to develop during warmer afternoon temperatures. In addition, its white color permits visual inspection for uniform coverage.

The white pigment used in the membrane acts as an abrasive that tends to enlarge the apertures of the spray nozzles and to reduce the efficiency of pumping equipment. Equipment used to apply membrane should be cleaned frequently and checked to see that it provides a uniform protective covering. Streaks, lines, and dribbles indicate malfunctioning sprayers. The Contractor must correct the equipment to provide uniform, consistent coverage over the entire pavement.

Figure 451.CC – Cure / texture machine

Water Curing

A water cure using wet burlap, waterproof paper, or polyethylene sheeting may be used; however, this type of curing must remain in place for 7 days unless test beams have attained a modulus of rupture of 600 psi. This type of curing should be placed as soon as possible without marring the surface.

The Contractor may choose to water cure by placing wet burlap on the exposed surfaces followed by waterproof paper or polyethylene sheeting. Make sure that the pavement is kept wet at all times. This type of curing requires constant checking throughout the curing period. This method is not used very frequently; therefore, it is not discussed in detail.

Waterproof paper or polyethylene meeting specification requirements (705.05 and 705.06) are placed on the concrete as soon as possible after finishing, without marring the surface, and are left in place for the full curing period.

The combination of wet burlap and waterproof paper or polyethylene sheeting is less labor intensive than a burlap-only cure, because it will keep the concrete wet and does not require regular wetting.

Curing blankets, sheeting, and burlap should be placed to cover the full lane width and lapped at least 12 inches (0.3 m). Edges should be completely covered when forms are removed. This may be done by turning down the edge of the blankets or narrow strips pulled out from under them. These narrow strips are placed on the concrete before main sheets are laid.

Curing materials should never be dragged over fresh concrete and should be placed so as not to mar the surface. One of the principal precautions in this curing method is to ensure edges along forms are sealed so there is no possibility of air getting under the curing material. This is important because air can circulate over the pavement drying out the

surface and resulting in inadequate curing. In addition, heavy winds will get under the blankets and rip them off leaving the pavement without any curing at all.

All physical curing blankets, sheeting, etc., must be free of holes and torn areas and must be securely anchored against blowing. These types of curing methods must be checked daily.

Removing Forms (451.12)

The presence of forms during early curing protects the pavement edges against damage and serves as a curing method (for the pavement edges only).

During warm weather, the common procedure is to remove the forms approximately 24 hours after the concrete is placed. During cold weather, it may be advisable to leave forms in place for a longer period. In any event, forms should not be removed until the concrete has attained sufficient strength to prevent damage to the concrete surface or breaking of the edges during removal.

The method used to remove the forms should not damage the concrete pavement. In addition, the Contractor should be encouraged to use a method that will not bend or otherwise damage the forms. The method used to move forms away from concrete should ensure that each form section is pulled horizontally away from the edge before it is lifted.

Pin keys should be loosened first, form joint locks unfastened, and nuts removed from the ends of hook bolts (single lane paving). Then, pins should be removed from their sockets using a direct vertical lift without any pressure toward the concrete. The action necessary to exert the vertical lift should be from the forms or the ground outside forms. If any equipment is used to pull pins that may ride on the concrete, make sure that no pressure is on the concrete other than the weight of the equipment.

After pins are removed and other preliminary work finished, light blows with a hammer or careful prying on base flanges may be used to separate forms from concrete. Prying against the concrete edges with bars to break forms loose should never be permitted.

When forms have been removed, edges should be checked immediately and honeycombed areas filled with mortar. Inspect filled areas to make sure the entire areas are tightly packed and struck off flush with surface of the pavement edge.

Curing must be applied to the edges as soon as forms have been removed and edge patching has been completed. This ensures curing was satisfactory as well as prevents the loss of water necessary for hydration of the cement.

Surface Smoothness (451.13)

There are two methods that could be used to check the smoothness of a completed concrete pavement. Item 451.13 requires the use of a 10-foot rolling straightedge or Proposal Note (PN) 420 that requires the use of a non-contact profiler to measure smoothness. When PN 420 is required as part of the Contract documents, 451.13 does not apply.

When 451.13 applies, the Contractor is required to check the surface smoothness of the completed pavement using a 10-foot rolling straightedge or equipment conforming to

Supplement 1058 and output using ProVal software conforming to PN 420 for a 25-foot localized roughness criteria (see the section on PN 420 below). The rolling straightedge can be two- or four-wheeled with an indicator wheel in the center that detects high and low areas in the pavement surface. This equipment must alert the operator when encountering any high or low areas of pavement in excess of a preset tolerance. This alert may be by a pointer scale, by audio, or by marking the pavement surface with dye or paint.

Testing is done after the final curing and cleaning of the pavement to detect any surface variations that are in excess of the allowable tolerances. For pavements, the tolerance is 1/8 inch in 10 feet (3 mm in 3.0 m). For ramp pavements, and for those pavements that exceed an 8 degree curvature or 6 percent grade, the tolerance is 1/4 inch in 10 feet (6 mm in 3.0 m).

Figure 451.DD – 10 foot rolling straightedge

The Contractor must tow or walk the equipment over the completed pavement. The Contractor must test two lines, one in each wheel path, in each 12-foot (3.6 meter) lane. The wheel paths are located 3 feet (1 m) measured transversely from the pavement edge on each side.

Proposal Note 420 – Surface Smoothness Requirement for Pavements

Larger concrete paving contracts (those exceeding 1 mile in centerline length) generally include Proposal Note (PN) 420 Surface Smoothness Requirements for Pavements. When this proposal note is included, the provisions of 451.12 do not apply and the Contractor is required to use the information included in PN 420 to determine surface smoothness. This proposal note requires testing of the surface of completed pavement with a non-contact profiler and ProVAL software that will produce an International Roughness Index (IRI).

The non-contact profiler must meet the requirements of Supplement 1058. The equipment and operator must be previously approved by the Department. All equipment and operators that are approved are listed on the Department's website. The equipment

and Operator must be checked against the Contractor's approval letter and against the Department's website. The Contractor must demonstrate the use of the equipment prior to its use on the project.

Figure 451.EE – Non-contact profilers
Low-speed type used for daily checks and high-speed type for payment

The Contractor is paid a bonus for exceptionally smooth concrete pavement and there are deductions if the pavement is not constructed smooth enough. The pavement must be of a certain level of smoothness to be accepted, otherwise, corrective work is required. The IRI is measured for localized roughness (bumps) for any 25-foot section and for smoothness of any 0.10 mile section. Where there is localized roughness with an IRI greater than 160 inches per mile in 25 feet, corrective work is required. For an IRI greater than the requirements of PN 420 (currently 95 inches per mile) in any 0.10 mile section, corrective work is also required.

Defective work, as described under PN 420, includes removal and replacement or diamond grinding to restore the surface to within the tolerances required.

Profile Grinding (451.14)

When 451.13 applies, and the surface deviations as measured with the 10-foot rolling straightedge must be ground, the diamond grinding equipment must conform to Item 257. Bush hammering, carbide tipped grinders, or any method that may damage the bond of the aggregate or shatter the aggregate is not permitted.

A 10-foot (3.0 meter) straightedge must be used to check for compliance when corrective work is in progress. The straightedge can be used to determine the transverse limits of the area to be corrected. Usually variations extend beyond the wheel path and may require diamond grinding and grooving the entire lane width. This determination can only be made by checking with a straightedge.

Low areas should be corrected by grinding on each side until within tolerance. If these areas cannot be corrected by grinding, they must be repaired or replaced to the satisfaction of the Engineer.

Pavement Grooving Corrections (451.15)

It may be necessary to restore grooves in concrete pavement after the concrete has hardened when the finishing operation does not conform to 451.10 and/or when the tining operation does not provide the correct pattern or depth. Grinding to restore trueness leaves a corduroy texture in the longitudinal direction. The randomly spaced transverse grooves must be restored as detailed to the dimensions given in 451.10.

The equipment required for transverse grooving must be self-propelled, power driven machines specifically designed to groove hardened concrete pavement with diamond impregnated blades or diamond impregnated cylinder rings. The blades or cylinder rings must be mounted on an arbor head so the resulting grooves are randomly spaced. The grooving equipment must have a depth control device that detects variations in the surface and adjusts the cutting head to maintain the proper groove depth.

Note: When pavement is ground to meet the requirements of 451.13 Surface Smoothness or PN 420, the restoration of transverse grooving is not required.

Sealing Expansion Joints (451.16)

Only expansion joints are required to be sealed. This should be done as soon as possible after saw cutting and before the pavement is open to construction equipment or any other traffic. Proper sealing prevents intrusion of stones and debris into the joint that would keep it from opening and closing as designed with the movement of the pavement.

The Engineer may allow the use of a temporary seal material to allow opening to traffic. This material must be removed prior to the final sealing of the joint.

All joints must be cleaned prior to filling. Cleaning consists of operating a saw blade backward through the saw groove to remove all pebbles, trash, dirt, etc. Any other operation which satisfactorily cleans the groove is permissible. The final step in cleaning consists of blowing out the joint opening using compressed air or by a jet of clean water.

Hot-applied joint sealer (705.04) is required for sealing expansion joints. Since the hot applied sealer requires heating, frequent checks should be made to avoid overheating to a temperature higher than the manufacturer’s recommendation.

Joint walls must be inspected just ahead of filling to make sure that they are dry and thoroughly clean. It is essential that the walls be in this condition if the sealer is to function properly. If the sealer fails to adhere to the concrete, water and foreign material will enter the joint.

Pour liquid sealing compounds in such a manner that complete filling from the bottom of the joint slot to approximately level with the surface of the pavement is assured. With some compounds it may be necessary to fill the joint in several applications. Workers should not allow the sealing compound to spatter or drip onto the adjacent pavement.

The sealing material will run to the low side if the joint is filled too fast. Hot poured compounds may flow out of the joint at the edge of the pavement if some method of plugging the edge is not used.

As air temperature increases, the pavement will expand or lengthen and the joints will close. Conversely, the slabs contract as the temperature falls, causing the joints to open. Joint filling should be such that the surface of the hot-applied sealing material will be

approximately level with the pavement surface when the pavement temperature is about 70 °F (21 °C).

Never over-fill a joint to the extent that a bump will be produced at the joint. Such a practice is a waste of material, creates an unsightly condition, and affects the riding quality of the finished pavement. The bumps created by the excessive material will be readily noticeable to the traveling public from a smoothness standpoint as vehicles pass over each joint.

Prior to final acceptance of the pavement, any unsatisfactory joint seal should be removed and replaced. All low spots in sealing compounds must be brought to the desired level, and any high spots should be cut off and the excess material removed.

Opening to Traffic (451.17)

The completed pavement may be opened to traffic, including construction traffic, after 7 days have elapsed. The pavement may be opened to traffic after 5 days provided the modulus of rupture of the test beams is 600 pounds per square inch (4.2 Mpa) or greater.

If it is determined by the Engineer that it will be necessary to open a portion of the pavement in fewer than 5 days, high early strength Class QCMS concrete may be used, and the pavement may be opened to traffic after 3 days provided the test beams attain a modulus of rupture of 600 pounds per square inch (4.2 Mpa) or greater. In no case should concrete pavement be opened in less than 3 days.

Concrete test beams are required for each 7,500 square yards (6,500 square meters), or fraction thereof, of pavement placed each day. Instruction for making and testing beams are found in Item 499. Beams are tested at the project by the project personnel.

Beams normally are tested at 5 and 7 days. If results are not needed before the end of 7 days, only one beam break is necessary. This break should be made at the age of 7 days.

The maximum capacity of the beam breaker is 1,000 pounds per square inch (6.7 Mpa) and is marked on the beam breaker dial. The capacity must not be exceeded. Beams that do not break when loaded to the capacity of the breaker should be recorded as >1,000 psi (>6.7 Mpa) or whatever the unbroken strength was when the test was stopped, such as 850 psi + (5.9 MPa +) for example.

Slump, air, and yield tests shall be made and recorded each time beams are cast. Concrete for these tests shall be obtained from the same batch of concrete that was used in casting the beams.

The Contractor is responsible for repairing cracked or deficient pavement at no cost to the Department. These deficiencies include:

- Transverse or diagonally cracked full-depth pavement.
    - There is an exception for reinforced 451 pavement that accepts a tight, mid-panel transverse crack. See 451.17.
- Longitudinal cracked full-depth pavement.
- Spalled pavement surfaces.
- Pavement panels which have cement or mud balls.

The Contractor must submit a detailed repair plan to the Engineer for review and approval prior to performing any repair work. The plan must specify location, repair type,

materials and procedures. Some common repair methods for isolated defects are listed in 451.17. These repair methods should only be used for isolated defects. Large or repeating areas of defects should be removed and replaced. Repairs for isolated defects may include the following:

A. Transverse or diagonally cracked full-depth pavement.

Repair with a full-depth repair according to Item 255 and applicable standard construction drawings. Repair cracks by replacing the pavement the full-width and full-depth between longitudinal joints, perpendicular to the centerline, and at least 6 feet (1.8 m) longitudinally. Install smooth dowel bars at the interface between the original pavement and the replaced pavement section. Locate and size the repairs to ensure that the repair limits are at least 7 feet (2.1 m) away from any transverse joint. Item 255 and Standard Construction Drawing BP-2.5 applies.

B. Longitudinal cracking cracked full-depth pavement.

Repair longitudinal cracks within 15 inches (380 mm) of a tied longitudinal joint by routing and sealing the crack according to Item 423. For longitudinal cracks beyond 15 inches (380 mm), repair the same as for transverse or diagonal cracks stated above.

C. Spalled pavement surfaces.

Repair spalled pavement with Item 256 Bonded Patching of Portland Cement Concrete Pavement.

D. Pavement panels which have cement or mud balls.

Repair cement balls or mudballs by coring out the area, full-depth with a diamond core bit, and replacing the removed concrete with the same concrete as in the pavement. Remove and replace any pavement panel with 5 or more cement balls or mudballs. Locate the limits of the repair along the longitudinal joints and at least 1 foot (0.3 m) past the transverse joints to remove any existing dowel bars. Install smooth dowel bars at the transverse limits of the repairs. Install Type D (Drilled Tied Longitudinal) Joint along the longitudinal limits.

Pavement Thickness (451.18.A)

The Contractor must cut cores from the completed pavement to check the pavement thickness and to determine a price adjustment if necessary. When the constructed pavement thickness is less than plan by more than 0.2 inches, a deduction to the contract bid unit price is made.

One random core must be taken for every (sublot) 2,000 square yards (1,650 square meters) of a pavement unit or a major fraction thereof. No less than three cores will be cut for any pavement unit. For the purpose of coring, the Department will consider the entire pavement area of a specified thickness a unit. The Engineer will determine the locations for the random cores according to Supplement 1064.

Core thickness must be measured by the Engineer in accordance with AASHTO T 148. When a core shows a deficiency in thickness of more than 1/2 inch (13 mm) from the

specified thickness, the Contractor must take additional cores as directed by the Engineer to determine the limits of the deficiency. Follow the procedures below to determine how and when to cut additional cores:

1. Take a core 5 feet (1.5 m) longitudinally on both sides of the deficient core. If both cores are less than 1/2 inch (13 mm) deficient in thickness, the zone of deficiency has been determined.
2. If either or both cores are more than 1/2 inch (13 mm) deficient in thickness, cut a core 50 feet (15 m) longitudinally from the deficient core(s). If the 50-foot (15 m) core(s) is more than 1/2 inch (13 mm) deficient, cut additional cores in 100-foot (30 m) longitudinal intervals until a core is less than 1/2 inch (13 mm) deficient in thickness, until the pavement ends, or until overlapping an adjacent pavement lot's core in the same lane.
3. If a pavement sublot has cores more than 1/2 inch (13 mm) deficient in thickness, and the sublot's constructed width is greater than 12 feet (3.6 m), obtain cores transverse to the location of the more than 1/2 inch (13 mm) deficient cores. Obtain transverse cores at a location one-half the distance from the deficient core to the furthest edge of pavement. Obtain transverse cores for each core more than 1/2 inch (13 mm) deficient in thickness.
4. The Engineer will use the cores that measure less than 1/2 inch (13 mm) deficient in thickness to define the limits of the deficiency. The price adjustment would apply to these limits of deficiency. Note: The zone of deficiency is also called zone of deficient thickness.

Pavement Strength (451.18.B)

Whether the concrete pavement item is "with QC/QA" or not, additional strength cores will be obtained from the sample location as the thickness cores.

The Contractor is required to obtain the cores at the same location as 451.18.A for the Engineer. The Contractor determines when he wants all the cores tested (from 28 to 90 days) and notifies the Engineer.

If the concrete is QC/QA the Contractor's laboratory performs the QC core testing conforming to the accepted QCP and Item 455. The Engineer will require a QA core be obtained for every 10 sublots for verification testing. Those QA cores will be provided to the Engineer for curing and testing by the District Laboratory. The Department will test the core at the number of Contractor specified days. QA Results are compared to the companion Contractor QC core result. Acceptable results are defined in Item 455.

An average strength and a standard deviation are calculated using the Contractor's verified QC core results. Follow the procedures of Supplement 1127.

If the concrete is not QC/QA, the Department will obtain the strength cores from the Contractor and the District Laboratory will perform the testing of the cores for acceptance. Strength acceptance will be based on the individual core results not an average and standard deviation.

Price Adjustments (451.19)

Pavement Thickness (451.19.A)

Price adjustments are based on the pavement average thickness. The pavement is to be constructed such that the thickness is not more than 0.2 inches (5 mm) less than the specified thickness at any location. When this criterion is met, the Contractor receives 100 percent of the contract bid price.

When a core or cores are greater than 1 inch deficient in thickness, the pavement must be removed and replaced. The Zone of Deficiency for the removal is determined as outlined above.

For zones of deficiencies with pavement thickness 1/2 inch to 1 inch deficient, the Engineer must calculate the average thickness of concrete pavement to determine price adjustments.

Two averages must be calculated as follows:

1. Calculate a Project Average Thickness (PAT) using all cores from all lots that are ≤ 1/2 inch deficient in thickness.
2. Calculate a Deficient Zone Average (DZA) using all cores with a thickness deficiency of >1 1/2 inch.

Note: When calculating PAT, cores > 1/2 inch thicker than the plan thickness are considered to be plan thickness + 1/2 inch for the PAT calculation. For example, if plan thickness is 10 inches and the core measured 10.75 inches, use 10 inches + 1/2 = 10.5 inches when calculating the PAT.

The PAT and DZA are used to determine the price adjustment for each section of deficient pavement using the zone of deficiency area previously determined based on the coring operation.

The following table illustrates how the price adjustment is applied:

TABLE 451.19-1

CONCRETE PAVEMENT THICKNESS PAY FACTOR (PF_T)

Deficiency in Thickness as Determined by Cores	Proportional Part of Contract Price
0.0 to 0.2 inch (0.0 to 5 mm)	100 percent
0.3 to 0.5 inch (6 to 13 mm)	$Ratio \left[\frac{PAT}{PST}\right]^6$
0.6 to 1.0 inch (15 to 25 mm)*	$Ratio \left[\frac{DZA}{PST}\right]^6$
Greater than 1.0 inch (25 mm)	Remove and replace

* The DCA will determine whether pavement areas from 0.6 inch (15 mm) to 1 inch (25 mm) deficient in thickness will be allowed to remain in place at the reduced price or must be removed and replaced.

If any deficient core is greater than 1 inch (25 mm) deficient in thickness, determine the limits of over 1 inch (25 mm) deficiency by following 451.17, Steps 1 through 4, to determine the limits. Remove and replace those areas greater than 1 inch (25 mm) deficient in thickness.

The Contractor must fill all core holes using the same concrete used in constructing the pavement. When filling the core hole, the surface should be damp and should be painted with a grout consisting of cement and water having the consistency of a thick paint. Stiff concrete should then be rodded into the core hole before the grout dries. The surface should be struck off, and curing membrane applied to provide curing essential for a durable repair.

The pavement areas represented by the PAT of DZA are to be calculated and paid separately.

Deductions are determined and applied to each separately placed width of pavement.

If any pavement area is removed and replaced, the replaced pavement must be cored, and core values determined are to be included in the average calculations.

Example:

> A Contractor places 150,000 square yards of 10-inch concrete pavement. The contract price is $38 per square yard. If the Project Average Thickness (PAT) is 9.7 inches and the Plan Specified Thickness (PST) is 10 inches, what would the Contractor be paid?
>
> The thickness deficiency is: 10 inches – 9.7 inches = 0.3 inches
>
> From Table 451.17-1, look up the price adjustment for a 0.3 inch thickness deficiency.
>
> Use that formula to determine the Proportion Part of Contract Price as follows:
>
> $$\text{Proportion Part of the Contract Price} = \left[\frac{PAT}{PST}\right]^6 = \left[\frac{9.7}{10}\right]^6 = 0.8330$$
>
> Then the Contractor’s Payment for 150,000 sq. yards is calculated as follows:
>
> (150,000 sq. yards) x ($38.00 per sq. yards) x (0.8330) = $4,748,100
>
> Note: this results in a deduction of $951,900 for this pavement area.

Concrete Strength (451.19.B)

Record the compressive strength results for each sublot of concrete. High-early strength mixes, QC MS and QC FS mixes, are calculated separately. Determine the strength pay factor according to Table 451.19-2.

TABLE 451.19-2

CONCRETE PAVEMENT STRENGTH PAY FACTOR

Design Strength = f'c from 499 or as per plan Individual Sublot Core Strength = x Project Average Strength ($\bar{x}$) = $\sum_1^n x \div n$ Project Standard Deviation (δ) = $\sqrt{\sum(x-\bar{x})^2/(n-1)}$ Project Required Strength (f'cr) = f'c + 1.65 δ Strength Pay Factor (PF_S) = $\bar{x}$ / f'cr *
* When PF_S is greater than 1.00, pay the unit bid price
For high-early strength sublots, determine the pay factor separately as follows: If the individual sublot core strength (x) is greater than f'c, PF_S = 100% of the Unit bid price for the quantity represented. If the individual sublot core strength (x) is less than f'c, the PF_S = (x/f'c) of the Unit bid price for the quantity represented.

Pavement Smoothness (451.19.C)

When the Project plans include Proposal Note 420 determine a lump sum payment adjustment following the requirements of Proposal Note 420.

Multiple Deficiencies (451.19.D)

When a pavement exhibits multiple deficiencies for thickness and strength, the reduced unit price will be calculated for each deficiency and the lowest reduced unit price will be used. Adjustment for smoothness under 451.19.C will conform to the lump sum requirements of 451.19.C.

Method of Measurement (451.20)

Concrete pavement is measured by the number of square yards (square meters) completed and accepted in place. The width of pavement used to calculate the area equals the pavement width shown in the typical sections of the plans. The Engineer will measure the length along the centerline of each roadway or ramp.

Irregular areas of pavement should be field measured and the area calculated in square yards (square meters) for payment.

Any plan changes that involve concrete pavement quantities must be shown fully documented. In addition, any areas found to be deficient in thickness must be documented and the adjustment made in the pay quantity.

Basis of Payment (451.21)

Payment is made for accepted quantities of pavement by the square yard (square meter) at the contract bid price. If pavement is found to be deficient in thickness or compressive strength, the Department will pay a reduced price according to 451.19.

Multiple Deficiencies

When a pavement exhibits multiple deficiencies for thickness and strength, the reduced unit price will be calculated for each deficiency and the lowest reduced unit price will be used. Adjustment for smoothness under 451.19.C will conform to the lump sum requirements of 451.19.C.

There is no additional payment for any pavement constructed and found to have an average thickness in excess of the thickness specified.

452 Non-Reinforced Portland Cement Concrete Pavement

Description (452.01)

This item of work involves construction of a non-reinforced Portland cement concrete pavement on a prepared surface. The same methods and practices are utilized in the construction of 452 Pavement with some exceptions listed below. The major difference between 451 and 452 Pavement is the elimination of the steel reinforcing mesh in the 452 specification.

Construction (452.02)

Non-reinforced Portland cement concrete pavement is constructed in accordance with 451 with the following exceptions:

1. Reinforcing mesh specified in 451.08 is not required.
2. Dowels are required in transverse contraction joints in mainline pavement, ramps, acceleration/deceleration lanes, and collector/distributor lanes, but not in concrete shoulders adjacent to the above-listed pavements unless the contraction joints are within 500 feet (150 m) of a pressure relief joint.
3. The spacing of contraction joints in 452 is 15 feet (4.6 m) unless the 452 Pavement is placed as a shoulder tied to 451 or 305 Pavement. In this case, the joints in the 452 Pavement must match the spacing, alignment, sawing, and sealing requirements of the adjacent pavement.
4. Construction joints in 452 Pavement must not be located closer than 6 feet (1.8 m) from another parallel joint.

Method of Measurement (452.03)

Non-reinforced Portland cement concrete pavement is measured by the square yard (square meter) of pavement completed and accepted. All of the provisions of 451 method of measurement apply to 452.

Basis of Payment (452.04)

Payment for 452 Pavement is the same as for 451 Pavement. Payment is made for accepted quantities of pavement by the square yard (square meter) at the contract bid price. If pavement is found to be deficient in thickness or compressive strength, the Department will pay a reduced price according to 451.19.

There is no additional payment for any pavement constructed and found to have an average thickness in excess of the thickness specified.

455 Quality Control Plan, Testing, and Assurance for QC/QA Concrete

Description (455.01)

Use this specification for Items 451, 452, 305, and 511 when the bid item description requires QC/QA. This specification defines the minimum Quality Control Plan (QCP) requirements, the Contractor's minimum quality control (QC) materials testing, and the Department's quality assurance (QA) materials verification testing requirements.

The Contractor will develop a QCP to ensure that all materials and construction practices for the item will conform to the specifications. Establish the responsibilities, duties, and frequency for both in-process controls and quality control testing at the concrete's source and at the job site. This plan is to be reviewed by the Engineer for compliance and then accepted. See 455.06 for the submission time requirements for the Contractor's QCP.

Quality Control Plan Basic Requirements (455.02)

This section outlines the minimum QCP requirements for any QC/QA Concrete that is to be produced. The QCP submitted by the Contractor should, at a minimum, contain the content listed in 455.02. The QCP should be reviewed by the Engineer for compliance with this section. The Engineer also should ensure that the content of the QCP is acceptable prior to approval.

Additional Quality Control Plan Requirements for Structures (455.03)

This section outlines the additional requirements that must be added to the Contractor's QCP when placing concrete for structures under Item 511. The Engineer should review the QCP to ensure that at a minimum, each item listed in 455.03 is contained in the QCP and is acceptable prior to approval. While most of the items listed in 455.03 have clear and definable measures, the following list provides some additional guidance on specific items:

Material Control Requirements

Ensure the QCP defines Lots and Sublots in accordance with 455.03 A. Approach slab concrete would be included with the lots for superstructure deck concrete, except parapet concrete would be considered separately. There should be at least three sublots of not more than 50 cubic yards in a lot. Ensure the QCP meets the minimum requirements of 455.03 A, including sampling, testing, and documenting Air Content, Slump, and Compressive Strength. Sample concrete at point of discharge and placement. All curing, transporting, capping and testing of compressive strength cylinders shall conform to ASTM standards. An AASHTO accredited laboratory must perform the compression testing. If the Contractor is proposing to use maturity for falsework removal and opening to traffic, they must provide the maturity curve to the Engineer per Supplement 1098.

Construction Process Quality Control Requirements

Ensure the QCP provides the minimum information required by 455.03 B, including procedures, methods and equipment to deliver, place, consolidate, finish, protect, cure and groove the structural concrete.

Reporting

This section lists the QC testing information that should be provided to the Engineer. The air content results must be sent to the Engineer within 1 day of completing the testing, and the compressive strength results within 5 days of completing the testing.

Additional Quality Control Plan Requirements for Concrete Pavement (455.04)

This section outlines the additional requirements that must be added to the Contractor's QCP when placing concrete for pavements under Items 305, 451, or 452. The Engineer should review the QCP to ensure that at a minimum, each item listed in 455.04 is contained in the QCP and is acceptable prior to approval. While most of the items listed in 455.04 have clear and definable measures, the following list provides some additional guidance on specific items:

E. **Division of Pavement into Lots:** Ensure the QCP defines Lots in accordance with 455.04.A and Supplement 1064.

F. **Division of Lots into Quality Control Sublots:** Ensure the QCP provides the placement sequence and placement widths for the pavement work. Ensure the QCP defines the sublots in accordance with 455.04B and Supplement 1064.

G. **Material Control Requirements:** Ensure the QCP meets the minimum requirements of 455.04.C. Plant verification intervals for portable plants should be defined by the Contractor but may require modification if issues arise during production. Tests performed during paving operations should at least comply with the minimum requirements but could be more frequent. Required tests include Air, Slump, and Temperature. Testing for opening to traffic must conform to 451.17.

H. **Pavement Cores for Compression and Thickness**: Ensure the QCP provides the minimum information required by 455.04.D. per 451.18.B. Strength cores must be tested at 28 to 90 days of age. The QCP should define the age for obtaining and testing cores within these limits.

I. **Concrete Strength:** The QCP should state the AASHTO accredited laboratory that test core strengths. The Engineer should validate the accreditation and approve the reporting time frame and method.

J. **Construction Process Requirements:** Most of the items listed in 455.04.F have specific requirements from 305, 451, or 452 that must be met. The Contractor's QCP should not only list the requirements from the related specification, but also state the methods, materials, and/or equipment that will be used to ensure compliance. The Engineer should cross-check each item listed with the related specification prior to acceptance.

K. **Reporting Requirements:** This section lists the daily QC testing information that should be provided to the Engineer. The Engineer should approve the forms and methods used to transmit the information and to whom it will be sent.

Department Quality Assurance (455.05)

The Engineer will perform Quality Assurance sampling and testing as specified or as deemed necessary. Following proper procedures in determining random sample locations, sampling, handling, and testing are vital to the process. The results of this testing will be used to validate or invalidate the Contractor's QC sampling and testing for payment.

Structure Concrete

Random Number Determination

The Engineer should use the table in Supplement 1127 or a random number generator to determine a random number for each sublot to determine from which load the QC sample will be taken. The Contractor should not be made aware of the QA random sample locations until just prior to sampling.

Slump and Air

The Engineer will perform side-by-side air and slump field testing with the Contractor and compare results. If the difference between the Department's and the Contractor's test result is greater than the tolerances listed below, the Contractor and Engineer will determine the reason for slump or air content differences and make necessary adjustments. The Engineer may stop the placement until the reason for the difference is established and corrected. The Engineer will check one of the first three loads delivered. Once the results are within the tolerances listed below, the Engineer may reduce the QA sampling and testing frequency to 10 percent of the Contractor's subsequent QC tests.

Slump ±1 inch (25 mm)

Air Content ±1%.

Compressive Strength

The Engineer will obtain compressive strength QA samples from the same location as the Contractor's quality control samples at a frequency of one QA sample for every 10 sublots or at least one per lot. The Engineer will make six 4- by 8-inch (100 x 200 mm) cylinders for each sample. The Engineer will mark the cylinders with identification and the Contractor shall provide initial curing at the project.

After the initial curing at the project site, deliver three QA cylinders to the Department's Laboratory and three QA cylinders to the AASHTO accredited laboratory for standard curing and testing. The AASHTO accredited laboratory will test the QA sample and the QC sample and report the test results on the form accepted by the QCP. Distinguish the QA from the QC results for the sublot.

The Engineer will compare and verify that the Department tested QA, Contractor tested QA, and the matching QC test results are within 14 percent of the Departments QA result. If the comparison is favorable, the Contractor QC testing is considered verified.

When the comparison of the results are more than 14 percent, investigate the results with the Engineer to determine the reason for the difference. If the reason for the difference cannot be determined to the Engineer's satisfaction, the Engineer will require the Contractor to either non-destructively test or core the concrete represented by the cylinder tests to determine compressive strength. Hire an independent AASHTO accredited laboratory to perform this additional testing. The Engineer will witness the testing and evaluate the results. The Department will reimburse the Contractor for all testing costs when the Department's results are in error. If the QC results are found to be valid, use the QC results. If the QC results are not valid, use the core results to determine the compressive strength values for pay factors, 511.22.

Pavement and Base Concrete

Air Content and Slump

The Engineer should randomly choose at least 10 percent of the Contractor's QC samples to perform side-by-side quality assurance testing of the air content and the slump. The results of the Department's and Contractor's tests should compare to within ±1 percent, or ±1 inch. If the results do not compare, the Engineer should stop placement until the reason for non-comparison is determined and corrected.

Compressive Strength

The Engineer will randomly select one out of every 10 Contractor QC core locations to have an additional core obtained as a QA strength sample according to Supplement 1127. The Engineer should monitor the cutting and take immediate possession of the QA core. The QA core sample will be cured and tested by the District Test Lab on the date specified by the Contractor. If the Department's QA core results and the matching Contractor's QC core results compare to within 13 percent, the Contractor QC is verified. If the results do not compare to within 13 percent, follow the procedure as outlined in 455.05.

QCP Submittal and Corrective Action (455.06)

The Contractor should submit the proposed QCP to the Engineer for acceptance at least 10 days prior to placing concrete. If the submission is not found acceptable, the Contractor is required to revise and resubmit the QCP and allow another 10 days for review and acceptance. This may require the Contractor to reschedule a concrete pour.

The QCP acceptance is based on the concept that the proposed QCP procedures will provide work which meets all specification requirements. If the accepted QCP is not being followed, the Engineer will require compliance or resubmittal of any modifications for review and acceptance.

When the actual work produced by the QCP does conform to specification requirements, the Engineer will require modification of the QCP to return the work to conformance. The Engineer must notify the Contractor when QCP modifications are required and work

should not continue until the Engineer has accepted the QCP changes proposed by the Contractor.

Basis of Payment (455.07)

The cost of developing and implementing the QCP is incidental to the cost of the concrete sold with the QC/QA requirement.

499 Concrete – General

Control of concrete is divided into two categories: large quantity critical usage and small quantity non-critical usage. All pavement and structure concrete, and in general any other concrete usage exceeding 200 cubic yards (150 cubic meters) per day, is considered large quantity critical usage.

When placing small quantity non-critical usage concrete from sources having a record of supplying approved material, the concrete may be accepted by field tests and backed up by random test beams, concrete cylinders, and random plant inspections as deemed necessary by the Engineer. The following list shows examples of small quantity non-critical usage concrete:

1. Sidewalks - Not to exceed approximately 500 square yards (418 square meters) per day.
2. Curbing, combination curb, and gutter - Not to exceed approximately 500 linear feet (152 linear meters) per day.
3. Patching and temporary pavements.
4. Building foundations and floors.
5. Slope paving and paved gutter.
6. Guardrail and fence post anchorages.
7. Metal pile castings.
8. Culvert headwalls.
9. Catch basins, manhole bases, and inlets.
10. Sign, signal, and light bases.

Acceptance of concrete under the small quantity non-critical usage procedure does not waive the responsibility for using approved materials. Concrete accepted under these provisions must be reported using an abbreviated TE-45 form along with company tickets indicating quantity, class, slump, and air test results and time of batching.

At least one concrete control inspector must be present whenever small quantity non-critical usage concrete is being placed and two or more inspectors are required for large quantity critical usage placement.

Introduction

Concrete used in highway construction is a mixture of coarse aggregate, fine aggregate, Portland cement, water, entrained air, and permissible mineral or chemical admixtures. In this mixture, each aggregate particle is completely coated by a paste of cement and water. This paste binds the aggregate particles into a mass called concrete. The cement paste can consist of Portland cement, fly ash, ground granulated blast furnace slag (GGBFS), or microsilica, water, air voids, and any admixtures. The cement paste comprises from 25 to 40 percent of the total concrete volume. To have quality concrete, it is necessary that both aggregate and paste be sound and durable.

Aggregate, cement, and admixtures to be used in concrete are sampled and tested by the Laboratory to ensure that ingredients meet quality standards. However, the quality of the paste depends on proper construction techniques. These techniques include the minimum use of water and favorable temperature and humidity during the curing period.

Approximately 30 pounds of water is required to complete the chemical reaction with 100 pounds of cement. Although a small amount of water is needed to complete the chemical reaction with cement, additional water is necessary to make the concrete workable. As the paste is thinned out with water, its quality is lowered: it will have less strength and less durability. For quality concrete, a proper proportion of water and cement is essential. This proportion is called water-cement ratio. The water-cement ratio is determined by dividing the weight in pounds (kilograms) of the total actual mixing water by the weight in pounds (kilograms) of cement and pozzolans used in the mix. A maximum water-cement ratio is specified to avoid excess water and to ensure quality paste, and therefore, quality concrete.

To provide a dense mixture of the aggregate, cement, and water, it is necessary to have various sizes of aggregate particles so that the smaller particles fill the voids between the larger particles. Therefore, aggregate is divided into two categories: coarse aggregate and fine aggregate. Coarse aggregate is aggregate with 95 to 100 percent of its particles larger than the 4.75 mm (No. 4) sieve. Fine aggregate is aggregate with 95 to 100 percent of its particles smaller than the 4.75 mm (No. 4) sieve. Coarse and fine aggregate are graded, that is, they contain several sizes of particles combined together. When placed in concrete, these various sizes of particles become coated with the cement paste and form a dense mass with the voids filled.

In addition to requirements that it be strong and dense, concrete must be durable. Durability means resistance to the elements. Concrete that is not exposed to the elements such as water, freezing, and thawing, generally will be durable. When non-durable concrete is subjected to these destructive forces, scaling and deterioration generally follows and progresses with each cycle of freezing and thawing unless preventive measures are taken. In order to provide concrete with additional durability, an air-entraining admixture is added to the concrete to generate billions of air bubbles of microscopic size in the concrete. This air-entraining agent may be interground with the cement, or it may be an admixture, or both. These microscopic air bubbles form in the paste of the concrete as it hardens and create tiny air pockets in the hardened concrete. When moisture is present and freezing takes place in air-entrained concrete, the water expands and moves through capillaries to these very small air pockets and the expansive force is relieved. Without these relief air pockets, the forces created by the expanding ice formation would rupture the concrete at its surface. This rupturing is known as scaling.

Basically, this is the theory of concrete mixes. Quality concrete consists of a mixture of sound, durable, fine-graded, and coarse aggregate mixed together with cement, water, and air entrainment. When properly mixed, placed, and cured, the resultant concrete has strength and durability and provides the service life for which it was designed. Only by vigilant inspection can fulfillment of these requirements be ensured.

Duties and Responsibilities

The concrete control inspector is responsible for the fulfillment of all required tests and validation of all specification requirements for concrete. The Inspector cannot alter or waive any provision of the proposal, plans, or specifications. Any failure of the work or materials to conform to specifications must be corrected immediately. If necessary, production must be stopped for correction rather than permitting work that does not meet specification requirements to proceed. The Inspector must notify the Contractor and the

Engineer of such action. The Inspector's duties include verifying that approved materials are used, verifying the Job Mix Formula (JMF) is approved, performing tests as outlined in this manual, requiring adjusts of the mix when out of specification allowances, and enforcing the mixing requirements for the mixes used.

Copies of forms to be filled out or verified by the Inspector are interspersed within the text of this section and the use of the forms is described.

Materials (499.02)

All materials to be used in the production of concrete must be tested and approved or accepted by certification prior to use. A copy of the Laboratory report or e-mail indicating approval of material must be in hand before a material is used. When necessary, material may be used when notification of its approval has been given by phone from the Laboratory, provided the phone approval is recorded in the project records prior to use. When written approval is received, it is filed in the project records. No material is used unless it is determined that it has been approved.

Portland Cement

Cement generally is shipped in bulk quantities by truck from the cement plant or terminal to the concrete plant. The cement normally will be from a plant operating under the "Cement Certification Procedure" outlined in Supplement 1028 and will require a 1/2-gallon sample which equals to a 10-pound (4.6 kg) sample every 180 days from each ready mixed concrete plant. The Office of Materials Management (Laboratory) or the District Test Lab typically samples Portland cement.

Normally Type I Portland cement (701.04) is used. However, the general specifications permit the use of Type IA air entraining Portland cement (701.01), Type II moderate sulfate resistant Portland cement (701.02), Type III high-early strength Portland cement (701.05), and Type I(SM) Portland blast furnace modified slag cement (701.09).

An approved air-entraining admixture is required to provide the specified air content when non-air entraining cements are used and may be required if air-entraining cement is used to obtain the proper amount of air.

Only Type I (701.04) Portland cement is the standard cement used. There are other cement options in 701 but they may only be used when accepted within the JMF.

If high-early-strength concrete is specified, Type III (701.05) must be used.

If moisture is exposed to cement prior to mixing, it may cause the concrete to have slower setting time and reduced strength. Therefore, cement must be stored in waterproof bins or silos.

Truck transports generally load the cement into the storage bins using compressed air, so it is important that adequate vents are placed at the top of the bins. Unless adequate vents are provided, cement must not be loaded at the same time concrete is being batched. Small or restricted vents may be inadequate and could result in inaccurate weighing of the cement at the time cement was being loaded into the bins.

Aggregate

Fine and course aggregate must be approved prior to use under the Supplement 1069 Pre-qualified Aggregate Supplier Program and meet the requirements of 703.01. Pre-qualified aggregate suppliers and producers are listed on ODOT's website.

Controlling the use of aggregate is the responsibility of project personnel, while the Laboratory is responsible for approving material.

Fine Aggregate

Fine aggregate for concrete includes natural sand and sand manufactured from stone. Natural sand is required to be used in any exposed concrete riding surface including 255, 256, 451, 452, 526, and 511(bridge deck concrete).

Fine aggregate consists of relatively small particles and does not tend to separate as much as coarse aggregate. Therefore, segregation generally is not a problem with the fine aggregate unless extremely careless methods of handling are employed.

Coarse Aggregate

If concrete is used for 305, 451, or 452 pavement it must also comply with 703.13 which is a test for freeze-thaw resistance (D-cracking susceptibility).

Coarse aggregate is a graded material consisting of a combination of various particle sizes that require extreme care when handling to prevent the smaller particles from separating from the larger ones. The separation that may occur during handling is known as segregation. If aggregate is dropped from a bucket or from a belt and allowed to form a cone-shaped stockpile or if it is pushed over the edge of a stockpile, the larger aggregate particles will roll to the bottom, outside edge of the pile. The smaller particles are less likely to roll because of their small size and weight and remain closer to the center. This results in a segregated stockpile. Non-uniformity results when such material is used in the concrete mix and difficulty can be encountered in controlling the water demand, slump, and yield of the resultant concrete.

Coarse aggregate must be maintained with uniform moisture content above saturated surface dry condition. Watering or sprinkling of aggregate may be desirable to provide concrete of uniform slump, to lower the aggregate temperature during hot weather, in addition to overcoming the possibility of a rapid slump loss. When placing concrete during freezing weather, however, it is impractical to water a stockpile to maintain uniformity.

When sprinkling is desirable, it should be done in advance so that the water will be distributed uniformly throughout the stockpile. If stockpiles are large or contain aggregate having high absorption, such as slag, it may be necessary to start watering several days in advance. However, the sprinkling should be discontinued to permit excess moisture to drain off overnight.

Microsilica

Microsilica, also known as silica fume or condensed silica fume, is a pozzolanic admixture that must comply with 701.10. In its finely-divided form and in the presence of water, it will chemically react with calcium hydroxide released by the hydration of Portland cement to form compounds with cementitious properties. This light to dark

gray powdery product is the result of the reduction of high-purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloys. Silica fume rises as an oxide vapor from a furnace 3,630° F (2,000° C). It cools, condenses, and is collected in cloth bags. The condensed silica fume is then processed to remove impurities and control particle size.

Condensed silica fume particles are 100 times finer than cement particles. The specific gravity of silica fume varies between 2.10 and 2.25 but can be as high as 2.55. When used in concrete it will fill the void space between cement particles resulting in impermeable concrete.

Microsilica or condensed silica fume is provided in dry densified powder form and must be protected from moisture. The microsilica normally will be from a plant operating under the "Microsilica Certification Procedure" outlined in Supplement 1045 and will require a 10-pound (4.6 kg) sample every 180 days from each ready mixed concrete plant.

Ground Granulated Blast Furnace Slag (GGBFS)

Ground Granulated Blast Furnace Slag (GGBFS) is a material that may be allowed or required by certain specifications. It is used as a cement replacement. The GGBFS material is produced from granulated blast furnace slag granules that are ground to a consistency somewhat finer than cement. The granules are produced by tapping molten slag from an iron blast furnace and using high-pressure water to rapidly quench the material. The granules produced have a consistency and color of sand and are composed primarily of glass. The granules are then ground in a cement mill into a fine white powder.

The material is required to meet the ASTM C 989 Specification. This specification identifies three grades of material: Grade 80, Grade 100, and Grade 120. Only Grades 100 and 120 are permitted under the Department's specifications. GGBFS generally is shipped in bulk quantities by truck from the cement plant or terminal to the concrete plant. The GGBFS normally will be from a plant operating under the "GGBFS Certification Procedure" outlined in Supplement 1034 and will require a 10-pound (4.6 kg) sample every 180 days from each ready mixed concrete plant.

Concrete produced using GGBFS will have a slower strength gain in cooler temperatures than normal mixes without it. Due to this, there are certain prohibitions for its use during cooler temperatures; GGBFS must be kept dry as with Portland cement and fly ash. It is handled generally in the same manner as cement and fly ash. It is normally delivered in bulk; however, for a small project, it can be provided in bags. In either case, it should be stored in a dry location.

Fly Ash

When coal is used to fire the boilers of modern power stations it is first finely ground or pulverized to the fineness of face powder before being fed into the furnace. The burning powdered coal gives off heat to generate electricity, any coarse particles fall to the bottom of the furnace, and hot gasses given off are swept away to be exhausted up the chimneystack. The fine particles that are in this exhaust and which are trapped before passing into the atmosphere are "fly ash." During the combustion process, the bulk of these particles assume an almost spherical shape, like microscopic ball bearings. One of the properties of fly ash is that, in the presence of hydrating Portland cement, it behaves

like cement. Fly ash reacts with calcium hydroxide to form compounds possessing cementitious properties.

Two classes of fly ash are allowed for concrete in 701.13. The two classes are Class F and Class C. Class F fly ash is produced from burning anthracite or bituminous coal. Class C fly ash is produced from burning lignite or sub-bituminous coal. Class F fly ash is the type normally found in Ohio. However, Class C fly ash is also becoming available to concrete producers now. Class C fly ash has some cementitious properties by itself while Class F does not.

Fly ash used in Department work must meet the requirements of ASTM C 618 except the maximum loss on ignition (LOI) must not exceed 3 percent. The LOI is a measurement of the carbon content or unburned coal in the fly ash. In order to maintain air entrainment at a particular level (in concrete containing fly ash), the fly ash must have a low LOI. The ASTM specification allows a higher LOI than our specifications. ODOT specifications require the lower LOI to minimize problems entraining air in the concrete.

Fly ash will normally be shipped in bulk quantities by truck from the power station to the concrete plant. Fly ash, like cement, has a certification process. This process is described in Supplement 1026, “Fly Ash Certification”. Certified fly ash requires a half-gallon (2L) sample every 180 days from each ready mixed concrete plant. Non-certified fly ash shall be sampled every 100 tons (91 metric tons) and be approved prior to use.

Bulk fly ash must be stored in waterproof bins prior to use. Normally fly ash is handled in the same manner as cement. Only one source of fly ash is permitted in any one structure unless otherwise approved by the Director.

Air-Entraining Admixture

Air-entraining admixtures are used to entrain the proper amount of air in concrete for freeze thaw durability. These admixtures must comply with 705.10 and conform to Supplement 1001 Approval and Testing of Air Entraining Agents and Chemical Admixtures for Concrete. The list of approved air entraining admixtures for Department use can be obtained from the SiteManager or from the Qualified Products List (QPL) on the ODOT website.

Air-entraining admixtures are randomly sampled at the concrete plant. The Laboratory generally takes these samples.

Chemical Admixture for Concrete

Approved set-retarding or water-reducing and set retarding admixtures are permitted in order to increase the workability of the concrete. These admixtures are permitted and often required for superstructure concrete.

Should the Contractor propose to use calcium chloride as an accelerator in the concrete, it must be determined if such use is permitted by specification, plan, or proposal note. If not, the Contractor must request permission of the Director, in writing, to use such admixtures.

Admixtures used under 499 must meet the requirements of 705.12 that specify that they meet ASTM C 494, except that the relative durability factor shall be 90. These admixtures must comply with Supplement 1001 Approval and Testing of Air Entraining Agents and Chemical Admixtures for Concrete.

The list of approved admixtures for Department use can be obtained from the SiteManager or from the Qualified Products List (QPL) on the ODOT website.

Chemical admixtures as defined by ASTM C 494 include:

- TYPE A - Water reducing
- TYPE B - Retarding
- TYPE C - Accelerating
- TYPE D - Water reducing and retarding
- TYPE E - Water reducing and accelerating
- TYPE F - Water reducing, high range
- TYPE G - Water reducing high range and retarding

Generally, liquid admixtures are shipped and stored at the plant in drums or tanks. The admixture material is withdrawn directly from the drum and dispensed into the concrete. Drums or tanks containing liquid admixtures should be agitated before being used. In the absence of a dispenser, the admixture must be introduced accurately into the mix by hand. Drums or tanks for storage of liquid admixtures should be watertight and protected from freezing.

At ready mix plants producing large volumes of concrete, the air entraining and other chemical admixtures are delivered in bulk quantity by tank trucks. These bulk admixtures are pumped into storage tanks at the plant and then dispersed into concrete batches.

Water

Water that is suitable for drinking is satisfactory for use in concrete (potable water). Water must be free of sewage, oil, acid, strong alkalis, vegetable matter, clay, and loam. Water from such sources should be avoided. Whenever there is a reason to suspect that water proposed for use in concrete is not suitable, it must be tested and approved before it may be used. A one-gallon (3.8L) sample in a non-corrosive container (plastic or glass) must be transmitted to the Laboratory with a TE-31 Sample Data form for comparative testing.

Wash water used to clean out ready mixed concrete must be discharged from the mixing drum prior to recharging any truck with new materials.

An adequate supply of water must be available at the concrete plant to provide for mixing and stockpile watering for uninterrupted production. Adequate storage tanks kept filled or a connection to a water supply system usually will provide a sufficient supply.

Proportioning (499.03 and 499.04)

Concrete is to be proportioned (mixed) and controlled as per the requirements of 499.03 and 499.04. Slump and air content are given in Tables 499.03-1 and 499.03-3. Water/cement ratio is limited by the specific Job Mix Formula (JMF). The JMF also provides the aggregate weights, and cement content for each concrete mix.

Slump should be maintained within the nominal slump range shown in table 499.03-3 for the mix design. The slump of concrete delivered to a project may be increased by the addition of water only if the maximum water cement ratio (or water to cementitious ratio) is not exceeded.

TABLE 499.03-1 CONCRETE MIX DESIGN REQUIREMENTS

Quantities per Cubic Yard (Cubic Meter) Provide Concrete with 6±2% Air Content				
Class	Design Strength psi (MPa)	Permeability [1] Maximum (Coulombs)	Cementitious Content [2] Minimum. lbs (kg)	Aggregate Requirements
QC 1	4,000 (28.0) at 28 days	2,000	520 (236)	Well-Graded
QC 2	4,500 (31.0) at 28 days	1,500	520 (236)	Well-Graded
QC 3 Special	As per plan	1,500 or as per plan	520 (236) or as per plan	Well-Graded or as per plan
QC 4 Mass Concrete	4,000 (28.0) or as per plan [3]	2,000 or as per plan	470 (213) [4] [5] or as per plan	Well-Graded or as per plan
QC 5 [8]	4500 (31.0) at 28 days	N/A	520 (236)	1 inch or 3/8 inch nominal maximum size
QC MS	See Supplement 1126	N/A	800 (363)	1 inch nominal maximum size
QC FS	See Supplement 1126	N/A	900 (408)	1 inch nominal maximum size
QC Misc [6]	4,000 (28.0) at 28 days	N/A	550[7] (249)	1 inch nominal maximum size

[1] AASHTO T277 Modified.
[2] Cementitious Content includes cement and pozzolan materials, denoted as Cm.
[3] Strength for Mass Concrete (QC 4) may be tested at either 28 or 56 days.
[4] Do not use Type III cement or accelerating admixtures in mass concrete.
[5] The maximum fly ash or GGBFS content may be increased up to 50%.
[6] For QC Misc mixes only –Water/Cementitious ratio limited to 0.50 maximum.
[7] Cement or a combination of cement and up to15% fly ash or up to 30% GGBFS.
[8] For QC 5 mixes with 3/8 inch nominal size, provide an air content of 8±2%.

Do not allow the use of any concrete that exceeds the maximum slump. An occasional load of concrete with a slump in excess of the nominal slump, but below the maximum limit shown in the table, may be incorporated into the work provided that an immediate adjustment is made to reduce the slump.

In some cases, it will not be practical to use this maximum slump due to a required cross-slope or a super-elevation.

Concrete Classes (499.03)

The Department uses contractor designed mixes that are found by looking up the Contractor’s submitted JMF in SiteManager. Table 499.03–1 shows the requirements of basic classes of concrete mix designs.
Note: As of July 15, 2016 the air content requirement has been updated to 7±2%.

The class of concrete is generally called out in the specification of the item of work in which the concrete is to be used. The proportioning of these classes is based on developing an average compressive strength at 28 days as shown in the table.

Additional Classes of Concrete for Rigid Replacement

The Specifications provide for two other classes of concrete (Class QC FS and Class QC MS) normally used for full-depth rigid pavement removal and rigid replacement (Item 255). These concretes are intended for high-early-strength; therefore, the previously described proportioning options do not apply to these classes of concrete.

It should be noted that Class QC FS or QC MS concrete is for use in full-depth rigid pavement removal and rigid replacement (Item 255). It allows No. 57 and No. 67 size coarse aggregate that does not have to be tested in accordance with 703.13 (testing for D-cracking susceptibility). If it is necessary to use either Class QC FS or QC MS concrete in 451 or 452, and JMF size coarse aggregate is to be used, the aggregate must comply with 703.13.

When either FS or MS concrete is used, ensure the JMF for the mix design proposed by the Contractor or the ready mixed concrete company has been accepted. The specific gravity of all aggregates must be known to figure the absolute volumes at all component materials to ensure that the concrete yields a cubic meter (cubic yard) of concrete. Just like any concrete, the air, slump, and yield must be controlled, and the water-cement ratio must not be exceeded.

Class QC FS Concrete (Fast Setting Concrete)

Class QC FS concrete must be proportioned with a minimum 900 pounds per cubic yard (534 kilograms per cubic meter) and a maximum water/cement ratio of the accepted JMF. Accepted JMF's will have the original time to strength curves available. Not all mixes will achieve 400 psi (2.76 MPa) in 4 hours. Available aggregates and weather conditions in the field will affect the results. This concrete may be opened to traffic after 4 hours if test beams have attained a modulus of rupture of 400 psi (2.76 MPa). This concrete must have either a Type B or a Type D admixture (a set retarder) added at the plant. Immediately prior to placing the concrete, calcium chloride (an accelerator) must be added and mixed at the project site.

Calcium chloride with 94 to 97 percent purity is limited to 1.6 percent by weight of cement, and calcium chloride with 77 to 80 percent purity is limited to 2.0 percent by weight of cement. If calcium chloride is added in liquid form, the water in the solution must be considered to be part of the mixing water and an appropriate adjustment must be made to not exceed the JMF water cement ratio.

In lieu of calcium chloride, any other approved accelerating admixture is permitted if the product was used in the accepted JMF.

After curing compound is applied, the concrete is to be covered with polyethylene sheeting and further covered with insulation board that has been wrapped with plastic. The intent is to keep the heat in the concrete so that the concrete can gain strength rapidly. During warm weather, 400 psi (2.76 MPa) is normally attained in 5-1/2 hours.

Class QC MS Concrete (Moderate Setting Concrete)

This class is a moderate setting Portland cement concrete for accelerated strength development. Class QC MS concrete is to consist of a minimum of 800 pounds of cement per cubic yard (475 kilograms of cement per cubic meter) and the maximum water cement ratio is defined in the accepted JMF. This mix may be opened to traffic after 24 hours provided test beams have attained a modulus of rupture of 400 psi (2.76 MPa).

Basics Concepts used in Concrete Quality Control

Volume

There are three types of volumes used in concrete quality control:

1. solid (absolute)
2. loose (bulk)
3. liquid volume

Solid and loose volume is normally defined by the number of cubical units of enclosed or occupied space. Normally one speaks of the number of cubic feet or cubic yards (cubic meters) of concrete. Liquid volume is designated by gallons (liters) for measurement of water and ounces (milliliters) for measurement of admixture dosage rates.

Unit Weight

Unit Weight is an important volume relationship used in concrete quality control. Unit weight is defined as the ratio of the weight of a material in pounds (kilograms) to the space or volume that it occupies in cubic feet (cubic meters). The unit weight of any material is calculated by Equation 499.1:

$$Unit\ Weight = \frac{Weight\ of\ Material}{Volume\ of\ the\ Material\ Weighed}$$

Equation 499.1 – Material Unit Weight

Concrete is sold by volume, but is batched by weight. The Inspector determines the unit weight of the concrete and uses it to calculate the yield of the batch. The yield is the actual number of cubic feet (cubic meters) or volume of concrete that a batch or load produces. Equation 499.2 shows how yield is calculated:

$$Yield = \frac{Total\ Batch\ Weight}{Unit\ Weight}$$

Equation 499.2 – Batch Yield

Specific Gravity

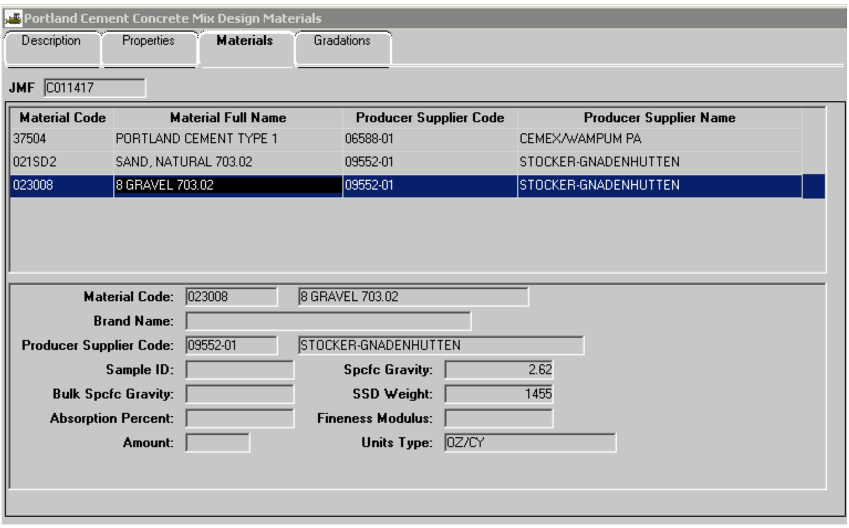
Specific gravity values of aggregates are used to calculate aggregate weights used in concrete mix design. Where the actual specific gravity of an aggregate varies by more than ±0.02 from those listed in accepted JMF, the mix design weights shown in the JMF must be adjusted. This section shows how to make those adjustments.

The specific gravity of any material is the ratio of the weight in pounds (kilograms) of the material to the weight of an equal volume of water. Another way to say this is that it tells how much heavier or lighter a given material is than water. Water has a specific gravity of 1.00. The unit weight of water is 62.4 pounds per cubic feet, lb/ft^3 (1,000 kilograms per cubic meter, kg/m^3).

The concrete proportion section of SiteManager for the JMF give the quantities of all materials to be used in each cubic yard (cubic meter) of concrete, depending on what

class of concrete and the type of aggregate is used. The aggregate weights given in the tables are the saturated surface dry (SSD) design weights.

See example of SiteManager JMF info below.



Portland Cement Concrete Mix Design Materials

Description | Properties | **Materials** | Gradations

JMF C011417

Material Code	Material Full Name	Producer Supplier Code	Producer Supplier Name
37504	PORTLAND CEMENT TYPE 1	06588-01	CEMEX/WAMPUM PA
021SD2	SAND, NATURAL 703.02	09552-01	STOCKER-GNADENHUTTEN
023008	8 GRAVEL 703.02	09552-01	STOCKER-GNADENHUTTEN

Material Code: 023008 8 GRAVEL 703.02
Brand Name:
Producer Supplier Code: 09552-01 STOCKER-GNADENHUTTEN
Sample ID: **Spcfc Gravity:** 2.62
Bulk Spcfc Gravity: **SSD Weight:** 1455
Absorption Percent: **Fineness Modulus:**
Amount: **Units Type:** OZ/CY

If the specific gravities of the proposed aggregate materials for use on a project vary by more than 0.02 on the approved aggregate list from the specific gravities shown in the JMF, the Engineer should require adjustment of the table weights as specified in the JMF. This is done by dividing the SSD design table weight by the design specific gravity (from the JMF) and multiplying this by the actual specific gravity that is going to be used on the project. Equation 499.3 shows this calculation:

$$Adjusted\ \ DW_{SSD} = \frac{DW_{SSD}}{DSG} * ASG$$

Equation 499.3 – Adjusted SSD Design Weight

Where:

DW_{SSD} = Design Weight (SSD) from the Job Mix Formula (JMF)

DSG = Design Specific Gravity from the JMF

ASG = Actual SSD specific gravity to be used on the project

Adjusted DW_{SSD} = Design Weight (SSD) adjusted for the actual aggregate specific gravity

Example:

Class QC 2 concrete, using natural sand and limestone coarse aggregate, is to be used on a project. The specific gravity of the fine aggregate is 2.66 and there is the specific gravity of 2.68 for the coarse aggregate. Determine the adjusted SSD design weights of fine and coarse aggregate based on these specific gravities.

The SSD design weights and design specific gravities for Class QC 2 concrete in JMF for natural sand and limestone coarse aggregate are:

Aggregate Type	**Design Weight (SSD)**	**Design Specific Gravity**
Fine Aggregate (Nat. Sand)	1,240 lbs	2.62
Coarse Aggregate (Limestone)	1,510 lbs	2.65

The SSD design weights adjusted for the specific gravities are calculated as follows:

Fine Aggregate Adjusted: $DW_{SSD} = \dfrac{1{,}240}{2.62} \times 2.66 = 1{,}259\ lbs$

Coarse Aggregate Adjusted: $DW_{SSD} = \dfrac{1{,}510}{2.65} \times 2.68 = 1{,}527\ lbs$

These adjusted aggregate weights (DW_{SSD}) would be further adjusted for moisture contained in them at the time of use instead of the table weights.

Absolute Volume

The material proportions for concrete mixtures JMF given in pounds (kilograms). Any adjustments to the aggregate proportions must be done using absolute volumes. For example, the yield of a batch of concrete is required to be accurate within a tolerance of ± 1 percent at the target (design) air content and slump. If an over-yield or under-yield is experienced, adjustments in the batch weights need to be made. The Inspector should notify the Engineer and Contractor of the yield issue. An adjustment to the proportions needs to be made if the Contractor wants the mix to stay within tolerance. Based on the yield calculated by the Inspector or Contractor, it will be necessary to calculate the weight in pounds (kilograms) of aggregate required for a certain amount of yield correction in cubic feet (cubic meters). Adjustments to correct yield are to be based on the absolute volume.

When the specific gravity of any material is known, the absolute volume of any weight of that material can be calculated as shown in Equations 499.4 and 499.5:

$$Absolute\ Volume\ (ft^3) = \frac{Weight\ of\ Material\ (lbs)}{Specific\ Gravity\ \times\ 62.4\ (lbs/ft^3)}$$

Equation 499.4 – Absolute Volume (US)

$$\left(Absolute\ Volume\ (m^3) = \frac{Weight\ of\ Material\ (kg)}{Specific\ Gravity\ \times 1{,}000\ (kg/m^3)} \right)$$

Equation 499.5 – Absolute Volume (metric)

Example:

The absolute volume of 94 lbs (42.6 kg) of Type 1 cement that has a specific gravity of 3.15 is:

$$Absolute\ Volume\ (ft^3) = \frac{94\ lbs}{3.15 \times 62.4\ lbs/ft^3} = 0.48\ ft^3$$

$$\left(Absolute\ Volume\ (m^3) = \frac{42.6\ kg}{3.15 \times 1{,}000\ kg/m^3} = 0.0135\ m^3 \right)$$

This calculation shows that 94 lbs (42.6 kg) of cement, which represents 1 cubic foot of loose volume, has an absolute volume of 0.48 ft^3 (0.0135 m^3).

Yield Adjustment using Absolute Volume

To make a yield adjustment, a volume of over-yield or under-yield is first determined. This absolute volume must be converted to a weight of material. An absolute volume of any material can be converted to a weight of that material by using Equations 499.6 and 499.7:

$$Weight\ (lbs) = AV \times SG \times 62.4$$

Equation 499.6 – Weight from Absolute Volume (US)

Where:

AV = absolute volume of the material (ft^3)

SG = specific gravity of the material

62.4 = lbs/ft^3

$$\left(Weight\ (kg) = AV * SG * 1{,}000\right)$$

Equation 499.7 – Weight from Absolute Volume (metric)

Where:

AV = absolute volume (m^3)

SG = specific gravity

1,000 = kg/m^3

Example:

Calculate how many pounds (kg) of **a coarse aggregate**, with a specific gravity of 2.66, would be required to adjust an under-yield of 0.64 ft^3 (0.018 m^3). The calculation is as follows:

Weight (lbs) = (0.64 ft^3) x (2.66) x (62.4 lbs/ft^3) = 106.2 lbs

Weight (kg) = (0.018 m^3) x (2.66) x (1,000 kg/m^3) = 47.88 kg

Thus, 106 lbs per cubic yard (48 kg per cubic meter) of coarse aggregate, with a specific gravity of 2.66, would have to be added to correct the above under-yield volume of 0.64 ft^3 (0.018 m^3).

While the example shows only a coarse aggregate correction, a correct over-yield or under-yield would have all aggregate proportions corrected to make up the yield different.

If the aggregate for a mix was:

40% No. 57 stone
20% No. 8 stone
40% natural sand

You would determine the percentage for the under-yield (above):

40%/100 x .64 = .26 ft^3	No. 57 stone
20%/100 x .64 = .14 ft^3	No. 8 stone
40%/100 x .64 = .26 ft^3	natural sand

Then, calculate (using the above) formal and the specific gravity for each to determine the amount of materials to be added for each aggregate type.

Moisture Correction

Aggregate can be in one of four moisture conditions:

1. Oven-dry aggregates are heated until they are completely dry. There is no moisture within the aggregate particles or on the surface of the particles.
2. Air-dry aggregate is dry on the surface, but still contains some water within the aggregate particles. Air-dry aggregate will absorb a small amount of mixing water if used in concrete. Aggregate in this condition requires adjustments to the design weights and adjustment of the batch water.
3. Saturated surface dry (SSD) aggregate looks damp, but it contains no free water on the surface. The aggregate particles have completely absorbed all the water possible and do not contribute water to the batch. The concrete tables in the JMF give SSD weights of coarse and fine aggregate, but aggregate in this condition rarely exists in aggregate stockpiles.
4. Wet (damp) aggregate has water on the particle surface and shows water sheen. The aggregate particles have absorbed all the water they can and will contribute water to the concrete mix. Aggregate in this condition requires adjustments to the design weights and adjustment of the batch water.

In the field, aggregate used in concrete will be in a wet (damp) condition or air-dry condition. Aggregate in the SSD or oven-dry conditions is used by contractors and inspectors to determine moisture correction factors for use in adjusting the SSD design weights.

Before concrete can be batched, the concrete mix SSD design weights shown in the JMF must be converted to batch weights. This is done by adjusting the design SSD weight of each aggregate and adjusting the amount of batch water to compensate for the moisture in the aggregates. If all aggregates at the concrete plant were in the SSD condition, the weights given in the concrete tables could just be weighed up and incorporated into the concrete batch and no adjustments to the water would be necessary. Seldom, if ever, will aggregate in the field be found in the SSD condition.

It is necessary to determine the amount of total moisture in all aggregate in order to determine the weight of wet (damp) or air-dry aggregate necessary to give the correct weight of SSD aggregate. This total moisture content is used in the determination of the water-cement ratio. For example, if an aggregate is determined to contain 5 percent total moisture, then each 105 pounds (kilograms) of that aggregate actually consists of 100 pounds (kilograms) of aggregate and 5 pounds (kilograms) of water. In order to obtain 100 pounds (kilograms) of aggregate by dry weight, it is necessary to take into account the water that will be weighed along with the aggregate.

Total Moisture Correction Factor

The Total Moisture Correction Factor (TMCF) is a term that is useful in determining the batch weights from SSD design weights (that have been corrected for specific gravity). The TMCF can be determined by a moisture test. To determine the TMCF use Equation 499.8.

$$TMCF = \frac{WW\ (or\ ADW)}{ODW}$$

Equation 499.8 – Total Moisture Correction Factor (TMCF)

Where:

TMCF = Total Moisture Correction Factor

WW= Wet weight of the sample

ADW = Air Dry Weight of the sample

ODW = Oven Dry Weight of the sample

If the total moisture content (in percent) has been determined by an aggregate moisture test, use Equation 499.9 to calculate the TMCF:

$$TMCF = \frac{(\%\ Total\ Moisture)}{100} + 1.0000$$

Equation 499.9 – Total Moisture Correction Factor (TMCF)

The total moisture percent is changed to a decimal (by dividing it by 100) and then added to 1.0000 to get the TMCF. For example, if the total moisture in an aggregate sample, after testing, is determined to be 5.8 percent, then the TMCF is determined as follows:

$$TMCF = \frac{5.8\,\%}{100} + 1.0000 = 1.0580$$

Absorbed Moisture Correction Factor

Another factor that is useful to determine the batch weights from SSD weights (that have been corrected for specific gravity) is the Absorbed Moisture Correction Factor (AMCF). This factor can be determined by a test. It is defined as follows:

$$AMCF = \frac{SSDW}{ODW}$$

Equation 499.10 – Absorbed Moisture Correction Factor (AMCF)

Where:

AMCF= Absorbed Moisture Correction Factor

SSDW= Saturated Surface Dry Weight of the sample

ODW= Oven Dry Weight of the sample

The percent of absorption of the fine aggregate and coarse aggregate is obtained from the aggregate reports furnished by the Laboratory. The percent of absorption represents the amount of water, expressed as a percentage of its own dry weight, which an aggregate will absorb. The water that is absorbed by aggregate is not available as mixing water in the concrete. Adjustments must be made in the amount of total allowable mixing water to compensate for the free water on the aggregate surface.

The percent absorption of any aggregate can be found on the Office of Materials Management website under Materials Information, Aggregate, and Specific Gravities List.

The Materials Management website is listed below:

http://www.dot.state.oh.us/Divisions/ConstructionMgt/Materials/Pages/default.aspx

The percent absorption is on the far right column of this list. The sources are listed in alphabetical order. Once the percent absorption of any aggregate is known, the AMCF can be determined by Equation 499.11:

$$AMCF = \frac{(\%\ \ Absorption)}{100} + 1.0000$$

Equation 499.11 – AMCF

The percent absorption of the aggregate is changed to a decimal (by dividing the percentage by 100) and then it is added to 1.0000 to get the AMCF. For example, if the percent absorption for a coarse aggregate is 2.22 % then the AMCF is determined as follows:

$$AMCF = \frac{2.2\ \%}{100} + 1.0000 = 1.0220$$

Free Moisture Correction Factor

The Free Moisture Correction Factor (FMCF) can be calculated once the TMCF and the AMCF are determined by using Equation 499.12:

$$FMCF = \frac{TMCF}{AMCF}$$

Equation 499.12 – FMCF

Where:

FMCF= Free Moisture Correction Factor

TMCF= Total Moisture Correction Factor

AMCF=Absorbed Moisture Correction Factor

The FMCF is used to adjust the corrected SSD design weights of the coarse aggregate and the fine aggregate from the concrete tables in the JMF’s batch weights that are used to produce a batch of concrete. The batch weight for any aggregate is determined by either Equation 499.13 or 499.14:

$$Batch\ Weight = Adjusted\ \ DW_{SSD} \times FMCF$$

Equation 499.13 – Batch Weight method 1

$$Batch\ Weight = Adjusted\ \ DW_{SSD} \times \frac{TMCF}{AMCF}$$

Equation 499.14 – Batch Weight method 2

Where:

$Adjusted\ \ DW_{SSD}$ = Design Weight (SSD) from the concrete table, adjusted for the specific gravity

FMCF= Free Moisture Correction Factor

TMCF= Total Moisture Correction Factor

AMCF= Absorbed Moisture Correction Factor

Example:

Assume that the following are the design weights SSD adjusted for specific gravity for a cubic yard of Class QC 1 concrete:

Cement	600 lbs
SSD Fine Aggregate	1,160 lbs
SSD Coarse Aggregate	1,735 lbs
Maximum Water	300 lbs
Total Design Weight	3,795 lbs

Prior to concrete placement, the total moisture contents of the fine and coarse aggregates are determined. The fine aggregate has total moisture of 4.95 percent and the coarse aggregate has total moisture content of 3.25 percent. The absorption of the fine aggregate is 2.85 percent and the absorption of the coarse aggregate is 2.2 percent. Determine the batch weights using the above moisture data.

First, determine the TMCF and the AMCF for each aggregate type using Equations 499.9 and 499.11:

Fine Aggregate TMCF	$= \frac{4.95\%}{100} + 1.0000$ $= 1.0495$	(Equation 499.9)
Fine Aggregate AMCF	$= \frac{2.85\ \%}{100} + 1.0000$ $= 1.0285$	(Equation 499.11)

Coarse Aggregate TMCF	$= \dfrac{3.25\ \%}{100} + 1.0000$ $= 1.0325$	(Equation 499.9)
Coarse Aggregate AMCF	$= \dfrac{2.2\ \%}{100} + 1.0000$ $= 1.022$	(Equation 499.11)

Next, use Equation 499.14 to determine the fine and coarse aggregate batch weight:

Fine Aggregate Batch Weight	$= 1{,}160 \times \dfrac{1.0495}{1.0285}$ $= 1{,}184\ lbs$	(Equation 499.14)
Coarse Aggregate Batch Weight	$= 1{,}735 \times \dfrac{1.0325}{1.022}$ $= 1{,}753\ lbs$	(Equation 499.14)

Next, determine the amount of water added to the mix by each aggregate. To determine this weight, subtract the SSD design weight from the batch weight determined above:

Water in Fine aggregate = 1,184 – 1,160 = 24 lbs

Water in Coarse aggregate = 1,753 –1,735 = 18 lbs

Next, the mix design weight of water must be adjusted to determine the batch weight of water. In this example, the fine aggregate and coarse aggregate would both contribute water (24 lbs and 18 lbs respectively) to the mix. The batch weight of water is calculated by subtracting the amount of water added by the aggregate from the design water weight as follows:

Water Batch weight = 300 lbs - 24 lbs – 18 lbs = 258 lbs

Once the batch weights of all the ingredients have been determined, they should add up to the same as the original design weights. This is a good check to ensure that no errors were made in the calculations. The batch weights for a cubic yard of concrete based on the total moistures and the aggregate absorptions given in this example are:

Cement	600 lbs
SSD Fine Aggregate	1,184 lbs
SSD Coarse Aggregate 1	1,753 lbs
Maximum Water	258 lbs
Total Batch Weight	3,795 lbs

Since the total batch weight equals the original adjusted SSD design weights in this example, the mix has been adjusted properly for the moisture in the aggregates. Even

though the maximum water value in the total batch weight (258 lbs) is different than the original design weight of water (300 lbs), the net water was not changed. The free moisture in the aggregates will contribute 42 lbs to the mixing water. In this example, the w/c ratio was kept the same as the original design.

Job Control Tests

The concrete control Inspector must perform various field tests to determine whether a concrete mixture is within specifications for slump, air content, and yield. In QC/QA, these tests have specific frequency. Yield is not an acceptance test but may be used to determine additional information where there are problems. The Inspector is there to verify the Department receives product which meets the specifications. Moisture testing also has to be performed for use in the concrete mix design control.

Specification 499.04 requires that concrete quality control QC tests are performed. Tests for total air content and slump may be made at ready mix and central mix plants for control purposes. These tests are desirable to detect loads that will not conform to specification requirements before they leave the plant. Any variances to the JMF should be reported by the plant to the Contractor so that necessary adjustments can be made in the following batches. This type of testing determines quality and is the responsibility of the Contractor. When concrete is produced in accordance with a QC/QA specification (Items 451, 452, 511), additional quality control requirements are to be specified by the contractor and carried out at the placement site.

Department testing is always considered quality assurance (QA) to verify that the Contractor provided product meets specifications.

Unless otherwise directed by the Engineer, perform any QA tests for pavement on plastic concrete samples taken from the concrete after it has been placed on the base. In the event excess slump is encountered, it may be desirable to visually observe the consistency (slump) of the concrete in the bucket or trucks before deposition to avoid the necessity of costly removal after it is placed.

Perform QA tests for structural concrete at the site at the time the concrete is being placed. Normally, concrete may be obtained directly from the hauling units for testing. However, when concrete is transferred from the hauling units to the point of use by means of conveyors or by pumping, the amount of slump and air may change slightly.

Perform testing at the required frequency of the specification or at a higher frequency if problems are noted. Do not perform the QC testing, but provide QA test results to the Contractor so the Contractor can make necessary corrections.

There may be occasions where it is not practical to test concrete samples at the point of placement since this would interfere with placing operations such as for a pier cap. Usually there is not adequate space for testing. In this situation, the sample could be taken from the point of placement and tested at a different location. Correlation of test data between point of test and placement may be necessary to ensure specification material is being placed. Tests could be conducted on concrete obtained from the hauling units and allowance made for a change in slump and air as determined by the comparative tests at the point of placement.

Slump, yield, and entrained air tests are made by the concrete control Inspector. In addition, it is the Inspector's duty to make required test cylinders and beams. Any

adjustment of batch weights that may be necessary because of the routine job control tests must be relayed to the concrete plant for immediate use. The concrete Inspector must be familiar with the tests being conducted and should occasionally review the test procedures to ensure that all tests are properly conducted.

Representative Concrete Samples

When obtaining a sample from dump trucks, side dump hauling units, or other types of hauling units that do not discharge by a chute, the contents are first discharged or spread on the base. Samples are then taken from several different locations within the load.

When sampling from truck mixers, truck agitators, end dumps, or other units discharging by a chute, the sample is obtained at three or more regular intervals throughout the discharge of the entire batch. Do not sample at the beginning or end of discharge. Sampling is done by repeatedly passing a receptacle through the entire discharge stream, or by diverting the stream so that it discharges into a container. The rate of discharge must be regulated by the rate of revolution of the drum, and not by the size of the gate opening.

The sample consists of not less than 1 cubic foot (0.03 cubic meters) when it is used for cylinders and not less than 1 cubic foot (0.03 cubic meters) per beam. Smaller samples may be permitted for routine air content and slump test.

The sample is carried to the place where cylinders and beams are to be molded or where the test is to be made. The sample is then remixed with a shovel just enough to ensure uniformity. The sample must be protected from sunlight and wind during the period between sampling and testing. The test must be conducted immediately so that the time between sampling and test completion is held to a minimum.

Moisture Testing

This test is the responsibility of the Contractor under QC/QA specification or the concrete producer when not under QC/QA (499.04) a moisture test is made for each aggregate size to be used. These tests must be made just prior to the start of concrete production and are used to adjust the batch weights and to determine the water-cement ratio. Therefore, moisture tests are required at the start of production, daily for all major concrete placements, and anytime a sizeable change occurs in the moisture content of the stockpiles. Moisture tests by concrete suppliers are often performed using calibrated probes in their stockpiles. These are acceptable if the results are accurate. Those results can and should be used by the Contractor or supplier to adjust SSD mixes for local moisture content.

Space is provided on Form TE-45 for documenting the moisture content test on each aggregate used.

Any appreciable change in the amount of water added at the mixer must be investigated, additional moisture tests made, and if necessary, the batch weights adjusted accordingly. Concrete suppliers use of stockpile probes can help with the variations as they make readings throughout the mix process

Following a heavy rainfall, periodic moisture tests are necessary until the moisture content becomes uniform. Slight variations in the mixing water requirements do not

require a moisture test and adjustment. However, it may become necessary to alter the methods of watering, stocking, and withdrawing the aggregate to avoid fluctuations in water.

The total percent moisture is determined by using Equation 499.15:

$$Total\ Percent\ Moisture = \left(\frac{NWW - NDW}{NDW} \right) \times 100\ \%$$

Equation 499.15 – Total Percent Moisture

Where:

NWW = Net Wet Weight of the aggregate sample

NDW= Net Dry Weight of the aggregate sample

To determine the percentage of moisture or water in fine or coarse aggregate, place a representative sample of 5 to 10 pounds (3 to 5 kg) in a pan that has been weighed empty and determine the wet weight of aggregate and pan. Place pan and aggregate over a fire, or in an oven, and dry to constant weight. Subtract the weight of the empty pan from both the wet and dry weights obtained. The results will be the net wet weight and the net dry weight. Next, subtract the net dry weight from the net wet weight, which results in the moisture content (weight of water) in the wet aggregate sample in pounds (kilograms). Divide the moisture content by the net dry weight and multiply by 100 percent to obtain the percent moisture in the sample.

Example:

Assume that the following weights are obtained for a sample of aggregate:

Empty Pan Weight	= 1.22 lb (0.553 kg)
Weight of Wet Aggregate + Pan	= 8.68 lb (3.937 kg)
Weight Dry Aggregate + Pan	= 8.44 lb (3.828 kg)

The calculations involved to determine the moisture content in the sample are:

English calculation

A. Tare Weight of Pan = 1.22 lbs.

B. Wet Aggregate + Pan Weight = 8.68 lbs.

C. B - A = Wet Aggregate Weight = 8.68 - 1.22 = 7.46 lbs.

D. Dry Aggregate + Pan Weight = 8.44 lbs.

E. D – A = Dry Aggregate Weight = 8.44 – 1.22 = 7.22 lbs.

F. C – E = Weight of Water = 7.46 – 7.22 = 0.24 lbs.

G. (F ÷ E) x 100% = (0.24 ÷ 7.22) x 100% = 3.3% moisture

Metric calculation

A. Tare Weight of Pan = 0.553 kg

B. Wet Aggregate + Pan Weight = 3.937 kg

C. B - A = Wet Aggregate Weight = 3.937 – 0.553 = 3.384 kg

D. Dry Aggregate + Pan Weight = 3.828 kg

E. D – A = Dry Aggregate Weight = 3.828 – 0.553 = 3.275 kg

F. C – E = Weight of Water = 3.384 – 3.275 = 0.109 kg

G. (F ÷ E) x 100% = (0.109 ÷ 3.275) x 100% = 3.3 % moisture

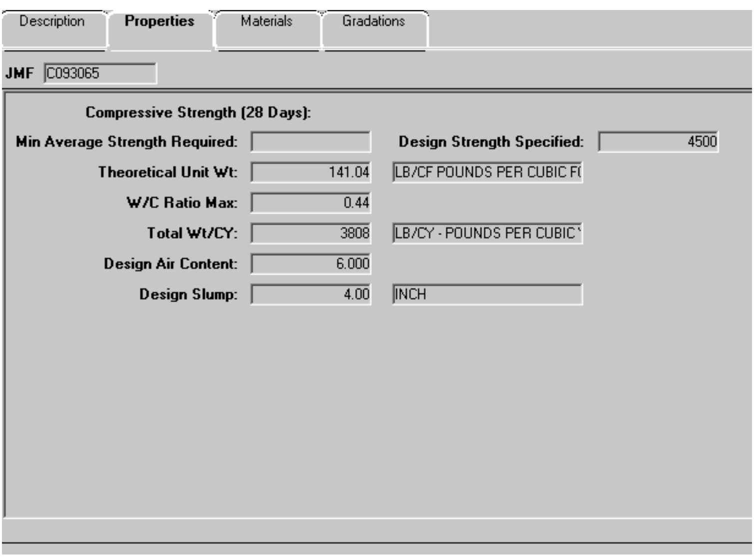
Space is available on the TE-45 form for documenting the moisture content of the aggregate used.

Control of Mixing Water

Moisture testing of the aggregate used in the concrete mix design allows the calculation of the total amount of mixing water that can be used per cubic yard of concrete. This mixing water limit should not be exceeded for the batch of concrete.

The field adjustment of slump to workable limits can be obtained by added water (up to the mixing water limit) only if the maximum water/cement ratio is not exceeded and the air content is within specification. The Contractor and/or the Supplier assume the responsibility and financial loss for concrete that is rejected because it is outside the specification limits. Therefore, the Contractor/Supplier should have the right to adjust the amount of mixing water.

All approved JMF concrete mixes maximum water-cementitious (w/cm) ratios are limited by the accepted JMF:



1. The w/cm ratio is a ratio of the weight of water to the weight of cementitious materials in a batch of concrete.

For the Department's work, cementitious materials include cement, fly ash, GGBFS, and micro silica. The maximum w/cm ratio and maximum w/cm ratio are expressed mathematically by Equation 499.16:

$$Maximum\ w/cm\ Ratio = \frac{Max.\ Allowable\ Water\ Weight,\ lbs\ (kg)}{Weight\ of\ Cementitious\ Materials,\ lbs\ (kg)}$$

Equation 499.16 – Maximum w/cm Ratio

The maximum w/cm ratios are used by the Inspector to determine the maximum allowable water in a concrete batch. The concrete tables give the weight of cement and cementitious materials and the maximum allowable w/cm ratio for a cubic yard (cubic meter) of concrete. The maximum allowable weight of water can be determined for any of the concrete mixes by using 499.17:

$$\mathrm{MAWW, lbs\ (kg)} = (Max.\ w/cm\ Ratio) \times CMW,\ lbs(kg)$$

Equation 499.17 – Maximum Allowable Water Method 2

Where:

MAWW= Maximum Allowable Water Weight

Max. w/cm Ratio = Maximum water/cementitious ratio given in the concrete JMF

CMW = Cementitious Material Weight specified in the JMF

Once the maximum allowable water weight per cubic yard (cubic meter) is determined for a certain class of concrete, it is adjusted based on the moisture contained in each aggregate at the time of use and the moisture that each aggregate will absorb. The batch weight of water is determined by multiplying the adjusted water weight per cubic yard (cubic meter) by the number of cubic yards (cubic meters) in the batch.

The Inspector must recognize the Contractor's/Supplier's right to make a change in water to prevent the possibility of having concrete rejected for excessive slump. Inspectors are still required to record all adjustments of mixing water and to control slump and yield. If water is added to the concrete truck at the project site, the amount must be recorded and added to the total batch weight and used in the calculation of the w/cm ratio to ensure that they are not exceeded.

The Contractor/Supplier does not have the right to adjust the water requirements without informing the Inspector. The Inspector must know when a change is made and the amount of change in order to control and enforce the specification requirements. Inspectors are encouraged to cooperate with the Contractor to effectively control the mixing water to provide concrete of uniform slump.

The amount of water to be added to the mix to produce concrete of the proper slump cannot be determined accurately. Therefore, it is necessary to rely on past experience with the materials being used to estimate the amount of water to use at the start of concrete placements.

CAUTION: Additional water may be added if the estimated quantity of water produces low slump concrete, but excess water cannot be removed if the slump is in excess of maximum allowed. Estimating water should be on the conservative side unless relying

on recent experience. When the Inspector is not familiar with the materials being used, it is good practice to choose an amount of water about 5 gallons per cubic yard (25 liters per cubic meter) less than the estimated net mixing water.

Example:

Determine the maximum allowable water content for an 8-yd³ load of Class QC 1 with the following one cubic yard design weights:

Cement	385 lbs
GGBFS	165 lbs
Fine Aggregate	1,310 lbs
Coarse Aggregate	1,670 lbs
Max. w/cm ratio	0.50

First, determine the maximum allowable water per cubic yard by use of Equation 499.17:

$$\mathrm{MAWW, lbs\ (kg)} = (Max.\ w/cm\ Ratio) \times CMW,\ lbs(kg)$$

$$= 0.050 \times (385 + 165)$$

$$= 0.50 \times 550$$

$$= 275\ lbs$$

Since 1 gallon of water weighs 8.32 lbs, the maximum allowable water per cubic yard can be calculated as follows:

$$\text{Gallons of Water} = \frac{275\ lbs}{8.32\ lbs/gallon} = 33 \text{ gallons}$$

Next, to determine the maximum allowable water for the 8-yd³ batch, multiply the one yd³ allowable water by the size of the batch:

(275 lbs/yds³) x (8 yds³ /batch) = 2,200 lbs

or

(33 gallons /yd³) x (8 yds³ /batch) = 264 gallons

Therefore, the maximum allowable water is 2,200 lbs or 264 gallons for the 8-yd³ batch. This 2,200 lbs (or 264 gallons) is the maximum allowable water; that is, the amount of water that would be adjusted depending on the moisture contained in the aggregates used in the concrete.

Slump

Slump is a measure of the workability of the concrete and nominal and maximum slump values are given in 499.03. It is measured by a standard test in accordance with ASTM C 143. This test is done at the point of placement.

Slump is controlled by the amount of water that is batched into the concrete. Slump is increased as water is added to a batch of concrete. There are chemical admixtures (Type F and G) that can increase the slump chemically, without the addition of extra water.

The specifications in Section 499.04 require that the saturated surface dry (SSD) aggregate weights in the concrete tables be corrected to compensate for the moisture contained in each aggregate at the time of use. The amount of free water in the aggregate contributes to slump and to the water-cementitious ratio.

Table 499.03-3 Concrete Slump (below) shows the nominal slump and maximum slump allowed for certain items of work. Note that the nominal slump for any of the listed work items can be increased to 6 inch (150 mm) if a high-range water-reducing (superplasticizing) admixture is used in the concrete. The maximum slump may be increased to 7 inches (180 mm) if high-range water-reducing (superplasticizing) admixture is used.

Table 499.03-3 Concrete Slump

Type of Work	**Nominal Slump inch (mm)[1]**	**Maximum Slump inch (mm)[2]**
Concrete pavement (305, 451, 452, 615)	1 to 3 (25 to 75)	4 (100)
Structural Concrete (511, 610, 622)	1 to 4 (25 to 100)	5 (125)
Superstructure concrete (511, 526)	2 to 4 (50 to 100)	4 (100)
Non-reinforced concrete (601, 602, 608, 609, 611, 622)	1 to 4 (25 to 100)	5 (125)
[1] This nominal slump may be increased to 6 inches (150 mm), provided the increase in slump is achieved by adding a chemical admixture conforming to the requirements of 705.12, Type F or G.		
[2] This maximum slump may be increased to 7 inches (180 mm), provided the increase in slump is achieved by adding a chemical admixture conforming to the requirements of 705.12, Type F or G.		

Slump Test Requirements

This test is the responsibility of the Department except for work under a QC/QA specification, when it is that of the Contractor. A slump test using the slump cone will be made each time a set of cylinders is cast for structures or a set of beams is cast for pavements. Further tests are required as needed to maintain control of the slump within the limits specified.

Slump requirements apply at the point of use; therefore, slump must be determined at the work site on concrete being placed in the forms. When concrete has to be conveyed by any means (by a concrete pump, concrete conveyor, or bucket) from the hauling units to the forms where it will be incorporated into the work, the slump should be determined from concrete obtained as it is being placed in the forms. Usually, such tests cannot be conducted properly at the point of use, but the sample can be obtained and removed to a convenient site for immediate slump determination. By correlating such tests with tests

on the same concrete being discharged from hauling units several times a day, the difference in slump can be determined and applied to all other tests conducted on concrete from the hauling units. In this manner, there will be less interruption in production and less interference in conducting the tests.

At the ready mix and central mix plants, loads may be checked for slump so that appropriate adjustments may be made to avoid shipment and rejection of concrete at the work site. Loads that only slightly exceed the slump requirements when tested at the plant should not be rejected. However, adjustment should be considered for subsequent loads to avoid the possibility of rejecting succeeding loads.

Conducting tests at the plant does not eliminate the necessity of conducting test at the site. Further tests will be required as the concrete is being placed.

The specification requirements for slump vary depending on the type of work being constructed. Table 499.03-3 lists the required nominal slump and the maximum slump in inches (millimeters). These slumps are achieved using water and any required admixture. If the Contractor wants more slump than specified on Table 499.03-3, a Type F or Type G admixture may be used, and the nominal slump may be increased to 6 inches (150 mm) and the maximum slump may be increased to 7 inches (180 mm). The higher slump is allowed regardless of the type of work.

A retarding admixture (Type B or D) is required in all concrete if the plastic concrete temperature exceeds 75° F (24° C). The admixture must be dispensed in accordance with the admixture manufacturer's recommendations and the water cement ratio must not be exceeded.

Slump must be maintained at the specified nominal slump, except that an occasional load, exceeding the nominal range, but within the maximum slump limit, may be used. This is allowed provided an immediate adjustment is made to reduce the slump of succeeding loads to within the nominal slump range. Before using concrete exceeding the nominal slump, the Contractor or supplier must take positive action to reduce the slump of following loads. If the high slump was the result of adding too much water at the site, less water should be added to the next load. If high slump results from water added at the plant, notify the plant before using the batch and order an immediate reduction in water. Use of concrete having the slump between nominal and maximum should be restricted to an occasional load.

Slump Test (ASTM C 143)

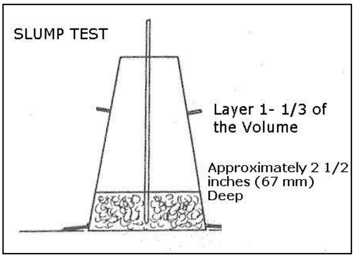
Start the slump test within five minutes of obtaining a composite sample. The inner surface of the slump cone is dampened and placed on a clean, flat, moist, non-absorbent, rigid surface, such as a smooth plank.

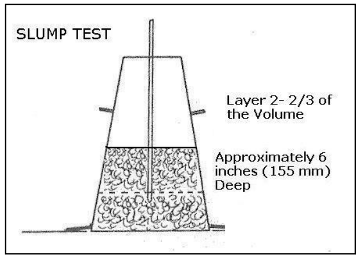
Figure 499.A – Pulling the slump cone vertically from a prepared sample

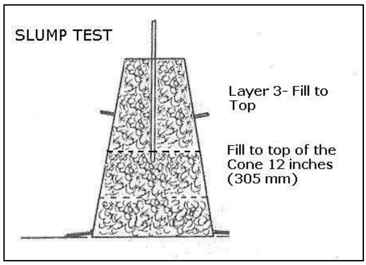
Figure 499.B – Equipment necessary for the slump test- slump cone, tamping rod, scoop, and ruler

Component Parts and Accessories

1. Slump Cone – A metal mold in the shape of a cone with an 8-inch ± 1/8-inch (203-mm ±3.2-mm) diameter base, a 4-inch ± 1/8-inch (102-mm ±3.2-mm) diameter top that is 12 inches tall. The mold must be made of metal no thinner than 0.045 inch (1.14 mm). The inside metal surface must be smooth.
2. Accessories
3. Tamping rod – A straight, 5/8-inch (16 mm) diameter rod that is approximately 24 inches (600 mm) long with a rounded (hemispherical) tip.
4. Ruler – A ruler or tape to measure the slump of the sample.
5. Scoop – A metal scoop that is used to place the concrete sample into the slump cone.







Method of Operation

The Inspector holds the cone firmly in place, while it is being filled, by standing on the foot pieces.

The mold is filled in three layers, each approximately one-third the volume of the mold: the first layer approximately 2 1/2 inches (67 mm) deep, the second layer 6 inches (155 mm) deep, and the third layer 12 inches (305 mm) to the top of the cone.

In placing each scoop of concrete in the slump cone, the scoop is moved around the top edge of the cone as the concrete slides from it in order to ensure uniform distribution of concrete within the cone.

Each layer is rodded 25 strokes with the tamping rod. The strokes are distributed in a uniform manner over the cross-section of the mold and should penetrate into, but not through, the underlying layer. The bottom layer is rodded throughout its depth.

In filling and rodding the top layer, the concrete is heaped above the mold and any excess is maintained above the top while rodding. After the top layer has been rodded, the surface of the concrete is struck off with the tamping rod so that the mold is exactly filled.

Next, release the foot pegs while pressing down firmly on the hand holds on the slump cone, while being careful to keep the cone firmly on the base. Remove any excess concrete at the base of the slump cone.

Lift the slump cone straight up in one steady motion. The operation of raising and removing the mold is performed in 3 to 7 seconds by a steady, upward lift, with no lateral or twisting motion being imparted to the concrete sample.

The slump is the distance the concrete drops from the original height of the sample, which is 12 inches (305 mm). To measure the distance, place the slump cone beside the slumped concrete and place the tamping bar on top of the cone so that the bar is level and

above the displaced original center of the sample. Measure the distance from the displaced original center of the sample to the bottom of the tamping rod. The distance measured is the slump of the concrete.

Figure 499.C – Measurement of slump

The entire operation from the start of filling through mold removal must be completed within the elapsed time of 2-1/2 minutes. The slump must be recorded in inches (millimeters) to the nearest 1/4-inch (6 mm). Slump cone test results should be recorded in the column labeled, "Slump Inches (millimeters)," on the TE-45 Report.

Slump Flow of Self Consolidating Concrete (ASTM C 1611)

This test is performed to determine the slump flow of self-consolidating concrete (SCC), and is used to monitor the flow potential of a SCC mix design. Since SCC fills formwork and flows around reinforcing steel without mechanical vibration, ensuring correct flow potential is important. This test is to be performed on a clean, flat, moist, non-absorbent, rigid surface. In this test, the slump cone will be turned upside down to carry out the procedures. The set-up of the slump flow test is shown below in Figure 499.D.

Figure 499.D – Slump flow test set-up

Component parts and Accessories

1. Slump Cone – A metal mold in the shape of a cone with an 8-inch ± 1/8-inch (203-mm ±3.2-mm) diameter base, a 4-inch ± 1/8-inch (102-mm ±3.2-mm) diameter top that is 12-inches tall. The mold must be made of metal no thinner than 0.045-inch (1.14-mm). The inside metal surface must be smooth.
2. Base Plate – a clean, flat, moist, non-absorbent, rigid plate having a minimum of dimension of 3-feet.
3. Strike off Bar – A flat, straight, steel, high-density polyethylene, or other plastic bar.

Method of Operation

The inspector must ensure that the interior of the mold is dampened before beginning the procedure. The mold is placed upside down and centered on the base plate, as shown in Figure 499.D. The mold must be centered on the base plate to ensure that concrete will not flow off of the base plate once the testing procedures are carried out.

The mold is to be filled using a pouring vessel, such as a concrete cylinder mold or other container. The mold is filled with SCC by tilting the vessel, ensuring an even distribution of concrete while pouring. No rodding or tapping of the mold is allowed.

Figure 499.E – Filled and leveled mold on clean base plate

Once the mold is filled, strike off the surface of the SCC using the strike-off bar. Once the mold has been leveled off and the base plate is free of any excess concrete as shown in Figure 499.E, remove the mold from the concrete by lifting it straight up in one steady motion without any lateral or torsional movement. This procedure is illustrated below in Figure 499.F.

Figure 499.F Lifting procedure for slump flow test

Figure 499.G – Final spread of SCC (Note: Concrete should not fall off the base plate at any time.)

Once the SCC stops flowing as shown in Figure 499.G, measure the largest diameter (d_1) of the resulting spread of concrete. Measure a second diameter (d_2) of the resulting spread perpendicular to the original measurement. Figure 499.H below shows the measuring procedure for the slump flow test. The average of d_1 and d_2 is the slump flow for the sample.

Figure 499.H – Measurement procedure for slump flow test

The entire procedure from the start of filling through the mold removal must be completed within the elapsed time of 2 ½ minutes. Slum flow must be recorded in inches (millimeters) to the nearest ¼ inch (5-mm). If the measurement of the two diameters differ by more than 2-inches (50-mm), the test is invalid. Figure 499.I below shows an example of a failed slump flow test.

Figure 499.I – Failed slump flow test

Concrete Yield

The yield of a concrete batch is the volume that it occupies. Concrete is sold by volume, but it is batched by the weight of each ingredient. This test is not specifically required for QC/QA specifications. It is the Contractor's responsibility. For non QC/QA concrete, the Inspector should run a QA for each day's production after the slump and entrained air content have been properly adjusted. A yield test is then done to confirm the volume of concrete in the batch.

Yield tests are made whenever the yield is in doubt, after adjustments are made in the mix, or when cylinders or beams are cast. Unless the quantity of concrete to be mixed is small, at least two tests should be made each day.

Yield must be within a tolerance of ± 1 percent at the design air content and at the specified slump. Therefore, 1 cubic yard (27 cubic feet) may vary from 26.73 to 27.27 cubic feet per cubic yard (1 cubic meter may vary from 0.99 to 1.01 cubic meter). An 8 cubic yard load is 216 cubic feet (8 x 27 cu.ft. / cu.yd.). This load may vary from 213.84 to 218.16 cubic feet (a 7-cubic meter load may vary from 6.93 to 7.07 cubic meters). A consistent over-yield or under-yield, even within the tolerance, should be corrected in order to maintain the correct cement factor.

Yield Test (ASTM C 138)

The yield is calculated by performing a field test to determine the unit weight of a representative sample of concrete taken from the batch. The Department uses the bottom pot of the pressure meter to determine the unit weight of a concrete sample. The unit weight of the concrete is then used to calculate the yield by the following formula:

$$Yield = \frac{Batch\ Weight}{Unit\ Weight}$$

Equation 499.18 – Yield

Unit weight is the ratio of the weight of a material to the volume that it occupies. Unit weight is expressed in pounds per cubic foot (kilograms per cubic meter).

Figure 499.J – Equipment used for the yield test

Figure 499.K – Scale used for the yield test

Component Parts and Accessories

1. A volume measure, a pressure meter air pot at least 0.20 ft^3 (0.006 m^3.) capacity. The container volume must be known or an air pot factor must be determined prior to use.
2. Accessories
   a. Strike-off bar.
   b. Scoop.
   c. Strike-off plate – A flat square plate at least 2 inches wider than the diameter of the measure and at least 1/4 inch (50 mm) thick if made of steel and 1/2 inch thick if made of glass.
   d. Tamping rod – A straight 5/8-inch (16 mm) diameter steel rod which is approximately 24 inches (600 mm) long with a rounded (hemispherical) tip.
   e. Scale – A scale of a capacity to weigh the pot filled with concrete.
   f. Rubber mallet, 1.25 ± 0.50 lbs (0.6 kg ± 0.25 kg).

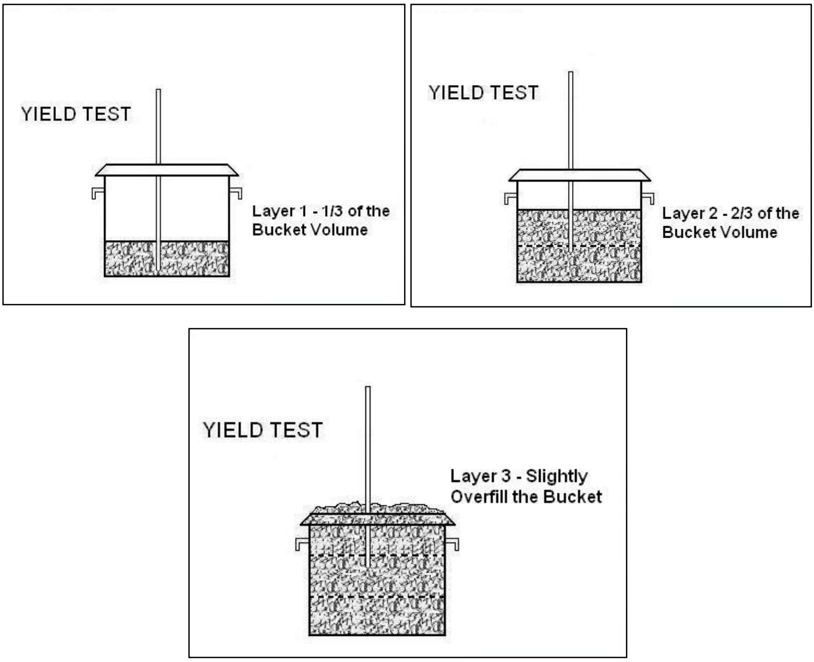


Figure 499.L – Yield Test – Bucket is filled in three equal layers

Method of Operation

The concrete yield is determined as follows:

1. To determine the unit weight of a concrete sample, first weigh the bottom of the empty air pot to the nearest 0.01 pound (0.005 kg).
2. Next, fill the measure with concrete, representative of that being placed in 3 equal layers, rodding each layer with 25 strokes of the tamping rod. After rodding each layer, tap the measure on the sides 10 to 15 times with an appropriate mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped.
3. After the consolidation is completed, strike-off excess concrete and finish even with the top edge of the measure with the metal strike-off plate. After strike-off, clean all excess concrete from the exterior of the measure and determine the gross weight of the measure and the concrete sample.
4. Calculate the net weight of the concrete sample in pounds (kilograms) by subtracting the weight of the measure from the gross weight.
5. The net weight of the concrete sample is then used to determine the unit weight. The unit weight is the product of the net weight of the sample under test and the air pot factor as follows:

$$Unit\ Weight = (Net\ \ Weight\ \ of\ \ the\ \ Sample) \times (Air\ \ Pot\ \ Factor)$$

Equation 499.19 – Unit Weight

The air pot factor is the inverse of the volume of the air pot in cubic feet, as shown in Equation 499.20:

$$Air\ Pot\ Factor = \frac{1}{Air\ Pot\ Volume}$$

Equation 499.20 – Air Pot Factor

Therefore, an air pot volume of 1/4 cubic feet or 0.25 cubic feet would have a pot factor as follows:

$$Air\ Pot\ Factor = \frac{1}{1/4\ ft^3} = \frac{1}{0.25\ ft^3} = 4.00$$

Note: The air pot factor is determined by a Laboratory test and is written on the side of all air pots. This factor is determined by a calibration process described in the section entitled, Determination of the Air Pot Factor.

When the air pot factor is multiplied by the net weight of the concrete sample that is consolidated and struck off into the air pot's volume (per Equation 499.19), mathematically it is the same as dividing the net weight of the sample by the volume of the concrete sample weighed. This gives the Unit Weight of the sample in pounds per cubic foot (kilograms per cubic meter).

The calculated unit weight of the concrete is the number of pounds per cubic foot (kilograms per cubic meter) for the sample under test. The unit weight is used to calculate the yield.

Next, calculate the yield using Equation 499.18:

$$Yield = \frac{Total\ Batch\ Weight}{Unit\ Weight}$$

The total batch weight of the concrete is the weight of all the ingredients used in the batch or a cubic yard. This includes cementitious materials, moist coarse and fine aggregate, water added at the plant, plus any water added at the job site to adjust slump. This total batch weight is divided by the unit weight of the concrete sample to determine yield. The yield is the number of cubic feet (cubic meters) of concrete in the batch.

Example:

The following are the batch weights for an 8-cubic yard (7-cubic meter) load of concrete, delivered to the project:

		English (lbs)	Metric (kg)
1	Cement	4,800	2,492
2	Fine Aggregate	10,698	5,550
3	Coarse Aggregate	13,229	6,868
4	Water	1,664	864
5	Total Batch Weight (1+2+3+4)	30,391 lbs	15,774 kg

An air pot with an air pot factor of 4.022 (141.24) is weighed empty and determined to be 7.98 lbs (3.62 kg). The gross weight of the air pot and the concrete sample is determined to be 43.52 lbs (19.83 kg). Determine the unit weight of the sample and the yield of the batch of concrete.

First determine the net weight of the concrete sample:

Gross wt. of measure + concrete	43.52 lbs (19.83 kg)
Tare weight of measure empty	-7.98 lbs (- 3.62 kg)
Net weight of concrete sample	35.54 lbs (16.21 kg)

Now that the net weight of the sample is known, the unit weight is determined by the use of Equation 499.19 as follows:

$$Unit\ Weight = (Net\ Weight\ of\ Sample) * (Air\ Pot\ Factor)$$

$$= 35.54 \text{ x } 4.022 \qquad (16.21 \text{ x } 141.24)$$

$$= 142.94 \text{ lbs/ft}^3 \qquad (2289.5 \text{ kg/m}^3)$$

Next, determine the yield of the 8-cubic yard (7-cubic meter) load of concrete by using Equation 499.18 as follows:

$$\text{Yield} = \frac{Total\ Batch\ Weight}{Unit\ Weight}$$

$$= \frac{30{,}391\, lbs}{142.94\, lbs/ft^3} \left(\frac{15{,}774\, kg}{2289.5\, kg/m^3} \right)$$

$$= 212.61 \text{ ft}^3 \; \left(6.89\, m^3\right)$$

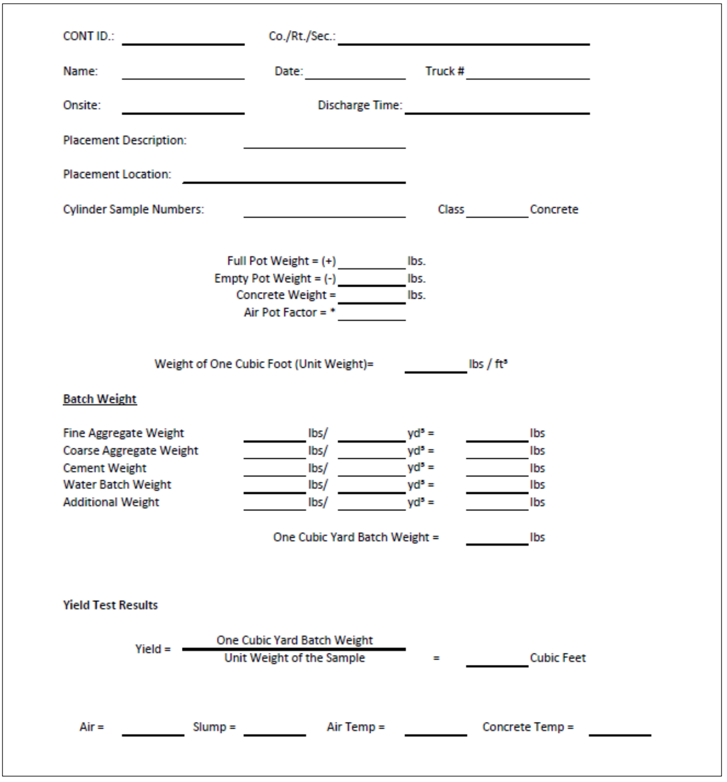
In English units, the intended number of cubic feet per batch is determined by multiplying the number of cubic yards in the batch by 27 cubic feet per cubic yard (27 x 8 = 216 = the intended number of cubic feet per batch). If the number of cubic feet per batch, as determined by the yield test, is within 1 percent of the design, at the specified air and slump, no change is necessary in the batch weights. However, if the volume of concrete is not within 1 percent of the intended volume, or if there is a continued over-yield or under-yield even though within 1 percent, then a yield adjustment must be made. A yield adjustment involves reducing or increasing the batch weights to correct an over-yield or under-yield situation.

In the above example, 8 cubic yards or 216 cubic feet was the intended yield but the calculated yield was 212.61 cubic feet. Therefore, there was an under-yield of 1.6 %, which exceeds the allowable 1%. To correct this under-yield the batch weights of the coarse and fine aggregate batch weights must be increased (thus adding more volume of material to the batch). Adjustment to correct an over-yield or under-yield should be based on the absolute volume of dry material.

In Metric units, the yield is compared to the design number of cubic meters batched to determine if the batch is within the one percent yield tolerance. The allowable deviation in yield for a 7 m^3 batch is 6.93 m^3 to 7.07 m^3. In the above example, the yield was found

to be 6.89 m³, which is less than the allowable range. Again, this under-yield situation requires an adjustment in the batch weights.

A Concrete Control Test Form is provided for documenting and calculating the tests run in the field. An example of this form is shown in Figure 499.M.



CONT ID.: ____________ Co./Rt./Sec.: ____________

Name: ____________ Date: ____________ Truck # ____________

Onsite: ____________ Discharge Time: ____________

Placement Description: ____________

Placement Location: ____________

Cylinder Sample Numbers: ____________ Class ________ Concrete

Full Pot Weight = (+) ________ lbs.
Empty Pot Weight = (-) ________ lbs.
Concrete Weight = ________ lbs.
Air Pot Factor = * ________

Weight of One Cubic Foot (Unit Weight)= ________ lbs / ft³

Batch Weight

Fine Aggregate Weight	______ lbs/	______ yd³ =	______ lbs
Coarse Aggregate Weight	______ lbs/	______ yd³ =	______ lbs
Cement Weight	______ lbs/	______ yd³ =	______ lbs
Water Batch Weight	______ lbs/	______ yd³ =	______ lbs
Additional Weight	______ lbs/	______ yd³ =	______ lbs

One Cubic Yard Batch Weight = ________ lbs

Yield Test Results

Yield = One Cubic Yard Batch Weight / Unit Weight of the Sample = ________ Cubic Feet

Air = ________ Slump = ________ Air Temp = ________ Concrete Temp = ________

Figure 499.M - Concrete Control Test Form

Making a Yield Adjustment

Assume the actual calculated number of cubic feet (cubic meters) per batch is 212.61 cubic feet (6.89 cubic meters), which is more than 1 percent under the 216-cubic foot (7.0-cubic meters) intended volume. Therefore, the batch weights must be increased. Equation 499.21 shows the calculation of the under-yield:

$$Percent\ OY\ or\ UY = \left(\frac{Actual\ Yield}{Intended\ Yield} \times 100\% \right) - 100\ \%$$

Equation 499.21 – Under-yield Calculation

Where:

Percent OY or UY= Percent Over-Yield or Percent Under-Yield

If the number obtained by Equation 499.19 is a negative number, there is an under-yield and volume must be added to get the yield back to the intended yield. Conversely, if the number is positive, there is an over-yield situation and volume must be removed from the batch to reduce the yield back to the intended yield.

Using the example numbers, the Percent Under- or Over-Yield can be determined:

Percent OY or UY =

$$\left(\frac{212.61\,ft^3}{216.00\,ft^3}\times 100\ \%\right) - 100\ \% = 98.4\ \% - 100\ \% = -1.6\%$$

$$\left(Percent\ OY\ or\ UY = \left(\frac{6.89\ m^3}{7.00\ m^3}\times 100\%\right) - 100\ \% = 98.4\ \% - 100\% = -1.6\%\right)$$

The total batch weight should be increased to adjust the under-yield. Since the batch of concrete did not produce the intended volume, additional volume of material must be added to adjust the under-yield. Adjustments are made in the fine and coarse aggregate based on absolute volume. The cement is the minimum specified, and therefore, is not changed. Water may vary slightly, and must be considered in making the adjustment. The calculations for adjusting the mix are as follows:

Total under-yield = 216 ft^3 - 212.61 ft^3 = 3.39 ft^3 (7.00 m^3 - 6.89 m^3 = 0.11 m^3)

Thus, the 8 yd^3 (7 m^3) load must be adjusted by adding 3.39 ft^3 (0.11 m^3) of volume. By adding this much volume to the load, the yield should increase in subsequent loads after the adjustment is made. The volume needed to adjust the under-yield is replaced with sand and stone in the same proportion as in the original concrete sample.

Next, determine the percent of fine and coarse aggregate in relation to the total aggregate weight in the original mix design. For this calculation, the corrected SSD design weights are to be used.

Fine aggregate (SSD)	10,160 lb	(5271 kg)
Coarse aggregate (SSD)	12,944 lb	(6720 kg)
Total Aggregate (SSD)	23,104 lb	(11,991 kg)

% Fine Aggregate =

$$\frac{10{,}160\ lbs}{23{,}104\ lbs}\times 100\ \% = 44\ \%$$

$$\left(\frac{5{,}271\,kg}{11{,}991\,kg}\times 100\ \% = 44\ \%\right)$$

% Coarse Aggregate =

$$\frac{12{,}944\ lbs}{23{,}104\ lbs} \times 100\ \% = 56\ \%$$

$$\left(\frac{6{,}720\ kg}{11{,}991\ kg} \times 100\ \% = 56\ \%\right)$$

Next, determine the proportion of the 3.39 cu. ft. (0.11 cubic meters) under-yield volume that must be fine and coarse aggregate. These adjustments maintain the same proportion of aggregate in the adjusted mix design as was in the original mix design.

Fine Aggregate	= 3.39 ft³ x 0.44	= 1.49 ft³ (= 0.11 m³ x 0.44 = 0.048 m³)
Coarse Aggregate	= 3.39 ft³ x 0.56	= 1.90 ft³ (= 0.11 m³ x 0.56 = 0.062 m³)
Total	= 3.39 cu. ft³	(= 0.110 m³)

Now that the absolute volume of fine aggregate and coarse aggregate necessary to correct the under-yield are known, the weight of each material can be calculated since the specific gravities of each aggregate are known.

Fine Aggregate Adj.	=1.49 ft³ x 2.59 x 62.4 lbs/ ft³ (Equation 499.6)
	= 241 lbs
	= (0.048m³ x 2.59 x 1000 kg/m³) (Equation 499.7)
	= (124 kg)
Coarse Aggregate Adj.	=1.90 ft³ x 2.63 x 62.4 lbs/ft³ (Equation 499.6)
	= 312 lbs
	= (0.062 m³ x 2.63 x 1000 kg/m³) (Equation 499.7)
	= (163 kg)

Thus from the above, it can be seen that 241 lbs (124 kg) of fine aggregate and 312 lbs (163 kg) of coarse aggregate are required to adjust the yield of this 8-cubic yard (7-cubic meter) load.

If the mix appears to be over-sanded, only the coarse aggregate needs to be adjusted. However, if the mix appears under-sanded, or bony, the adjustment should be in the fine aggregate only.

The adjustments in the SSD weight of fine and coarse aggregate for the above example are as follows:

Fine Aggregate	10,160 + 241 = 10,401 lb (5,271 + 124 = 5,395 kg)
Coarse Aggregate	12,944 + 312 = 13,256 lb (6,720 + 163 = 6,883 kg)

The new adjusted batch weights must next be determined, and the water-cement ratio must be checked to make sure the specified water-cement ratio is not exceeded with the new batch weights.

Determination of the Air Pot Factor

This test is done by the Laboratory or the District Test Lab and is shown here.

The air pot container is filled with water at room temperature and the top covered with a glass plate to eliminate all air bubbles and excess water. Determine the weight of water in the measure to the nearest 0.01-pound (.005 kg). Measure the temperature of the water and determine its density from the table below:

Density of Water			
English		**Metric**	
Temperature (Degrees F)	Density (lbs /cu. ft.)	Temperature (Degrees C)	Density (kg/ m^3)
60	62.366	16	999.10
65	62.337	18	998.64
70	62.301	21	998.06
75	62.261	24	997.42
80	62.216	27	996.70
85	62.166	29	995.90

Calculate the air pot volume factor by dividing the density of water (from the table) by the weight of water required to exactly fill the measure. Measures should be calibrated once each year and the pot factor painted on the measure. This air pot factor should be nearly 4.000 (141.24) indicating that the measure is about 0.25 cubic foot (0.00708 m^3) of volume.

Example:

Assume the temperature of the water used to fill the air pot bottom is 70º F and the following is determined in the laboratory:

1. Weight of air pot bottom empty plus the glass plate = 8.98 lbs
2. Weight of air pot bottom plus glass plate plus water = 24.47 lbs
3. Weight of water in air pot bottom = (2) - (1) = 15.49 lbs
4. Density of water at 70º F, from the above table = 62.301 lbs/cu.ft.

$$\text{Air Pot Factor} = \frac{\textit{Density of water}}{\textit{Weight of water in air pot bottom}} = \frac{62.301\, lbs/ft^3}{15.49\, lbs} = 4.022$$

Total Air Tests (ASTM C 231 or ASTM C 173)

The air content of concrete is measured by a standard test in accordance with either ASTM C 231 (Pressure Meter Method) or ASTM C 173 (Volumetric Method).

Figure 499.N – Pressure meter method

Figure 499.O – Volumetric method

Air tests must be made for several loads or batches at the start of daily production and after any adjustment in the batch weights. A test is made whenever it is suspected that

adequate air entrainment is not being maintained. An air test must also be made when a yield test is made and when cylinders or beams are cast.

The requirements apply at the point of use; therefore, these tests must be made by the concrete control Inspector at the job site. However, it may be desirable to check the air content of the concrete at the plant for the first few batches of the day and also after any adjustment has been made in the concrete mix design. These checks can detect deficiencies in air content at the plant where immediate corrections can be made.

The approximate amount of entrained air may be determined quickly by using a Chace Indicator. Every load of transit mix concrete used in superstructures must be checked for air entrainment. The Chace Indicator permits a quick check of every load. Its use also is desirable for all concrete work to quickly check the requirement for entrained air. Whenever the specification limits are exceeded according to the Chace Indicator, a more accurate determination must be made using an air meter (Pressure Meter or Volumetric Meter).

Make a test from the same batch of concrete at least once a day using the Chace Indicator and an air meter to compare the results. Comparison of these results provides the Inspector with a guide when using the Chace. If the Chace indicates 4.5 percent and the meter test result is only 4.0 percent, the air must not be permitted to drop below 4.5 percent when checked using the Chace.

Use a Pressure Meter or Volumetric Meter to determine the air content to be reported when making yield tests and when casting cylinders. An accurate determination is necessary in each case; therefore, an accurate test is required.

A Chace Indicator and Volumetric air pot can be used for all types of concrete. The Pressure Meter must not be used when slag or light weight coarse aggregate are used in the concrete. The Pressure Meter is limited to concrete consisting of relatively dense coarse aggregate such as gravel or limestone. A Volumetric Meter test must be used when slag or lightweight aggregates are used. Detailed explanation of each method follows.

Air Content of Freshly Mixed Concrete by the Pressure Meter (ASTM C 231)

This test method is used with dense aggregate concretes for which the aggregate correction factor can be determined. This method is not applicable to light weight aggregates, air-cooled blast furnace slag, or aggregates of high porosity. If these aggregates are incorporated, a volumetric air test (ASTM C 173) must be used.

This air test measures the entrapped and entrained air in the concrete sample. The air content from this test is the apparent air content of the sample. A separate test is made on the aggregates used to make the concrete to determine an aggregate correction factor for the concrete aggregates. This percentage value is subtracted from the apparent air content to obtain the amount of entrained air in the concrete. Department specifications specify the amount of entrained air that is required in the concrete at the point of use.

Figure 499.P – Assembled pressure meter

Figure 499.Q – Equipment necessary for pressure meter test

The Pressure Meter Test is performed as follows:

Parts and Accessories

1. Component Meter.
    a. Pot at least 0.20 ft³ (0.006 m³) capacity.
    b. Top, including gauge, pump, and clamps.
2. Accessories.
    a. Calibration cylinder.
    b. Section of straight tubing.
    c. Section of curved tubing.
    d. Strike-off bar.
    e. 16-mm (5/8") Tamping rod.
    f. Rubber syringe.
    g. Rubber mallet, 0.6 kg ± 0.25 kg (1.25 ± 0.50 lbs).

h. Wooden carrying case.

Method of Operation

Follow these steps to use a Pressure Meter to determine the percentage of air in a sample of concrete:

1. Place a representative sample of the concrete in the bowl in three equal layers, consolidating each layer by 25 strokes of the tamping rod distributed over the entire cross-section of the bowl. After each layer is rodded, tap the sides of the measure smartly 10 to 15 times with the rubber mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. Rod the bottom layer through its depth, but do not forcibly strike the bottom of the bowl. When rodding subsequent layers penetrate the previous layer only about 1 inch (25 mm).
2. Strike off the concrete surface, level full using the straightedge (or a plate when determining the unit weight), then clean the edge and exterior of the pot thoroughly.
3. At this point, the pot and sample is weighed. This gross weight is documented for later use when determining the yield.
4. Next, place the top on the pot and clamp securely. Close the air valve between the air chamber and the bowl and open both petcocks.
5. Using the rubber syringe, inject water through one petcock until all air is expelled through the opposite petcock. Leave petcocks open.
6. With built-in pump, pump up air to the "Initial Pressure" line on gauge. This initial pressure line is given on the paper in the carrying case lid.
7. Wait a few seconds for the compressed air to cool to normal temperature and then stabilize the gauge hand at the proper initial pressure line by pumping or bleeding off as needed.
8. Close both petcocks and press down on the thumb lever to release air into the base. Hold thumb lever down for a few seconds. Tap the sides of the bowl several times sharply with the mallet. Lightly tap the gauge to stabilize the hand on the dial.
9. Read and record the percent of air entrainment as shown on the gauge. This is the apparent air content of the concrete in percent.
10. The true percentage of air-entrained in the concrete is the apparent air content, as found is in 9 above, minus the aggregate correction factor as determined is in the following section entitled, Determination of Aggregate Correction Factor. Therefore, subtract the aggregate correction factor from the apparent air content found in 9 and record it on the TE-45 Report as percent of entrained air in concrete.

Determination of Aggregate Correction Factor

Since aggregate particles generally are porous, they contain a small amount of volume of air that is included in the apparent air content, as measured in 9 above. This volume percentage must be deducted from the total air content percentage to obtain the true entrained air content of the concrete. To obtain the aggregate correction factor it is necessary to run an air determination (with the pressure meter) on equivalent amounts of fine aggregate and each size of coarse aggregate that would be contained in the air pot volume of concrete. This factor varies with different aggregate sources and must be determined by actual tests. The aggregate correction factor is determined prior to any concrete placement and is applied as long as there is no change in the source of the aggregate or proportioning used in the concrete under test.

The Aggregate Correction Factor is determined as follows:

1. The amount of each aggregate to be used in the test is determined by dividing the volume of the air pot by the intended volume of the concrete batch. This ratio is multiplied by the actual batch weight of the particular aggregate that was used in the concrete. Use equation 499.24 to determine the weight of each aggregate to be used in the test.

$$\text{Aggregate weight} = \left(\frac{APV}{IBV}\right) \times ABW$$

Equation 499.24 – Weight of each Aggregate

Where:

APV = Air Pot Volume in cubic feet (m^3)

IBV= Intended Batch Volume in cubic feet (m^3)

ABW = Aggregate Batch Weight in lbs. (kg) for the intended volume

Example:

Given the following information determine the amount of fine and coarse aggregate necessary for an aggregate correction test:

Volume of Air Pot = 0.25 ft^3 (0.00708 yd^3)

Intended Volume of Concrete per Batch = 8 yd^3 or 216 ft^3 (7 m^3)

Aggregate Batch Weight for Fine Aggregate = 10,698 lbs (5550 kg)

Aggregate Batch Weight for Coarse Aggregate = 13,229 lbs (6868 kg)

Fine Aggregate Weight	$=\frac{0.25\,ft^3}{216\ \ ft^3}\times 10{,}698\ lbs$	(Equation 499.24)
	$=12.38\ lbs$	
	$=\left(\frac{0.00708\ m^3}{7.00\ m^3}\times 5550\ kg\right)$	(Equation 499.24)
	$=(5.6\ kg)$	
Coarse Aggregate Weight	$=\frac{0.25\,ft^3}{216\,ft^3}\times 13{,}299 lbs$	(Equation 499.24)
	$=15.31\ lbs$	
	$=\left(\frac{0.00708\ m^3}{7.00 m^3}\times 6868\ kg\right)$	(Equation 499.24)
	$=(6.9\ kg)$	

Therefore, 12.38 pounds (5.6 kg) of sand and 15.31 pounds (6.9 kg) of stone are used to determine the correction factor.

2. Fill the air pot one-third full of water. Carefully add a portion of the coarse aggregate then a portion of the fine aggregate. Jar the pot and rod the aggregate to eliminate any entrapped air. Carefully repeat, adding portions of each aggregate until all the aggregate is inundated into the pot. Each aggregate addition must be added carefully as instructed in order to get the entire quantity into the volume of the pot. Make sure that aggregate in the pot remains submerged at all times. If the sand is not rodded into the voids between the coarse aggregate particles, the aggregate quantities will overflow the pot. Aggregates should be in approximately the same moisture condition as those used in the concrete.
3. Strike-off any excess foam and keep the aggregates inundated for a period of time approximately equal to the time between introduction of water into the mixer at the concrete plant and the time of performing the air test in the field.
4. Screw the short piece of straight tubing into the threaded petcock hole on the underside of the top cover. Place the top on the pot and clamp securely. Close the air valve between the air chamber and the measuring bowl and open both petcocks.
5. Add water with a syringe through the petcock having the pipe extension below until all air is expelled from the second petcock. Leave both petcocks open.
6. Pump up the air pressure in the air chamber to a little beyond the initial pressure line marked in the carrying case lid. Wait a few seconds for the compressed air to cool to normal temperature, and then stabilize the gauge at the proper initial pressure line by pumping or bleeding off air as needed and tapping the gauge slightly.
7. Screw the curved tube into the outer threaded end of the petcock. Close both petcocks and press the thumb lever to release the air into the bowl. Fill the 5

percent calibrating vessel level full of water from the base by controlling the flow of water with the petcock valve on the curved tube.

8. Release the air at the free petcock and let the water in the curved pipe run back into the base. The air meter now has 5 percent of its volume removed.
9. With both petcocks open, pump the air pressure in the air chamber to slightly beyond the initial pressure line. Wait for the compressed air to cool, and then stabilize the gauge hand at the proper initial pressure line by pumping or bleeding off air as needed and tapping the gauge slightly.
10. Close both petcocks and press the thumb lever to release the air into the bowl.
11. Read and record the air content shown on the meter. The aggregate correction factor will be the difference between the air content on the meter minus 5 percent.

Note: Normally the aggregate correction factor will be between 0.1 and 0.8 percent. This factor will ordinarily remain constant (with limestone or gravel coarse aggregate) for the same combination and quantity of aggregate. It is essential, therefore, to determine the aggregate correction factor accurately since any errors made in the factor will be reflected in all air content determinations. BE SURE THAT ALL AIR ENTRAPPED IN THE INUNDATED AGGREGATE IS ELIMINATED WHEN PREFORMING THE TEST.

Checking Calibration of Gauge

All Pressure Meters are calibrated and tested for leaks. Any changes found in the manufacturer's initial pressure line is marked in red on the paper in the carrying case lid, before the meters are issued by the Laboratory. However, rough handling or worn or damaged parts will affect the calibration. Therefore, the operator should check the meter every 3 months. The method of checking is as follows:

1. Fill the base with water.
2. Screw the short piece of straight tubing in the threaded peacock hole on the underside of the cover. Clamp cover on the base with the tube extending down into the water.
3. With both petcocks open, add water with syringe through the petcock having the pipe extension below, until all air is forced out of the opposite petcock. Leave both petcocks open.
4. Pump up air pressure to a little beyond initial pressure line marked in carrying case lid. Wait a few seconds for the compressed air to cool to normal temperature and then stabilize the gauge hand at the proper initial pressure line by pumping or bleeding off as needed.
5. Close both petcocks and immediately press down on the thumb lever exhausting air into the base. Wait a few seconds until the hand is stabilized. If all the air was eliminated and the initial pressure line was correctly selected, the gauge should read 0 percent. If two or more tests show a consistent variation from 0 percent, then change the initial pressure to compensate for the variation. Use the newly established initial pressure line for subsequent tests.
6. Screw the curved tube into the outer end of petcock, and by pressing on the thumb lever and controlling flow with petcock lever, fill the 5 percent calibrating vessel lever full of water from the base.
7. Release the air at the free petcock. Open the other petcock and let the water in the curved pipe run back into the base. There is now 5.0 percent air in the base.
8. With petcocks open, pump air pressure in the exact manner as outlined in Step 4 above. Close petcocks and immediately press the thumb lever. Wait a few

seconds for the exhaust air to cool to normal temperature and for the needle to stabilize. The dial should now read 5.0 percent.

9. If two or more consistent tests show that the gauge reads less than 4.9 percent or more than 5.1 percent then remove the gauge glass and reset the dial hand to 5.0 percent by turning the recalibrating screw located just below and to the right of the center dial.

Air Content of Freshly Mixed Concrete by Volumetric Method (ASTM C 173 modified for ODOT use)

This test method can be used on concrete containing any type of coarse aggregate. This method gives the total air content, which includes both entrapped and entrained air. This method must be used if lightweight coarse aggregate, air-cooled blast furnace slag coarse aggregate or aggregate of high porosity is used in the concrete under test.

The method involves taking a known volume of concrete and breaking it down by washing it with water in a sealed container. A fixed amount of water is used to wash the sample of concrete in the container. After the washing, the volume of the sample and wash water decreases by the volume of air washed from the known volume.

Figure 499.R – Assembled brass volumetric air meter

Figure 499.S – Plastic volumetric air meter and accessories

Parts and Accessories

1. Meter.
   a. Bottom Pot, 0.075 cu. ft. (2.1 L) capacity.
   b. Top cone, including gauge glass, clamps and top plug.
2. Accessories.
   a. Water filler and dispersion tube.
   b. Strike-off bar.
   c. 5/8-inch (16 mm) diameter tamping rod.
   d. Brass cup capacity 23 milliliter.
   e. Small rubber syringe.
   f. Can of 70 percent isopropyl alcohol (poison).
   g. Rubber mallet 1.25 ± 0.50 lbs (0.6 kg ± 0.25 kg).
   h. Carrying case.

Method of Operation

The percent of entrained air in a sample of concrete is determined as follows using the volumetric air meter:

1. Place a representative sample of the concrete in the bowl in two equal layers, consolidating each layer by 25 strokes of the tamping rod. After each layer is rodded, tap the sides of the measure 10 to 15 times smartly with the rubber mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped.
2. Strike-off the concrete surface, level full using the straightedge.
3. Place the cone on the pot and clamp securely.
4. Insert the dispersion tube into the neck of the meter. Add at least one pint of water followed by one pint of isopropyl alcohol. Continue adding water until it appears in the graduated neck of the top section of the meter. Remove the dispersion tube. Bring the water level up until the bottom of the meniscus is even with the 0 mark.
5. Attach and tighten the water-tight cap.
6. Repeatedly invert and agitate the unit for a minimum of 45 seconds to free the concrete from the base. Do not invert the meter from more than five seconds at a time.
7. Tilt the meter approximately 45 degrees and vigorously roll and rock the meter for approximately 1 minute keeping the neck elevated at all times.
8. Set the meter upright and allow it to stand while the air rises to the top until the liquid stabilizes. Consider the liquid stabilized when it does not change more than 0.1 percent within a one-minute period.
9. If the liquid level is obscured by foam, use the rubber syringe to add sufficient alcohol from a calibrated cup equaling 1 percent of the base's volume. Record the number of calibrated cups of alcohol required to disperse the foam.
10. Repeat the rolling and rocking procedure until two consecutive readings do not differ by more than 1/4 percent.
11. Once the level has stabilized, determine the level of water in the neck of the meter to the nearest 1/1/4 percent. Add the number of cups of alcohol used to disperse the foam to the meter reading.
12. Disassemble and empty the contents in the bowl and examine the bowl to make sure that all of the concrete was dislodged during the agitating and rolling and

rocking procedures. If there is a significant amount of concrete remaining in the bowl, the test is invalid and must be redone.

Chace Air Indicator for Determination of Entrained Air (AASHTO T-199)

This method of test covers the determination of the air content of freshly mixed concrete by displacing the air with alcohol and observing the change in level of the liquid in a tube. The apparatus is light and small, and the test procedure requires only a few minutes.

This method is satisfactory for determining the approximate air content of freshly mixed concrete. It should not, however, be considered suitable for replacing the pressure method) or volumetric method and in no case should the value obtained through the use of this method be accepted as determining the compliance of the air content of concrete with the requirements of specifications. The method is most useful for determining whether the concrete has a low, medium, or high air content and whether the air content is reasonably constant from batch to batch of concrete.

Parts and Accessories

1. Air Indicator.
   a. 0.22 cubic inches (3.6 ml) capacity cup.
   b. Rubber stopper.
   c. Glass top.
2. Accessories.
   a. Rubber syringe.
   b. Tamping blade.
   c. Can of 70 percent isopropyl alcohol (poison).

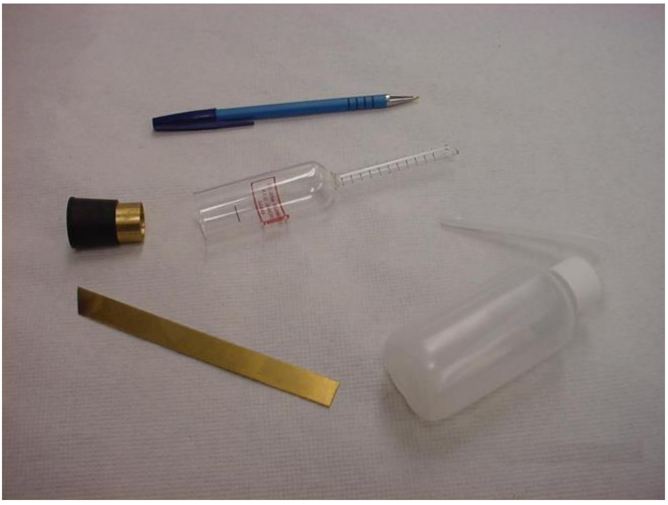


Figure 499.T – Chace air indicator equipment

Method of Operation

The percent of entrained air in a sample of concrete is determined as follows:

1. Fill the metal cup with cement mortar taken from the concrete, from which any particles larger than a No. 10 (2.00 mm) sieve have been removed with the tamping blade. A No. 10 (2.00 mm) sieve has openings of 0.0787 inches (2 mm) wide or a little less than 3/32 inches (2.38 mm). Use the tamping blade to pick up mortar. The mortar should not be wet screened to remove the material larger than a No. 10 (2.00 mm) sieve. Spade material into the cup with tamping blade to compact the mortar. Strike-off excess even with top of cup.
2. Hold finger over stem opening of glass top and fill the glass tube with alcohol to the marked line about 1 inch (25 mm) from the large end of the glass.
3. Carefully insert cup filled with mortar into the glass top and turn indicator to a vertical position with the graduated stem up. Be sure stopper is firmly in place. Adjust liquid to top line of stem by adding alcohol with syringe, making sure that all air bubbles are removed. This can be done by slightly tilting the indicator.
4. Place finger over the stem opening to prevent liquid loss. Gently roll the indicator from vertical to horizontal and back several times until the mortar has been washed out of the cup.
5. With the indicator in the vertical position, carefully remove finger from the opening and count the number of spaces from the top line to the new liquid level estimating to the nearest 0.1. Each space represents 1 percent of entrained air. The air indicator is designed to read directly for a concrete mix having 15 cubic feet of mortar per cubic yard (0.56 cubic meters of mortar per cubic meter) of concrete. Therefore, the air content as determined by each test must be corrected for mixes with different mortar content.
6. No conversion factor is used when gravel coarse aggregate is used in the concrete mix. In this case, the percentage of entrained air is read directly from the stem. However, when limestone or slag is used, it is necessary to multiply the stem reading by 1.05 to determine the percentage of entrained air. Record the result to nearest 0.1 percent.

Figure 499.U – Chace air indicator

Temperature of Freshly Mixed Portland Cement Concrete (ASTM C -1064)

Parts and Accessories

Container – The container must be large enough to provide at least 3 inches (75 mm) of concrete in all directions around the sensor of the temperature-measuring device.

Temperature Measuring Device – The device used must be capable of measuring freshly mixed concrete to ± 1° F (± 0.5° C) throughout the entire temperature range to be encountered.

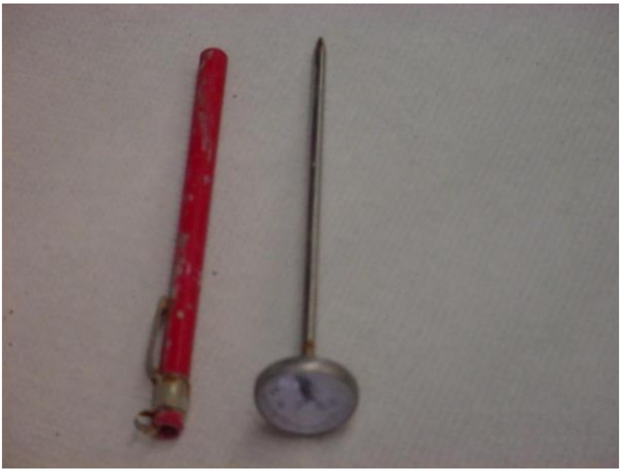


Figure 499.V – Concrete thermometer

Method of Operation

The temperature of freshly mixed concrete may be measured in the transporting equipment provided the sensor of the temperature measuring device has at least 3 inches (75 mm) of concrete cover in all directions. The temperature is measured as follows:

1. Place the temperature measuring device in the freshly mixed concrete so that the temperature sensing portion is submerged a minimum of 3 inches (75 mm).
2. Gently press the concrete around the temperature-measuring device at the surface of the concrete so that the ambient temperature does not affect the reading.
3. Leave the temperature-measuring device in the freshly-mixed concrete for a minimum of 2 minutes or until the temperature reading stabilizes, then read and record the temperature.
4. Complete the temperature measurement within 5 minutes after obtaining the sample.
5. Report the temperature to the nearest 1°F (0.5 °C)

Gradation of Aggregate

If aggregate is from a certified source there is no need for further sampling and testing. However a routine sieve analysis can be made to check compliance with gradation requirements. Gradation can be checked if there are questions about the concrete you are getting. If there is an issue, obtain a representative sample and send to the District Test Lab for evaluation and results.

Making and Handling Concrete Cylinders (ASTM C-31)

The preparation and handling of concrete test specimens are an important part of the Inspector's duties, since the cylinders furnish an indication of the quality of the concrete being produced as the work progresses. Cylinders must be made and handled strictly in accordance with the following instructions.

On structures over 20-foot (6.1 m) span, three test cylinders 4 inches (100 mm) in diameter and 8 inches (200 mm) high are made from each 200 cubic yards (150 m^3) of each class of concrete, or fraction thereof, incorporated into the work. On structures of 20-foot (6.1 m) span or less and bridge deck overlay projects, at least two cylinders are made for each 50 cubic yards (40 m^3) of each class of concrete.

Parts and Accessories

1. Cylinder molds
2. Scoop
3. 3/8-inch (16 mm) steel tamping rod

The cylinder molds are placed on a firm, level surface, such as a board, so that the bottoms will not become deformed in the process of making the cylinders.

Cylinders are always made in sets of threes from the same batch of concrete.

Figure 499.W – Equipment for making concrete cylinders

Method of Operation

The molding of the specimens is performed as follows:

1. With the scoop, fill each mold evenly one-half full of fresh concrete and rod each mold 25 times with the tamping rod, distributing the strokes evenly over the cross-sectional area of the mold and completely penetrating the layer of concrete. The rod should lightly touch the bottom of the mold. Tap the mold lightly 10 to 15 times to close any air voids left by the tamping rod.
2. Finally, fill the mold to overflowing and rod 25 times as before. Again, the sides of the mold should be tapped lightly 10 to 15 times to close any voids left by the tamping rod.
3. Using the tamping rod or trowel, strike-off the excess concrete flush with the top of the mold. This concludes the operation and there should be no further manipulation of concrete or mold. Specimens are made in one continuous operation.
4. After making the three 4-inch x 8-inch cylinders, place lids on the cylinders.
5. Install the retaining ring with three 4-inch diameter holes into the curing bucket.
6. Place the cylinders into the curing bucket through the holes in the retaining ring.
7. In <u>Hot Weather</u> conditions, add water to the bucket to buffer the cylinders against the heat. Shade the bucket from the sunlight. Pour the water out of the bucket (for weight purposes) before transporting the cylinders to the lab
8. In <u>Cold Weather</u> conditions, cover the buckets with thermal blankets, burlap and plastic, etc. to prevent heat loss and provide a heat source if possible.
9. For projects with a curing box required by 619.02, carefully move the cylinders in the buckets to curing box after 24 hours. Otherwise, move the bucket to the field office to maintain samples within appropriate temperatures.

When cylinders are made, the following tests should also be made using concrete from the same batch:

1. Slump
2. Yield
3. Concrete temperature
4. Air test

Be sure and acquire a sufficient quantity of concrete to provide for all these tests. Record the test values on the TE-45 Report or directly into a SiteManager sample on test screens.

1. PCC INSPECTOR DAILY REPORT TE45 PART 1 – BATCH WT
2. PCC INSPECTOR DAILY REPORT TE45 PART 2 – TESTS

Reporting these values from the same batch as used for casting cylinders provides valuable data for evaluating compressive strengths of cylinders. Therefore, always determine slump and air from the same batch of concrete used in cylinders.

Documentation:

Write the Specimen numbers on the cylinder molds.

Create a TE-10 tag with the SiteManager sample number and attach the tag to the handle of the bucket.

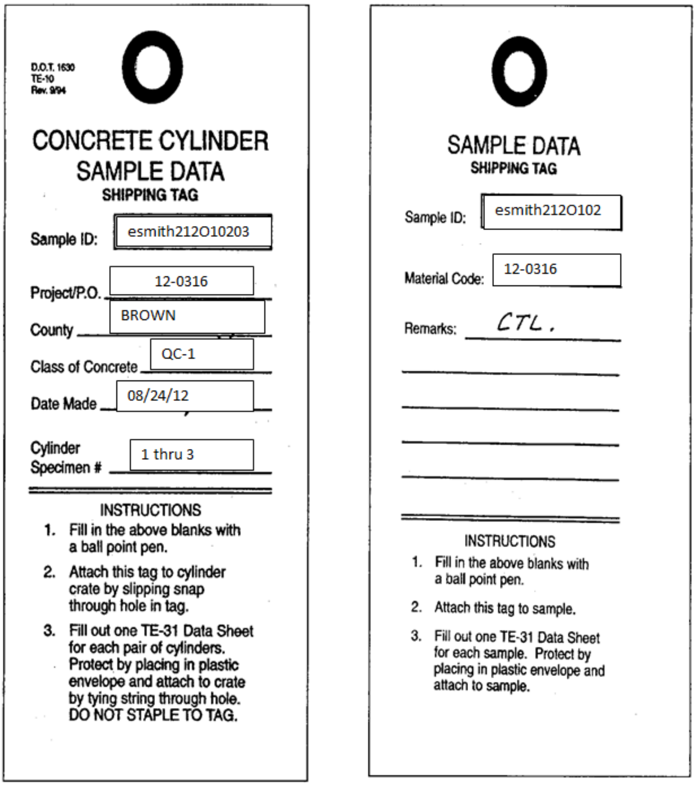
Either one TE-31 form describing detailed information on the concrete to be tested or a screen print from the SiteManager test screen. Put the paper in a plastic envelope and put the envelope in the bucket.

Concrete cylinders using ordinary Portland cement concrete mixes are prepared for shipment and sent to the District Laboratory 48 hours after molding. If high-early-strength cement is used, cylinders are shipped to the District laboratory when required by the project but not sooner than 24 hours after molding

The three cylinders are packed in a shipping barrel with water and one TE-10 tag is taped before engaging the snap to the ring on the strap on the top of the case. A filled out copy of a TE-10 tag is shown in Figure 499.X and a filled out copy of a TE-31 form is shown in Figure 499.Y.

Cylinder test results will be reported in SiteManager in PCC INSPECTOR DAILY REPORT TE45 PART 2 – TESTS screen.

When project concrete requires, “with QC/QA,” Contractor’s test results only need to be reported. Make a SiteManager sample but only complete the PCC INSPECTOR DAILY REPORT TE45 PART 2 – TESTS screen. Do not complete the PCC INSPECTOR DAILY REPORT TE45 PART 1 – BATCH WT screen.



D.O.T. 1630
TE-10
Rev. 9/94

CONCRETE CYLINDER SAMPLE DATA
SHIPPING TAG

Sample ID: esmith212O10203
Project/P.O. 12-0316
County BROWN
Class of Concrete QC-1
Date Made 08/24/12
Cylinder Specimen # 1 thru 3

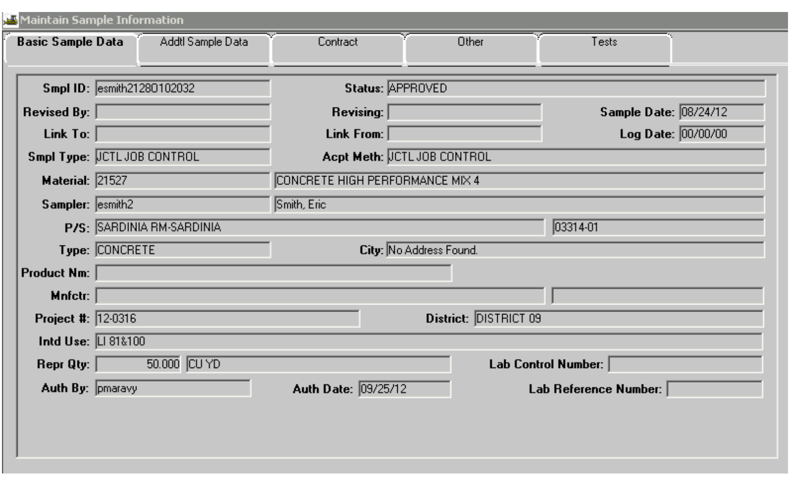
INSTRUCTIONS
1. Fill in the above blanks with a ball point pen.
2. Attach this tag to cylinder crate by slipping snap through hole in tag.
3. Fill out one TE-31 Data Sheet for each pair of cylinders. Protect by placing in plastic envelope and attach to crate by tying string through hole. DO NOT STAPLE TO TAG.

SAMPLE DATA
SHIPPING TAG

Sample ID: esmith212O102
Material Code: 12-0316
Remarks: CTL.

INSTRUCTIONS
1. Fill in the above blanks with a ball point pen.
2. Attach this tag to sample.
3. Fill out one TE-31 Data Sheet for each sample. Protect by placing in plastic envelope and attach to sample.

Figure 499.X - Filled out TE-10 tags



Maintain Sample Information

Basic Sample Data | Addtl Sample Data | Contract | Other | Tests

Smpl ID: esmith21280102032
Status: APPROVED
Revised By:
Revising:
Sample Date: 08/24/12
Link To:
Link From:
Log Date: 00/00/00
Smpl Type: JCTL JOB CONTROL
Acpt Meth: JCTL JOB CONTROL
Material: 21527 CONCRETE HIGH PERFORMANCE MIX 4
Sampler: esmith2 Smith, Eric
P/S: SARDINIA RM-SARDINIA 03314-01
Type: CONCRETE
City: No Address Found.
Product Nm:
Mnfctr:
Project #: 12-0316
District: DISTRICT 09
Intd Use: LI 81&100
Repr Qty: 50.000 CU YD
Lab Control Number:
Auth By: pmaravy
Auth Date: 09/25/12
Lab Reference Number:

Figure 499.Y - Filled out SiteManager screen

Making Concrete Test Beams

When required by specification, the concrete control inspector will make and test concrete beams as described here, and report the results in the ODOT SiteManager as explained in Supplement 1023.

Where beam tests are made to determine when a section of pavement or base may be opened to traffic, two 6-inch x 6-inch x 40-inch (152 mm x 152 mm x 1016 mm) concrete beams are made using the same concrete being placed in the pavement or base.

Section 511.14 Table 511.14-1b of the specifications requires falsework for structures to remain in place until the concrete has attained adequate strength as determined either by the length of curing time or by the testing of standard concrete beams. When beams are desirable to determine removal of falsework, they must be made from the same concrete as that supported by the falsework.

The Laboratory (through the District Engineer of Tests) will provide the Inspector with the equipment for making and testing of concrete beams.

Parts and Accessories

1. 6-inch x 6-inch x 40-inch (152-mm x 152-mm x 1,016-mm) steel molds
2. Spading tool
3. Trowel
4. Rubber mallet
5. Beam testing machine

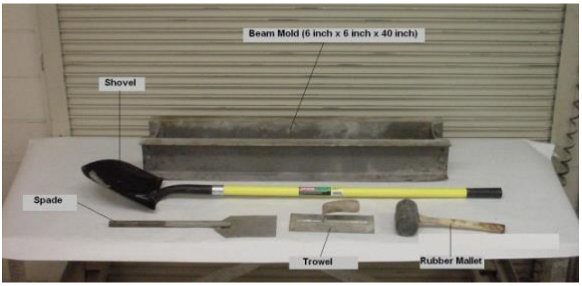


Figure 499.Z – Equipment for beam testing

Method of Operation

The beams must be made as described here. Beams must be made and tested in accordance with Supplement 1023. Steel beam molds must be free of dirt, hardened concrete, or rust. They are placed on a smooth, clean, level, and unyielding surface that has been lightly oiled to prevent the concrete from sticking. The inside of each mold is oiled in the same manner.

1. Using a shovel, fill each mold half-full with 3 inches (75 mm) of concrete representative of that in the batch.
2. With the blade of the spading tool held at an angle to the ends of the mold, spade the concrete 20 times at equal intervals from one end of the mold to the other.
3. Then, turning the blade of the spading tool, cross-spade 20 times at equal intervals back in the opposite direction of the end of the mold.
4. Spade entirely around the side and ends of the mold.
5. Tap along each side of the mold 15 times (total of 30 taps per lift) with the rubber mallet.
6. Fill the mold to overflowing with concrete and repeat the spading and taping operations as before.
7. Strike-off the excess concrete and trowel the concrete flush with the top of the beam mold.
8. After concrete is set, the beam numbers are scratched into the concrete for future identification.
9. Beams must be cured as nearly as possible in the same manner as the concrete from which they are made.

Pavement beams for 451 and 452 are normally tested at 3, 5, or 7 days of age. If the results are not needed before the end of the 7-day curing period, only one beam break is necessary and should be made at the age of 7 days.

The beams must be tested with the center loading, hydraulic type-testing machine. The load is applied with a hydraulic jack. The machine scale reading is a direct reading of the modulus of rupture in pounds per square inch (megapascals).

Testing Beams with Center-Loading Hydraulic Type Testing Machine

The hydraulic, center-loading, beam breaker is designed to test 6-inch x 6-inch x 40-inch (152-mm x 152-mm x 1,016-mm) concrete beams. Two flexural strength tests can be made with each beam. The breaker shows a direct read out in pounds per square inch (megapascals) directly on the dial. No charts or conversion tables are needed to change total load to flexural strength, as is the case with other types of beam breakers now in use. The standard 6-inch x 6-inch (152-mm x 152-mm) beam is the only size beam on which this breaker can be used.

Figure 499.AA – Hydraulic beam tester in position on beam

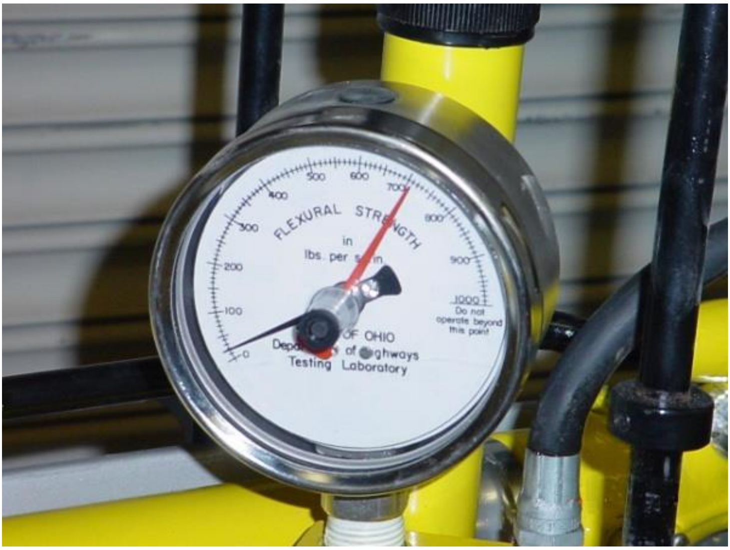


Figure 499.AB – Pressure gauge dial

Parts and Accessories

1. Beam Breaker.
    a. A main frame with two 7-inch (178 mm) channels containing two fixed rollers.
    b. Yoke assembly containing hydraulic ram, pressure gauge with four 1/2-inch (114 mm) dial choker valve located just below the gauge, and center roller.
2. Accessories.
    a. Carrying Case.
    b. Rubber Mallet.
    c. Spade.
    d. Trowel.

Method of Operation

The flexural strength, in pounds per square inch (megapascals) is obtained is in the following manner:

1. Prepare the beam for testing by rotating it 90 degrees around the long axis from the position in which it was molded. The original top of the beam should now be on the side and the top and bottom of the beam should be the sides of the beam that were originally against the mold. Raise the beam at least 2 inches (50 mm) off the ground by supporting each end. This allows clearance under the beam so that the center pin from the yoke of the beam breaker can be inserted under the beam.
2. Lift the breaker from the carrying case and set it on the beam to be tested with the two fixed rollers resting firmly on the surface and one of them about 1 inch (25 mm) from the end.
3. Remove the center roller, a 1-inch (25 mm) round pin from the two U-shaped clevises by sliding it out. The yoke assembly, containing the ram, pressure gauge, and choker valve now can be pivoted into the vertical (operating) position with the clevises extending below the bottom surface of the beam. There is a stop on one side of the main frame with which the yoke assembly hinge-bracket must be in contact in order for the yoke assembly to be in the vertical position. Return the pin to the clevises. The yoke pin should now be underneath the beam.
4. Close the choker valve (the valve just below the gauge dial) by turning it in a clockwise direction, when facing the dial, and open it approximately one-fourth of a turn. Once this valve is adjusted to the position of one-fourth turn open, this procedure does not need to be repeated with each test but only if the valve has been inadvertently turned to some other position. Do not attempt to operate the beam breaker with the choker value closed.
5. Close the pump valve by turning the pinned extension valve stem in a clockwise direction. This valve is located on the right side of the pump when facing the dial and is opened and closed by an extending through the flange of the aluminum channel forming the top of the main frame. This valve must be closed firmly so that the pump will operate properly.
6. Adjust the black hand of the gauge to the zero point by turning the knurled brass knob on the side of the gauge housing.
7. Set the red hand (maximum indicating hand) near zero by turning the knurled brass knob in the middle of the plastic dial cover.

8. Operate the pump by slow steady stokes until the beam breaks or the specified strength plus 100 psi (1.0 mPa) is reached. Read the flexural strength, in pounds per square inch (megapascals), as indicated by the red hand. Unless otherwise required by the specifications, discontinue the test at 100 psi (1.0 mPa) over the specified strength in order to avoid unnecessary damage to the beam breaker and note on the report that the test was terminated before failure.
9. Open the pump valve and the pump plunger will retract so that the center roller can be withdrawn and the broken portions of the beam can be removed. If additional tests are to be made immediately, repeat the foregoing procedure.
10. If no more tests are to be made immediately, the yoke assembly should be folded down into the horizontal (carrying) position and the center roller again inserted through the clevises in the preparation for storage. Then place the beam breaker in the carrying case.

Recording Results

Record the slump, air content, concrete temperature, and concrete yield on the TE-45 or TE-45 Supplement form. Record all beam tests results on the TE-45 later after they are tested and enter them in SiteManager as detailed in Supplement 1023.

Care and Maintenance of Concrete Testing Equipment

Testing equipment represents a considerable monetary investment by the Department and therefore, it is essential that the equipment be given proper care to avoid damage. The equipment has been provided for testing purposes and must be used in the appropriately to avoid unnecessary abuse or damage. Periodic review of test procedures is desirable not only to ensure accurate and uniform testing but to prevent damage by improper use of equipment.

The equipment is subject to wear and will need repair and replacement of parts at times. When this repair work is needed, the piece of equipment should be sent to the District laboratory at once. Equipment must be in good working condition in order to provide test results that are representative of the material being tested. In addition, with the volume of work in progress, it is vital that testing equipment be repaired quickly and returned to the project in order to provide the equipment necessary for job control. If this cannot be accomplished, the Engineer must make arrangements for temporary use of other equipment rather than omit any required tests.

All equipment must be thoroughly cleaned immediately after use, being especially sure that all concrete and mortar is removed from around gaskets, seals, and moving parts. Thorough cleaning will prevent build-up of hardened concrete that can affect the operation of the equipment as well as the test results.

Pressure Meter

When the top assembly is removed, it should be placed on a clean surface to prevent damaging the gasket and any earth or fresh concrete from clogging the clamping mechanisms. All fresh concrete should be removed from all parts of the meter to facilitate its accuracy and continue its efficient service.

Volumetric Air Meter

The volumetric meter should not be rolled, rocked, or bumped on hardened concrete, stone, or steel. It should be used on a clean board or sack. When the top cone is removed, it should be placed on a clean surface to prevent earth or fresh concrete from clogging the springs around the fasteners. The inside of the glass tube should be kept clean of cement particles so as not to obscure readings. All fresh concrete should be removed from all parts of the meter to facilitate its accuracy and continue its efficient service.

Chace Air Indicator

When emptying the instrument at the completion of a test, flush out particles of sand from between the glass and cup to prevent damage when removing stopper. This can be done by holding the indicator with stem end down, finger over stem, and opening and shaking gently. Carefully remove stopper and wash and clean the indicator with clean water. Keep the equipment in protective container when not in use. Should the glass be broken, the remainder of the set should be returned to the Laboratory for repair.

Center Loading Hydraulic-Type Beam Testing Machine

This beam breaker is a piece of testing equipment and should be handled and cared for like any other precision instrument. The following precautionary measures will help keep the breaker in proper operating condition:

1. Be sure that the choker is open one-fourth turn before applying load.
2. Do not operate beyond the maximum point indicated on the dial.
3. Store in the carrying case when not in operation.
4. Remove curing membrane, rust, etc., from the center roller so that it will fit in the devices easily.
5. Keep thin film of oil on steel parts to prevent rust.
6. Make frequent checks for worn places or breaks in the rubber hose. Do not operate the breaker with worn or damaged hose. This beam breaker is actuated by a high-pressure hydraulic system and might be unsafe if operated with worn or damaged parts.
7. DO NOT ATTEMPT TO REPAIR THE BEAM BREAKER IN THE FIELD. Return the beam breaker to the Laboratory for any repairs or adjustments that may be necessary.

Concrete Mix Adjustments (499.04)

During concrete production and placement, the Contractor is responsible for adjusting the yield of the concrete mix design. While a contractor and the supplier are responsible for adjustments, the concrete control inspector is responsible for ensuring the Department’s contract is met. There will be times were the concrete control inspector must validate and therefore understand what affects the yield so that the yield can be maintained within a certain tolerance. ASTM establishes an industry standard for yield tolerance of ±1.0 percent.

Verifying the Yield

As discussed earlier, the yield of a concrete mix is the volume occupied by the mix. The concrete is designed to occupy a given volume. Concrete is batched by weight (not volume) so monitoring the volume (yield) after batching is of extreme importance. Control of yield is the Contractor and supplier responsibility. Verification of yield by the Department is done to check that the truly reflect what has been added or not added into the concrete batch.

Relative Yield

The term relative yield is used to understand the effects on yield. The relative yield of a concrete mix is defined as the one cubic yard (one cubic meter) batch weight divided by the one cubic yard (one cubic meter) unit weight of a representative sample of the concrete, as shown in Equation 499.25:

$$\text{Relative Yield} = \frac{\text{Batch Weight for } 1\ yd^3\ (1\ m^3)}{\text{Unit Weight for } 1\ yd^3\ (1\ m^3)}$$

Equation 499.25 – Relative Yield Method 1

Another way to calculate the relative yield is to divide the actual yield by the intended yield, as shown in Equation 499.26:

$$\text{Relative Yield} = \frac{\text{Actual Yield } yd^3 (m^3)}{\text{Intended Yield } yd^3 (m^3)}$$

Equation 499.26 – Relative Yield Method 2

The relative yield is a dimensionless number (it has no units). When working with relative yield, it is less confusing to include [yd^3] or [ft^3] ([m^3]) in brackets so the units are not mixed. A relative yield expressed in [yd^3] is multiplied by 27 ft^3/yd^3 to change it to the number of cubic feet [ft^3] of relative yield.

A relative yield of less than 1.00 is an under-yield and a relative yield of greater than 1.00 is an over-yield.

Example:

An 8-cubic yard batch of concrete has the following batch weights:

Coarse Aggregate	13,328 lbs
Fine Aggregate	9,448 lbs
Cement	5,080 lbs
Water	2,400 lbs
Total Batch Weight	30,256 lbs

The result of a unit weight test performed on a concrete sample is 141.35 lbs/ft³. Determine the yield and relative yield of the batch.

First, the yield can be calculated from the data given:

$$\text{Yield} = \frac{30{,}256\ lbs}{141.35\ lbs/ft^3} \quad \text{(Equation 499.2)}$$

$$= 214.03\ ft^3$$

Next, determine the one cubic yard batch weight:

$$\text{Batch Weight for 1 yd.} = \frac{30{,}256\ lbs}{8\ yds^3} \quad \text{(Equation 499.2)}$$

$$= 3782\ lbs/yd^3$$

The unit weight for one cubic yard is determined using the unit weight given:

Unit Weight for 1 yd³ = (141.35 lbs/ft³) x (27 ft³/yd³) = 3816.45 lbs/yd³

Note that in the above calculation, the 1-cubic yard unit weight is determined by multiplying the 1-cubic foot unit weight by the conversion factor of 27 ft³/yd³. This converts the unit weight to lbs/yd³ instead of lbs/ft³.

Now, the relative yield can be determined by the use of Equation 499.25 as follows:

$$\text{Relative Yield} = \frac{3782\ lbs/yd^3}{3816.45\ lbs/yd^3} \quad \text{(Equation 499.25)}$$

$$= 0.991\ yd^3$$

Another way to calculate the relative yield is to divide the actual yield by the intended yield (Equation 499.27):

$$\text{Relative Yield} = \frac{\left(214.05\ ft^3\right) \div \left(27\ ft^3/yd^3\right)}{8.00\ yd^3} \quad \text{(Equation 499.26)}$$

$$= 0.991\ yd^3$$

In the above calculation, the actual yield (in cubic feet) is divided by a conversion factor of 27 ft³/yd³ to convert the actual yield in cubic feet to cubic yards.

The relative yield expressed in cubic feet is:

Relative Yield = 0.991 [yd³] x 27 ft³/yd³

= 26.76 [ft³]

In the above example, the relative yield is less than 1.000 [yd³] or 27.00 [ft³], therefore, there is an under-yield. The amount of the under-yield can be determined as follows:

Under-Yield = 0.991 – 1.00

= -0.009 [yd^3]

or

Under-Yield = 26.76 – 27.00

= - 0.24 [ft^3]

The negative sign indicated that there is an under-yield. A positive number would have indicated an over-yield.

The under-yield expressed as a percent is determined by multiplying the amount of the under-yield in decimal form by 100 percent as follows:

Under-yield (%) = -0.009 x 100 %

= -0.9 %

Cement or Cementitious Factor

The cement factor is defined as the weight of cement in a cubic yard (cubic meter) of concrete, based on the concrete's yield. The cement factor is expressed as the number of pounds of cement per cubic yard (kilograms of cement per cubic meter).

If the concrete is over-yielding, the cement that was batched into the load is spread over a greater volume of concrete than intended by the mix design. If this happens, the cement factor is less per cubic yard (cubic meter) than intended. The opposite is true if there is an under-yield. In the case of an under-yield situation, the cement that was batched into the load is concentrated into less volume than for which it was designed. In this situation, the cement factor is greater per cubic yard (cubic meter) than was intended by the design.

The relative yield is used to determine the cement factor as shown in Equations 499.27 and 499.27M:

$$Cement\ Factor\ (lbs/yd^3) = \frac{Cement\ Weight\ (lbs/yd^3)}{Relative\ Yield}$$

Equation 499.27 – Cement Factor

$$\left(Cement\ Factor\ (kg/m^3) = \frac{Cement\ Weight\ (kg/m^3)}{Relative\ Yield} \right)$$

Equation 499.27M – Cement Factor (metric)

The cement weight in the above equations is the amount of cement intended to be in a cubic yard (cubic meter) of concrete.

In the above example, the relative yield was 0.991 and the cement content was 635 lbs per cubic yard (5080 lbs / 8 cubic yards = 635 lbs/yd^3), therefore, the cement factor is:

$$Cement\ Factor = \frac{635\,lbs/yd^3}{0.991} = 641\,lbs/yd^3$$

(Equation 499.27)

As shown by the above calculation, the under- yield resulted in a cement factor of 641 lbs per cubic yard instead of 635 lbs per cubic yard.

The cement factor can influence the strength of the concrete. An excessive over-yield results in less cement per cubic yard (cubic meter), as the cement factor will be less than intended. This could result in less strength than expected from the batch. An excessive under- yield results in a higher cement factor, and therefore, higher strength than anticipated. There should not be a noticeable effect on strength if the yield is maintained within 1 percent of the design as required by 499.03 of the specifications.

Air Content Effects on Yield

Air content in concrete has a significant effect on the yield. Air content in a concrete mix has no weight but does contribute volume. The air content used in the design is the target air content. At the target air content, the yield should be within the tolerance of ±1.0 percent as specified in 499.03 of the specifications.

If the Inspector determines the yield problem is the result of an air content that is higher or lower than the target air content before a mix adjustment is made. There is a way to compute what the relative yield of a concrete batch would be at an air content that is different from the tested air content.

First, determine the relative yield and the tested air content of a concrete sample. Next, compute the non-air portion of the mix. The non-air portion of the mix is the volume of all of the component materials except air. This value is determined by multiplying the actual relative yield by the actual non-air decimal. Once the non-air volume is determined, the relative yield at any other air content can be calculated. Equation 499.29 is used to determine the relative yield at a different "target air" content:

$$\text{Relative Yield at a Target Air} = (RY\ actual) \times \left(\frac{NAD\ actual}{NAD\ target}\right)$$

Equation 499.28 – Relative Yield at Target Air

Where:

RY actual = actual relative yield (yd^3)

NAD actual = actual non-air decimal

NAD target = target non-air decimal

Example:

As an example, the relative yield of a concrete mix is found to be 0.974 [yd^3] and there is 4.2% percent air content. What is the relative yield at 6% percent air content?

The actual non-air portion of the mix at 4.2% percent air content is 95.8 percent (100% - 4.2% = 95.8%) of the total volume. The actual non-air decimal then is 0.958 (95.8%). To calculate the relative yield at 6% percent air, the target non-air portion of the mix would be 94 percent (100% - 6 % = 94 %) of the total volume. The target non-air decimal is 0.94 in decimal form. Now the relative yield at 6 percent% air can be calculated as follows:

$$\text{Relative Yield} = \frac{0.974\ yd^3 \times 0.958}{0.94} = 0.993\ yd^3$$

Equation 499.28

The calculations show that by increasing the air content of the concrete from 4.2% percent air to 6% percent air, the relative yield changes from 0.974 [yd^3] to 0.993 [yd^3]. The Inspector should not adjust the batch weights to correct the yield to within ±1.0 %percent but should direct the Contractor to increase the air content percentage in subsequent concrete loads to bring the concrete to the proper yield.

The air content affects the unit weight of the concrete. When the air content percentage in the concrete is increased, the unit weight of the concrete is decreased. This is due to the increased volume of air bubbles within the mortal fraction of the concrete volume. This lower unit weight results in raising the yield higher than it was at the lower air content, assuming the batch weights are identical. When the yield is calculated, the same batch weight is divided by a lower unit weight, so the yield increases.

Adjusting Yield

The concrete control inspector should not make adjustments in the mix design. Mix design adjustments are the responsibility of the Contractor and the supplier. If during quality assurance inspections the concrete control inspector finds the concrete is out of tolerance, notify the Contractor and require adjustments be made before acceptance of the concrete.

Mix design adjustments should not be made every time high or low air content affects the yield, because when the air content is at the target air, the yield will be off. The specifications typically allow air content to deviate ±2 percent% from the target air content. For all Department mix designs, the desired yield should be established at the target air content. Once the mix design is adjusted to yield properly at the target air content, future mix design adjustments are rarely needed.

To adjust the mix design to correct the yield, the adjustment is always made in the aggregate weight by adding or subtracting material. The adjustment is made by volume, and the volume of the adjustment is converted to a weight of coarse and fine aggregate proportionately.

Modifying Mix Designs

It may be necessary to modify an existing concrete mix design while under production. The Contractor accepted JMF mix designs are designed to produce one cubic yard or 27 cubic feet per cubic yard (one cubic meter) of concrete. During production, it may be necessary to change the quantity of a material in the mix due to specific gravity changes for that material. Adjustments for a change in the actual aggregate sources are not

allowed unless the new the JMF has been modified to show the new aggregate and the JMF has been approved.

The yield must be maintained if a component material's specific gravity is changed. Specific gravity changes do not change the volume of the material in the mix design, but they will change the weight of the material in the mix design.

If of one material is changed, then the volume of another material must be adjusted to compensate for the volume change made. If any volume is added or removed from the design volume, an equivalent volume must be removed or added respectively to maintain the yield.

Modifying Aggregate Proportions

Section 499.04 does provide for the Contractor to adjust SSD aggregate proportions up to 100 lbs (44 kg) per cubic yard (cubic meter). This may be necessary to improve the finishing characteristics of the concrete, to ensure a workable mix within the slump range, or to control the yield. These modifications made in the aggregate proportions are not to change the total weight of aggregate specified per cubic yard (cubic meter), except for the following reasons.

1. To correct the SSD aggregate weights to compensate for the moisture contained in the aggregates at the time they are used.
2. If it is not possible to make concrete of the proper consistency without exceeding the specified water-cement ratio, the Contractor must either use a water-reducing admixture or increase the cement content. If cement is added to the concrete, the absolute volume of aggregate must be adjusted by the amount of cement absolute volume added. There is no compensation to the Contractor for the use of an admixture or additional cement.
3. If at any time the specific gravity of the aggregate being used changes by more than 0.02 from the specific gravity specified in the JMF, the design weights need to be adjusted to conform to the new specific gravity.
4. To adjust the batch weights based on the yield determined from field tests at the work site. Maintain the cement content within ±1 percent and do not exceed the water-cement ratio specified.

It may be necessary or required by specifications to add an intermediate-size coarse aggregate. If it is necessary to add a quantity of aggregate, the yield will change unless an adjustment is made to offset the volume added to the concrete. The same thing is true if it is necessary to remove a component material from the original mix design. If any volume of material is removed, the same volume must be added to the concrete mix to adjust the yield for the volume removed. The following example illustrates how a volume change is made.

<u>Example:</u>

To improve the finishing characteristics of a Class QC 2 concrete using limestone coarse aggregate, it is decided to remove 100 lbs of coarse aggregate from the following original SSD mix design:

Cement	700 lbs
Coarse Aggregate	1530 lbs, (Specific Gravity = 2.65)
Fine Aggregate	1260 lbs, (Specific Gravity = 2.62)

Water	350 lbs

What is the new SSD mix design if 100 lbs of coarse aggregate is removed? Make the volume adjustment by adding fine aggregate without affecting the yield of the mix.

The new amount of coarse aggregate is 1,430 lbs (1,530 – 100 = 1,430). The absolute volume of 100 lbs of this coarse aggregate removed from the concrete is:

$$\text{Absolute Volume} = \frac{100}{(2.65)\times(62.4)} \qquad \text{(Equation 499.4)}$$

$$= 0.60\ ft^3$$

Since 100 lbs of coarse aggregate is removed, the volume is decreased by 0.60 ft³. In order to maintain the yield, 0.60 ft³ of fine aggregate must be added. This volume is used to calculate the weight of fine aggregate necessary to be added to maintain the original yield as follows:

$$\text{Addition of Fine Aggregate} = (0.60)\times(2.62)\times(62.4) \qquad \text{(Equation 499.6)}$$

$$= 98 \text{ lbs}$$

This calculation shows that 98 lbs of fine aggregate (of specific gravity 2.62) must be added to offset the 100 lbs of coarse aggregate (of specific gravity 2.65) removed from the mix design. The new fine aggregate SSD design weight becomes 1,358 lbs (1,260 + 98 = 1,358).

Therefore, the following is the new SSD mix design:

Cement	700 lbs
Coarse Aggregate	1,430 lbs, Specific Gravity = 2.65
Fine Aggregate	1,358 lbs, Specific Gravity = 2.62
Water	350 lbs

Note that the specific gravities of the coarse and fine aggregates are similar; therefore, the difference in the weight between the coarse aggregate removed and the fine aggregate added is only 2 lbs.

Modifying the Slump

It may be necessary to increase the slump of the concrete by adding water to the mix design, or reduce the slump by removing water from the mix design. With the addition or removal of water from a mix design, both the water-cement ratio and the yield will change.

If the concrete in use is being batched at the maximum water-cement ratio, no additional water is permitted, or the water-cement ratio would be exceeded. It may be necessary to add cement, to maintain the water-cement ratio. Only allow this type of modification after approval of the Engineer. If allowed, the follow example defines the method to determine the additional cement.

Example:

A concrete mix has a water-cement ratio of 0.50 and the slump is 2 inches at the maximum allowable water. It is decided to add 10 lbs of water to the mix design to increase the slump. Determine the amount of cement necessary to maintain the 0.50 water-cement ratio. Determine the amount of volume added due to the addition of the 10 lbs of water and this necessary amount of cement.

Since the water-cement ratio is defined as follows (Equation 499.13):

$$\text{Max. w/cm Ratio} = \frac{Weight\ of\ Water}{Weight\ of\ Cement}$$

The following form of Equation 499.13 calculates the weight of cement from the w/cm ratio:

$$\frac{Weight\ of\ Water}{Max.\ w/cm\ Ratio}$$

Equation 499.29 – Cement Weight from w/cm Ratio

Therefore, the amount of cement necessary is:

Weight of Cement $= \frac{10\ lbs}{0.50}$ (Equation 499.29)

$= 20\ lbs$

To maintain the yield, a volume adjustment must be made for both the 10 lbs of water and the 20 lbs of cement as follows:

Volume of Water Added $= \frac{10}{1.00 \times 62.4}$ (Equation 499.4)

$= 0.16\ ft^3$

Volume of Cement Added $= \frac{20}{3.15 \times 62.4}$ (Equation 499.4)

$= 0.10\ ft^3$

The total added volume due to the water and cement is 0.26 ft ^{3} (0.16 + 0.10 = 0.26) in this example. In order to maintain the yield, 0.26 ft^3 of aggregate must be removed from the design. Aggregate removed will be proportional to the aggregate in the mix. If the coarse aggregate is 60 percent% and the fine aggregate is 40 percent% (and the specific gravity of the aggregates are the same), the volume of coarse aggregate removed would be 0,60 x 0.26 ft^3 = 0.16 ft^3. Fine aggregate would be 0.26 ft^3 - 0.16 ft^3 = = 0.10 ft^3.

Modification of Aggregate Specific Gravity

If there is specific gravity changes in the aggregates used, the yield of the concrete mix will change. If there is a specific gravity increase, then the volume occupied by the same

weight of aggregate will decrease and there will be an under-yield. If there is a specific gravity decrease, the volume of the same weight of aggregate increases and the mix will over-yield.

Example:

A concrete mix contains 1,735 lbs of a crushed limestone with specific gravity of 2.65. The aggregate stockpile is depleted and the Contractor changes to natural gravel coarse aggregate with a 2.57 specific gravity. Adjust the 1,735 lbs to the new specific gravity and show how this would affect the yield.

Determine the original volume in the mix design:

$$\text{Original Mix Design Volume} = \frac{1{,}735\ lbs}{2.65 \times 62.4\ lbs/ft^3} \qquad \text{(Equation 499.4)}$$

$$= 10.492\ ft^3$$

If the specific gravity changes to 2.57, this same weight of aggregate would have the following absolute volume:

$$\text{New Mix Volume} = \frac{1{,}735\ lbs}{2.57 \times 62.4\ lbs/ft^3} \qquad \text{(Equation 499.4)}$$

$$= 10.819\ ft^3$$

These calculations show that same weight of a lower specific gravity aggregate has a greater volume and would result in an over-yield. To correct the over-yield the original volume is used to determine how much weight of the new, lower specific gravity aggregate to use:

$$\text{New Aggregate Weight} = 10.492\ ft^3 \times 2.57 \times 62.4\ lbs/ft^3 \qquad \text{(Equation 499.6)}$$

$$= 1{,}683\ lbs$$

In summary with the lower specific gravity, the weight decreased from 1,735 lbs to 1,683 lbs per cubic yard.

Use Equation 499.30 to calculate a weight adjustment due to a specific gravity change:

$$Weight\ at\ a\ New\ Specfic\ Gravity = \frac{W_{Original} \times SG_{New}}{SG_{Original}}$$

Equation 499.30 – Weight Adjustment due to Specific Gravity Change

Where:

$W_{Original}$ = Original weight of aggregate (at the original specific gravity)

$SG_{Original}$ = Original specific gravity of the aggregate

SG_{New} = New specific gravity of the aggregate to be used

For the above example, the calculation is as follows:

New Weight = $\frac{1{,}735 \times 2.57}{2.65} = 1{,}683\ lbs$	(Equation 499.30)

Equipment for Batching and Mixing Concrete (499.05)

Batching Plants (499.05.A)

The various materials for each batch of concrete are proportioned at a batch plant. Batch plants may be classified as:

1. Portable or stationary
2. Manual, semi-automatic, or automatic
3. One or two stop
4. Separate or accumulative weighing

These classifications are dependent on the mobility and the method of weighing and discharging. Batch plants used on the project site usually are portable and may be moved from job to job. They may be manual, semi-automatic, or automatic with the latter two categories most common. If all materials for a batch are discharged at the same point, it is a one-stop plant. A two-stop plant is a plant where two stops of the truck mixer is required.

Portable plants are moved from site to site to reduce the length of haul to the placing site. Stationary plants usually are used at commercial ready-mix or central-mix plants. Central-mix plants used for concrete paving are set up at the job site, and, therefore, are portable.

Plants may employ accumulative weighing for the coarse and fine aggregate; however, separate weighing devices must be used for weighing cement. Accumulative weighing permits the weighing of coarse aggregate and then the fine aggregate, using the same hopper and scale. The predetermined weights for the two materials are set on the scale for the cut-off. Cement must be weighed separately on a separate scale and hopper, regardless of how the aggregate is weighed.

For manual plants, each material is weighed and discharged by manually pulling levels to open and close gates. In semi-automatic plants, these gates are operated through electronic controls to open and close at the touch of a button. If the electric controls are interlocked, and the completion of one weighing signals the start of next weighing, etc. and the whole cycle, if weighing and discharging is interlocked completely, the plant is classed as automatic.

Automatic plants are coming into widespread use with many being computerized. Some plants use punched cards which have the weights of the materials represented by holes punched in the card. The size of the batch is dialed by a selector knob, the punched card is placed into the control panel, and a button is pressed to start the cycle. Materials for the batch size selected are automatically weighed and discharged.

A system of interlocks prevents a batch from being discharged that does not contain the correct amount of each material. All automatic plants have this feature. This prevents incorrect batches in the event that an aggregate bin becomes empty or other trouble develops which would tend to result in incorrect batch weights. Most automatic plants may be operated manually or semi-automatically, which permits production in case of an electronic failure.

The accuracy of the weighing mechanisms used to weigh each component in the concrete is specified in 499.06. These weighing tolerances are shown below:

Weighing Tolerances	
Item	Weighing Tolerance* (Percent)
Cement	± 1.0
Fly ash	± 1.0
GGBFS	± 1.0
Micro silica	± 1.0
Coarse aggregate	± 2.0
Fine aggregate	± 2.0
Water	± 1.0
Admixtures	± 3.0

*** Weighing tolerances apply throughout the range of use.**

Prior to use of a concrete plant, make an inspection to assure that all requirements of the specifications are fulfilled and that scales meet the batching tolerances specified. This inspection includes checking:

1. Plant bins for adequate partitions to prevent intermingling of materials.
2. All weighing and metering devices to assure ensure that their accuracy has been attested to within a 12-month period immediately prior to use by one of the following methods:
    a. By a Sealer of Weights and Measures.
    b. By a Scale Servicing Company.
    c. By a Certificate of Performance issued by the National Ready Mixed Concrete Association.
3. The plant must maintain ten 50-pound (23 kg) standard test weights or the services of a scale servicing company for testing weighing devices for accuracy. The ten 50-pound (23 kg) test weights must be sealed within a 3-year period by the Ohio Department of Agriculture. If the service of a scale servicing company is used, these weights will not be required; however, all weights used in testing by the Scale Servicing Company must conform.
4. Water meters for accuracy.
5. That a separate weighing device is used for weighing cement.
6. Admixture dispensers to assure proper dosage will be used.

If a Certificate of Performance has been issued by the National Ready Mixed Concrete Association, the weighing and metering devices will not require checking for accuracy and the concrete batch facilities may be approved. The certification from the National

Ready Mixed Concrete Association must be within a 6-month period prior to use and must certify that the plant's weighing and metering devices do meet 499 batching tolerances.

Plant bins are checked for holes in partitions and to see that separator plates are extended high enough to prevent spillage of materials when the bins are charged. Accumulation of aggregate in the corners must be avoided. Any evidence of this should be called to the attention of the plant operator and corrected immediately.

The test weights must have a seal indicating that they have been checked by the Ohio Department of Agriculture or some other acceptable agency and certified for accuracy. These seals must be renewed every 3 years. Each scale must be checked with test weights through the range in which it is to be used. Should a scale be used to weigh the aggregate accumulatively, say for example, totaling 13,356 pounds (6058 kg), it must be checked through 13,400 pounds (6078 kg). This will require that the weights be attached and the scale checked for 500 pounds (227 kg), then the weights removed, 500 pounds (227 kg) of aggregate added, and the scale checked again with the weights, this time to 1,000 pounds (454 kg). This process is repeated until 13,400 pounds (6078 kg), or the total range, actually being used, is reached. All scales shall be checked within the 12-month period immediately prior to use.

If a scales servicing company is employed by the producer to check and adjust the scales, the test weights used may range up to 1,000 pounds (454 kg). When these test weights are used, the scales should be checked by adding the weights to the scale and checking the scale as outlined in the previous paragraph. All weights used by the Scale Servicing Company must be sealed every 3 years by the Ohio Department of Agriculture.

A weight increment greater than 500 pounds (227 kg) may be used to check the batch plant scales in the lower range of use when large batches of concrete will be produced. However, smaller increments will be necessary when nearing the limit of use. This situation occurs for a paving operation with a central mix plant that consistently producing produces larger batches. On the other hand, when the batch plant will be produces small or varied size batches of concrete, a maximum of 500-pound (227 kg) increments should be maintained. The testing must be for the range of use for the scale, and tolerances mentioned previously should be maintained. Adjustments should be made when necessary.

Water meters also must be checked and calibrated prior to use. Whether the water is metered by weight or by volume, the amount of water required for one cubic yard (cubic meter) of central mix, or transit mix concrete, or one batch of site mix concrete, should be metered and carefully collected for immediate weighing. The weight of the collected water must be within 1.0 percent of the weight indicated on the meter if the water is weighed. If the water is metered by volume, the water should be collected and weighed, then divided by 8.32 pounds per gallon (1 kg per liter). The volume in gallons (liters), thus obtained, must be within 1.0 percent of the volume metered. Variations outside the tolerance must be corrected and the water meter rechecked until it is within the required accuracy.

Admixture dispensers are checked by actually discharging a given amount of admixture to verify the accuracy of the unit. Admixture dispensers must be accurate to within 3.0 percent of the indicated amount.

Admixtures held over from the previous year should be either replaced or retested by the admixture manufacturer. Agitation of the old admixture may bring the materials within specification but it should be tested and checked.

All checks made prior to starting production for each construction season must be documented. Checks made during concrete production must be noted on the TE-45 Report. Weighing and dispensing devices must be tested as often as the Engineer deems necessary to assure ensure their continued accuracy.

During the batching operation, the Inspector should occasionally observe the amounts of the materials being weighed to ensure that proportioning complies with the mix design. Therefore, the Inspector must know the various weights for the volumes being used as well as be familiar with plant components. Checks must be made to determine that the indicator dials return to zero when the batch is discharged. This is especially important for the cement scale. If the scale does not return to zero, it is an indication that material is building up or hanging up in the hopper. This material must be removed and the dial adjusted to read zero. Any scales not zeroing properly must be repaired.

Concrete Mixers (499.05.B and 499.08)

Transit mix trucks are used to haul plastic concrete batches to the concreting site. The concrete may be mixed at the plant and agitated during hauling, agitated during hauling and mixed at the point of use, or mixed in transit if it can be shown that mixing is accomplished during transit. Transit mixers also may be used to haul mixed or partially-mixed central mix concrete. When used for hauling concrete that has been mixed completely in a central mixer, the mixer is operated at agitation speed. If the concrete is only partially mixed, all materials must be mixed for at least 30 seconds in a stationary mixer and then mixed in the transit mixer for no less than 50 revolutions at mixing speed. This latter mixing is known as shrink mixing.

Central mix concrete may be hauled in truck agitators, commonly known as dumpcrete trucks, or trucks having bodies without agitation. Non-agitating equipment must have smooth, mortar-tight bodies capable of discharging concrete at a satisfactorily controlled rate. If dump trucks are used for non-agitation hauling, they must have smooth bodies with rounded corners and be free of internal ribs.

Mixers and agitators must meet certain sections of AASHTO M 157. Section 499.05.B requires conformance with AASHTO M 157 Sections 10, 11.2, 11.5, and 11.6, except that the Department will allow mechanical counters. These sections are reprinted at the end of this section in a section entitled AASHTO M 157.

Handling, Measuring and Batching Materials (499.06)

Stockpile foundation areas must be cleared of all wooded brush or other debris, and shaped to provide drainage. The area may be compacted, stabilized, or paved to prevent the existing ground from infiltrating into the bottom of the pile. If the aggregate is placed directly on the ground, the bottom foot of aggregate must not be removed until final clean-up, and any material that has become contaminated must be reprocessed to meet specifications before use.

Where one stockpile adjoins another of a different size material, a substantial bulkhead or divider of sufficient length and height must be placed between the two to prevent intermingling of the different sizes. Intermingling of stockpiles must not be tolerated.

Aggregate must be dumped directly on the prepared stockpile as near to its final location as possible without additional handling. After the first layer is placed directly on the foundation, trucks must unload at the outside edge of the pile and the material moved into position on the succeeding layers. A crane with a bucket is ideal for picking up the aggregate and placing it on top of the material in place. Exercise care to deposit each bucket in a manner that prevents the aggregate from rolling and segregating. Therefore, the bucket should not be high in the air when the aggregate is released.

Front-end loaders are satisfactory to build a stockpile provided they stay off the stockpile (unless they are equipped with rubber tires) and if care is exercised to place each scoop load in a manner to avoid segregation. Equipment having steel treads must not be used on coarse aggregate stockpiles, nor should any equipment be permitted to push, shove, or roll coarse aggregate as segregation may result. If the Contractor uses equipment that appears to be causing segregation, additional tests must be run, and, if there is a variance from specification gradation requirements, the use of the equipment must be discontinued.

Sand may be dumped directly on the prepared foundation for the bottom layer and succeeding layers placed by crane with bucket, by front-end loader, or by dozer.

Equipment that operates on stockpiles must not be permitted to move on and off the stockpile unless the foundation is stabilized or paved to prevent tracking of foundation material onto the stockpile. The tracking of foreign material onto stockpiles, (while stockpiling aggregate or removing aggregate from stock piles to charge the concrete plant, can result in mud balls in the concrete.

Coarse aggregate is absorptive and will attract and absorb mixing water when used in a dry condition in concrete. This absorption of water needed for workability can result in a rapid slump loss when the aggregate is dry. Such a slump loss usually results in finishing and texturing problems. Coarse and fine aggregate is required by 499.04 to be maintained with a uniform moisture content.

A moisture test must be made to determine the moisture content for use in adjusting the batch weights and the mixing water. When the actual moisture content of the fine and coarse aggregate is compared with the absorption of the aggregate, the Inspector will know if the aggregate is in a damp or saturated condition. Moisture contents greater than absorption indicate saturation, while those less indicate a damp condition.

Batching Coarse Aggregate

Segregation is possible when withdrawing coarse aggregate from stockpiles for charging into the plant bins, unless care is exercised. Cranes with buckets, and front-end loaders, are satisfactory for this operation, provided the aggregate is handled in such a manner to avoid segregation. Any operation that results in excessive segregation, such as sliding or rolling, must not be permitted.

Batching Fine Aggregate

The use of a dozer is satisfactory for moving fine aggregate from large stockpiles to a conveyor for the transfer to the plant bins. With a dozer, material from the same level in

the stockpile is pushed into a hopper feeding the conveyor. Being from the same level, the sand has the same moisture content and uniformity is maintained.

Fine aggregate will be handled in such a manner that the moisture content will be reasonably uniform for each day's production. Whenever the moisture content is suspect for a given stockpile, the stockpile should be rotated or mixed prior to charging the hopper feeding the conveyor. This will assure uniformity of the moisture content.

Batching Cement and Cementitious Materials

Cement is usually fed by gravity from storage silos to weigh hoppers. Cement may also be pumped or blown from an auxiliary storage silo to a cement bin in the plant.

Batching Water

Water may be pumped into a measured storage tank, having the capacity required for the batch, where it flows by gravity into the central mixer or transit mixer. Water meters are in common use and can measure the water accurately per batch by volume or by weight. Water measuring devices should be checked and adjusted to an accuracy of 1 percent.

Batching Tolerances

The batching tolerances are specified in 499.06 and are shown on the following table:

Table 499.06-1 Concrete Batching Tolerances

Batching Tolerances	
Item	Batching Tolerance (Percent)
Cement	± 1.0
Fly ash	± 1.0
GGBFS	± 1.0
Micro silica	± 1.0
Coarse aggregate	± 2.0
Fine aggregate	± 2.0
Water	± 1.0
Admixtures	± 3.0

Batching tolerances are different from the weighing tolerances. Weighing tolerances apply to the scales that are used to weigh the individual components of the concrete mix. Batching tolerances apply to the batching process. For instance, a 10 - cubic yard load of Class QC 1 concrete requires 6,000 lbs of cement. During the process of weighing this amount of cement into the cement weigh hopper, it sometimes is not possible to stop the cement flow exactly at 6,000 lbs. The plant operator should be shooting for 6,000 lbs but is permitted a tolerance of 1.0 from this amount. Therefore, for this amount of cement, the variance can be anywhere from 5,940 lbs to 6,060 lbs.

Batch Plant Tickets (499.07)

A concrete batch ticket must be furnished with each load of concrete delivered to the project. This ticket will be computer generated. Look at 499.07 for the required information on each ticket of delivered concrete that certifies the ingredients in the load as well as other required data.

The Contractor must provide additional information with the first load of concrete delivered to each project for each JMF. Table 499.07-2 below shows this additional

information that must be provided either on the batch ticket or as a separate computer generated form and attached to the batch ticket for the first load each day.

TABLE 499.07-2 FIRST TICKET EACH DAY, EACH JMF

Cementitious Materials:	Source:	Grade or Type:
Cement		
Fly ash		
GGBFS		
Microsilica		
Other		
Admixtures	Brand:	Type:
Air-entrainer		
Retarder		
Superplasticizer		
Water-reducer		
Other		

It is a contract requirement that the above information be provided by the Contractor. If a Contractor is purchasing concrete from a ready-mix concrete supplier, it is the Contractor's responsibility to ensure compliance even if it means putting a person at the plant to provide the required information. If the information is not provided as specified, the concrete is not to be accepted.

Mixing Concrete (499.08)

Concrete is to be mixed in either a central mixing plant or by a truck mixer.

Classifications of Concrete Mixers

Concrete mixers are classed as central mixers or transit mixers. Central mixers are stationary and are located at the batch plant where they are charged directly from the plant. Mixed batches from central mix plant may be transported to the placing site in dumpcrete trucks, dump trucks, or transit mix trucks. Transit mixers are charged directly from the batch plant and mixed in truck-mounted mixers at the plant or at the job site.

Central and Transit Mixing

For central mixing and transit mixing, the proportioned materials are charged directly into the mixer from the weigh hoppers. Caution must be observed, especially with transit mixers having narrow openings, that materials are not spilled during the charging of the mixers. Usually it will be necessary to feed the batch gradually from the weigh hoppers into the transit mixers to avoid spillage. The common practice is to revolve the mixer at high speed during charging to aid material entry into the mixer and avoid clogging of the intake opening.

Pre-blending of materials, prior to or during charging of the mixer, plays an important role in obtaining proper mixing. This pre-blending or pre-mixing may be accomplished by depositing materials onto the charging belt in such a manner that all materials enter the drum at the same time or by discharging all materials directly into the mixer simultaneously rather than separately. If the plant capacity is limited and the entire batch

cannot be weighed into the weigh hopper in one operation, smaller complete batches should be required rather than weighing and discharging each ingredient independently. Proper mixing will not be obtained in the minimum mixing time if materials are charged separately; therefore, this method must not be tolerated.

Most central mix plants are equipped with a "slump meter" which provides the operator a control of concrete consistency. These meters indicate concrete consistency indirectly by measuring the current or amperage being drawn by the motor that drives the mixer. The mixer operator maintains a predetermined amperage by adjusting the amount of mixing water. The result is uniform consistency between batches.

Mixers and agitators shall conform to paragraphs 10, 11.2, 11.5, and 11.6 of AASHTO M 157, except that mechanical counters are permitted. A copy of these paragraphs of AASHTO M 157 is contained in this manual.

Generally, water is started into mixers first and is charged at such a rate that it will not cease until all other ingredients are in the mixer. In this manner, water is present initially for mixing material during the charging period and provides a washing action around the drum opening after all the dry materials have entered.

Air-entraining agents and water-reducing set retarders are the most common admixtures for concrete. It is very important that these admixtures do not become blended or mixed in any manner prior to the actual mixing of the concrete. Any mixing of the two could cause plugging of the supply lines. Also, the effectiveness of either or both of the additives may be reduced. To avoid any problem, they should be introduced into the batch separately.

Mixing Concrete (499.08)

The minimum mixing time for central mixers is 60 seconds, beginning when all the materials are in the drum and ending when discharge begins. Transit mixers must operate at the rate of rotation stated by the manufacturer as mixing speed, for no less than 70 revolutions. Checks must be made for compliance with these mixing requirements and the results recorded on the appropriate project documents.

Checks made of mixing time for central mixers are the responsibility of the concrete control Inspector. At least once a day (more often if possible), a check must be made and recorded on the concrete Inspector's daily report. The counter reading on transit mixers before and after mixing must be noted and recorded. The rate of rotation must also be checked. The initial counter reading and number of revolutions at mixing speed are recorded. The Contractor is responsible for ensuring proper mixing of all batches. Any deficiencies must be called to the Contractor’s attention.

If possible, for large quantity-critical usage concrete, the Engineer should periodically check the mixing operation at the plant to ensure compliance with specified mixing requirements. Counter readings and rate of rotation are noted and recorded as described above. Excessive speed of rotation may cause inadequate mixing. Centrifugal force causes the materials to cling to the drum rather than be mixed by being picked up and dropped repeatedly by the mixer blades. The Department's interpretation of mixing speed is the speed (called “mixing speed”) that is noted on the metal plate required on every truck mixer. When there is an overlap of agitating speed and mixing speed, only the rate of rotation in excess of agitation is considered as mixing speed. Therefore, the

Inspector should examine the metal plate on each truck for the capacity and the rate of mixing. Trucks that have no metal plate are not permitted for state work.

If for some reason it is not practical to mix with transit mixers at the plant, the mixing may be done at the site in the presence of a Contractor's quality control personnel or the concrete control inspector. If the mixing is done on site, the Contractor will document this for the Department on a TE-45 form. Whether mixing is accomplished at the plant or the site, transit mixers shall rotate at agitation speed while in transit.

If mixing in transit is requested by the ready mix producer, the producer must show that the mixers can and do revolve at a rate in excess of the range for agitation, indicated on the metal rating plate attached to the mixer. Use of counters listing the number of revolutions at agitation speed and the number of revolutions in excess of the agitation range separately will be adequate proof. The Inspector must record both counter readings when counters of this type are used.

The metal rating plate indicates a range for agitation speed and a range for mixing speed. Normally there is an overlap of the two. For example, agitation speed may be listed from 2 to 6 revolutions per minute, while mixing speed may be from 4 to 12 rpm. To qualify as mixing speed in such instance, the mixer shall rotate at 7 rpm (next higher over agitation speed). At this rate, 10 minutes of mixing would be required for the required 70 revolutions.

The Contractor must ensure that the temperature of the plastic concrete does not exceed 95 ºF (35 ºC) until it is placed in the work. During hot weather, it may be necessary to use ice in the mixing water or to put sprinklers on aggregate piles to lower the concrete temperature.

Transporting Concrete

The time lapse, from the time water and cement are combined until the concrete is discharged into the work, must not exceed 90 minutes. The Inspector in the field must document the time when the concrete is unloaded and ensure that 90 minutes have not been exceeded. The Contractor may use, at his own expense, an approved Type F or Type G admixture for retempering the load to adjust the slump after discharge. In this case, a minimum of 30 revolutions at mixing speed after addition of these admixtures is required.

Use of completed subgrade or base as roadway for transporting materials should be discouraged, except in the case of crossovers or in the case of unusual circumstances, when it is impractical to operate outside the pavement area. When these unusual conditions exist and equipment is operated on the subgrade or base, increased inspection must focus on these areas to ensure compliance with specification requirements before concrete is placed. Increased inspection is necessary to avoid displacement of forms, rutting of surface, and variation from crown tolerances.

When hauling units operate on completed pavement that is opened to construction traffic, they must observe the legal load limits. Generally, dual rear axle units hauling 7 cubic yards (5.4 cubic meters) of concrete are in excess of the legal limit and will not be permitted to operate on the completed pavement when loaded. If the Contractor desires to haul loads containing more than 7 cubic yards (5.4 cubic meters) of concrete and intends to use portions of the completed pavement for the loaded trucks, the Contractor

must submit the necessary data to show that the loaded trucks are within legal limits. This data must be submitted to the District office for review.

Periodic inspection must be made of all hauling units. Items to be checked include:

1. Do not permit build-up of hardened concrete or cement.
2. Mixing blades of transit mix trucks should be in working order.
3. Revolution counters on transit mix trucks must be in working order.
4. Wash water in the drum of transit mix trucks should be discharged from the mixers before recharging unless the water is metered accurately by a water meter on the transit mixer and results in uniformly consistent concrete.

Concrete Testing Reports

When the Department is performing acceptance testing, the Concrete Inspector's Daily Report, Form TE-45 and/or the SiteManager Test Screens, must be filled out completely for each class of concrete used each day or at the frequency required to meet the sampling requirements.

The Engineer may determine if the quantity of concrete for the day is a small quantity (generally less than 50 cubic yards [38 cubic meters] of concrete is used). The TE-45 and SiteManager test screens would not be required but a SiteManager sample would still need to be completed. It is still recommended that some testing be performed on small quantity samples, such as air content, to ensure durability. The test result can be recorded in remarks.

Sample SiteManager TE-45 forms are shown in Figures 499.AC and 499.AD. The Inspector may choose to fill out a SiteManager sample and the two test screens instead of a TE-45.

1. PCC INSPECTOR DAILY REPORT TE45 PART 1 – BATCH WT
2. PCC INSPECTOR DAILY REPORT TE45 PART 2 – TESTS

The SiteManager TE-45 is filled out or the SiteManager Test Screens are filled out for each class of concrete used each day. Reports are numbered consecutively for each day when concrete is used, but numbered reports are kept separate for each class of concrete.

PCCRPT31
1/4/2012

OHIO DEPARTMENT OF TRANSPORTATION
PCC INSPECTOR DAILY REPORT

Sample ID		JMF	
Material Code		Alt Contract ID	
Prod/Supp Code		Date	

				BRAND/PRODUCT	QTY OZ/CY
LOCATION			AEA		
CEMENT P/S			ADMIX1		
FLY ASH P/S			ADMIX2		
GGBF SLAG P/S			ADMIX3		
MICRO SI P/S			ADMIX4		

LOT/SUBLOT						
TEST QTY						
BATCH TK #						
CEMENT WT						
FLY ASH WT						
GGBF SLAG WT						
MICRO WT						
FA BATCH WT						
FREE MOIST %						
FA SSD WT						
CA1 BATCH WT						
CA1 FREE MOIST %						
CA1 SSD WT						
A2 BATCH WT						
A2 FREE MOIST %						
A2 SSD WT						
A3 BATCH WT						
A3 FREE MOIST %						
A3 SSD WT						
A4 BATCH WT						
A4 FREE MOIST %						
A4 SSD WT						
BATCH WATER (lbs)						
FIELD WATER ADDED (lbs)						
W/CM RATIO						
TOTAL BATCH WT						

SIGNATURE / DATE ____________________

REMARKS: ____________________

Figure 499.AC – Form SiteManager TE-45, concrete inspector's daily report

The worksheet above that matches input information for the SiteManager Test Screen [PCC INSPECTOR DAILY REPORT TE45 PART 1 – BATCH WT] is available on the OMM website at: Site Manager TE Forms - All Documents

The following are instructions for filling out the TE-45 form part 499.D.

1. SAMPLE ID – The Sample ID number is a computer-generated number. This number is generated by SiteManager when data is entered onto the Sample screen. The number is used to refer to the TE-45 and any cylinder and/or beam specimens made that day.

2. JMF – The JMF space on the form is for the Job Mix Formula Number assigned to the concrete being produced and tested. The JMF is a list of the materials that are in the mix and should be provided by the Ready Mix producer supplying the concrete. The JMF can be verified by going to SiteManager icon 

, then 

, and then, 

to look up the Concrete JMF's.
3. MATERIAL CODE - The Material Code section of the TE-45 form is a number assigned to the type of concrete represented by the sample. These codes are available on the JMF in SiteManager.
4. ALT CONTRACT ID – SiteManager term for project number.
5. P/S CODE – This is the Producer/Supplier code. In this case, it is the code for the Ready Mixed Concrete Company. This number can be found in SiteManager by going to the JMF screen.
6. DATE MADE - This is the date that the concrete is made.
7. LOCATION - Location of Sample C, also note CLASS OF CONCRETE - The class of concrete to be used on any given item should be determined from the plans. Just place the name of the class in this box.
8. CEMENT P/S – Name on first ticket of each day and compared to JMF for QC mixes. Actual producer supplier code can be found in the JMF or SiteManager icon 

.
    a. CEMENT - Look on the approved list on the Materials Management website under S 1028 - Cement Certified List. Make sure to use the code for a MFG PLANT and not a TERMINAL Location. The MFG PLANT location should be on the Bill of Lading for the cement
9. FLY ASH P/S – Name on first ticket of each day and compared to JMF for QC mixes. Actual producer supplier code can be found in the JMF or SiteManager icon 

.
    a. FLY ASH - Look on the approved list on the Materials Management website under S 1026 - Fly Ash Certification List.
10. GGBF SLAG P/S – Name on first ticket of each day and compared to JMF for QC mixes. Actual producer supplier code can be found in the JMF or SiteManager icon 

.
    a. GGBF SLAG - Acceptable sources of this material can be found in the ISRC screen of SiteManager. Use material code 37603 for GRADE 100 material and 37604 for GRADE 120 material.
11. MICRO SI P/S – Name on first ticket of each day and compared to JMF for QC mixes. Actual producer supplier code can be found in the JMF or SiteManager icon 

.
    a. MICRO SILICA - Acceptable sources of this material can be found in the ISRC screen of SiteManager. Use material code 37601 for POWDER material and 37601S for SLURRY material.
12. AEA – Company and brand name on first ticket of each day. Approved types can be checked on the QPL list.
13. ADMIX 1 – Company and brand name on first ticket of each day. Approved types can be checked on the QPL list.

14. ADMIX 2 – Company and brand name on first ticket of each day. Approved types can be checked on the QPL list.
15. ADMIX 3 – Company and brand name on first ticket of each day. Approved types can be checked on the QPL list.
16. ADMIX 4 – Company and brand name on first ticket of each day. Approved types can be checked on the QPL list.
17. LOT/SUBLOT – If QC/QA concrete with sublots – record the number of the sublot and lot you are testing.
18. TEST QUANTITY – The space is to show how many cubic yards (cubic meters) of concrete the TE-45 test represents. The space shows how much concrete was produced during the day the report represents.
19. BATCH TK# – The number of the on the batch ticket for the concrete being tested.
20. CEMENT WT – Batched ticket cement weight for a cubic yard (cubic meter).
21. FLY ASH WT – Batched ticket fly ash weight for a cubic yard (cubic meter).
22. GGBF SLAG WT – Batched ticket GGBFS weight for a cubic yard (cubic meter).
23. MICRO SI WT – Batched ticket micro silica weight for a cubic yard (cubic meter).

FINE AGGREGATE

24. FA BATCH WT – Reported batch weight – can be worked per cubic yard.
25. FA FREE MOISTURE % – Percent reported on ticket – absorption for the aggregate.
    Aggregate absorptions are posted on OMM website on aggregate information page:
    http://www.dot.state.oh.us/Divisions/ConstructionMgt/Materials/Pages/AggregateInformation.aspx
26. FA SSD WT – Weight with water absorbed. See Example 2 below.
27. CA1 BATCH WT – Reported batch weight – can be worked per cubic yard.
28. CA1 FREE MOISTURE % – Percent reported on ticket – absorption for the aggregate.
    Aggregate absorptions are posted on OMM website on aggregate information page:
    http://www.dot.state.oh.us/Divisions/ConstructionMgt/Materials/Pages/AggregateInformation.aspx
29. CA1 SSD WT – Weight with water absorbed. See Example 2 below.
30. FA SSD WT – Weight with water absorbed. See Example 2 below.
31. A1 BATCH WT – Reported batch weight – can be worked per cubic yard.
32. A1 FREE MOISTURE % – Percent reported on ticket – absorption for the aggregate.
    Aggregate absorptions are posted on OMM website on aggregate information page:
    http://www.dot.state.oh.us/Divisions/ConstructionMgt/Materials/Pages/AggregateInformation.aspx
33. A1 SSD WT – Weight with water absorbed. See Example 2 below.
34. BATCH WATER (lbs) – Water batch according to Batch Ticket.
35. FIELD WATER ADDED (lbs) = Water added by truck tank meter.
36. W/CM RATIO = Total water divided by total cement, fly ash, GGBFS, etc.

Example 1:

1. CORRECTED SSD WEIGHT (for Sp. Gr) - This is the SSD design weight of the aggregates adjusted for specific gravity. This is calculated by multiplying the SPECIFIED SSD WEIGHT by the actual SSD specific gravity and dividing by the design specific gravity.

$$Adjusted\ DW_{SSD} = \frac{DW_{SSD}}{DSG} * ASG$$

Equation 499.3

Where:

DW_{SSD} = Design Weight (SSD) from the appropriate table in 499.03 or 499.04

DSG = Design Specific Gravity from Table 499.A

ASG = Actual SSD Specific Gravity to be used on the project

Adjusted DW_{SSD} = Design Weight (SSD) adjusted for the actual aggregate specific gravity

<u>Example 2</u>: Aggregate Batch Weight – Determine Free Moisture

1. AGGREGATE QUANTITIES FOR 1 yd^3 BATCH WITH CORRECTIONS FOR MOISTURE -. Each aggregate used should be adjusted for moisture in the following manner:
   a. BATCH WEIGHT - The batch weight is the weight on the ticket corrected to 1 cubic yard. (Example = 12,400 lbs for 10 yards = 12,400/10 = 1,240 lbs per cubic yard.)
   b. TMCF = The Total Moisture per Cubic Yard (%). The reported aggregate moisture content for the batch. IF QUESTIONING THE VALUE FROM THE READY MIXER, ASK HOW MEASURED OR REQUIRE AN AGGREGATE MOISTURE TEST.
   c. AMCF – Absorbed Moisture per Cubic Yard (%). The Department's established moisture absorption for the aggregate source.
      i. Aggregate absorptions are posted on OMM website on aggregate information page: http://www.dot.state.oh.us/Divisions/ConstructionMgt/Materials/Pages/AggregateInformation.aspx

FMCF = $\dfrac{TMCF}{AMCF} = \dfrac{(\%\,Total\ Moisture/100) + 1.0000}{(\%\ Absorbed\ Moisture/100) + 1.0000}$

The formula involves changing the two percentages into a decimal form by moving the decimal two places to the left and adding 1.

$$FMCF = \frac{TMCF}{AMCF} = \frac{\left(\frac{4.67\%}{100}\right) + 1.0000}{\left(\frac{0.74\%}{100}\right) + 1.0000} = \frac{1.0467}{1.0074} = 1.039$$

BATCH WEIGHT A	**SSD weight (B) A * 1/FMCF**	**free water a-b**
1382	1382 x 1/1.039 = 1330	1382-1330 = 52

Example 3:

1. W/CM RATIO – Determine the required Water/Cementitious Ratio (W/Cm) from the contract documents or JMF.
2. TOTAL CM WEIGHT – Sum the weights of all of the cementitious materials.
3. TOTAL WATER – Sum the BATCH WATER + the FIELD ADDED WATER + aggregate BATCH WEIGHTS – aggregate SSD WEIGHTS. Equals TOTAL WATER.
4. WATER IN ADDITIVES - Water in additives needs to be accounted for in the mix water. This is generally used when the micro silica used is in slurry form. You would then determine the amount of solid, determine how much is used, and how much of the slurry was water.

   Example: A slurry mix is used in a Class QC 3 mix. There is to be 30 lbs of micro silica in each yd3 of concrete. Determine how much slurry is needed per yd3 and how much water is contributed to the mix if the slurry contains 42 percent micro silica solids.

   30 lbs micro ÷ 0.42 = 71.4 lbs of slurry required
   71.4 lbs slurry - 30 lbs micro = 41.4 lbs of water added to the mix

BATCH WATER + FIELD WATER ADDED + (FA BATCH WT – FA SSD WT) + (CA BATCH WT – CA SSD WT) + (A1 BATCH WT – A1 SSD WT)
200 lbs + 15 lbs + (1382 – 1330) + (1240 – 1260) + (350 – 335) = 200 + 15 + 52 – 20 + 15 = 262 lbs

TOTAL CM WEIGHT = CEMENT WT + FLY ASH WT + GGBF SLAG WT + MICRO WT. = 350 + 100 + 150 + 20 = 620 lbs

W/CM RATIO = 262/620 = .43

PCCTEST31
1/3/2012

OHIO DEPARTMENT OF TRANSPORTATION
PCC AIR / SLUMP / YIELD / STRENGTH

Sample ID		Status	
Material Code		Material Name	
Prod/Supp Code		Prod/Supp Name	
Test Method		JMF	
Sampler		Effective Date	
Intended Use			
Control Number		Sample Type	
Sample Date		Rep Qty	
Test Number		Alt Contract ID	

TEST QTY		AIR %	
BATCH TICKET #		SLUMP IN	
DATE/TIME OF TESTING		BATCH WT LBS	
LOCATION OR STATION			
PCC TEMP F		WT / CU FT	
CYL or BEAM		ACTUAL YIELD CU FT	
CYL MOLD SIZE			

	CYL 1 / BEAM 1	CYL 2 / BEAM 2	CYL 3 / BEAM 3
SPECIMEN #			
DATE TESTED			
AGE			
STRENGTH PSI			
TRACKING #			
FINAL RESULTS			
TYPE OF FRACTURE			

	CYL 4 / BEAM 4	CYL 5 / BEAM 5	CYL 6 / BEAM 6
SPECIMEN #			
DATE TESTED			
AGE			
STRENGTH PSI			
TRACKING #			
FINAL RESULTS			
TYPE OF FRACTURE			

SIGNATURE / DATE ______________________

REMARKS: ______________________

Figure 499.AD – Form SiteManager TE-45, concrete inspector's daily report

The worksheet above that matches input information for the SiteManager test screen [PCC INSPECTOR DAILY REPORT TE45 PART 2 – TESTS] is available on the OMM website at:

Site Manager TE Forms - All Documents

The following are instructions for filling out the TE-45 form part 499.E.

1. SAMPLE ID – The Sample ID number is a computer-generated number. This number is generated by SiteManager when data is being entered onto the

Sample screen. The number is used to refer to the TE-45 and any cylinder and/or beam specimens made that day.

2. MATERIAL CODE – The Material Code section of the TE-45 form is a number assigned to the type of concrete represented by the sample. These codes are available on the JMF in SiteManager.
3. MATERIAL NAME – Note CLASS OF CONCRETE – The class of concrete to be used on any given item should be determined from the plans. Just place the name of the class in this box.
4. P/S CODE – This is the Producer/Supplier code. In this case, it is the code for the Ready Mixed Concrete Company. This number can be found in SiteManager by going to the JMF screen.
5. P/S NAME – In this case, it is the name for the Ready Mixed Concrete Company. This name can be found in SiteManager by going to the JMF screen.
6. TEST METHOD – number of the SiteManager test screen.
7. JMF – The JMF space on the form is for the Job Mix Formula Number assigned to the concrete being produced and tested. The JMF is a listing of the materials that are in the mix and should be provided by the Ready Mix producer supplying the concrete. The JMF can be verified by going to SiteManager icon 

, then 

, and then 

 to look up the Concrete JMF's.
8. SAMPLER – Your name.
9. EFFECTIVE DATE
10. INTENDED USE – What the concrete is being used for – deck, pier, column, etc.
11. CONTROL NUMBER
12. SAMPLE TYPE – Typically this will be a Control Sample (JCTL), Independent Assurance Sample (IAS), or Information (INF) sample. Other options for type of sample can be found in SiteManager.
13. SAMPLE MADE – This is the date that the concrete is made.
14. ALT CONTRACT ID – SiteManager term for project number.
15. TEST QUANTITY – The space is to show how many cubic yards (cubic meters) of concrete the TE-45 test represents. The space shows how much concrete was produced during the day the report represents.
16. AIR % – Test value from running air content test
17. BATCH TK# – The number of the batch ticket for the concrete being tested.
18. SLUMP IN – Slump test results in inches.
19. DATE/TIME OF TESTING
20. BATCH WT LBS
21. LOCATION OR STATION
22. PCC TEMP F = Tested temperature of the concrete.
23. WT/CU FT = Tested weight of the concrete.
24. CYL or BEAM – Type of strength test sample made.
25. ACTUAL yield in CUBIC FT – Tested yield.
26. CYL MODL SIZE – 4 inch x 8 inch or 6 inch x 12 inch
27. SPECIMEN # – Number assigned to the strength samples – cylinders or beams (example 1A, 1B, and 1C for three 4-inch x 8-inch cylinders specimen's).
28. DATE TESTED – Date the laboratory tests the specimens.
29. AGE – Number of days from the date sampled to the date tested.
30. STRENGTH PSI
31. TRACKING # - Internal laboratory number.

32. TYPE OF FRACTURE – Description of how the sample broke.

Check List for Inspection

Concrete Plants – Either Ready Mix or Plant on Site

Producer/suppliers of concrete are responsible for delivery of concrete and quality control. Items below are their responsibility but you or your District Concrete Monitor should randomly ensure these items comply. When concrete delivery is not good, these items become more critical.

When making these checks, ensure the supplier is with you, and obtain documentation from the supplier as to what corrections they will be making to conform to requirements.

1. Check foundations of stockpiles for proper preparation and adequate drainage.
2. Observe stockpiling of aggregate to ensure that handling does not cause segregation, contamination, or intermingling.
3. Observe charging of plant bins to ensure that materials are not being intermingled.
4. Check bins for adequate partitions to prevent intermingling of aggregate.
5. Check scales with test weights throughout range of use and determine percent of error. If error is greater than ± 0.5 percent, scales must be adjusted and rechecked. Record checks made and issues. Do not accept concrete until corrected.
6. Determine how the supplier will determine moisture content of their aggregates. Calibrated probes are acceptable as are moisture tests. Agree on the frequency of moisture and probe calibration. Work with your district concrete monitor on these issues. Depending on the job size, randomly verify moistures of aggregates.
7. Check scales for seal by the Sealer of Weights and Measures or of a scale servicing company. Record. If not sealed, do not accept concrete.
8. Check scales for "zeroing." Have adjustments made when needed.
9. Check water meter, both plant and truck, for accuracy. Record information. Do not accept concrete from equipment not meeting requirements of 499.
10. Randomly ensure that truck wash water is removed from the truck.
11. Check admixture dispensers for accuracy.
12. Check mixers to ensure that hardened concrete is not built up around blades.
13. Inspect hauling units for cleanliness, condition of blades, and operation of counters.
14. Check to ensure that all materials have been sampled, tested, and approved or certified prior to start of concrete production.
15. Ensure quantities obtained from the Job Mix Formula (JMF) are adjusted for changes in specific gravity, moisture, and absorption. Discuss with the supplier how they are doing this before delivery of concrete.
16. Ensure aggregate quantity adjustments are within the acceptable range of 499.04 based on the JMF quantities.
17. Observe batching operations at start of production and periodically when required.
18. During mixing or delivery from the truck, do not accept balling of materials. Do not accept attempts to remove balls by hand. Reject the mixing operations or trucks.

19. If water is added at project site, ensure 30 additional mixing revolutions are required
20. Ensure you receive both batch tickets. If the first ticket of the day is not provided, immediately notify the supplier.
21. Do not accept handwritten batch tickets.
22. Assure retarder is added at the required temperature and assure the dosage meets the manufacturer’s requirements.
23. Notify supplier to make adjustments as needed to maintain air, slump, and yield within tolerance. When slump adjustments are done with superplastizer on the jobsite, ensure a Type F or G is used and dosages are within manufacturer’s recommendations.
24. Ensure W/Cm ratios are not exceeded at any time. Immediately require corrections and report the quantity of material with high W/Cm ratios and non-specification material.
25. Ensure trucks discharge all concrete within 90 minutes from batching to discharge (499.08).
26. When adjustments are made in the mix design, check to ensure that proper batch weights are shown on tickets.
27. Periodically check transit and central mixers to ensure compliance with manufacturer's recommended mixing speeds.
28. Complete SiteManager TE-45 Report or test screens and submit to the District laboratory.

Conversion Factors:

	MULTIPLY	BY	TO GET
Area	1 square foot 1 square inch	0.0929034* 645.16*	square meter (m²) square millimeter (mm²)
Length	1 inch 1 foot 1 mile	25.4* 0.3048* 1.609344	millimeter(mm) meter (m) kilometer (km)
Mass	1 pound	0.453592 4	kilogram (kg)
Mass per volume	1 pound/cubic foot 1 pound/cubic yard 1 pound/gallon	16.018846 0.5932764 0.1198264	kilogram/cubicmeter (kg/m³) kilogram/cubic meter (kg/m³) kilogram/liter (kg/L)
Pressure (stress)	1 pound/square inch 1 pound/square foot	0.0068944 47.88026	megapascals (Mpa) pascal (Pa)
Temp	Fahrenheit (ºF)	(ºF-32)/1.8)	Celsius (ºC)
Volume	1 fluid ounce 1 cubic yard 1 cubic foot 1 cubic foot 1 gallon	29.57353 0.7645549 0.02831685 28.31685 3.785412	milliliter (mL) cubic meter (m³) cubic meter (m³) liter (L) liter (L)
Volume per mass	1 fluid ounce / cubic yard 1 fluid ounce / 100 pounds 1 gallon / cubic yard	38.68071 65.19847 4.951132	milliliter/cubic meter (mL/m³) milliliter/100 kilogram (mL/100 kg) liter/cubic meter (L/m³)

**exact conversion*

AASHTO M 157

The following is a direct reprint from AASHTO M 157 Standard Specification for Ready-Mixed Concrete. The reprint is only the paragraphs referenced in 499.05 B. of the specifications (Sections 10, 11.2, 11.5, 11.6).

AASHTO M 157 Sections 10, 11.2, 11.5, 11.6

10. Mixers and Agitators

10.1 Mixers may be stationary mixers or truck mixers. Agitators may be truck mixers or truck agitators.

10.1.1 Stationary mixers shall be equipped with a metal plate or plates on which are plainly marked the mixing speed of the drum or paddles, and the maximum capacity in terms of the volume of mixed concrete. When used for the complete mixing of concrete, stationary mixers shall be equipped with an acceptable timing device that will not permit that batch to be discharged until the specified mixing time has elapsed.

10.1.2 Each truck mixer or agitator shall have attached, thereto in a prominent place, a metal plate or plates on which are plainly marked the gross volume of the drum, the capacity of the drum of container in terms of the volume of mixed concrete, and the minimum and maximum mixing speeds of rotation of the drum, blades, or paddles. When the concrete is truck-mixed, as described in 11.1.3, or shrink mixed as described in 11.1.2, the volume of mixed concrete shall not exceed 63 percent of the total volume of the drum or container. When the concrete is central mixed as described in 11.1.1, the volume of concrete in the truck mixer or agitator shall not exceed 80 percent of the total volume of the drum or container. Truck mixers and agitators shall be equipped with means by which the number of revolutions of the drum blades, or paddles may be readily verified.

10.2 All stationary and truck mixers shall be capable of combining the ingredients of the concrete within the specified time or number of revolutions specified in Section 10.5, into a thoroughly mixed and uniform mass and of discharging the concrete so that no less than 5 of the 6 requirements shown in Table 5 shall have been met.

Table 5 – Requirements for Uniformity of Concrete

Test Requirement Expressed as Maximum Permissible Difference in Results of Tests of Samples Taken from Two Locations in the Concrete Batch	
Weight per cubic foot (weight per cubic meter) calculated to an air-free basis, lb/ft^3 (kg/m^3).	16 (1.0)
Air content, volume percent of concrete.	1.0
Slump:	
If average slump is 102 mm (4 in.) or less, mm (in.).	25 (1.0)
If average slump is 102 mm to 152 mm (4 to 6 in.), mm (in).	38 (1.5)
Coarse aggregate content, portion by weight of each sample retained on No. 4 (475-mm) sieve, percent.	6.0
Unit weight of air-free mortar [a] based on average for all comparative samples tested, percent.	1.6
Average compressive strength at 7 days for each sample,[b] based on average strength of all comparative test specimens, percent.	7.5 [c]
a - "Test for Variability of Constituents in Concrete." Designation 26, Bureau of Reclamation Concrete Manual, 7th Edition. Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. b - Not less than 3 cylinders will be molded and tested from each of the samples. c - Tentative approval of the mixer may be granted pending results of the 7-day compressive strength tests.	

Note 5 - The sequence or method of charging the mixer will have an important effect on the uniformity of the concrete.

10.3 The agitator shall be capable of maintaining the mixed concrete in a thoroughly mixed and uniform mass and discharging the concrete with a satisfactory degree of uniformity as defined by Appendix A.

10.4 Slump tests of individual samples taken after discharge of approximately 15 percent and 85 percent of the load may be made for a quick check of the probable degree of uniformity (Note 6). These two samples shall be obtained within an elapsed time of

no more than 15 minutes. If these slumps differ more than that specified in Annex A1, the mixer or agitator shall not be used unless the condition is corrected, except as provided in 10.5.

Note 6 - No samples should be taken before 10 percent or after 90 percent of the batch has been discharged. Due to the difficulty of determining the actual quantity of concrete discharged, the intent is to provide samples that are representative of widely separated portions, but not the beginning and end of the load.

10.5 Use of the equipment may be permitted when operation with a longer mixing time, a smaller load, or a more efficient charging sequence will permit the requirements of Appendix A to be met.

10.6 Mixers and agitators shall be examined or weighed routinely as frequently as necessary to detect changes in condition due to accumulations of hardened concrete or mortar and examined to detect wear of blades. When such changes are extensive enough to affect the mixer performance, the proof-tests described in Appendix A shall be performed to show whether the correction of deficiencies is required.

11. Mixing and Delivery

11.2 Mixers and agitators shall be operated within the limits of capacity and speed of rotation designated by the manufacturer of the equipment.

11.5 Truck-Mixed Concrete – Concrete that is completely mixed in a truck mixer, 70 to 100 revolutions at the mixing speed designated by the manufacturer to produce the uniformity of concrete indicated in Appendix A. Concrete uniformity tests may be made in accordance with 11.5.1. and if requirements for uniformity of concrete indicated in Appendix A are not met with 100 revolutions of mixing, after all ingredients, including water, are in the drum, that mixer shall not be used until the condition is corrected, except as provided in Section 10.5. When satisfactory performance is found in one truck mixer, the performance of mixers of substantially the same design and condition of blades may be regarded as satisfactory. Additional revolutions of the mixer beyond the number found to produce the required uniformity of concrete shall be a designated agitating speed.

11.5.1 Sampling for Uniformity of Concrete Produced in Truck Mixers – The concrete shall be discharged at the normal operating rate for the mixer being tested, with care being exercised not to obstruct or retard the discharge of approximately 0.1 m^3 (2 ft^3 approximately) shall be taken after discharge of approximately 15 percent and 85 percent of the load (Note 6). These samples shall be obtained within an elapsed time of not more than 15 min. The samples shall be secured and shall be kept separate to represent specific points in the batch rather than combined to form a composite sample. Between samples, where necessary to maintain slump, the mixer may be turned in mixing direction at agitating speed. During sampling, the receptacle shall receive the full discharge of the chute. Sufficient personnel must be available to perform the required tests promptly. Segregation during sampling and handling must be avoided. Each sample shall be remixed the minimum amount to ensure uniformity before specimens are molded for a particular test.

11.6 When a truck mixer or truck agitator is used for transporting concrete that has been completely mixed in a stationary mixer, any turning during transportation shall be at the speed designated by the manufacturer of the equipment as agitating speed.

AASHTO M 157 Appendix A

(Mandatory Information)

A1. CONCRETE UNIFORMITY REQUIREMENTS

A1.1 The variation within a batch, as provided in Table 5, shall be determined for each property listed as the difference between the highest value and the lowest value obtained from the different portions of the same batch. For this specification, the comparison will be between two samples, representing the first and the last portions of the batch being tested. Test results conforming to the limits of five of the six tests listed in Table 5 shall indicate uniform concrete within the limits of this specification.

A1.2 Coarse Aggregate Content, using the washout test, shall be computed from the following relations:

P = (c/b) x 100

Where:

P = Weight % of coarse aggregate in concrete.

c = Saturated surface-dry-weight in kg (lb) of aggregate retained on the No. 4 (4.75-mm) sieve, resulting from washing all material finer than this sieve from the fresh concrete.

b = Weight of sample of fresh concrete in unit weight container, kg (lb).

A1.3 Unit Weight of Air Free Mortar shall be calculated as follows:

A1.3.1. Inch-pound units:

$$M = \left(\frac{b - c}{V - \left(\frac{VxA}{100} + \frac{c}{Gx62.4} \right)} \right)$$

A1.3.2. Metric units:

$$M = \left(\frac{b - c}{V - \left(\frac{V \times A}{100} + \frac{c}{1000\,G} \right)} \right)$$

Where:

M = Unit weight of air-free mortar, kg/m³ (lb/ft³).

b = Weight of concrete sample in unit weight container, kg (lb).

c = Saturated surface-dry-weight of aggregate retained on No. 4 (4.75-mm) sieve, lb (kg).

V = Volume of unit weight container, ft³ (m³).

A = Air content of concrete, percent, measured in accordance with Section 18.1.4 on the sample being tested.

G = Specific gravity of coarse aggregate (SSD).

500 Structures

501 Structures - General

Verification of Dimensions (501.02)

In order to rehabilitate an existing structure, or construct a new one, the Contractor examines the bid documents and performs survey work to verify field and plan elevations, dimensions and geometries. The Engineer shall verify the Contractor's accuracy by observation of the work and review of notes. The Contractor's surveyor should cooperate with the Engineer and provide the notes on critical work, such as bridge seat elevations, profiles of beams or girders, and grade for finishing the deck for review and concurrence. Information that indicates the elevation of bridge seats and deck grades have been properly set must be recorded in the project file.

Shop Drawings (501.04)

The Shop Drawings describe portions of Items 513, 515, 516, 517 and 518 Work that is fabricated off site to be incorporated permanently with the project .These drawings are accepted by the Contractor and two copies are to be submitted to the Project with the material. This material is not to be incorporated into the Work without these Shop Drawings. Shop Drawings for Item 513 and 515 require an Ohio Registered Engineer to sign, seal and date the cover sheet to confirm that the shop drawings meet the contract intent.

Engineered Drawings (501.05)

When railroad involvement is required as specified in 501.05.A, for

1 .Bracing adjacent to the railroad tracks,
2. Demolition of structures within 14 feet of railroad tracks,
3. Erection of structures within 14 feet of railroad tracks,

Figure 501.05 - Excavation for structure adjacent to railroad tracks

It is the Contractor's responsibility to submit Engineered drawings to the involved railroads for acceptance at least 50 days before construction begins. The Contractor shall supply the Engineer with documentation proving railroad acceptance.

When railroad involvement is not required, the following Engineered Drawings should be submitted to the Engineer for acceptance before construction begins. Competent individuals shall prepare, check and initial each Engineered Drawing. An Ohio Registered Professional Engineer (PE) shall sign, seal and date the cover sheet or submittal letter.

1. Cofferdams and excavation bracing, (Item 503), when the edge line of a roadway used to maintain traffic is located within a distance of ½ times the excavation height or for excavations that expose any side of an excavation to a height over eight feet except when a complete design is shown in the plans.

Figure 501.05.1 - Excavation bracing should have been placed adjacent to traffic, note undermining of road

2. Demolition of bridges or portions of bridges, (Item 202), in which the work endangers the public welfare, or life, health or property.

Figure 501.05.2 - Slab Deck that collapsed during demolition

3. Falsework for cast-in-place concrete slab bridges.(Items 508 and 511)

Figure 501.05.3 - Falsework for Slab Deck

4. Erection of steel or precast concrete structural members, (Items 513 and 515).

Figure 501.05.4 - Concrete beam dropped during erection

5. Jacking and support of existing structures.(Item 516)

Figure 501.05.5 - Jacking and support of structure

6. Construction loads applied to a structure during construction, in excess of 75% of legal load.(Items 511, 513 and 515)

Figure 501.05.6 - Construction load applied to structure during deck removal

7. Structures for maintaining traffic.(Item 502)

An Engineered Drawing meeting will be scheduled 7 days or less, after the submittal. The Engineer who signed the submittal, the Superintendent, the Engineer and Inspector and responsible designer of the contract documents will discuss the work governed by the Engineered Drawing and resolve all issues to the Engineer's satisfaction. The Engineer is encouraged to invite the designer of the contract Plans to the meeting for assistance in reviewing the submittal. At the conclusion of the meeting, the Engineer will provide a written response to the Contractor in accordance with 105.02:

1. The Department will "Accept" the submittal, or
2. The Department will "Accept as Noted" the submittal, or
3. The Department will "Not Accept" the submittal.

Work covered by the Engineered Drawing cannot begin until the Engineer's acceptance. These Engineered Drawings should be utilized in the field as the standard to judge whether the Contractor is performing the work correctly.

Figure 501.05 - Engineered Drawing meeting

Stop all operations that do not follow the accepted Engineered Drawings. The Contractor must submit to the Engineer any revised Engineered Drawings, which are prepared by an Ohio Registered Professional Engineer, 24 hours before construction on the deviated work begins.

If a Contractor has to perform corrective work on structures items, 507, 511, 513, 515, 516, 517 and 524, the Contractor must submit three copies of a corrective work plan to the Engineer, for acceptance at least 30 days before construction begins, including supporting calculations prepared by an Ohio Registered Professional Engineer. The Engineer will submit the corrective work plan to the Office of Structural Engineering for review and acceptance prior to performing corrective work.

When traffic is maintained while an overhead structure is being removed, platforms, nets, or other devices must be provided to safeguard the traveling public from falling objects that might fall directly onto the roadway below, be deflected toward the traffic, or bounce into traveled lanes. Removal of superstructure concrete and structural steel shall, in no case, take place directly over traffic due to the possibility of large pieces falling through the protective devices.

Test Reports (501.06)

For Item 513, Contractor required to submit the following at least 7 days before shop inspection: (One copy for each structure, unless there is railroad involvement, one copy for each railway)

1. Certified test data in compliance with Item 711
2. Copies of mill shipping invoices showing quantity and size of material
3. Acceptance letter for material

For Items 516, 517 and 518, Contractor required to submit with fabricated material:

1. Letter of certification that materials conform to contract requirements
2. Tracebility to producing mill and proof of domestic origin

Welded Attachments (501.07)

If the Contractor requests to weld to a main structural member,(Item 513), and that weld is not shown on the Contract drawings, the Contractor must submit a detailed plan showing weld size, length, type and location to the Office of Structural Engineering for acceptance at least 20 days before construction begins.

Project File Requirements - 501 Structures

Use the Structures Submittals Checklist Form to assist reviewing the Contractor’s requirements for submittals of verification of dimensions, shop drawings before fabrication of structural items, Engineered Drawings of Contractor designed procedures for structural work, structural material certification, and Contractor requested welding procedures.

502 Structures for Maintaining Traffic

Description (502.01)

This item consists of the construction, maintenance, and subsequent removal of a temporary bridge or culvert for maintaining traffic.

Design and Construction (502.02)

The Contractor is required to submit construction Engineered Drawings in accordance with 501.05.

The waterway opening generally should be not less than 75 percent of the effective waterway of the proposed structure based on the 5 year water level. The deck of a bridge must have at least a 23 foot (7.0 m) clear roadway and, if pedestrian facilities existed, at least a 4 foot (1.2 m) wide sidewalk must be provided.

The proposed Engineered Drawing should be reviewed in the District for accuracy of existing features not shown on the project plans. If the proposed waterway is less than 75 percent, comments regarding local knowledge of stream fluctuations will be helpful. In lieu of a bridge, a pipe culvert, or multiple pipe culverts with required waterway, may meet the requirements for a bridge and will be considered when submitted.

All stress-carrying materials to be used in any temporary structure must be carefully examined since used materials generally are employed and may not possess the physical properties considered in the design. Timber elements must be examined for specified size and soundness. Steel members must be examined for holes and alterations that would reduce their section modules. Welded splices in members are not cause for rejection providing the welds have been made properly and are free from defects. Existing welded butt splices must be subject to radiographic inspection. Approved welders using approved welding consumables should perform welding. Hardware and miscellaneous materials must be as specified on the submitted plan.

Piles must be driven in accordance with 507. The bearing capacity of each pile must be as specified on the submitted plan, but in no case, less than 12 tons (107 kn). If piles are not driven to bedrock, the Contractor is responsible for performing the dynamic load necessary to determine the required blow count.

Construction of the temporary structure must be according to details and notes shown on the submitted Engineered Drawing. Proposed substitution of elements of equal or greater strength may be made. All other proposed substitutions or changes in design must be submitted in an amended Engineered Drawing meeting the requirements of 501.05.

When the plans permit the use of an existing superstructure as part of a temporary run-around, the bridge shall be relocated so there will be no reduction in load carrying capacity. The working drawings for temporary substructure units must be submitted in accordance with 501.05.

Maintenance (502.03)

The Contractor is required to maintain the temporary structure in good condition with respect to safety, ride quality, and waterway opening for the duration of the run-around. Periodic inspection of the structure must be made and any questionable members or connections that are damaged or over-stressed must be corrected immediately.

Project File Requirements - 502 Structures for Maintaining Traffic

Use the Structures Submittals Checklist Form to assist reviewing the Contractor's requirements for submittals on structures for maintaining traffic.

503 Excavation for Structures

Description (503.01)

This work consists of constructing, maintaining, and subsequently removing cofferdams and excavation bracing, and excavating materials not removed under other items of work that must be removed to enable construction of bridges, and other structures. This work also includes dewatering and backfilling the excavation, protecting the excavation against collapse, and disposing of materials not required or suitable for backfill.

When the cofferdam and excavation bracing item is not provided, drainage outside the forms and pumping necessary to keep the surface suitable for placement of concrete are included in the excavation item.

Classification (503.02)

For the construction of a structure, any material that is removed that is not included in other items of work, such as Item 202 –Portions of Structure Removed, or Item 203 – Excavation, is included in Item 503. 503 Items include

1. Unclassified Excavation- which may include bedrock and may require the removal of all materials necessary for the construction of structures according to plan.
2. Unclassified Excavation including rock or shale.
3. Rock or Shale Excavation

Cofferdams and Excavation Bracing (503.03)

The Contractor may construct the designs shown in the plans or prepare an alternate design for which an Engineered Drawing is required to be submitted for acceptance by the Engineer. The Contractor may select to use whatever materials or methods he considers necessary to accomplish this item unless specific details are required by the

plans. Many times when sheeting is installed into streambeds, the streambeds consist of sand or gravel. Sand and gravel are pervious materials and will allow water to flow through them. If this condition exists, water can flow under the sheets and come up through the bottom of the cofferdam. This can loosen the soil in the bottom of the cofferdam and cause it to be very soft and unstable. It can also result in water coming up through any freshly-placed concrete. If this situation exists, the Contractor should take measures to prevent the flow of water up through the bottom of the cofferdam. These measures can consist of driving the sheet piling deep enough to cut off the flow of water or placing a concrete seal in the bottom of the cofferdam prior to pumping out the water. If additional measures are required, they are considered to be part of the cofferdams and excavation bracing item and no additional compensation should be paid for these items.

In order to qualify as cofferdams and excavation bracing for a particular substructure unit, the Contractor must perform work to protect and maintain the excavation at that particular substructure unit. This work can include pumping out water, installing cribs or sheeting, sloping the sides of the excavation, or building an earthen cofferdam.

Support members should clear the top of the footings by at least 1 foot (0.3 m) or shall be structural steel and left it in place.

Cofferdams are to be constructed to accommodate a water elevation 3 feet (1.0 m) above the ordinary high water mark shown on the plans.

The Contractor is required to establish, certified by an Ohio Registered Surveyor, and maintain a monument upstream of all proposed cofferdams to visually monitor the water elevation in the waterway.

If the Contractor has exercised normal due diligence in maintaining the cofferdam, and the actual water elevation exceeds 3 feet (1.0 m) above the stated ordinary high water mark, the Department will reimburse the Contractor for any resulting damage to the work protected by the cofferdam.

If the Contractor constructs the cofferdam at a lower elevation, the Department will not reimburse the Contractor for repairs to the work nor grant additional time unless the water elevation exceeds 3 feet (1.0 m) above the ordinary high water mark shown on the plan.

Figure 503.03 - Cofferdam with bracing and whalers

Protection for Excavation (503.04)

Sides of excavation should be protected from caving. If side failure occurs, the disturbed soil should be removed and replaced with properly compacted soil. The sides must not be laid back to the extent where the slope will endanger the stability of adjacent foundations. The stability of the slopes needs to be determined by a competent person on the Contractor's staff.

Undercut for Spread Footings

When footings are not on piling, any material undercut, disturbed below plan, or authorized elevation must be replaced with concrete at the Contractor's expense. If the excavation is allowed to remain exposed for a considerable period of time, and the material becomes unsuitable, it must be removed and replaced with concrete at the Contractor's expense. The additional concrete may be placed with the footing concrete; however, the footing reinforcing steel must be located at the elevation indicated on the plans.

Many Contractors will place gravel in the bottom of the excavation to assist in dewatering and to provide a better work surface for the workers. This is unacceptable as any over excavation of spread footing subgrades must be replaced with concrete, not gravel.

Undercut for Pile Foundations

When footings are supported on piling, any material undercut or disturbed must be replaced with properly compacted material. If the bottom of the excavation becomes muddy, the Contractor may remove the muddy soil and replace it with suitable granular material.

Figure 503.04 - Compacted material around piling in foundation

Footings in Rock (503.05)

This item includes removal and disposal of material that, in the opinion of the Engineer, is rock or durable shale. Shale that is removed by the same methods and comparative effort as soil should be classified as nondurable shale.

Methods

Rock or durable shale may be removed by whatever methods the Contractor chooses. These usually are blasting, jack hammering, or ripping. Note the option to excavate by blasting may be excluded due to the close proximity of existing facilities. It is desirable to have rock excavation below the tops of footings and as near to the sides of the footings as practical.

Qualifications for Payment

To qualify for payment as rock excavation, the Engineer must determine that the excavated material is indeed rock or durable shale. In addition, all of the rock excavation below the footing top must be filled with concrete. Rock excavation performed above the top of footing may be to any width; however, payment above, as well as below, the top of footing is to the plan dimensions of the footing only.

Elevation Changes

In the event bedrock is encountered over 1 foot (0.3 m) higher than indicated by the borings, or bedrock is not encountered at plan elevation, report the findings to the District Construction Administrator for consideration of a change in elevation of the footing. A plan note will usually be provided indicating when raising the footing can begin. When bedrock is not encountered at footing elevation, an investigation of the soil should be made as deep as practical. Hand augers or probes are recommended for initial investigation.

Generally, when bedrock is found less than 1 foot (0.3 m) lower than plan elevation, the additional height of pier or abutment can be provided by additional footing concrete; however, reinforcement should be placed at plan elevation.

When bedrock is found 1 foot (0.3 m) or more below plan elevation, consideration should be given to lengthening the pier or abutment above the footing.

Relative costs should be investigated in either case, and if the cost difference is significant, should be reported to the District Construction Administrator for review.

Approval of Foundations (503.06)

When the foundations for a bridge are spread footings, they are designed to be supported on soil or bedrock as indicated by the soil borings. The Engineer must examine the soil or bedrock encountered at plan elevation for agreement with soil boring data and to assure that it will provide the intended bearing capacity. This bearing capacity will be listed in tons per square foot (tonnes per sq. meter) in the plan notes. Consult the District Geotechnical Engineer or Office of Geotechnical Engineering with any questions.

Questionable Support

The District Geotechnical Engineer or Office of Geotechnical Engineering should be consulted whenever there is doubt that the material encountered at plan elevation will provide the necessary bearing capacity. Whenever the material encountered is different, and of lesser quality than indicated by the borings, an investigation similar to that described in the section titled, "Elevation Changes," should be made and the findings reported to the District Geotechnical Engineer for review.

Cold Weather Excavation

Footings placed on pile foundations that were exposed to temperatures below freezing sometimes settle during the setting of the concrete and result in unsatisfactory footings. Therefore, it is imperative that soil in such cases be free from frost, and if disturbed by freezing, compacted to proper density.

Protection

When excavation for footings is performed, and freezing temperatures are expected during the time it is exposed, insulation such as an adequate thickness of straw is recommended for protection from frost.

Examination

When the excavated area has become frozen, and the area is heated in an enclosure, the effect of the supplied heat on the frozen soil is slight, and a thorough examination for complete removal of frost is required. Satisfactory temperatures found in spot checks of soil where frost may have penetrated are an indication of frost removal.

When frozen soil is thawed out, it requires re-compaction since frost heaving has lessened the density. If reinforcing steel has been placed in a footing area at the time the soil was frozen, it will be necessary for the Contractor to remove the reinforcing steel prior to re-compacting the soil.

Backfill (503.08)

The backfill material behind the abutments and beneath the approach slabs shall conform to Item 203 Granular Material Type B. The use of this material should facilitate compaction and help alleviate the settlement of the approach slab.

Figure 503.08 - Backfilling and compacting material behind abutment

Method of Measurement (503.09)

Measurement of Excavation Prior to Altering the Original Ground Line

When the plans do not require the original ground line to be altered by removal of the embankment, and when structural excavation is performed prior to building an embankment, elevations or measurements that establish the elevation of the original ground must be made. Measurements made and recorded from the Contractor's footing grade stakes can be used to establish the elevation of the original ground.

Measurement of Excavation Made After Altering the Original Ground Line

When the original ground is altered by removal or construction of an embankment prior to excavation, use the plan line of the excavation or embankment items for top boundary of excavation.

Verification of Footing Elevation

The bottom elevation of the footing is to be as shown in the plans. This elevation is to be verified by subtracting the total verified height of the substructure unit below the beam seat from the beam seat elevation.

504 Sheet Piling Left in Place

Description (504.01)

This work consists of furnishing and driving steel sheet piling that the plan designates to be left in place, including furnishing and installing any specified anchors or other attachments to structures.

Materials (504.02)

Material for sheet piling must conform to 711.03, which refers to ASTM A328. Sheet piling that conforms to ASTM A328 is acceptable. Used sheet piling may be used if it meets the project requirements and is approved by the Engineer.

The Contract Documents will specify the minimum section modulus in cubic inches per foot of wall length. Any hot rolled or cold rolled sheet piling which meets or exceeds this requirement is acceptable.

Driving (504.03)

Steel sheet piling is not driven based on any driving criteria, but is driven based on a specified tip elevation.

Steel sheet piling will normally be driven with a vibratory hammer suspended by a crane or an excavator mounted sheet driver. In difficult driving conditions, diesel impact hammers can be used, but it is more likely that the top of the sheets will crush.

Sheet piling is always interlocked with the adjacent sheets. The manufacturer will fabricate a special shape if sharp corners or junctions are required in the wall.

Figure 504.03 - Sheet piling left in place, and trimmed

505 Pile Driving Equipment Mobilization

Description (505.01)

This work consists of mobilizing pile driving equipment to and from the project site and, as necessary, to install the required piling.

This work includes the fixed costs that are related to the installation of the required piling.

Basis of Payment (505.02)

Payment is not to be made when the equipment arrives on site, but once the first service pile is installed and accepted.

506 Static Load Test

Description (506.01)

Static load tests are performed on piles to determine the accuracy of dynamic load test results and to determine if the capacity of the pile being tested has increased or decreased after it has set in the ground for some period of time. The intent of performing the static load test is to potentially reduce the driven length of pile by fine-tuning the pile capacity determination. There must be a substantial amount of piling at a structure to justify the

expense of a static load test. Generally, 10,000 feet of piling (all of the same size and ultimate bearing value) is the amount required before specifying a static load test.

Static load tests are not performed very often and can be complex and must be performed properly for the results to be useful. Always contact the Office of Construction Administration or the Office of Geotechnical Engineering for assistance before performing a static load test.

With the 2013 C&MS, the Department adopted the ASTM Quick Load Test method for static load testing. The duration of the static load test using this method is generally 8 to 10 hours. Using the previous method, the test could take longer than 24 hours. The other significant change with the 2013 C&MS is that the Contractor is responsible for taking the readings. Previously, the Department was responsible for taking readings during the test.

Determination of Need

The Office of Construction Administration or the Office of Geotechnical Engineering must be consulted before non-performing the static load test. Consult either of these two offices to determine if a subsequent static load test should be performed.

Static load tests are not performed on piles driven to refusal on bedrock.

General (506.02)

Pile Wall Thickness

Most static load tests are performed on cast-in-place piles (also called pipe piles or tube piles). The static load test will place a load on the test pile that is twice the Ultimate Bearing Value (UBV); therefore, the test pile may need a thicker wall than that required by 507.06 or the Contractor will have to fill the pile with concrete and allow the concrete to cure for 5 days.

For test piles, if the wall thickness is less than the required wall thickness given by the equation below, then the Contractor must fill the pile with concrete and allow the concrete to cure for 5 days before performing the static load test.

$$t = \frac{2\,R}{113000\,D}$$

Where:

t = Shell wall thickness (inches)

R = Ultimate Bearing Value, UBV (pounds)

D = Diameter of pile (inches)

If the test pile wall thickness is equal to, or greater than the wall thickness given by the above equation, the Contractor can perform the static load test 72 hours (3 days) after he has finished driving the test piles and anchor piles. Generally, piles with a diameter of 16 inches or greater will meet the minimum wall thickness requirement for the test pile. Depending on the UBV, 12-inch and 14-inch piles may not be available with the

minimum wall thickness for test piles. These piles will have to be filled with concrete before the static load test.

Driving Test Piles

The test pile can be, and usually is, a production pile. The test pile must be vertical. Sometimes people are concerned about "failing" a production pile. This should not be a concern. In fact, it is desirable to "fail" the test pile as when this happens, we determine the true capacity of the pile and achieve the most value from the test. In the case where a test pile, which is also a production pile, "fails" during the static load test at a capacity lower than required, the solution is usually as simple as splicing on more pile length and driving the pile deeper.

The standard plan note for a static load test requires the Contractor to drive four piles, not including the anchor piles. The first two driven piles are test piles. Each one is driven to the required UBV as determined by the dynamic load test. This means both of these piles are dynamic load tested (that is one dynamic load test item). Do not overdrive these first two piles. Perform the static load test on one of these two piles. If the first pile is not suitable to use for the static load test, the second pile is driven as a backup. The dynamic load test on the second pile gives additional data that can be used to interpret the static load test results. The third and fourth piles are driven to reduced blow counts 75 and 85 percent of the driving criteria. For example, if the driving criteria from the dynamic load test is 40 blows per foot (bpf), then the third pile is driven to 30 bpf (0.75×40), and the fourth pile is driven to 34 bpf (0.85×40). It is important that the third and fourth piles be shorter than the test pile, so that the person interpreting the test data can make an accurate evaluation. The exact method of determining shorter length is not critical. They can also be driven to 75 and 85 percent of the length, or some other lengths shorter than the test pile. The third and fourth piles are also dynamic load tested (one more dynamic load test item).

In some soil, piles will gain capacity with time. This is called pile set-up or sometimes, pile freeze. The reduced capacity piles are driven to see if the pile will gain enough capacity with time to meet the Ultimate Bearing Value requirement. If there is some increase in capacity, but not enough to meet the UBV, then we can still estimate the appropriate driving criteria if we know the amount of pile set-up. To do this, we need to know the capacity at the end of the initial pile driving, which we can determine from the dynamic load test. This is why we dynamic load test the reduced capacity piles.

Anchor Piles

Production piles can be used as anchor piles. Vertical piles are preferred for the anchor piles, but the Contractor may use battered piles for the anchor piles as long as the battered piles are symmetric around the test pile. The Contractor determines the number of piles to use as anchor piles and the required length of penetration. Anchor piles must be at least 8 feet (2.5 m) from the test pile, measured from center-to-center. If the anchor piles are also production piles, they may need to be re-driven to the required driving criteria after the static load test, depending on the test results.

Generally, the test pile should be driven before the anchor piles, but this is not required. If the anchor piles were driven first and there was a problem with the first test pile so that the backup test pile had to be tested, then the Contractor would have to drive additional anchor piles around the backup test pile.

No other production piles are to be driven until after the results of the static load test have been interpreted. However, the Engineer can allow the Contractor to proceed with pile driving at his own risk, with the understanding that the Department will not pay for piling driven deeper than required based on an evaluation of the static load test results.

Figure 506.02 - Static load test setup with anchor piles

Application of Load (506.03)

The Contractor must wait at least 72 hours (3 days) after driving the test pile and anchor piles before applying the test load. If the Contractor has filled the test pile with concrete because it does not meet the minimum wall thickness requirement, then the Contractor must wait 5 days before applying the test load. The plan notes may require a longer waiting period.

The test pile should be cut off as near to the ground as practical and the jack placed along the axis of the pile with full bearing on the required load cell and bearing plate.

Instruments

The Contractor must furnish a set of gauges or devices capable of accurately determining settlement of the pile to 0.001 inch (0.025 mm) and a calibrated load cell for determining the load applied. Dial gauges must have graduations every 0.01 inch (0.25 mm) or less.

The gauges used to measure the settlement of the pile should be placed opposite each other and should be placed at the sides of the pile. They should be supported from posts or fixed objects. The post or fixed objects are to be independent of the test load set-up and at least 4 feet (1.25 m) away from the test pile. However, the gauges should be placed as close to the test pile as possible. Dial gauges are furnished and should have sufficient travel to measure up to 2 inches (50 mm). A backup system is required in case

of problems with the gauges. The backup system usually consists of a ruler applied to the test pile, with a mirror and string line for measuring settlement.

The primary means of determining the applied load is a calibrated load cell. The pressure gauge on the hydraulic jack can be used as a backup load measuring system. The pressure gauge alone is not accurate enough for the static load test. Also, if the jack should bind up, the hydraulic pressure would increase while the load transmitted to the pile would not necessarily increase.

Loading

The load is to be applied in increments consisting of a first increment of 1/10 the UBV of the pile (R). The Contractor records the dial gauge readings for each gauge 1, 2, 4, 8, and 15 minutes after each load increment is applied. Calculate the average pile settlement from the gauge readings. Apply the next load increment after the 15 minute reading.

Maintain the test load during each load increment. Due to settlement of the pile, the load and pressure in the jack may decrease with time. The Contractor should run the hydraulic pump as necessary to maintain the load on the pile.

Continue to increase the test load until the load is twice the UBV or the pile reaches plunging failure. Plunging failure is defined when continuous jacking is required to maintain the test load.

Unloading

After loading is complete or plunging failure is reached, unload the pile in five equal decrements in 15 minute intervals. Record the settlement readings at 1 and 15 minutes after each load decrement. After the entire test load has been removed from the test pile, record the settlement after 1 and 15 minutes.

If it is necessary to remove and reapply the load, such as a problem with the jack or load cell, reapply the test load using the same procedure used to apply the initial loads.

Figure 506.03 - Jack for loading pile and gauges to measure settlement

Load Test Results

The test load Ultimate Bearing Value (Q_f) is the maximum capacity of the test pile. To determine Q_f, it is necessary to plot the settlement of the top of the pile versus the load on the pile. Draw a straight line through the zero point and the theoretical elastic settlement of the pile using the equation in the specification. This line represents the elastic compression of the pile (the distance that the pile compresses under the test load). Draw another line parallel to the first, but offset by the distance given in Equation 506.1. The second line is called the Davisson criterion line.

$$0.15 \text{ inch} + 0.008\,D \qquad (3.8 \text{ mm} + 0.008D)$$

Equation 506.1 – Settlement Offset

Where:

D = Diameter of pile (inches or millimeters)

The point where the load-settlement curve from the static load test intersects the Davisson criterion line is the test load Ultimate Bearing Value (Q_f). An example from an actual static load test is shown in Figure 506.A.

In some cases, the slope of the unloading portion of the curve can be used to determine the elastic compression of the pile.

If the load-settlement curve does not intersect the Davisson criterion line, then Q_f is equal to the greatest test load applied (2R).

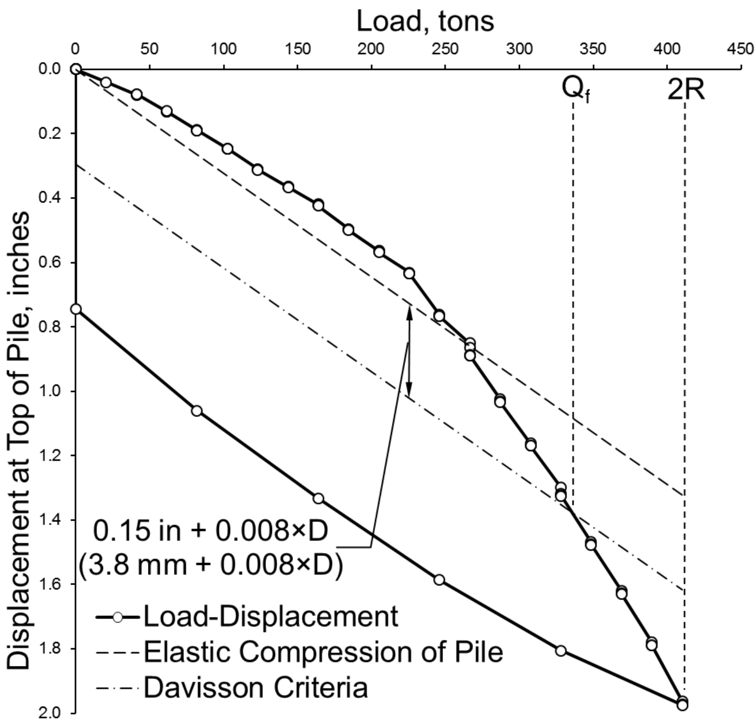


Figure 506.03.B - Load-Settlement Curve

Restrikes

The standard plan note for a static load test requires the Contractor to restrike the test pile and the two reduced capacity piles. The note may require re-striking the backup test pile. The restrikes are performed at least 7 days after the piles were driven. Each restrike test consists of dynamically testing two piles and determining the capacity of the piles. Pile set-up is the increase in capacity for a pile from the time it was initially driven to the time it was re-struck. Ideally, the capacity from the restrike test on the test pile should be close to the results of the static load test.

Application of Results

Either the Office of Construction Administration or the Office of Geotechnical Engineering will review the pile driving logs, the static load test results, the dynamic load test results, and the restrike test results, and then recommend the driving criteria for the production piles. Wait for the recommended driving criteria before letting the Contractor drive the rest of the production piles. However, the Engineer can allow the Contractor to proceed with pile driving at his own risk, with the understanding that the Department will not pay for piling driven deeper than required based on the recommended driving criteria after the evaluation of the static load test results.

The static load test results will apply to the same type and size of piling, driven with the same type of hammer, to approximately the same depth, with similar driving characteristics as the test pile.

The pile hammer used for driving the test pile shall be used for driving all piles represented by the static load test. If the Contractor subsequently finds it necessary to use a different size and type of hammer, the Office of Geotechnical Engineering or the Office of Construction Administration will determine if an additional static load test is required; any such additional static load test shall be completed at no additional cost to the Department.

Static Load Test results include:

1. Driving Logs of the test piles and reduced capacity piles
2. Dynamic Load Test Report
3. Restrike Test Report
4. Load Settlement readings from the Static Load Test

Project File Requirements - 506 Static Load Test

Documentation for the static load test consists of the driving logs of the test piles and reduced capacity piles, the dynamic load test report, the restrike test report, and the load-settlement readings from the static load test. Identify the piles using the pile numbering system on the plans if the piles tested are production piles.

507 Bearing Piles

Description (507.01)

A pile is a structural column of steel, concrete, timber, etc. that is installed in the ground to support a structure above it. Piles are required when the soil near the surface is not strong enough to support the structure or when the soil may be scoured away. Piles transfer the loads from the structure to deep layers of soil or rock that are capable of supporting the load.

The term, "bearing pile," refers to a pile that is used to support a structure. A bearing pile is also called a service pile or a production pile.

The plans include a foundation layout which identifies each pile with a unique number and indicates the pile type, size, and direction of batter (if any). Use the unique number to identify the pile in the construction documentation.

General (507.02)

There are many types of piles; however, the Department generally uses either cast-in-place reinforced concrete piles or steel H-piles that are driven into the soil using an impact hammer. The cast-in-place piles are constructed by driving a hollow steel tube, capped at the bottom with a steel plate, into the ground, and then filling the tube with concrete.

The plans give the estimated length for each pile. However, the Contractor decides whether to drive a single pile segment for the entire estimated length or to drive shorter segments and splice them together as he drives the pile into the ground.

Materials (507.03)

The steel for H-piles must conform to 711.03 which refers to ASTM 572, Grade 50 (F_y=50 ksi). This is the industry standard for H-piles. The steel pipe for cast-in-place piles must conform 711.07 which refers to to ASTM A 27 Grade 65-35 or Grade 70-36 or AASHTO M103 or ASTM A 148 Grade 90-60.

Driving of Piles (507.04)

Piles are typically driven to a specified capacity (Ultimate Bearing Value) or to refusal on bedrock. The Ultimate Bearing Value, or UBV, is equivalent to the ultimate pile capacity (in Allowable Stress Design) and the nominal pile resistance (in LRFD). The UBV is the required capacity of the pile. Sometimes the plans list the design bearing, the design load, or the factored load in addition to, or in place of, the UBV. Do not mistake the design load for the capacity to which the piles are to be driven.

Typically, H-piles are used when piles are driven to refusal on bedrock, and cast-in-place piles are used when piles are driven to a specified capacity. However, H-piles are sometimes used when driving to a specified capacity.

In some cases, such as bridges over water, where scour may be a concern, the plans may indicate a minimum pile tip elevation in addition to the UBV. If both a UBV and a minimum pile tip elevation are specified for the piles, both criteria must be met. If the pile is driven to the required tip elevation before reaching the UBV, continue driving until the pile has the required capacity. If the pile is driven to the UBV before reaching the minimum pile tip elevation, continue driving until the pile tip is at the required elevation.

If during the driving operation the pile begins to crush, the driving operation must immediately cease and the crushed section of the pile removed. This is due to the fact that the crushed section will behave similar to a sponge and the energy from the pile hammer will no longer be properly transmitted to the tip of the pile. This results in higher blow counts with minimal penetration of the pile into the ground.

Piles Driving Longer or Shorter than Estimated

In the event a pile reaches 150 percent or more of the estimated depth without achieving capacity or in the event of a pile reaching capacity in less than 80 percent of the estimated depth, about two more piles should be driven in scattered locations to verify this trend. If these piles also exceed the above limits, contact the Office of Construction Administration or the Office of Structural Engineering for advice. You may also contact the District Geotechnical Engineer for advice. Complete information regarding equipment, the driving logs, and any unusual driving experiences should be provided for review. During this review, the Contractor may be permitted to continue his driving operation. However, the Contractor should not be required to attempt to drive the piles to 80 percent of the estimated penetration. He should also not cut the piling off until after the review.

Occasionally when bearing is achieved before the pile has been driven 80 percent of the estimated penetration, project personnel require the Contractor to continue driving the pile to achieve a penetration of 80 percent of the estimated depth. This is not recommended. The value of 80 percent of the estimated penetration is only a guide to aid project personnel. Overdriving the pile may result in damage to the pile or the pile hammer. Do not require the Contractor to overdrive the pile to obtain the 80 percent length without first consulting with the Office of Construction Administration, the Office of Structural Engineering, or the District Geotechnical Engineer.

Pile Driving Equipment

A driving cap that centers the pile under the hammer and uniformly transmits the blow must be used.

Driving leads guide the travel of the hammer and cap during driving and must be capable of keeping the hammer in line with the axis of the pile. The leads should be equipped with a yoke at the base to center the pile and project beyond for anchorage.

Pile Hammers

Pile hammers are powered by compressed air, hydraulic oil pressure, or igniting diesel fuel. These hammers are classified as either single-acting hammers or double-acting hammers.

In addition to power driven hammers, a drop hammer may be used which has a ram weight of at least 3,000 pounds (1,360.8 kg) and a distance of fall not exceeding 7 feet (2.1 m).

Single-acting hammers are those that have their rams lifted by compressed air, hydraulic oil pressure, or igniting diesel fuel. When the ram reaches the top of its stroke, it falls back to its original position by gravity. Hammers that are powered by igniting diesel fuel and open on the top are considered open-end diesel hammers. These hammers allow the ram to become exposed during driving.

Figure 507.04.A - Single acting diesel, note the top of hammer rises above body

Double-acting hammers are those that not only have the ram lifted by compressed air, hydraulic oil pressure, or igniting diesel fuel, but in addition to gravity, compressed air, or hydraulic oil pressure also impart a downward force on the ram.

Double-acting hammers that are diesel powered and are closed at the top are considered closed-end diesel hammers. The space between the top of the ram and the top of the hammer casing is called the bounce chamber. As the ram rises in the hammer, the volume of the bounce chamber decreases and increases the pressure of the air inside the bounce chamber. This increased air pressure imparts a downward force on the ram.

Figure 507.04.B - Double acting diesel hammer, note hammer is encased in housing

Hammer Size

The Contractor chooses the size of the hammer to use. The hammer must be sized to the UBV of the piles. Typically contractors in Ohio use an open ended diesel hammer with a rated energy in the range of 40 to 45 kip-ft, but may be different. A hammer that is too small will not be able to drive the pile to the required UBV. A hammer that is too big may result in pile damage and may increase the risk of alignment difficulties.

The hammer must be large enough to drive the pile to the required UBV and successfully perform dynamic load testing. The use of a hammer that is too small will result in a hammer that will not be large enough to impact the piles with enough energy to successfully perform a dynamic load test. Dynamic load testing cannot determine the total capacity of the pile being driven if the energy applied to the pile by the pile hammer is too low. An example of this situation is the case where a cast-in-place pile has been driven to the top of a hard layer of sand and gravel that may be capable of supporting a load of over 300 tons. If the maximum load that the pile hammer is able to place on the pile is only 120 tons, then the dynamic pile test will only register 120 tons and not 300 tons. If the required UBV is 120 tons or less, then the hammer is large enough. However, if the required UBV is greater than 120 tons, then the pile hammer is not large enough to successfully perform a dynamic load test. Note: This is a simple example to demonstrate the concept. The actual relationship between hammer energy and pile capacity is much more complex.

Performance of the Pile Hammer

The driving criteria or blow count that a pile must be driven to depends on the performance of the pile hammer. If the performance of the hammer changes, then the appropriate driving criteria will also change. Therefore, the performance of the hammer should be constantly observed. The performance of the hammer should be compared with the results of the dynamic load testing to determine the required blow count. The Contractor is required to provide the Inspector with a means to monitor this operation.

Open-end diesel hammers are the most common type of pile hammer for highway contractors in Ohio. A relatively easy way to monitor the performance of an open-end diesel hammer is to watch the stroke of the ram. During the dynamic load testing, watch how far the rings on the ram come out of the hammer. Then, during pile driving, make sure that the rings are coming out of the hammer about the same distance.

Figure 507.04.C - Single acting hammer, with rings to monitor stroke height, saximeter to measure stroke

When using open ended diesel hammers, the Contractor is to provide electronic equipment, such as a saximeter, or equivalent, for the Engineer's use to accurately measure and record the stroke for each unit of length driven The ram of an open-end diesel hammer falls by gravity; therefore, the stroke of an open-end diesel hammer can be estimated from the blow rate (blows per minute) using the following equation.

$$h = 4.01\left(\frac{60}{\text{bpm}}\right)^2 - 0.3\ \text{ft}$$

Where:

h = Stroke of pile hammer (feet)

bpm = Blows per minute

(From Design and Construction of Driven Pile Foundations, FHWA NHI-05-043, pages 21-28)

For convenience, the following table gives the results of the above equation for a typical range of values. Additionally, the relationship between stroke and blows per minute for a particular pile hammer can be determined from the dynamic load test.

Blows per Minute	Stroke (ft)	Blows per Minute	Stroke (ft)
37	10.2	42	7.9
38	9.7	44	7.2
39	9.2	46	6.5
40	8.7	48	6.0
41	8.3	50	5.5

Trying to count the blows per minute while also keeping track of the blows per foot is difficult. An easier way to determine the blows per minute while counting the blows per foot during pile driving is to measure the number of seconds required to drive one foot of piling. Use the following equation to calculate the blows per minute.

$$\text{bpm} = \frac{\text{blows per foot}}{\text{time (seconds)per foot}} \times 60$$

Closed-end diesel hammers must be equipped with a gage placed on the ground and connected to the bounce chamber by a hose. The gage shows the pressure developed for each stroke of the ram. A graph, included with the gage, can be used to convert the pressure to the energy developed by the hammer for each blow. The hose connecting the gage to the bounce chamber comes in different lengths that can affect the reading on the gauge. Therefore, it is important to check that the graph corresponds with the length of hose used.

The Contractor can control the hammer's operating energy by the use of a throttle or fuel setting. The hammer must be operated during pile driving at the same setting used when the dynamic load test was performed.

Figure 507.04.D – Pressure gauge for a double acting diesel hammer

Alignment in Leads

If the hammer is not properly aligned with the pile, the energy from the hammer will not be properly transmitted to the pile. For the full effect of the hammer energy to be transmitted to penetration of the pile, the axis of the hammer must be in line with the axis of the pile.

The Contractor is required to maintain a minimum radius of 15 feet (4.5 m) between simultaneous work of placing concrete and driving piles. The concrete is required to have cured for five days before driving piles within the 15-foot (4.5 m) radius.

Determination of Required Driving Criteria (507.05)

The driving criteria, or required blow count, is determined from the dynamic load test results. See Section 523. The first two piles are driven with the dynamic load test equipment attached. The testing company should provide a preliminary recommendation for the driving criteria immediately after driving these two piles. The driving criteria will be a minimum blows per foot for the pile driving. For open-end diesel hammers, the driving criteria will also include a minimum hammer stroke.

Drive the rest of the piles to the recommended driving criteria. Generally, it is not necessary to ensure the pile has a blow count greater than the required blow count for 3 or more consecutive feet. For example, if the required blow count is 43 blows per foot, it is not necessary to drive the pile until the blow count is greater than 43 for 3 consecutive feet. See the following table for examples. The exceptions to this are if there is a

minimum pile tip elevation, the depth of penetration is less than 80 percent of the estimate, or the pile has to be struck with 150 blows to inspect a splice.

Pile Driving Examples
Required Blow Count is 43 blows/ft

Penetration	Blows/Ft		Penetration	Blows/Ft
37-38	28		41-42	21
38-39	33		42-43	40
39-40	42		43-44	40
40-41	45	Should stop	44-45	43
41-42	43	driving here.	45-46	44
42-43	41		46-47	48
43-44	43		47-48	41
44-45	44		48-49	46
45-46	46		49-50	50

Cast-In-Place Reinforced Concrete Piles (507.06)

A cast-in-place reinforced concrete pile consists of a steel shell that is filled with concrete. To minimize the possibility of the piles being damaged during the pile driving operation, it is important to maintain the minimum wall thickness specified in 507.06 of the Construction and Material Specifications.

Piles may be tapered or of uniform section. The tapered piles are cylinder shells with vertical fluting or corrugations commonly referred to as monotube piles. Monotube piles can be either tapered or of a uniform diameter. All other piles of uniform section are called pipe piles. Tapered monotube point sections come equipped with a bullet-nosed tip. Pipe piles usually have a plate welded on the point that must not extend more than 1/4 inch (6 mm) beyond the surface of the pile at any point. The Engineer should ensure that the cast-in-place metal shell is of domestic origin and it conforms to ASTM 252A 27 Grade 65-35 or Grade 70-36 or AASHTO M103 or ASTM A 148 Grade 90-60. A producing mill certification is often the simplest way to verify this.

The piles must be inspected and necessary measurements made. Due to the possibility of lateral earth pressure causing adjacent piles to collapse prior to filling with concrete, this inspection and measurement should be made after all the adjacent piles are driven. After the piles are driven, cover the tops until they are filled with concrete. Before filing with concrete, remove water and debris. Concrete required for filling the piles is Class QC 1 containing a superplasticizer admixture. After the superplasticizer has been added, the slump should range from 6 to 8 inches (150 mm to 200 mm). The concrete should be deposited in a steady, small stream to ensure complete filling and consolidation. If there is reinforcing steel in piles, the concrete could become segregated from coming into contact with the reinforcing steel while it is dropping in place. Use drop chutes to eliminate this problem.

Figure 507.06 – Placing concrete in a pile

Steel H-piles (507.07)

When H-piles are specified, the plans usually require that they be driven to refusal on bedrock. The standard plan note gives a driving criterion of 20 blows per inch. The note may allow the Contractor to perform a dynamic load test, at his own expense, to determine the driving criteria instead of using the 20 blows per inch criterion.

When the bedrock is hard and unweathered, refusal is obtained after the piles contact bedrock and have been struck at least 20 more times, with a penetration less than or equal to 1 inch (25 mm), to ensure that firm contact has been established. Use care to avoid damaging the piles.

When the bedrock is soft or weathered, driving refusal is obtained at a resistance of 20 blows per 1 inch (25 mm).

Many times pile points or pile shoes are specified to be welded to the tip of the piles. These points or shoes are made of cast steel as opposed to plates welded together and are used to protect the end of the pile from damage during the driving operation.

Mill test reports are required for steel H-piles and should be reviewed by the Engineer for conformance to 711.03 of the Construction and Material Specifications. If pile points or shoes are specified, mill tests should be reviewed for conformance to 711.07

Timber Piles (507.08)

Although still included in the specifications, timber piles are no longer used by the Department.

Splices (507.09)

Splicing may be necessary to provide the required length to achieve bearing. Numerous splices using small lengths in the same pile should be avoided, particularly in an area exposed to view. Splices should be made at least 3 feet above the ground so that the weld may be observed while it is subjected to the impacts from the pile hammer. If bearing is obtained prior to observing the weld during 3 feet of driving, the pile should still be driven a minimum of 150 blows after the splice is made in order to observe the weld. When splicing structural shapes (H-piles), and steel piles casings according to AWS D.1, welding must be performed in accordance with 513.21 of the Construction and Material Specifications, which, among other things, requires the use of a prequalified welder. Non-destructive testing is not required. See Figure 507.A - Joint Preparation for Groove-Welded H Pile for the method of making the required welded butt splice. For H-piles, the plans may include a note that allows the use of a manufactured splicer in place of the full penetration butt weld.

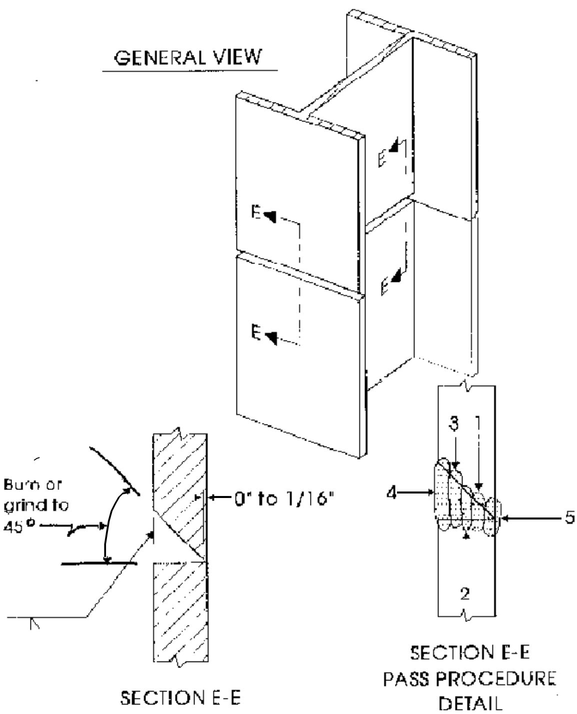


Figure 507.09.A - Joint Preparation for Groove-Welded H-Pile

Note: If a different number of passes is required than shown in Figure 507.A, a similar sequence must be followed with the finishing pass on the reverse side. Back gouge root pass prior to making the finishing pass.

Figure 507.09.B – Approved splicer, and welding for H-pile splice

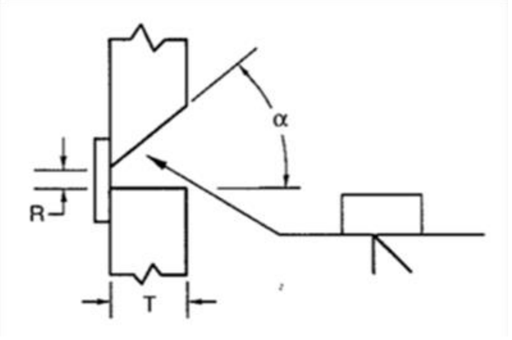


Figure 507.09.C- Joint Preparation for Butt Joint Welded Tube with Backing Spacer

In Figure 507.C, a backing spacer ring can be placed on the inside of the tube pile prior to welding.

Figure 507.09.D - Welding a tube pile

When pile points are specified in the plans, the Contractor must select a product from the Department's approved list. The pile points must be welded to the pile according to AWS D1.5 or the manufacturer's written welding procedure, which must be submitted to the Engineer before the welding is performed. Mill test reports must be submitted by the Contractor.

Figure 507.09.E - Pile points for H-pile

Defective Piles (507.10)

A pile is considered defective if damaged to the extent that the strength of its section is reduced over 20 percent. This can occur as a collapse of the shell where less than 80 percent of the cross-sectional area remains open or where the shell is ruptured to the extent that the pile will have over 20 percent less strength.

A pile is also considered to be defective if the location of the pile, at the ground surface, differs from the specified location by more than 1 foot (0.3 m) for piles that are capped below final grade or by more than 3 inches (75 mm) for pile capped above the ground surface, such as in a capped-pile pier. No attempt should be made to draw these piles to their specified location. Piles not meeting these location tolerances are defective piles..

Replacement Piles

If it is practical to withdraw a pile, the replacement can be driven in the specified location. If the defective pile is not withdrawn, it must be filled completely with concrete. If it is under a footing, it must be cut off slightly above the bottom of the footing where it will provide some support, but will not be paid for. A replacement pile will need to be driven beside it. The replacement should be located on the same line parallel to the side of the footing and battered slightly, if necessary, to avoid contacting the defective pile or adjacent piles.

When a replacement pile is driven alongside, rearrangement of reinforcing steel will be necessary. If sufficient space is not available to avoid crowding of bars, it may be necessary to cut the bars at the pile and provide bars on either side lengthened for bond. In lieu of this, the pile may be cut off below the reinforcement and the footing deepened approximately 1 foot (0.3 m) around the pile and below cutoff.

Only the replacement pile will be included for payment. Any additional material or work required to make it a satisfactory pile will be at the Contractor's expense.

Prebored Holes (507.11)

Abutment piling must be driven through embankments to bearing in the existing soil. Sometimes pre-bored holes are provided in the plans to ensure this. For round piles, the augered hole diameter must be from 2 inches (50 mm) less to 4 inches (100 mm) more than the pile diameter. For steel H-piles, the augered hole diameter must be from 6 inches (150 mm) less to 2 inches (50 mm) more than the pile's diagonal dimension.

The prebored holes do not need to remain open before the pile is driven, but voids between the pile and the prebored hole must be backfilled with a granular material

Figure 507.11 - Preboring hole equipment

Method of Measurement (507.12)

The two main pay items associated with the pile driving operation are piles furnished and piles driven.

The quantity of piles accepted for payment as piles furnished will be based on the total order length specified in the plans and required by the Engineer. The order length is the pile length that the Designer estimates, as necessary, to achieve bearing. The Contractor may elect to use piles longer or shorter than the order length as he determines necessary to meet his needs. The Contractor is responsible for the cost of the splice if he elects to use piles shorter than the order length which then results in the need to splice the piles to achieve the required order length.

The Contractor is responsible for putting foot marks on the outside of the piling so that the Department can count the blows per foot during driving and determine the length of the pile below the ground. Inch marks will need to be placed on H-Piles near the ground surface when the pile tip is approaching refusal. During the driving, the Engineer must monitor the length of piling necessary to obtain bearing. If the order length given in the plans is not sufficient to achieve bearing, the Engineer should inform the Contractor of the necessary additional order length. The Engineer should inform the Contractor as soon as possible to allow him to order the piles in a timely fashion and to avoid additional costs due to down time expenses. It will be necessary to negotiate with the Contractor and reimburse him for any additional splices necessary to provide additional length beyond the order length.

The pay quantity for piles driven shall be the sum of non-defective pile lengths measured along each pile’s axis from the bottom to the elevation of cutoff. This quantity will be paid in addition to the quantity of piles furnished and may not necessarily correspond with the quantity of piles furnished.

Figure 507.12.A - Marking for tube pile

Figure 507.12.B - Marking for H-pile including inch marks for determining refusal

508 Falsework and Forms

Description (508.01)

This work consists of designing, building and removing falsework and forms for concrete in the proper location and with the proper dimensions.

Falsework (508.02)

Falsework is the system of temporary support of formwork for concrete members. The falsework is to remain in place until the concrete members have attained required strength and are self-supporting. This includes the system of supporting formwork for deck slabs and pier caps.

Falsework Engineered Drawings

For cast-in-place concrete slab bridges, the Contractor must submit a falsework Engineered Drawing per 501.05.B.3. No superstructure concrete can be placed until the Engineered Drawing is received, accepted by the Department and the falsework conforms to the submitted Engineered Drawings. The Contractor may substitute elements of equal or greater strength if it does not involve a change in depth that effects elevations. Any other deviations from the accepted Engineered Drawing that the Contractor desires, or that becomes necessary due to unforeseen conditions, must be covered by submission of a revised Engineered Drawing.

District Review of Falsework Engineered Drawings

A review should be made at the project to ascertain that the existing conditions shown in the Engineered Drawing are representative of those found in the field. An Engineered Drawing meeting will be scheduled 7 days or less, after the submittal. The Engineer who signed the submittal, the Superintendent, the Engineer and Inspector and responsible designer of the contract documents will discuss the work governed by the Engineered Drawing and resolve all issues to the Engineer's satisfaction. At the conclusion of the meeting, the Engineer will provide a written response to the Contractor in accordance with 105.02:

Falsework Camber

The maximum deflection permitted in the falsework of a slab bridge is specified in 508.02. Camber equal to this deflection must be built into the falsework to compensate for falsework deflection. Camber equal to 1/800 of the span must be built into the falsework to compensate for deflection of the slab after falsework is released. Also, camber which conforms to the vertical curvature of the profile grade must be provided.

If unusual requirements for span of an existing road or channel or restrictions due to vertical clearance exist, contact the Office of Structural Engineering to evaluate acceptable site specific camber requirements.

Falsework Materials

Falsework members must be of the section and length shown on the submitted working drawings. Members having a greater section modulus may be used; but, if this involved a change in depth and affects elevations, details of modifications should be included on a resubmission of the effected working drawing.

Steel members such as stringers must be in good condition. They must not show loss of section through rusting, excessive weldments, or holes that would affect their strength. Inserts cast into prestressed members for the purposes of falsework support shall be galvanized according to 711.02 and shall be shown in the shop drawings according to 515.06

Timber shall be sound and of the required size. Used timber that shows deterioration and stress cracks may not perform its function and must not be used.

Piling and Posts

Piling to support falsework must be driven to the bearing called for on the submitted Engineered Drawings. In order to determine the required blow count, it will be necessary for the Contractor to perform dynamic load testing.

Consolidation of Wood

Allowance for consolidation of wood wedges and blocking must be provided. Using rough-cut timber, an allowance of 1/16 inch (2 mm) for each contact surface will be necessary.

Independent Support

Where phased construction or adjacent concrete decks are separated by an open joint or closure pour, forms for the cantilevered edges of each slab must be supported independently from the adjacent structure. This is necessary to avoid movement of the forms due to differential deflections during placing of the concrete.

The finishing machine must be supported by the structure on which the concrete is being placed and independent of any adjacent structure or support. If it is not, the finishing machine will not move with the deck as the concrete is placed and can result in areas where the superstructure concrete is either too thick or too thin.

Closure Pour

Closure pours are normally specified during phased construction when the cross bracing or diaphragms between the phases are not in place prior to the placement of the superstructure concrete. A closure pour is not to eliminate traffic vibration, but to allow differential deflection to take place between the phases when the superstructure concrete is placed. In order to properly place the superstructure concrete, the closure pour should not be waived unless the deadload deflection that occurs when the superstructure concrete is placed is less than 1/4 inch.

Superimposed Concrete

Prior to placing sidewalks, safety curbs, or other superimposed concrete on the deck of a slab bridge, the falsework must be removed or released and allowed to deflect.

Removal of Falsework

For QC/QA Concrete, falsework may be removed when the conditions tabulated in the table of section 511.14-1A of the Construction and Material Specifications have been

met. If QC/QA is not being used, falsework may be removed when the conditions tabulated in the table of section 511.14-1B have been met. Any piling not removed must be cut off at least to the slope line or rip rap line of the bed of stream.

Figure 508.02.A – Deck Slab Falsework support

Figure 508.02.B - Deck Falsework for Concrete beam bridge

Forms (508.03)

Location

Prior to the erection of the forms for each substructure unit, the Inspector should ensure that the Contractor is placing the forms in the correct location. This should be accomplished by available methods that do not require the use of instruments.

Types and Use

Footing concrete may be placed against rock, hard shale, or sheeting. All other concrete must be placed in substantial forms that are designed and constructed so that finished concrete will conform to plan lines and dimensions and will have a satisfactory surface. Forms for exposed surfaces are to be made of acceptable materials that will produce a smooth surface with a minimum number of joints. Acceptable materials include sheet plywood, fabricated metal forms, fabricated metal frames with plywood inserts, or dressed lumber of uniform thickness with a form liner of plywood, hardboard, or sheet metal.

Figure 508.03.A - Footing form construction

Previously used form lumber and bent metal forms that will not produce an acceptable surface on concrete when stripped, regardless of finish specified, are to be rejected. Exercise care to obtain as flush a fit as possible at panel joints. When rustication grooves are required, panel joints should, if possible, be made to coincide.

The underside of a deck that cantilevers out from the fascia beam is considered an exposed surface and requires forms with smooth surfaces. The underside of pier caps is considered an exposed surface and forms with smooth surfaces should be used and cut to fit neatly around columns or piles.

Figure 508.03.B - Deck forms with overhang brackets

Design

Forms must be adequately braced and provided with walers and form ties that are properly designed to maintain the proper dimension and alignment for the proposed height and rate of concrete placement. Some suppliers of form ties specify the height of concrete in feet (meters) per hour that can be placed for their design. All form ties and anchor bolts used for form support must be designed for removal of 2 inches (50 mm) in from the exposed surfaces of concrete.

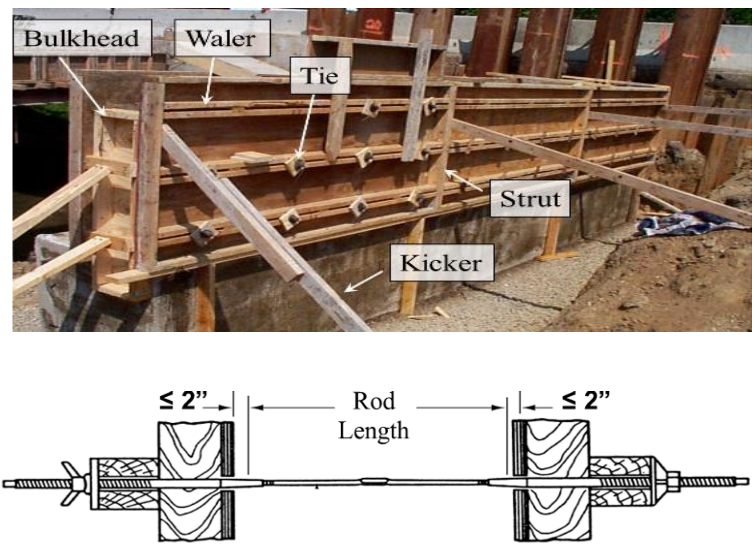


Figure 508.03.C - Wall forms and illustration of a tie

When forming pier, intermediate of end diaphragms for prestressed or post tensioned concrete members, care must be taken to avoid damaging reinforcing steel, strands, or

precast concrete. The Contractor should not place post installed anchors in these members. They should properly brace diaphragm forms externally or use approved form tie inserts cast into these members.

Incidental Work

Moldings for the 3/4-inch (19 mm) beveled edges and rustification grooves must be surfaced on all sides and be of uniform section. The bevel strip should be nailed at sufficient intervals to completely fill a corner or contact the form for the full length. Rustification strips are fastened to the forms in such a manner that the molding will remain in contact with the concrete when the forms are stripped and will not be removed until the concrete has set sufficiently to avoid damage.

Weep holes through abutments and retaining walls are formed in such a manner as to obtain a smooth circular opening. To form the hole, metal such as downspouts or sonotube may be used and later removed, or noncorrodible rigid plastic pipe may be used and left in place, provided the gradient and inside diameter are in accordance with 508.03.

All scrap wood, dirt, and other foreign material, including ponded water, must be removed from within the forms prior to placing concrete. If the forms are too deep or narrow to permit easy removal of foreign material from the top, a temporary opening should be left at the bottom for removal of foreign material. When necessary, an opening must be provided for inspection. Temporary openings must be made mortar tight after the forms have been cleaned and inspected.

Forms should be inspected for proper fit and for holes where leakage of cement paste may occur. Openings must be corrected in order to close the hole and provide a smooth form surface. Filler strips, plugs, and tin are commonly used to plug such openings. Forms should be watched closely during the placing of the concrete and any leaks must be corrected immediately.

Verification of Dimensions

Before any concrete is placed, form dimensions should be measured for compliance with the plan requirements and approved change orders. Measurements which result in concrete equal to or greater than plan dimensions are considered verified plan dimensions. The measurements must be checked for compliance with the plan dimensions and then recorded and filed in the project records. A statement that the dimensions have been checked and are in compliance with plan requirements is not acceptable verification. The recording may consist of any of the three following methods:

1. A tabulation of all the verified plan dimensions for simple shapes.
2. A sketch on an appropriate form showing all the verified plan dimensions.
3. The plan sheet for the structure unit with the verified dimensions checked thereon.

Whatever method is used, the Inspector should date and sign the sheet. If checks are made on different days, dates should indicate the day each check was made. If different inspectors check parts of the measurements, each should initial those checks that he has made.

If measurements are not in compliance, make correction and recheck the dimensions before the concrete may be placed.

Figure 508.03.D - Wall forms with reinforcing installed and properly braced

Figure 508.03.E -Pier cap forms

Oiling Forms (508.04)

The inside of all forms are to be coated with a bond-breaker. If the forms are not coated, and oiling is necessary, it should be done before placing the reinforcing steel, or preferably, before assembly of the forms.

509 Reinforcing Steel

Description (509.01)

This work consists of furnishing and placing supports, mechanical connectors, tie wires, steel dowels and reinforcing steel of the quality, type, size, and quantity at the locations designated in the plans for concrete reinforcement.

Materials (509.02)

The steel for the concrete reinforcement must conform to 709.01, 709.03, 709.05 for deformed bars, to 709.08 for cold drawn wire, to 709.09, 709.10, 709.12 for rod mats, welded wire fabric. Plastic supports for concrete reinforcement must conform to 709.15.

Care of Material (509.03)

The reinforcing steel must be cleaned of all dirt, oil, and grease. Oil or grease on the steel will seriously affect bond and must be removed with a solvent. Many times dirt cannot be removed with water alone, but must be loosened with the use of a rag or brush before rinsing it off the reinforcing steel. If steel requires cleaning before being placed, it should be cleaned outside the forms. Once reinforcing steel is placed in the forms, it is difficult to see the dirt, oil, or grease on the bottom side of the reinforcing steel.

Storage

All reinforcing steel received on the project must be stored off the ground and kept free from dirt, oil, and grease. Many times the Contractor will store the reinforcing steel on wood blocks or similar devices. If this is the method chosen by the Contractor to store the reinforcing steel off the ground, it is important that he use enough blocks to prevent the reinforcing steel from sagging and coming into contact with the ground. The reinforcing steel must not be stored in a place where it will be damaged or bent by equipment or be located in the path of drainage. If epoxy coated reinforcing steel is to be exposed to sunlight for more than 2 months, it needs be covered to protect the epoxy from UV breakdown. This requirement can be found in ASTM A775 which is incorporated by reference in section 709.00 of the C&MS.

Figure 509.03.A - Unacceptable faded epoxy rebar, not protected from uV during storage

Figure 509.03.B - Unacceptable rebar storage in wet location

Method of Placing (509.04)

Reinforcing steel should have a TE- 24 with the shipment. If the reinforcing steel does arrive without a TE -24 either the District Engineer of Test or the Office of Material Management should be notified. Check conformance of the delivered bars' length to plan specified length. During placement compare the fit of the reinforcing steel in the measured forms. All steel required in any structure unit must be included in that unit. Advance separation of the steel by structure units from prepared lists can preclude omissions. Check the total number of bars of each bar mark placed for each concrete placement and spot-check the spacing of the reinforcing steel. For the reinforcing steel

that comprises the mats in a deck,the total number of bars is more important than extreme accuracy in the space between adjacent bars.

Clearances

Reinforcing steel must be located at the specified distance from the surface in order for reinforced concrete members to have the proper clearance.

Reinforcement shall be placed in the position shown on the plans and kept in that position while the concrete is being placed. Attempting to position a reinforcing bar cage during or after the deposition of concrete is not permitted due to the fact that the consolidation of concrete around the perimeter of the reinforcing steel will be compromised.

Bolsters or chairs should be used, or the cage should be assembled and wired so that the proper clearances are obtained before encasement. The bolsters or chairs used to support reinforcing steel in slabs, beams, or girders must be spaced no more than 4 feet (1.2 m) apart both transversely and longitudinally. This spacing is a maximum. The Contractor needs to install enough supports to keep the reinforcing steel from experiencing substantial deflections induced from construction loads.

When placing reinforcing dowels extending out of a footing, they must be located accurately so they will lap properly with the reinforcement in adjoining concrete. This particularly applies to dowels for pier columns where the location of vertical column bars is specified.

Prior to placing concrete, it is important to check the clearance or cover over the surface of the reinforcing steel. The clearance between the reinforcing steel and the surface of the concrete shall not be less than:

1. 2-1/2 inches *[-0 inch, +0.25 inch] (65 mm [-0 mm, +6 mm]* to the top of sidewalks.
2. 3 inches *[-0 inch, +0.5 inch]* (75 mm *[-0 mm, +12 mm]*) at the face of footings placed against rock or earth.

Figure 509.04.A - Rebar supported directly on rock with bricks

3. 1-1/2 inch *[-0 inch, +0.25 inch]* (38 mm *[-0 mm, +6 mm]*) between the bottom steel and the bottom of a cast-in-place deck. The bottom steel must be spaced from the forms, never from the beams. The bolsters have a tendency to indent the forms and cause less than a 1-1/2 inch (38 mm) clearance. A tolerance of 1/8 inch (3 mm) plus or minus in bottom steel clearance is permitted

Figure 509.04.B - Rebar properly supported with 2" clearance

4. 2 inches *[-0 inch, +0.5 inch]* (50 mm) *[-0 mm, +12 mm])* at all other surfaces.
.

Figure 509.04.C - Rebar clearance measurement for a slip form operation

5. 2-1/2 inches *[-0.25 inch, + 0.75inch] (65 mm [-6 mm, +19mm]* between the reinforcing steel and the top surfaces of cast-in-place concrete deck slabs.

Figure 509.04.D - Deck rebar clearance measurement during a dry run

A piece of wood approximately 2 inches (51 mm) long with accurate side dimensions of 1-3/8 inches (35 mm) and 1-5/8 inches (41 mm) is recommended to check clearances from the forms for the bottom reinforcing steel.

Transverse reinforcing bars, fabricated slightly longer than plan, can result in less than the plan clearance to the fascia form. Where the transverse line of steel is made of more than one bar, any overrun can be taken in the lapped splices. For narrower decks where the line is a single bar, removal of any extra length that will not provide a 1 inch (25 mm) minimum clearance is required.

Tying Reinforcing Steel

Reinforcing steel must sufficiently be tied together so that each bar retains its proper position after encasement. When workers are on the steel, additional tying is necessary to meet this requirement. Bars in the superstructure must be tied at all intersections except where spacing is less than 1 foot (0.3 m) in each direction. In that case, alternate intersections shall be tied. This is an area where additional inspection may be required since many times the Contractor fails to adequately tie these bars. When the Contractor utilizes a tie wire gun to tie bridge deck reinforcing, it has been observed that the ties loosen or break under the repetitive loads invoked by the construction activities.

Figure 509.04.E - Example of rebar lap length measurement

Welding

Welding on reinforcing steel is prohibited. This is due to the fact that not only will the welding damage the epoxy coating, but will reduce the diameter of the reinforcing steel at the point where it has been welded.

Splicing (509.07)

In lieu of lap splicing, reinforcing steel will be spliced with the use of mechanical connectors. There are various types of mechanical connectors that include:

1. Steel castings that have grout injected.
2. Crimp type that are pressure clamped onto the reinforcing with hydraulic jaws.
3. Coupling type splices that have threads cut into the end of the rebar.
4. Coupling type splices where the rebar ends have been offset pressed and the threads rolled into the end of the rebar.
5. Cadweld where the ends of the rebar are butted together and a sleeve is placed over the ends. The sleeve is then filled with molten metal and allowed to cool. This kind of coupler are not acceptable for epoxy coated steel.

The most common type of mechanical connectors is the coupling type as described above in No. 3 and No. 4. The mechanical connectors described in No. 3 should come with two shorter pieces of reinforcing steel that are lapped to the reinforcing steel that is to be spliced. These two pieces of reinforcing steel will be a larger diameter (if a splice for a No. 6 bar is required, the lap section sent with the coupling will be a No. 7 bar) because the thread cutting process reduces the cross section area of the bar.

Number 14 and 18 (45 M and 55 M) bars are required to be spliced with accepted mechanical connectors.

The mechanical connectors must provide 125 percent of the yield strength of the bar and be installed according to the manufacturer’s instructions. Completed mechanical splices

including at least 18 inches of rebar on either side of the splice should be sampled and submitted to the Office of Materials Management for testing.

Bar shall be lapped for a length equal to one and one-half turns when splices in spiral reinforcement are made.

Figure 509.07.A - Rebar crimp type splicer

Figure 509.07.B - Rebar mechanical set screw splicer

Supports (509.08)

Reinforcement may be spaced by metal supports, plastic supports, or precast mortar blocks. Supports should be checked as soon as possible to determine that they will provide the proper clearance. The bolsters or chairs used to support reinforcing steel in slabs, beams, or girders must be spaced no more than 4 feet (1.2 m) apart both transversely and longitudinally. This spacing is a maximum. The Contractor needs to

install enough supports to keep the reinforcing steel from experiencing substantial deflections induced from construction loads. If the Contractor uses plastic supports, they must conform to 709.15 and Supplement 1125. The concrete must be vibrated properly to ensure there are no voids in the concrete under these supports.

Figure 509.08 - Plastic rebar supports and threaded rebar connectors

Epoxy Coated Reinforcing Steel (509.09)

When epoxy-coated reinforcing steel is specified, plastic-coated or epoxy-coated bar supports and tie wires are required.

Bars shall be carefully handled and installed so patching at the job site will be kept to a minimum. It is not expected that the coated bars, when ready for concrete placement in final position, will be completely free of damaged areas. However, numerous nicks and scrapes that expose the steel will not be allowed, regardless of the stage when they occur subsequent to coating in the plant. All damage defined as significant damage must be patched.

Significant damage is defined as any opening in the coating that exposes the steel and exceeds the following sizes.

1. An area of 1/4 inch (6 mm) square or 1/4 inch (6 mm) diameter.
2. An area approximately 1/8 inch (3 mm) square or 1/8 inch (3 mm) diameter if the opening is within 1/4 inch (6 mm) of another opening of the same or larger size, or a length of 6 inches (152 mm) in length, regardless of area.

All areas to be patched must first be cleaned to a near white metal, absolutely free of all rust and foreign material.

No concrete is to be placed against the patch until it has adequately cured. Prior to placing concrete the patches should be checked to insure that the patch has cured and is hard.

Method of Measurement (509.10) and Basis of Payment (509.11)

Verification

Reinforcing steel and any specified mechanical connectors are to be in place and accepted by the Engineer before any concrete is placed. Record this approval in the daily diary. The reinforcing steel and mechanical connectors in each structure unit are verified by a check-off inspection. This verification may consist of a separately prepared list of all bars and mechanical connectors in each unit, listing the number of bars by bar mark or checked off the record plan sheets with the checks identified and validated. With the exception of the mechanical connectors, all the lists and record plan sheets are summarized on the plan steel list that is verified by reference to them.

Pay Quantity for Reinforcing Steel

It is intended that the Contractor be paid for the weight of reinforcing steel shown in the plans and that no additional calculations are necessary.

If the Contractor believes the pay weight, as shown on the plans, is in error, he is responsible to prove this discrepancy by recalculating the total weight for the entire reference number involved. He must submit his figures to the Engineer for review and approval. The number of pounds (kilograms) of reinforcing steel must be the actual number of pounds (kilograms) of the various sizes incorporated in the concrete as shown on the plans, completed and accepted.

In checking the calculations for the length of bent bars, the centerline length of the bar is the pay length. This involves a deduction from the out-to-out dimension for bends that amounts to the following listed inches (mm) for the number bar shown in the table below.

The most commonly used spiral reinforcement consists of No. 4 (13M) bars on 30 inch (765) diameter with 1-1/2 additional turns of the spiral steel at each end. The weight of the spiral steel is calculated by adding 15.5 pounds (7.0kg), which is the weight of the additional turns for both ends, to the sum arrived at by multiplying the length of the spiral cage times 13.9 pounds per feet (20.7 kg/m). To determine the weight of spiral steel with diameters other then 30 inch, use Equation 509.1:

$$0.148\pi H\sqrt{\left(\frac{4.5}{2}\right)^2+(D-0.5)^2}+0.167\pi(D-0.5)$$

Equation 509.1 – Spiral Steel Weight

Where:

H = Length or height of spiral (ft)

D = Outside diameter of spiral (in)

When bars with standard hook ends are specified, the pay length allowed for hooked ends beyond the out-to-out dimension is not shown in the plans, but is shown in the

specifications. When checking the calculations for the length of bars with standard hook ends, a deduction must be made from the out-to-out dimension for bends that amount to the following listed inches (mm) for the number bar shown in the table below. The fabricator may add additional length to the bars in order to facilitate bending. This additional length is not to be included in the pay length.

STD. BAR LENGTH DEDUCTIONS FOR COMMON BENDS – INCHES (mm)				
BAR. NO.	STANDARD BENDS (DEGREES)			
	45	90	135	180
#3 (10M)	¼ (6)	1 (25)	1 (25)	1 7/8 (48)
#4 (13M)	¼ (6)	1 (25)	1 ¼ (32)	2 ½ (64)
#5 (16M)	3/8 (10)	1 1/2 (38)	1 5/8 (41)	3 3/8 (79)
#6 (19M)	3/8 (10)	2 (50)	2 (51)	3 ¾ (95)
#7 (22M)	½ (13)	2 (50)	2 ¼ (57)	4 3/8 (111)
#8 (25M)	½ (13)	2 ½ (65)	2 ½ (64)	5 (127)
#9 (29M)	5/8 (16)	3 1/2 (90)	3 3/8 (86)	6 7/8 (175)
#10 (32M)	¾ (19)	4 (100)	3 ¾ (95)	7 ¾ (197)
#11 (36M)	¾ (19)	4 (100)	4 ¼ (108)	8 5/8 (219)
#14 (43M)	1 (25)	6 (150)	5 5/8 (143)	12 (305)
#18 (57M)	1 3/8 (35)	8 (200)	7 ½ (191)	15 ¾ (400)

510 Dowel Holes

Description (510.01)

This work consists of drilling holes into concrete or masonry, and furnishing and placing grout into the holes. The furnishing and placing of steel for dowels is included in Item 509.

Materials (510.02)

Cement grout consists of one part of hydraulic cement conforming to Item 701 and three parts sand conforming to 703.03, by volume, and water.

Non-shrink, non-metallic grouts include polyester, vinyl ester, and epoxy grouts confirming to 705.20.

Drilling of Holes (510.03)

Drilled holes for cement grout are required to be at least 1/2 inch (13 mm) larger in diameter than the dowel bar at the location and the depth shown on the plans without spalling the concrete.

Drilled holes for nonshrink, nonmetallic grout are required to be at least 1/16 inch (1.5 mm) larger in diameter than the dowel bar at the location and the depth shown on the plans without spalling the concrete.

Figure 510.03 –Drilling of holes for dowels

Placement (510.04)

Note that when using cement grout, the interior surface of the hole needs to be damp, while use of non-shrink, non-metallic grout requires a dry hole.

It is necessary to use surface thermometers to determine the temperature of the concrete into which the dowels are to be inserted. The specification requires this temperature to be at least 40 °F.

Figure 510.04 - Injecting grout for dowels

511 Concrete for Structures

Description (511.01)

This work consists of providing falsework, forming, furnishing, placing, consolidating, finishing, and curing structural concrete. This work also includes diamond saw cutting longitudinal grooves into the surface of superstructure concrete.

Materials (511.02)

Item 511.02 requires all concrete above the ground line in a given substructure unit or all concrete for any given superstructure be made of aggregate of the same kind and color, except upon permission of the Engineer. Use high molecular weight methacrylate resin sealer conforming to 705.15, curing materials conforming to 705.05; 705.06 (white opaque); or 705.07;Type 1 or 1D, 1/4-inch (6 mm) gray sponge joint filler conforming to 711.28, preformed filler conforming to 705.03, and preformed elastomeric compression joint seals conforming to 705.11.

Concrete (511.03)

Concrete for structures will be Class QC 1, QC 2, QC 3, or QC 4, or as specified in the Contract documents. The mix design and control are outlined in Item 499 and in Supplement 1126, except when modified as specified.

The Contractor has to submit, in writing, the Department accepted Job Mix Formula (JMF) to the Engineer, for a check for conformance to contract requirements, at least ten days before placing concrete.

Quality Control Requirements and Mass Concrete (511.04)

When the contract requires Quality Control/Quality Assurance , (QC/QA) Concrete, in addition to the JMF, the Contractor is required to submit a Quality Control Plan (QCP) for the work and perform quality control testing of the concrete as specified in C&MS 455. Also per C&MS 455, the Department or its representative will perform Quality Assurance sampling and testing as specified or as deemed necessary.

For quality assurance, the Engineer will make acceptance test cylinders as follows:

1. Structure over 20 foot span. A set of test cylinders from each 200 cubic yards of concrete or fraction thereof incorporated into the work each day.
2. Structures of 20 foot span or less. At least one set of test cylinders for each 50 cubic yards of concrete.

The Contractor must provide a sealed, temperature controlled, Concrete Cylinder Curing Box (CCCB) capable of holding at least twelve 4 x 8 inch cylinders for both quality control and quality assurance cylinders.

Mass Concrete Requirements (511.04.A)

Mass Concrete is defined as concrete components with a minimum dimension of 5 feet. In C&MS 499, QC-4 is the designated class of concrete for Mass Concrete mix designs. In addition to submitting a mix design, per C&MS 499.03 and Supplement 1126, a Quality Control Plan per C&MS 455, the Contractor is also required to submit a Thermal Control Plan (TCP) to the Engineer, for a check for conformance to contract requirements, at least ten days before placing concrete. The purpose of the TCP is for the Contractor to explain how they plan to prevent shrinkage cracking in Mass Concrete placements.

Figure 511.04.A - Mass concrete protection for pier cap

The TCP must control the placement of mass concrete so that:

1. The highest maximum internal temperature in the concrete is not greater than 160 ° F,

2. The maximum differential concrete temperature does not exceed 36 ° F,

over 28 days from the time of concrete placement.

The TCP shall include

1. Duration and method of curing.
2. Procedures to control concrete temperature at the time of placement. The mix shall contain no frozen pieces of ice after blending and mixing components.
3. Methods and equipment used for controlling temperature differentials.
4. Temperature sensor types, locations and installation details. As a minimum, concrete temperatures shall be monitored at the calculated hottest location, on at least 2 outer faces, 2 corners, and top surfaces.
5. Temperature monitoring and recording system; operation plan; recording and reporting plan with example output; and a remedial action plan.
6. Criteria, (allowable air and concrete temperatures and time), for form removal to control the maximum temperature differential.

The Contractor may propose maximum differential temperature limits based on strength gain with time as an alternate to the maximum differential concrete temperature criteria.

All cracking of mass concrete where the differential temperatures exceed 36ºF is the responsibility of the Contractor.

The Contractor must monitor and document all temperature sensors during the cure period. If the maximum limit or differential temperature limits are exceeded, the Contractor must take immediate action to correct the problem and revise and resubmit the TCP. The Department will determine if the proposed repair methods are acceptable or if removal is required.

Figure 511.04.B – Examples of mass concrete internal temperature monitoring

Mixing of Concrete (511.05)

Control

All concrete used in structures must contain 6 ± 2% entrained air as specified in 499. An air determination should be made for each part of the structure. This determination should be made as early as possible on the first load of concrete. For substructure concrete, as many additional air tests as necessary should be made to ensure required air content. For superstructure concrete, an air test should be made for each load of concrete used. Concrete containing less than the specified amount of air may have the air content increased by the addition of an air entrained agent and an additional 30 revolutions of the concrete mixer drum at mixing speed.

Concrete that is pumped can lose air as the concrete passes through the pump. Therefore, it is important that air tests be made at the point of placement, after the concrete passes through the pump.

Figure 511.05 - Concrete testing at point of placement on bridge decks

Accepted chemical admixtures may be incorporated into concrete to improve workability and to extend the setting time. Chemical admixtures must meet the requirement of 705.12 that specifies they meet the requirements of ASTM C 494 chemical admixtures. These admixtures are as follows.

- TYPE A - Water reducing
- TYPE B - Retarding
- TYPE C - Accelerating
- TYPE D - Water reducing and retarding
- TYPE E - Water reducing and accelerating
- TYPE F - Water reducing, high range
- TYPE G - Water reducing, high range, and retarding

The type of admixture is optional with the Contractor.

Slump (511.06)

The slump of the workable concrete shall be maintained within the range specified in 499.03. An occasional load exceeding the nominal slump, but within the maximum, may be used, provided immediate steps are taken to adjust the slump of succeeding loads. Before concrete exceeding the nominal slump range may be used, the Contractor or supplier must take positive action to reduce the slump of following loads.

Figure 511.06 - Examples of concrete testing

Records

The results of the air tests together with yield tests are shown on the back of Form TE-45. The Ready Mixed Concrete Plant Ticket must show the number of revolutions at mixing speed. A mixer's rated RPM for mixing speed and agitation speed will be listed with the operating data on the mixer. The mixers must be checked to see that they are operating at the rated speeds. The structure unit in which that load of concrete is placed should be noted on the ticket. A full list of the required data to appear on a batch ticket is listed in Table 499.07-1.

Placing Concrete (511.07)

The Contractor must submit to the Engineer a description of proposed placing procedures. If the contract requires QC/QA Concrete, this procedure would be included in the QCP.

Advance Notice of Placing Concrete

The Contractor must notify the Engineer at least 24 hours in advance of placing concrete. Review this provision with the Contractor near the start of work on a structure. This ensures a clear understanding regarding the stage of completed work necessary to permit inspection before approval to proceed. The need for all or part of the 24 hours will depend on the amount of additional inspection required to ensure that the reinforcing steel has been properly placed and that the forms are in the correct location.

Placement Tolerances

The Contractor is required to place and finish concrete to the lines and grades shown in the plans. The concrete must provide coverage over or around reinforcing steel as described in 509.04. Table 511.07-1 lists placement tolerances from plan dimensions.

Evaporation Rate

In an effort to reduce or eliminate drying shrinkage cracks in the superstructure concrete, the concrete should not be placed when the evaporation rate of water from the freshly placed concrete is too high. Use the graph, (Figure 1) in C&MS Item 511.07 to check the evaporation rate.

The Contractor should check the evaporation rate immediately before the placement of superstructure concrete begins. The evaporation rate should also be checked if there is a change in temperature, humidity, or wind speed during the placement of superstructure concrete. Wind speed can have the greatest effect on the evaporation rate; therefore, changes in wind speed should be more closely monitored. Many times, during the summer months, it will be necessary to place superstructure concrete at night in order to comply with the evaporation rate limits.

In addition to the evaporation rate, superstructure concrete is not allowed to be placed when the ambient air temperature is 85 °F (30 °C) or higher or is predicted to go above 85 °F (30 °C) during placement. The temperature of the concrete is not allowed to exceed 95 °F (35 °C) during the mixing and placement. Many times it is necessary for the Contractor to reduce the temperature of the mixing water and/or aggregates in order to control the temperature of the concrete.

Figure 511.07.A - Example of sling Psychrometer and concrete thermometer

Evaporation retardant is mostly water and its use is not permitted. Be aware that evaporation retardants are also marketed as finishing agents, but under either name their use is prohibited.

Figure 511.07.B - Examples of improper use of finishing aids

Placement

Several methods may be used to convey the concrete to the forms. Any method that ensures placement of concrete of the proper consistency without segregation is satisfactory. Usually ready-mix trucks with open chutes, buckets, drop chutes, and concrete pumps are used to place substructure concrete. Open chutes must be sloped sufficiently to allow concrete of the proper consistency to flow readily. Drop chutes may be maneuvered to distribute the concrete, but the delivery end must be kept vertical. Concrete is deposited as near as possible to its final position with as short of a vertical drops as practical but not over 5 feet (1.5 m).

When concrete is delivered to the point of placement by means of pumping equipment, the air content at the point of placement is required to be within the specified parameters of Table 499.03-1 and Table 499.03-3. Adjust the pumping pressure, boom angles and use pumping aids to lower the friction in the piping to meet the specified parameters. Provide a hose at the end of the line that is at least 0.5 inch (12 mm) smaller in diameter than the line on the boom to minimize free-fall and maintain a continuous flow of concrete in the pipe lines and boom during discharge.

Figure 511.07.C- Concrete placement by pump and by bucket

Consolidation of concrete by the vibration method is required for structures. Spud vibrators generally are used and should have a workman assigned exclusively to each vibrator. The vibrator should be pushed into and pulled out of the freshly deposited concrete slowly and as vertical as possible. For narrow sections, the vibrator may be applied to the sides of the forms or a form vibrator may be used. Establish a pattern of placing and vibrating that provides practically horizontal surfaces and uniform vibrator coverage. Generally a vibrator can consolidate concrete in approximately a 4-inch to 8-inch radius depending on the type of concrete. Visual inspection of consolidation is a two-step process of one, seeing the surface of the concrete flatten out, and two, seeing air bubbles come to the surface within the vibration radius. Therefore, a uniform coverage pattern must be used to ensure uniform consolidation.

Figure 511.07.D- Concrete vibration in forms

Footings

Where concrete will be placed to bedrock, the rock should be free of mud and cleared of all loose rock or other accumulations. Soil serving as the footing bottom should be sufficiently dry and stable so that it will not be interspersed in the concrete.

Concrete may occasionally be placed in water; however, with the exception of drilled shafts, concrete is not to be placed under water. When concrete is placed in water, placement should begin in one corner of the forms and continue against the previously deposited concrete until full height of the footing is attained. Full height should be carried forward, displacing the water ahead and out a small opening in the opposite corner of the forms. Vibration of the concrete should be kept well back of the water. Concrete must never be deposited in running water since it will cause separation of cement from the mixture. If pumping is controlling the water level, the pumping may be halted or reduced immediately after the concreting is complete, so that the water level rises slowly and inundates the footing to provide the cure.

When the plans require a concrete seal, or it becomes necessary for the Contractor to use a seal to stop the upward flow of water, the concrete must be deposited under water in a manner that minimizes separation of the cement. This type of seal is sometimes referred to as a mud mat. A concrete seal is deposited in a compact mass with a minimum of disturbance from the water it displaces. When a tremie or concrete pump is used, the end of the pump or tremie hose or tube must be plugged prior to lowering into the water and kept filled during placement. Failure to keep the tremie or pump filled with concrete during placement could result in water entering into the tremie tube or pump hose. This will result in the cement being washed from the aggregate. The Contractor's plans for the mix and placement should be reviewed prior to the pour. Where the Contractor elects to use a seal, it is his responsibility to choose a thickness and methods that produce satisfactory results.

Figure 511.07.E - Concrete seal placement for large pier in a causeway

Piers and Abutments

Concrete for backwalls above the approach slab seat shall not be placed until the abutments have been backfilled to within 2 feet (610 mm) of the bridge seat elevation.

When expansion joints are involved, the backwall should not be placed until after the superstructure concrete is placed. As the superstructure concrete is placed, the beams will grow in length as the camber decreases. If the backwall is placed prior to placing the superstructure concrete, the required opening in the end dam will be lost as the beams grow in length.

The tops of backwalls that become roadway surface require special methods for setting the grade. Although the recommended methods have been used to set the end dams, the elevations can be slightly off grade. Therefore, the tops of the end dams should not be used alone to project the grade for the backwall. The preferred method of obtaining the correct grade is to place a 10 foot (3.05 m) straightedge as a screed supported on the superstructure concrete and the end dam. The backwall can be struck to the proper grade. Grade strips tacked to the backwall form that have their elevations established in a manner described above may be used to establish the grade. In the event that the grade for the surface of concrete is not flush with the end dam edge bar, it should be finished to the grade established above and edged to a radius equal to the offset where it abuts the edge bar.

After the forms have been stripped from backwalls and before the approach slabs are placed, the top surface of concrete is subject to damage by spalling of the sharp edge on the approach slab side. Covering the surface with a plank or any other method that will afford equal protection should be provided.

Concrete should never be deposited through closely spaced reinforcing steel where it may accumulate and take set prior to encasement or cause segregation of aggregate. The bars, such as the top main bars in a pier cap, should temporarily be moved out of the path of the concrete or hopper until the concrete level has reached the vicinity of the bars and then reset. If the plans require bearings for which anchor bolt holes will be drilled later, the bars must be reset accurately and checked with a template.

Bearing Seats

Bearing areas on abutments and piers must be finished accurately to the plan elevations in order that the deck may be placed on profile grade. The elevations should be checked accurately when finished to correct possible errors and settlement of the forms containing the original marks. Take elevations as soon as possible after completion of the substructure units and record them for future reference.

Bearing seats that are high or uneven must be leveled to the proper elevation by bush hammering or grinding and then smoothed with a thin film of Portland cement paste to fill the pitted surface. Bearing seats that are over 1/8 inch (3 mm) low are leveled as described above and raised to the proper elevation by steel shims placed under the masonry plates. If elastomeric bearings are specified, steel shims should not be placed under the bearing. In this case, consult the Office of Structural Engineering pertaining to the acceptability of the Contractor’s proposed method of correcting the bearing seat.

Where it is necessary to cut down the bearing area, the lowering is extended approximately 1 inch (25 mm) around the area of the masonry plate and carried full width to the face of the abutment or pier cap for drainage.

Pre-Pour Conference for Placing Concrete for Superstructures

Prior to the scheduled day for deck placement, preferably the day before, a conference should be held to review the plans and preparations for the pour (Forms CA-S-4 and CA-S-6). The Contractor's Superintendent and key personnel, together with the Engineer and available inspectors who will be involved, should attend. At this time, the Superintendent should state his plan of operation, and agreement should be reached with the Engineer on all of the following:

1. Provision for adequate concrete delivery to ensure continuous placing and to provide sufficient length of workable concrete for proper straight edging. This includes the number of trucks assigned and an access route where ingress and egress will be maintained at all times.
2. Spacing of the trucks, especially at the start and end, so that no load will be delayed unduly in discharging or will placing be delayed for lack of concrete.
3. A system of communicating with the concrete plant to permit ready adjustments in the mix or delivery
4. Proper tools and equipment on hand have been checked and are in good working order. A finishing bridge must be used when the deck cannot be reached for proper finishing.
5. A competent and experienced bridge superintendent who will be in charge and at least two experienced finishers.
6. Factors that might determine the need for chemical admixtures are explained.
7. Protection on hand in case of rain or low temperatures.
8. For decks with hinges, and where it is planned to terminate a pour at the expansion joint over the hinge, concrete placement should proceed in the direction that will load the longer part of the hinged span first. This will minimize the effects of unequal span loading, unless otherwise specified in the plans.
9. Properly curing the concrete and placing the wet burlap in a timely manner.

Closure Pour

Many times a bridge deck will be constructed part width at a time to maintain traffic on a portion of the existing or completed structure. At times, an existing structure will be widened by adding at least two beam lines. A closure pour will be used to account for the differential deflection that will occur between the portion of the deck that has already been placed and has yet to be placed. This closure pour is important and should be performed. A closure pour involves a strip of concrete several feet (a meter) or more wide that is not placed until after the deck concrete is placed in both phases. It is placed the entire length of the deck between the two portions of deck.

When a closure pour is specified, the forms on the second phase of the deck yet to be placed must not be supported by the first phase that has been previously placed. The reinforcing steel must not be spliced, and cross bracing shall not be placed between phases until the concrete in the second phase has been placed.

Immediately prior to placing the concrete in the closure pour, it is important that the cross bracing between the first two phases be completely installed. At this time, it is acceptable to support the forms for the closure pour from the two completed adjacent phases.

Figure 511.07.F - Examples of concrete closure pour construction

Setting the Grade for Finishing the Deck

When finishing a deck, setting the grade correctly is paramount for placing a deck on profile grade. A table of screed rail elevations is shown on the plans for composite box beam bridges, rolled beam, girder, and concrete I beam bridges. Screed elevations should be provided in the plans for all curb lines or deck edges, profile grade points, transverse grade-break lines and phased construction lines for the full length of the bridge. Bearing points, quarter span points, mid-span points and splice points, as well as any additional points required to meet a maximum spacing between points of 25’-0”, should be provided in the plans. Screed elevations above each beam/girder line are no longer required by the ODOT Bridge Design Manual due to the differential deflection between beam/girders. The amount of beam/girder deflection that occurs due to the wet weight of concrete at each screed cross-section will vary based on the span length of each beam/girder, the magnitude of concrete load applied to each beam./girder and the size of each beam/girder cross section.

Screed Elevations are control elevations for concrete deck finishing machines that represent the theoretical deck surface locations prior to deflections caused by deck concrete placement and other anticipated dead loads. Screed elevations are provided to ensure the bridge deck is completed to the correct elevations.

Top of Haunch Elevations represent the theoretical location of the bottom of the deck above the beam/girder haunch prior to deflections caused by deck placement and other anticipated dead loads. Elevations must be taken on the end dams and at every point on the beams required for setting the grade of the screed rail, including points over the piers. There should be no deflections at the bearing points over the piers and abutments, with the maximum deflections occurring at the mid-spans. The Haunch Height (Haunch Fill) equals the Top of Haunch Elevation (Deck Bottom) minus the surveyed Beam Top Elevation. These elevations provide the contractor the means to determine the proper haunch depths for setting deck falsework.. See Table 511.A.

Beam Row	**Elev.**	**Rear Abut**	**¼ Pt**	**½ Pt**	**¾ Pt**	**Pier 1**
A	Deck Bot	966.64	966.48	966.32	966.16	966.00
	Beam Top	956.97	965.82	965.68	965.5	965.33
	Haunch Ht	0.67	0.66	0.64	0.66	0.67
B	Deck Bot			966.42		
	Beam Top			965.77		
	Haunch Ht			0.65		
C	Deck Bot			966.52		
	Beam Top			965.87		

	Haunch Ht			0.65		
D	Deck Bot			966.42		
	Beam Top			965.76		
	Haunch Ht			.66		
E	Deck Bot	966.64	966.48	966.32	966.16	966.00
	Beam Top	965.97	965.82	965.66	965.50	965.33
	Haunch Ht	0.67	0.66	.66	0.66	0.67

Table 511.07.A - Determining Haunch Height

This is an acceptable method of recording this information.

The Final Deck Surface Elevations shown in the plans represent the deck surface location after all anticipated dead load deflections have occurred. These elevations should line up with the approach slab and pavement elevations off of the bridge. Whenever the profile grade of the deck is adjusted, this must be considered when setting the grade for the approach slabs and pavement in order to provide a smooth transition. Even though it has not been necessary to adjust the grade, the as-built grade of the deck should be used to establish the grade of the approach slabs, since the actual dead load deflections may vary from the calculated deflections shown on the plans.

Figure 511.07.G -Concrete deck forms between beams

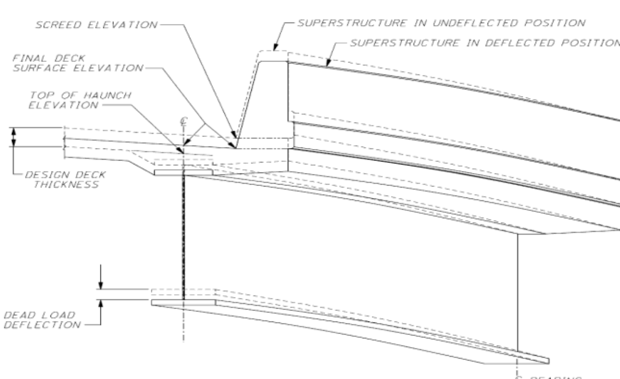


Figure 511.07.H- Deck elevations and deflections

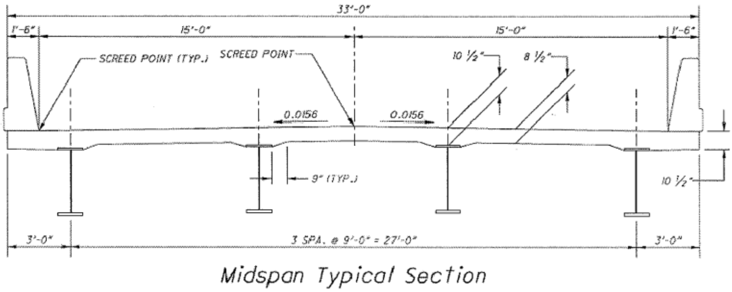


Figure 511.07.I- Screed points at curb lines, profile grade and grade- breaks

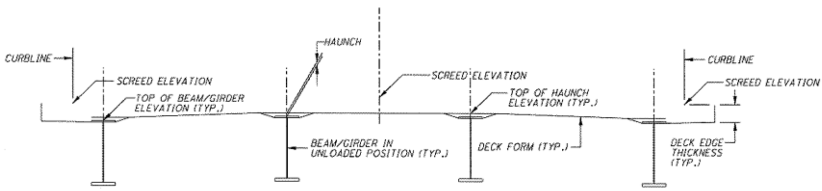


Figure 511.07.J -Top of haunch elevations in non-deflected (unloaded) position

Differential deflection should be built into the Camber Diagram.

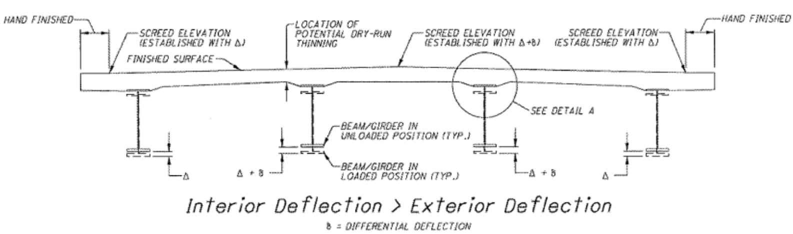


Figure 511.07.K- Interior deflection > Exterior deflection

Will occur with addition of concrete weight. Do not adjust screed rails to increase deck and cover thickness at interior of deck.

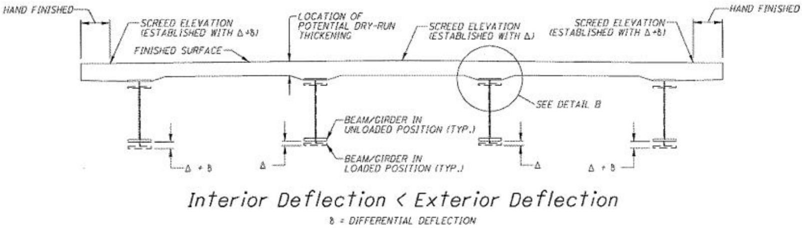


Figure 511.07.L -Interior deflection < Exterior deflection

Will occur with addition of concrete weight. Do not adjust screed rails to decrease deck and cover thickness at interior of deck.

The proposed beam seat elevations shown in the plans for prestressed beam superstructures are based on the design midspan camber for prestressed beams which are 30 days old (D_{30}). If the beams will be set at a different age, the beam fabricator and contractor have to be in contact to figure out what the camber will be when placed.

The beam seat elevations, deck haunches or profile might have to be adjusted based on this actual camber. If the prestressed concrete beams are unrestrained, (not loaded), the midspan of the beam will camber up due to creep and shrinkage.

The Contractor has to adjust each beam seat elevation using measured midspan camber data provided by the fabricator if available. In the absence of measured midspan camber, each beam seat elevation can be adjusted using the following:

$\Delta Y = D_t - D_{30} \geq 0$

Where:

ΔY = Distance that each seat elevation shall be lowered from plan elevation to account for midspan camber growth rounded to the nearest 1/8-inch

D_t = $(1 + \psi)\, D_0$

D_{30} = Design Midspan Camber at Day 30 provided in the plans; inch

D_0 = Design Midspan Camber at Day 0 provided in the plans; inch

ψ = $1.97\, K_S\, K_F\, K_{TD}$

K_S = $1.45 - 0.13\,(V/S) \geq 1.0$

V/S = Ratio of the prestressed concrete member's volume-to-surface area exposed to the atmosphere. For each of the standard I-beam sections, this ratio is provided on PSID-1-13; inch

K_F = $5/(1 + f'_{ci})$

f'_{ci} = Compressive strength of prestressed concrete at release provided in the plans; ksi

K_{TD} = $t/(61 - 4\, f'_{ci} + t)$

t = Age of prestressed concrete measured between release of prestressing force (i.e. 0.75 days) and time of deck placement; days

The Contractor is required to provide the Engineer with revised plan sheets and Design Camber calculations or measured camber data signed, sealed and dated by an Ohio Registered Professional Engineer at least 7 days prior to constructing the beam seats. The revised plan sheets shall include the measured camber data (if available), Design Camber (D_t) and beam age (t) assumed for establishing the revised elevations. Provide haunch reinforcement for prestressed I-beam members according to the ODOT Bridge Design Manual, Figure 302.5.2.3-2 as necessary to extend the beam's composite reinforcement at least two inches into the deck thickness. All revisions resulting from adjusted beam seat elevations shall be clearly marked as revised. Do not begin work until the Engineer approves the revised plan

Figure 511.07.M- Surveyor checking beam elevations

Superstructure Framing, Setting Falsework, Setting Screed Rails and Dry Run

The contractor's carpenter foreman should use the following procedure when setting the deck falsework, setting the screed rails, and performing the dry run with the Engineer:

1.Ensure all superstructure framing, (e.g. each intermediate crossframe and diaphragm), is permanently fastened according to C&MS 513.26.

2.Once beam/girder erection is complete, mark the elevation control locations on the top of the beam/girder flanges.

3. At each control location, survey and record the top of beam/girder elevation

4. Calculate the haunch depths at each control location as the difference between the plan Top of Haunch Elevation (Deck Bottom), and the surveyed Beam Top Elevation.

5. Using the haunch depths and screed elevations, erect the deck falsework. The bottom deck form in the overhangs shall be set by subtracting the deck edge thickness from the nearest screed elevation.

6. With the falsework in place, mark the screed elevation control locations on the surface of the falsework.

7. Set the screed rail elevations at control locations given in the plans using the screed elevations provided. Intermediate rail elevations may be determined by stringline between plan specified screed locations.

8. Once the finishing machine setup is complete, run the unit the full length of the screed rails and back using the machine's weight to take out any "timber crunch" or formwork settlement. Reset screed rail as necessary.

9. Locate the finishing machine at each screed rail control location with the carriage moved nearest the screed rail. Measure and record the screed rail elevation. The difference between rail elevations with and without the finishing machine represents the deflection due to the weight of the finishing machine. Each screed elevation should be adjusted upward by the measured deflection. Measured deflections of 0.25" or less may be ignored.

10. Starting at the beginning of the pour, locate the finishing machine at each screed cross-section and center the paving carriage above the interior screed elevations (e.g. crown points, profile grade lines, etc.) Adjust the finishing machine crown such that the elevation of the bottom of the paving rollers equals the screed elevation at that location.

11. Record the magnitude and direction of the crown adjustment necessary when moving the finishing machine from one screed cross-section to the next.

12. During placement, when the vertical crown adjustment is 0.25" or less, the total crown adjustment shall be made at the midpoint between adjacent screed cross-sections. For greater total adjustments, half of the total adjustment shall be made at the first quarter point between adjacent screed cross-sections and half at the third quarter point between adjacent screed cross sections.

13. Using the cross-slope adjustments noted for each screed cross section, move the carriage to locations above each beam/girder line and above each mid-bay. Measure and record the distance from the surface of the formwork to the paving rollers and verify concrete/rebar clearance.

14. When the thickness or cover does not meet plan requirements, verify the following:

a) Are screed rail elevations set properly?

b) Are haunch depths correct?

c) Are overhang thicknesses correct?

d) Do crown point elevations match screed elevations?

e) Were rail elevations adjusted for weight of machine?

f) Are the reinforcing steel chairs set to the correct height?

g) Is there a plan error for screed elevations?

15. If each of the preceding items are in order, differential deflections between beams/girders in the screed cross section may be involved.

DO NOT adjust screed rail elevations.

Use CA-S-22 Dry Run Form as a template.

When a closure pour is specified, the designer assumes that the finished elevation of the existing deck is correct. Due to conditions beyond his control or conditions he has overlooked, the finished elevation of the deck may not be as he assumed. If this condition exists, it should be detected prior to placing the widened or second portion of the deck. Therefore, prior to placing the widened or second portion of the deck, the Contractor should check the finished elevation of the existing portion of the deck to ensure that it is correct. If it is determined that the finished elevation of the existing portion of the deck is not correct, the Office of Structural Engineering should be contacted for additional instructions.

Figure 511.07.N- Deck finishing machine interior rail support

511.08 Slipform Construction of Bridge Railing

In lieu of conventional forming, the Contractor may be permitted to slipform the parapets. This operation is accomplished with concrete that has a slump of around ±1 inch.

Prior to placing the concrete, the Contractor must take additional measures to tie the reinforcing steel in order to prevent it from dislocating during the slipforming operation. If these measures are not taken, the slipforming operation will cause the reinforcing steel to move out of its proper location.

Due to the low slump, many times the Contractor will attempt to add water to the mix as it comes down the chute from the concrete truck and enters into the hopper of the slipforming machine. This is not allowed since it will result in concrete of inferior quality.

During the slipforming operation, small amounts of concrete will drop from the edge of the deck and onto the surface below the bridge. If the slipforming operation takes place directly over a traveled roadway, the Contractor should furnish all necessary platforms to protect the traffic from falling concrete. These platforms will allow access to complete the finishing operation and facilitate inspector access.

The Contractor should take steps to ensure that the finished concrete meets the specified tolerances. These steps should include adequately tying the reinforcing steel, determining the proper slump, and properly setting up the slipforming machine. Failure to meet the specified tolerances could result in the rejection of the parapet.

Any defects such as cracking, tearing, or honeycombing should be repaired immediately. Occasionally, when repairing defects, the Contractor will not completely fill the defect with concrete, but will only bridge over the defect by placing the concrete on the surface of the parapet. This is not acceptable. The Contractor should take steps to ensure that the defect is completely filled with concrete.

Normally, a small amount of hand finishing is required after the concrete has been formed. Hand finishing can be difficult due to the low slump of the concrete. To facilitate finishing the concrete, many times the Contractor will sprinkle water or evaporation retardant onto the surface of the concrete. The use of these substances to aid in hand finishing is not allowed since it will only result in a surface that is subject to scaling in the future. The contractor should not broom finish the surface.

After the concrete has initially set, it is important to saw the 1 ¼ inch deep control joints to the perimeter of the parapet as soon as possible. Any delay in performing this operation will result in additional shrinkage cracks in the parapet. Polyurethane caulk is required to be placed in these joints.

Figure 511.08- Finishing and curing slipformed parapet

Construction Joints (511.09)

The surface of construction joints should be even and have coarse texture such as produced by a wood float on fresh concrete. Vibrated concrete with a closed level surface is satisfactory. Where the construction joint terminates at an offset in the concrete surface, such as between the fascias of the deck slab and the sidewalk, the joint should be finished neatly at the corner with a wood float.

Transverse joints as permitted in 511.09, or longitudinal construction joints placed in deck slabs of steel beam or girder bridges, are constructed with keys located between the reinforcing mats and having a depth of 3/4 inch (19 mm). Form construction joints using bulkheads with keyways. Locate keyways clear of exposed surfaces by approximately one-third the thickness of the joint.

If the Contractor desires a longitudinal construction joint due to an excessive slab width and because it is not provided by the plans or specifications, the request must be submitted to the Office of Structural Engineering for review.

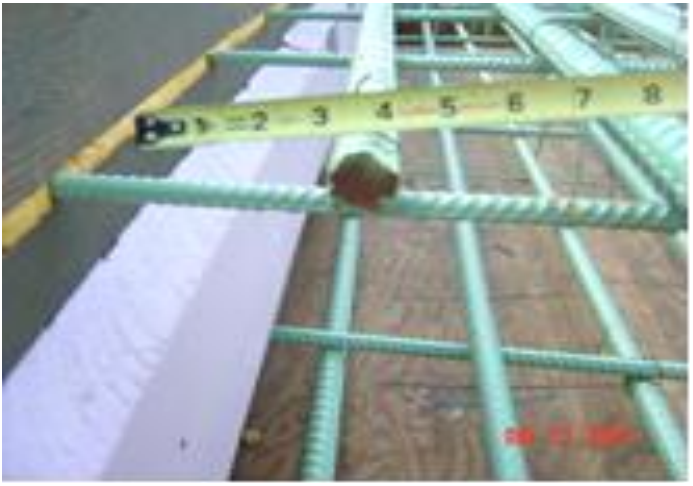


Figure 511.09 -Forming key of deck construction joint

511.10 Work Stoppage

During the placing of a deck, unexpected difficulties may occur that halt further placing. These may be a sudden shower, a breakdown in the concrete plant or the finishing machine, or other unforeseen interruptions.

When a shower occurs, no manipulation of concrete should be performed other than channeling the concrete that was last deposited so that water will not pond on the concrete and run back on the finished or partially finished surface. The textured surface should be covered with the curing material as rapidly as possible. Non-textured surfaces should be covered with polyethylene sheeting. After the shower, all ponded water should be removed from the concrete and out through the forms before resuming placing and finishing operations. The last surface covered with the curing material should be inspected. If it has been marred, the texture should be restored.

Investigate stoppages immediately. If it is found that it will not allow resumption of concrete placing in sufficient time, a bulkhead must be placed immediately. If practical, the location should not be over a pier. The emergency bulkhead may consist of a wood strip laid across the top of the longitudinal reinforcing bars. This strip should be as deep as the plan cover, usually 2-1/2 inches (64 mm). Kickers can be used to secure the strip or shims inserted between the bars in order to obtain proper crown and grade. The concrete below the wood strip should be compacted to approximately a 45 degree slope

and all excess removed as far from the joint as possible and disposed of before it hardens. After the concrete has set, but still fractures easily, the bottom edge should be broken to provide a vertical face below the bottom reinforcing steel. This may be accomplished with a pry bar prying up from the forms. Exercise care to ensure the surface of the forms is not damaged. See Figure 511.G - Emergency Bulkhead.

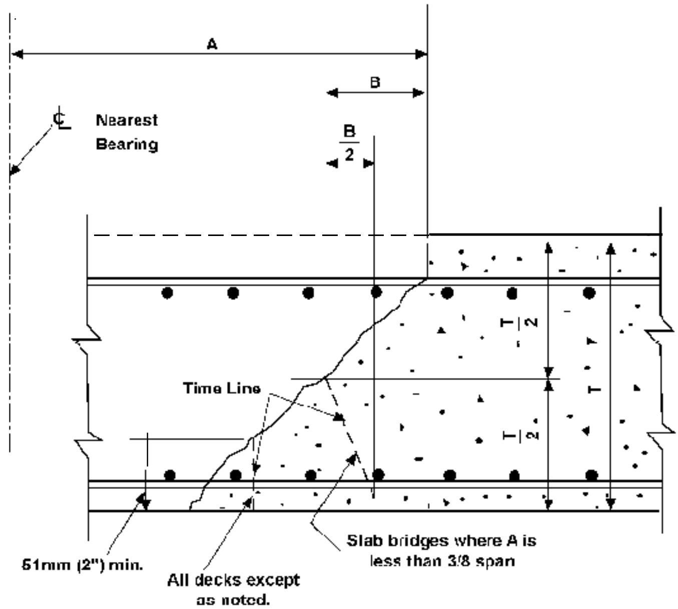


Figure 511.10 - Emergency bulkhead

511.12 Depositing and Curing Concrete During Cold Weather

Heated concrete and protection must be provided whenever concrete is placed at an atmospheric temperature of 32 °F (0 °C) or lower or whenever weather forecasts predict temperature below 32 °F (0 °C) within the curing period. Concrete must not be placed in contact with material having a temperature of less than 32 °F (0 °C).

The official U.S. Weather Bureau forecast for any curing period generally can be obtained from the District Office. This information also can be obtained from some local airports and radio stations.

When the 5-day weather forecast does not predict 32 °F (0 °C) or lower temperatures at any time during the period, the Contractor should not be required to erect enclosures or to use insulated forms. However, during the fall, winter, and spring, adequate material and equipment should be on hand to provide for unpredicted temperatures below 32 °F (0 °C).

To ensure freedom from freezing until protection can be established, the temperature of concrete should not be less than the minimum of 50 °F (10 °C) specified, but should not exceed 90 °F (32 °C) maximum. Concrete placed at low temperatures above freezing develop higher ultimate strength and greater durability than concrete placed at higher temperatures. Higher temperatures require more mixing water, cause slump loss, possible quick setting, and increase thermal shrinkage. Rapid moisture loss from hot, exposed concrete surfaces may cause plastic shrinkage cracks. It is recommended that the temperatures of fresh concrete, as placed, be kept as close to the 50 °F (10 °C) minimum temperatures as practicable. When the air temperature is 32 °F (0 °C) or lower, it is necessary to raise the temperature of the concrete by heating the mixing water or aggregate or both. The concrete must be protected from freezing, and specified curing temperatures must be maintained by a heated enclosure, insulated forms, or by either of these in combination with flooding.

Decks slabs less than 10 inches (254 mm) thick must be protected from freezing, and specified temperatures maintained for the curing period by a heated enclosure.

Arrangements for covering and insulating newly-placed concrete must be made in advance of placement and should be adequate to maintain the specification temperature in all parts of the concrete.

During the first few days which require protection, most of the hydration heat of the hardening cement is developed. As a result, if heat generated in the concrete is adequately conserved, outside heat generally is not required to maintain concrete at the correct temperature. This heat may be conserved by using insulating blankets and insulated forms where repeated reuse of forms makes this practical. Outside temperatures at concrete walls, piers, abutments, or slabs above ground may be protected with insulation under various conditions (see chart to follow). On work where protection by insulation is permitted, project personnel should check the protection proposed by the Contractor and be reasonably sure that the proposed insulation is adequate for the expected exposure before concrete placement is permitted to begin.

The application of insulation should be as follows:

1. Blanket insulation is applied tightly against wood forms with nailing flanges extending out from the blankets so they can be stapled or battened to the sides of the framing. Seal the ends of the blankets by removing a portion of the mat and stapling or battening the blanket to headers to exclude air and moisture. Corners and angles are most vulnerable. Take extreme care to ensure they are well insulated and the insulation is held firmly in place.
2. In case of steel forms, the insulation should be applied tightly against the form and held securely with the ends sealed to exclude air and moisture.
3. Where practicable, the insulation or insulated form should overlay any cold concrete previously placed by at least 1 foot.
4. Any tears in the liner are to be repaired immediately with accepted waterproof material.
5. Where tie rods extend through an insulated form, a plywood washer, approximately 3/4 × 6 × 6 inches (19 x 150 x 150 mm), should be placed on top of the insulation blanket and secured in a satisfactory manner.
6. The tops of all pours must be covered with insulating blankets, except for areas around protruding reinforcing bars that may be insulated with straw or wrapped with insulation blankets. Waterproof covers should be used to cover the top of such pours, as required by specifications.

7. Protective enclosures may be constructed of canvas, plywood, polyethylene, plastic, etc. in such a manner that will maintain uniform temperatures and allow free circulation to the warmed air.
8. For the underside of deck slabs, 3/4 inch (19 mm) plywood forms have an equivalent thickness of 0.6 inch (16 mm) and will provide protection of 32 °F (0 °C) minimum air temperature.
9. Close packed straw under canvas may be considered a loose fill type if wind is kept out of the straw. The insulating value of dead air space greater than about 1/2 inch (13 mm) thick does not change greatly with increasing thickness.

511.12.A Heated Enclosure

When salamanders or other heaters supply heat, local drying and burning of the forms may result and necessitate moving or adjustment of the setup. Regular observance of the forms and burlap should be made to ensure that the concrete is kept wet for the duration of the curing period, as required in 511.14. Combustion type heating units shall be vented from the enclosure to preclude damaging fresh concrete. The enclosure should surround the top, sides, and bottom of the concrete to be placed during cold weather.

Temperature Control

Thermometers for use in enclosures should be the high-low recording type and be furnished by the Contractor. If the enclosure is long or high, more than one thermometer may be required. The readings in the morning and the afternoon normally represent the low and high temperature respectively; carefully select the time when the high-low recording thermometers are checked.

When insulated forms are used, the thermometer must be furnished and installed by the Contractor. They must be capable of indicating surface temperature of the concrete. In case of a tall section, such as pier shafts or retaining walls, more than one thermometer will be required because of the temperature gradient. Temperatures should be read twice daily for high and low readings. When insulated forms are used, temperature of concrete will cause a lag in the temperature change of the surrounding air. Time of observance need not be as selective for representing the high and low, but is used to indicate a trend that may require venting of the forms or erecting an enclosure. When venting of a vertical form is necessary, it should be raised slightly at the bottom to create a chimney effect.

The temperature record must include the required temperature readings for the entire curing period. Outside air temperatures may be local reported temperatures.

Temperature and control methods used, as well as temperature readings, must be recorded on the Inspector's Daily Report.

Cold Weather Curing Time

To fulfill the curing requirements for concrete placed in cold weather, the surface temperature must be maintained as specified in 511.14 or be exposed to ambient air temperatures no less than 50 °F (10 °C) for 5 days.

In case any day's temperature readings fall below the minimum specified, the duration of heating must be extended to provide the required number of days. In case of loss or

breakage of thermometers, replacements or other provisions must be made to provide a complete record.

Figure 511.12.A- Blankets and heater for concrete placed in cold weather

511.13 Removal of Forms

Falsework must not be removed until after the time-temperature requirements of 511.14 are met or satisfactory beam tests are attained. During cold weather, forms are to be removed after the curing period in such a manner that the temperature of the concrete does not drop more than 20 °F (7 °C) in any 24-hour period.

Note 1 in Tables 511.14-1A and B states that span is defined as the horizontal distance between faces of the supporting elements when measured parallel to the primary reinforcements. For slab deck bridges, the primary steel runs longitudinally down the deck. For beam supported structures, the primary steel runs transversely across the deck.

Curbs and Parapets

Forms for curbs and parapets should be observed carefully for condition of surface, flush fit of panel joints, proper installation of bevel strips, and visual and measured alignment and elevation. Adequate form supports should be provided to ensure proper position of concrete during and after placement. Surface rubbing does not justify the use of inferior forms or lack of adequate supports.

When expansion devices are used to allow for bridge deck expansion, more open space for expansion must be provided in the curb and parapet than is required for expansion devices. Where conduits cross this opening, give special attention to clearance for expansion fittings to ensure free movement of the deck.

Transverse joints may be placed in the sidewalk or curb section near the center of any span.

511.14 Curing and Loading

Curing is governed by 511.14 that requires either Method A, Water Curing or Method B, Membrane Curing. Curing time is 7 days. No curing is required for surfaces covered by forms for the duration of the curing period. Concrete that will be overlaid with concrete or sealed, as well as all superstructure concrete, must be cured in accordance with Method A, Water Curing. The top surface of superstructure deck concrete must be cured for 7 days in accordance to Method A and then cured within 12 hours in accordance with Method B. Do not shorten the minimum required Method A curing time regardless of strength gain.

The curing material must be applied as soon as possible to avoid cracking of the concrete. Application of the curing material should be applied immediately after the finishing operation is complete.

When it is necessary to work on concrete during the curing period, such as placing deck concrete adjacent to a construction joint, only the area immediately adjacent to the joint should be exposed and the remaining area protected from damage by the workers. Plywood sheets may be used for protection. The exposed area should be kept moistened until adjacent work is complete, after that, the cover should be restored and normal cure resumed.

Floor forms provide the cure for the underside of the slab and are not to be removed before the end of the curing period.

Method A, Water Curing (511.14.A)

When two thicknesses of burlap are used to water cure the concrete, they should be kept wet by the continuous application of water from soaker hoses or other sprinkling devices during the required period. In lieu of continual sprinkling devices, white polyethylene sheeting or wet plastic coated blankets may be used to cover the concrete.

On bridge decks, a single layer of wet burlap is kept wet by a continuous application of water and covered by white polyethylene. The polyethylene should be placed transversely. The edges should be lapped and held securely to maintain a moisture seal. The curb area may be covered with a longitudinal strip that is held securely to the fascia form and laps the transverse strips. A continuous batten may be used to seal the blanket to the form and reinforcing bars may be laid on the laps to make the seal. Check areas suspected of having the seal broken during subsequent work or weather disturbances. If these areas are found to be drying out, soak the burlap and reseal the white polyethylene.

Plastic-coated blankets must be inspected prior to use to ensure that they are sound and will retain the moisture required to cure the concrete. All holes and tears must be repaired so that they are watertight. The material should be rejected if defects are numerous and repairs are questionable or if the plastic coating has cracked from aging.

Burlap and plastic-coated blankets must be thoroughly soaked with water prior to placing on the surface of the concrete. Dry material placed on the surface of the concrete will draw moisture out. This will increase the chances of drying shrinkage cracks. If new burlap is used, extra measures may need to be taken to ensure that it is properly soaked since it doesn’t soak up water as well as used burlap. If burlap to be soaked is delivered

to the project in a tightly wrapped condition, it should be loosened to allow the penetration of water.

Figure 511.14- Installation of burlap and polyethylene sheeting for wet cure

Method B, Membrane Curing (511.14.B)

The concrete curing membrane is white-pigmented material meeting specifications 705.07. The material may be either Type 1 (clear or translucent without dye) or Type-D (clear or translucent with fugitive dye).

The membrane should be applied in one or more separate coats by spraying a fine mist at a uniform application rate of one gallon per 200 square feet (70.3 square meters) of surface. The rate of application is controlled by laying out in advance, on the surface to be cured, an area that will be properly covered by the number of gallons of compound in the spray container. The procedure helps ensure that the membrane is applied at not less than the required rate.

Loading Requirements for QC/QA Concrete

See Table 511.14-1 in C&MS 511. Falsework may be removed from any span and all piers caps, and the concrete open to traffic when the compressive strength of sample cylinders is greater than or equal to 0.85 % f'c or the flexural strength of sample beam is greater than or equal to 650 p.s.i.. Per Supplement 1098, the maturity curve method may be used for determining strength of the concrete. Do not shorten the minimum required Method A curing time regardless of strength gain. When placing concrete for a superstructure between October 15 and March 15, open the deck no sooner than 30 days after placement.

Loading Requirements for Non QC/QA Concrete

See Table 511.14-2 in C&MS 511.No traffic is to be permitted on a structure until the concrete has attained the age specified in 511.14. For all spans, this is 14 days without a beam test or 7 days with satisfactory beam test. Do not shorten the minimum required Method A curing time regardless of strength gain. When placing concrete for a superstructure between October 15 and March 15, open the deck no sooner than 30 days after placement.

Loading of Completed Structure Units

No load is to be applied or work conducted that will damage new concrete or interfere with its curing. This applies to loading or work on any part of the structure

that will, in the opinion of the Engineer, cause damage. Where bending stresses will not occur, before loading new concrete, allow at least 36 hours and until the field cured compressive strength cylinders or maturity results reach 85% f'c; or if using flexural beams, the average of two beam tests is greater than 650 psi (4.5 MPa).

Surface Finish (511.15)

Patching

For concrete that is to be sealed according to 512.03,, perform surface profiling according to 512.03.F., immediately after removing forms. After the removal of forms, all cavities produced by form ties and all other holes, honeycomb spots, broken corners or edges, and other defects (except air bubble holes that may be filled by grout cleaning) must be cleaned. After being saturated with water, all cavities shall be completely filled, pointed, and trued with a mortar of the same proportions used in the concrete being finished.

On all exposed surfaces, all fins and irregular projections must be removed with a stone or power grinder, taking care to avoid contrasting surface textures. Sufficient white cement must be substituted for the regular cement in the filling of holes and other corrective work to produce a finished surface of the same color as the surrounding concrete.

If shown on the plans, exposed surfaces that have an appearance not satisfactory to the Engineer shall be grout cleaned in a manner satisfactory to the Engineer.

The Contractor should be advised that it will be necessary to use good formwork to obtain satisfactory surfaces.

Grout Cleaning (511.15.A)

Grout cleaning shall be performed as outlined in 511.15.

Rubbed Finish (511.15.B)

When specified on the plans, rubbing shall be performed as outlined in 511.15.

Forms should be removed within 2 days after the concrete is placed. Exceptions are the slab fascia form on which other fascia forms are set and wall forms that overlap a joint. If parapets are placed in cold weather, make provisions to remove forms and begin surface finishing on the day following placing, while maintaining a minimum temperature of 50 °F (10 °C), or postpone the placing of parapets until weather conditions are suitable for proper performance.

Roadway Finish (511.16)

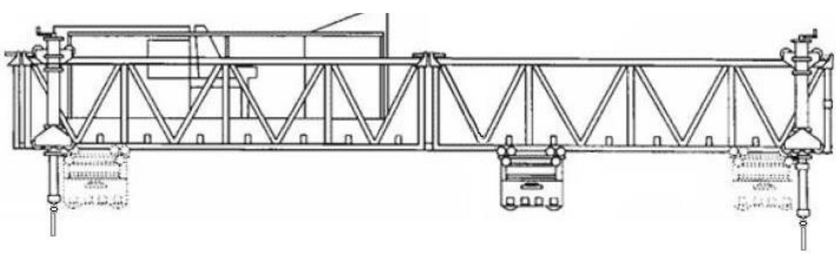
Machine Finishing

A machine finish is required except for extremely narrow bridges where vibrating or roller screeds are to be used to finish the surface after vibration of the total thickness. Mechanized finishing machines are superior to hand finishing methods for both

consistency of surface finish and economics. The finishing machine must be self-propelled with forward and reverse drive. Mechanized finishing machines are comprised of fabricated truss sections pinned together to span the bridge deck width to be paved. The truss spans are supported at each end on a set of wheels, called “bogies,” which ride along the length of the bridge on screed rails. Suspended below the truss is a finishing head, called a “carriage,” which levels, compacts, vibrates and finishes the concrete. The machine shall have two rotating rollers, leveling augers and either a vibrating pan or vibrating rollers. See Figure 511.H. Field verify that the vibrating frequency of the pans or rollers is between 1500 and 5000 pulses per minute. The contractor must supply the instrument to check the frequency. The roller fins should not protrude more than ¼ inch from the roller. Protruding fins can mechanically depress the aggregate too far from the surface of the concrete. The contractor should detail the method used to support the machine on the deck and the complete procedure for placing the slab and submit to the Engineer for review. Supports for the riding rails must be equipped to handle the weight of the machine in order to avoid failure or any vertical deflection. The concrete handling, placing, and finishing procedure should be planned to ensure that the concrete will be placed and struck off with a minimum of manipulation and at a sufficient rate in order to provide workable concrete in an area adequate for proper, final hand finishing. Success of the Contractor’s procedure on previous decks should be considered.

Figure 511.16.A-Machine and hand finishing of bridge deck

Pin Connection ∨



Screed Rail with Bogies (wheels) **Carriage with rollers & augers**

Figure 511.16.B - Finishing Machine

For transverse machines, the screed should be assembled or adjusted to the required crown established from a taut line while suspended in the same manner as it will be in operation.

Prior to ordering concrete, and after the finishing machine has been made ready, make a dry run over the entire deck. Check slab thickness and reinforcing steel cover along with crown conformance to both end dams and expansion joints. If the rate of crown varies, and the machine can be adjusted during operation, the required crown should be determined at regular intervals not exceeding 25 feet (7.62 m), the required increment of adjustment established and the location referenced on the side of the bridge.

Plan dimensions for deck thickness, the reinforcing of steel cover which was verified during the dry run, and the witnessing of screed adjustments to the required crown must be recorded in the project records. A last-minute check that form dimensions and reinforcement have been verified and documented should be made at this time on the Inspector’s Daily Report. Use CA-S-22 Dry Run Form as a template.

Finishing machines can be placed such that the truss sections are skewed with respect to the screed rails. This orientation allows for concrete placement parallel to the substructure skew as required by the C&MS 511. For skew angles of 15º and greater, the finishing machine can be skewed to within 5 degrees of the plan specified skew angle. See Figure 511.I.

The carriage can also be skewed with respect to the truss sections. This feature allows the carriage to finish the concrete transverse to the bridge when the truss sections are placed at some other orientation (e.g. parallel to the substructure skew). In order to ensure a proper finish at transverse grade breaks (e.g. crown points), the carriage should always be oriented to finish the concrete transverse to the bridge. A special length truss section insert is required above the grade break locations such that the grade break line lies directly below opposite corners of the section. For skewed bridges without transverse grade breaks, skewing the carriage with respect to the truss sections is not required. The finishing machines can be hinged at the pin connections between truss sections in order to provide transverse grade breaks (e.g. crown points).

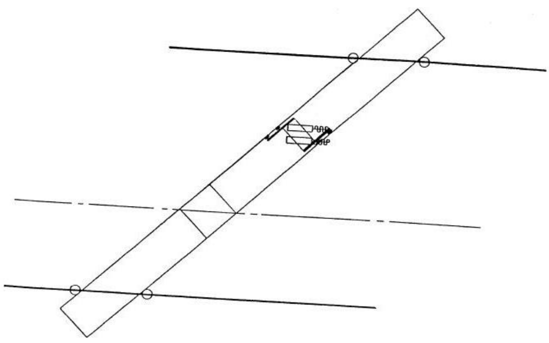


Figure 511.16.C -Finishing machine oriented with skew (Paving Direction --->)

Although proper measurements made during the dry run should ensure plan dimensions, check measurements after the concrete is struck to grade in order to verify that the machine is still in adjustment and reinforcing steel remains in place. Slab thickness measurements can be obtained by probing with a 1/4-inch (6 mm) straight wire and the cover over re-steel with a 90 degree bent wire of the same size. These measurements should be taken shortly after the start of the finishing operation, and periodically thereafter, or when an area appears questionable. Wide, flat sections such as super

elevated slopes are questionable and must be checked. The probing should be performed in plastic concrete where it will be easier to close the void.

Some cover checks are required; however, they do not need to be as numerous as the depth checks that also reflect cover. It is recommended that as many depth checks as possible be made as time permits. A statement should be entered in the project records indicating that check measurements have been made and conform to plan dimensions. If localized areas do not conform to plan dimensions, they should be noted, and any corrective action documented.

During operation, a uniform head of concrete should be maintained along the full length of the screed. Screeds should be lifted from the surface when not in use. During operation, only the operator is permitted on the machine. The machine should continually be in operation as long as practical and the concrete placing procedure should not exceed the speed of the machine.

Tracking or walking in the screeded surface is not tolerated.

Final Finishing

It is imperative that final finishing follow immediately behind the finishing machine. If this final finishing should fall behind, the rate of concrete placement should be reduced.

The construction joint surface under the sidewalk or the safety curb should not be used as a place for finishers to stand or as a passageway for workers. Planks may be placed on the sidewalk reinforcement providing sufficient additional ties and braces are used if necessary to obtain a rigid framework that will not disturb the bond of the stirrups.

Minor surface irregularities left after screeding can be corrected with long handled floats. This operation should be held to a minimum and any major irregularities encountered should be corrected by the use of a straightedge. Use of water, evaporation retardants, or finishing agents on the surface of the concrete to facilitate finishing is not permitted. If a Contractor adds water by continually “washing” his tools, require that they use a towel to dry the tools prior to reuse.

Bridge Deck Grooving (511.17)

The deck surface must be textured by using a broom to provide a surface satisfactory to the Engineer. The broom must produce a uniform, gritty texture in either the longitudinal or transverse direction. The texturing should take place as the pour progresses after other finishing operations have been completed. Note: If the concrete tears or “mud balls” are produced on the surface, the Contractor needs to apply less pressure to the broom or wait a few minutes until the concrete has begun to set.

After the water curing of the concrete is complete, and either before applying curing compound, or some period after applying curing compound, and before opening the bridge to traffic, longitudinal grooves, parallel to the bridge centerline, must be sawed into the surface of the deck. Apply curing compound within 12 hours after grooving the deck. The grooves must be sawed in a continuous, uniform pattern spaced at 3/4 inch minus 1/4 inch or plus 0 (19 mm minus 6mm or plus 0) and must be approximately 0.15 inch (4 mm) deep and 0.10 inch (3 mm) wide. Grooves must be within 9 to 12 inches from devices such as scuppers or expansion joints. On skewed bridges, in order to accommodate the equipment used to saw the grooves, the grooves must be sawed from

2 inches to 2 feet from the expansion joint. This results in grooves with a staggered or stepped appearance. Maintain a minimum clearance of 9 inches (220 mm) to a maximum of 30 inches (750 mm) clearance between the grooves and the curb or parapet toe. However, at no point shall un-grooved portions of deck extend beyond edge line and into the temporary or permanent travelled lanes. Maintain a minimum of ¾ inch (19 mm) to a maximum of 2 ¼ inches (56 mm) transverse distance between adjacent passes of the grooving machine head.

For staged, or phase bridge deck work, the grooves must be sawed parallel to the final, permanent bridge centerline. If the different stages or phases of the bridge deck work occur within one construction season, any stage opened to traffic shall receive an interim coarse broom finish during placement. Then the longitudinal grooves are sawed after the final stage. The interim broom finish will not be allowed as a surface texture when opened to traffic over a winter season. Longitudinal grooves must be sawed in the deck prior to opening to traffic for a winter season.

For bridge decks that widen from one end to the other, the longitudinal grooves must be sawed parallel to the centerline of the roadway. On the side of the bridge that widens, saw the longitudinal grooves to follow the edge line. Saw longitudinal grooves in the gore areas, avoiding the overlapping of grooves

Figure 511.17- Bridge deck grooving machine

Sidewalk Finish (511.18)

Float Finish

Concrete for sidewalks, safety curbs, and tops of substructure units are struck off with a template and finished with a float to produce a sandy texture.

Sealing Joints and Cracks (511.19)

After curing, all cracks, transverse and longitudinal joints in the deck, joints between the concrete deck and steel end dams, and joints between the concrete deck and safety curbs, barriers and parapets must be sealed with high molecular weight methacrylate (HMWM), prior to opening the deck to traffic.

Compressive Strength (511.20)

Sample and test concrete strength according to C&MS 511.04.

A. Concrete Requiring QC/QA. When the bid item requires QC/QA, the Engineer will evaluate the QC compressive test sublot results according to Supplement 1127 to determine pay factors for structure concrete .

If a single test result for compressive strength of a sublot of concrete is found to be less than 88% f'c ,the Engineer will determine the location for evaluating the strength of the sublot represented by the low compressive strength concrete. Nondestructive testing or coring will be performed at such locations. If the reported nondestructive test results are greater than the specified f'c,, the Engineer will accept the concrete and use the original cylinder results for calculating the compressive strength pay factor (PFc). If coring is performed, the core results will be used in place of the original cylinder results for pay factor determination.

If the nondestructive test results are less than the specified f'c,, the concrete must be cored. The Engineer will determine the locations for the required concrete coring by the contractor for testing by the Department. The contractor must patch core holes with approved patching material. If the core results are above 88% f'c, the core strength results will be used for calculating the compressive strength pay factor (PFc).

If the core results indicate that the compressive strength of the concrete is below 88% f'c, the contractor must submit a plan for corrective action to the Engineer for approval. If the corrective plan is not approved, the Engineer will require the Contractor to:

1. Remove and replace the unacceptable concrete that the sublot represents and retest the new sublot at no cost to the Department or

2. Leave the unacceptable material in place and be paid for the sublot with a pay factor of 0.75.

If three or more sublot compressive strength acceptance test results are less than f'c but greater than 88% f'c the Engineer will require an investigation by the contractor of the reasons for the consistent low strengths. No additional placements of the concrete JMF will be made .until the investigation is completed to the satisfaction of the Engineer. The investigation should include all facets of the concrete operation including batching, mixing, delivery, clean up, sampling, testing, quality control plan, etc. If the Engineer is unsatisfied with the results of the investigation, the JMF and the quality control plan will become not approved. The contractor will have to develop and submit a new JMF and quality control plan conforming to the requirements of Supplement 1126, C&MS 499.03 and C&MS 511.04. Pay factors under C&MS 511.22 for these low strength sublots will be based on the original reported cylinder strengths.

B. Concrete Not Requiring QC/QA. When the bid item does not require QC/QA, the Engineer will evaluate the strength results following the requirements of Table 511.22-2 and as follows:

If a single compressive strength test result is less than f'c the material will be considered unacceptable material and the Department will determine acceptance according to C&MS 106.07.

If three or more compressive strength test results are less than f'c the contractor will be required to perform an investigation of the reasons for the consistent low strengths. No additional placements of the concrete JMF will be made until the investigation is completed to the satisfaction of the Engineer the investigation should include all facets

of the concrete operation including batching, mixing, delivery, clean up, sampling, testing, etc. If the Engineer is unsatisfied with the results of the investigation, the JMF will become not approved. The contractor will have to develop and submit a new JMF conforming to the requirements of C&MS 499.03.

Air Content (511.21)

For concrete that requires QC/QA, test the air content of the concrete according to C&MS 455.03. When QC/QA concrete is not required, the Department will test the air content as directed by the Engineer.

A. Concrete Requiring QC/QA. Any concrete with air results outside the requirements of Table 499.03-1 that is placed into the structure is unacceptable material according to C&MS 106.07. The amount of unacceptable material will be the amount represented by the test result. The contractor must re-evaluate the unacceptable material, at no cost to the Department, by coring the location containing the unacceptable concrete. The contractor must patch the core hole with approved material. If the concrete had high air content, the core must be tested for compressive strength. Concrete with a minimum strength of *f'c* may be left in place. If the concrete had low air content, the core must be tested to determine the in-place hardened air content, specific surface and spacing factor according to ASTM C 457. The contractor must remove and replace unacceptable materials with specific surface results less than 600 in^{-1} (25 mm^{-1}) or spacing factor results are more than 0.008 in (0.20 mm). The contractor must hire an independent laboratory, acceptable to the Department, to perform the testing.

B. Concrete Not Requiring QC/QA. Any concrete with air results outside the requirements of Table 499.03-1 that is placed into the structure is unacceptable material, according to C&MS 106.07. The amount of unacceptable material will be the amount represented by the test result. The contractor must re-evaluate the unacceptable material,at no cost to the Department. The Department will core the location containing the unacceptable concrete. The contractor must patch the core hole with approved materials. If the concrete had high air content, the Department will test a core for compressive strength. Concrete with a strength of *f'c* may be left in place. If the concrete had low air content, the Department will determine the in-place hardened air content, specific surface and spacing factor according to ASTM C 457. The contractor must remove and replace unacceptable materials with specific surface results less than 600 in^{-1} (25 mm^{-1}) or spacing factor results of more than 0.008 in (0.20 mm).

Pay Factors (511.22)

Apply pay factors as follows:

A. Concrete Requiring QC/QA

The Department will use pay factors based on the percent within limits (PWL) to establish a final adjusted price. The PWL will be established per lot(s) accepted in the QCP for each bid item quantity of concrete. The Department will calculate a PWL according to Supplement 1127 using either the Contractor's verified QC compressive test results or core results when the QC could not be verified. The compressive strength pay factor (PF_C) from Table 511.22-1for the lot will be applied to each bid item represented in the lot. The Department will combine approach slab and deck concrete test results in the same lot to determine final pay factors.

If the PWL value determined for the lot of concrete is below 75%, the contractor must submit a plan for corrective action to the Engineer for approval. If the corrective plan is not approved, the Contractor must remove and replace the lot of unacceptable material, at no cost to the Department, or leave the unacceptable material in place and be paid for the lot of with a pay factor of 0.75.

B. **Concrete Not Requiring QC/QA**

For concrete items that the Department performs compression testing, the Department will use a pay factor of 1.00 based on the individual compressive strength results greater than or equal to *f'c* for the quantity represented by the test results. If the compressive strength results are less than *f'c*, that material represented by the test result is unacceptable material, according to C&MS 106.07.See Table 511.22-2 .

Method of Measurement (511.23) and Basis of Payment (511.24)

The quantity of concrete for every reference number will be determined from the plan dimensions, in place, complete, and accepted with adjustments made for necessary changes or errors. Plan dimensions shall be verified and recorded.

The final quantity for structure concrete is rounded off to the unit for the item that is listed in the proposal. Where plan dimensions are in inches (mm), these should be converted to feet (m) and carried to a decimal place that will not affect the accuracy of the final unit.

Calculations made for necessary changes or plan errors are to be identified properly with the structure unit and reference number and to be validated by the signature or initials of the person who made the calculations and the date they were made.

The Department will calculate separate quantities of concrete due to unacceptable compressive strength per 511.20 and air content per 511.21.

. The Department will initially pay the full bid price to the Contractor upon completing the work. The Department will calculate the final adjusted payment for each item as follows:

PF1 - The final adjusted pay per cubic yard (cubic meter) or square yard (square meter), for accepted quantities of concrete:

$$PF1 = (\text{Contract Bid Price}) \times PF_C$$

PF2 - The final adjusted pay per cubic yard (cubic meter) or square yard (square meter) for unacceptable quantities of concrete due to compressive strength or low air content and allowed to stay in place, according to 511.20 or 511.21.

$$PF2 = (\text{Contract Bid Price}) \times 0.75$$

Calculate the adjusted price per bid item by multiplying PF1 or PF2 by the appropriate quantities of concrete, then sum the values. Subtract the full bid price paid to the Contractor from the adjusted price to determine the difference. The Department will execute final adjustments by change order upon receipt of all test data.

512 Treating Concrete

Description (512.01)

This item deals with a variety of concrete treatments, including concrete surface sealing, horizontal crack sealing, vertical crack sealing, and waterproofing.

Materials (512.02)

For sealing of concrete surfaces, the Contractor must use products from the Qualified Product List (QPL) listed on the Office of Materials Management's (OMM) website for Epoxy-Urethane sealers per C&MS 705.23A and Non-Epoxy sealers per 705.23B.

For sealing concrete bridge decks, the Contractor must use products on the QPL for High Molecular Weight Methalcrylate (HMWM) Resin per 705.15, for Soluble Reactive Silicate (SRS) per 705.24, and Gravity Fed Resin per 705.25.

For sealing concrete cracks, the Contractor must use products on the QPL for Epoxy Injection per 705.26.

For waterproofing concrete surfaces, the Contractor must use products on the QPL for fabric and membrane material per the applicable sections of 711 and for asphalt primers and sealers from the applicable sections of 702 and 705.

Sealing of Concrete Surfaces (512.03)

Equipment (512.03A)

The Contractor must follow the manufacturers' recommendation for applying the sealer. Although spraying methods allow for higher production rates and cover profiled surfaces more easily than rollers, over –spraying must be contained and respirators and personal protection will be required. The sealer is commonly applied with rollers. When using rollers, brushes may also be required to apply the sealer to bug holes and joints. The equipment must be clean, free of contaminants, oil and water.

Mixing (512.03B)

The Contractor must mix the sealer according to the manufacturer's recommended procedures. Mixing paddles must be jiffy type, not wire whips. The mixer should be run at 400 to 600 rpm and be able to efficiently move the material for blending and not incorporate air into the mix. Material should be mixed to a consistent color for not less than three minutes.

Materials can not be extended or thinned. Improper mixing may cause poor or no hardening and inconsistent color. Induction or rest periods impact the materials viscosity and pot life. Do not use material beyond its pot life.


Figure 512.03.B- Poorly Mixed Material Remnants of material applied beyond Pot Life

Storage (512.03C)

The sealer needs to be stored in a location where the temperature stays within the manufacturer's recommended range. It should not be stored in direct sun light or allowed to freeze. A thermometer should be provided by the Contractor. Do not use material beyond its shelf life.

Surface Condition (512.03E)

Improper surface preparation is one of the main reason we see sealer failures. When the sealer is applied to a damp, dusty, or laitance laden surface, the sealer cannot gain the proper adhesion and will peel off, normally in sheets.


Figure 512.03.E.- Sealers not properly bonded

All surfaces must be cleaned of dust, dirt, oil, grease, wax, curing compounds, efflorescence, laitance, coatings and other foreign materials. All unsound areas should be repaired prior to surface profiling. Patched areas should air dry for ten days prior to sealer application. All concrete should attain its 28 day strength prior to sealer application. Do not apply sealer to joint sealants that have not cured to the manufacturers' instructions. Check for dust contamination prior to applying the sealer.

Surface Preparation (512.03F)

The purposes of surface preparation are to remove dust, dirt, oil, grease, wax, curing compounds, efflorescence, laitance, coatings and other foreign materials from the concrete surface and to leave the concrete with an open, absorptive surface, exposing the sand matrix of the concrete. For Epoxy-Urethane Sealers, the concrete surface which is to be sealed should look and feel like 100 grit sandpaper or coarser (surface profile). An inadequate surface profile will not provide the anchor pattern needed for proper bonding. The Contractor is required to supply 100 grit sandpaper for comparison. If requested by

the Engineer, for a physical record of the profile, the Contractor is to perform the ASTM D7682-12, Method B, Standard Test Method for Replication and Measurement of Concrete Surface Profile Using Replica Putty to obtain a replica coupon of the prepared concrete surface on a flat, test section, on the first day of production. With a micrometer, measure the surface profile obtained on the coupon, and provide the coupon to the Engineer.

Figure 512.03.F Replica putty comparator and micrometer

If the concrete surface had curing compound applied, the surface must be acid tested after blasting to check if the curing compound was completely removed. Perform the acid test for every 500 square feet.

1. Use a solution of one part 20° Baume muriatic acid and two parts water.
2. Apply four to five drops to the concrete surface. (If foaming/fizzing occurs the curing compound was removed.)
3. If foaming/fizzing does not occur, use products approved by the sealer manufacturer to remove the curing compound.
4. Rinse the tested location with an ammonia solution to neutralize the concrete surface.

The manufacturers of the sealer materials recommend the complete removal of existing coatings from the concrete in order for their sealer to adhere to the concrete.

There is now a separate pay item for the removal of existing coatings.

Figure 512.03.f Barrier surface profiles

Surface preparation of concrete surfaces can be done by water, abrasive blasting, or a combination of both.

Water blast at 7000 psi minimum. The blasting equipment should have a gauge to verify the pressure.

Abrasive blasting needs to be followed by air brooming or power sweeping to remove dust and abrasive from the surface of the opened pores.

Ensure all wastes from the surface preparation operation are managed in accordance with C&MS 107.19. The Contractor must control fugitive dust and waste water. They must contain, collect, and properly dispose of all wastes.

Figure 512.03.G- Containment for blasting debris waste

Make sure the Contractor is standing a reasonable distance away from the surface being blasted, typically 18 inches. Using a 7,000 psi water blast from 6 feet away does not gain the level of cleanliness needed to correctly apply the sealer.

Figure 512.03.H- Combination water/abrasive blaster versus Abrasive blaster.

Application and Coverage (512.03.G)

If using water blasting methods, the Contractor must apply the sealer between 12 and 48 hours after surface preparation.

If using abrasive blasing methods, the Contractor must apply the sealer within 48 hours after surface preparation.

There must be no rain within 6 hours of sealer application. The ambient temperature must be above 50 ° F within 6 hours of sealer application. Time between coats shall meet manufacturer’s written recommendations. Sealer must be applied at the approved coverage rate in a continuous, unbroken film.

Epoxy-Urethane Sealers (512.03.G.1)

Epoxy-Urethane sealers must be applied at the approved application rates listed on the Qualified Product List (QPL) listed on the Office of Materials Management's (OMM) website. Application rate for Epoxy is 120 square feet per gallon, (150 square feet per gallon if authorized), for Urethane is 200 square feet per gallon. Application rates for sealers will vary for form liner surfaces. Application areas should be marked to confirm coverage rates. The Contractor is required to provide documentation to the Engineer that the ambient, surface and material temperature is 50 ºF (10 ºC) or above, 5 ºF higher than the dew point, and the relative humidity is 80% or below during the application of the sealer.

For sealed sidewalks, or other non-skid horizontal surfaces, sand is broadcast and the sealer backrolled to encapsulate the sand.

Sags, runs, drips, holidays, and discolorations are not acceptable.

Non-epoxy sealers (512.03.G.2)

Non-Epoxy sealers must be applied at the manufacture's recommended mode of application. Do not apply non-epoxy sealer if the ambient temperature is below 40 ° F or will fall below 32 ° F within 12 hours after application. Application rate for Non-Epoxy is 100 square feet per gallon for decks and sidewalks, 125 square feet per gallon on vertical surfaces, and 150 square feet per gallon on parapets, abutments, pier caps and median dividers.

These sealers are clear by nature, but are to be tinted with a vanishing dye; therefore, it will be difficult to see where progress ended on the preceding day. Establish a method to mark the stop point that will not permanently be visible in the completed work.

Test Site/Application (512.03.H)

Ensure that test sites include a variety of surfaces: horizontal, vertical, inverted, steel formed finish, troweled, floated, rubbed, etc.

Sealing Concrete Bridge Decks with HMWM Resin (512.04)

HMWM stands for High Molecular Weight Methacrylate.

If the Contractor supplies 3-part HWWM, which means the promoter, resin, and initiator are supplied separately, be aware that the promoter and initiator will react violently with each other. This chemical reaction is so violent that these components normally arrive to the job site on different trucks.

Poor surface cleanliness is a major problem encountered in the field. The concrete surface must be swept, sand or water blasted and blown dry to remove all non-concrete material. Dust and debris clog up the cracks and do not allow the HMWM to penetrate effectively. The contractor is required to remove existing pavement markings using a method specified in 614.11.G.1.a. The temperatures of the concrete surface to be treated must be the range from 50 °F to 120 °F. Do not apply the HMWM resin within 24 hours after

rain or when rain is forecast within 12 hours of application. The application rate should be approximately 100 square feet per gallon.

Be sure to insist that the Contractor coordinate his initial application on the project with the presence of a manufacturer's representative. This representative should be a technical representative in lieu of a sales representative.

The application of sand at 0.80 to 1.2 pounds per square yard, is required to give the sealed surface a rough texture to assist with traction. If the sand is applied after the resin begins to harden, it will not become embedded and will merely brush off with the first wave of traffic leaving a potentially slick surface.

Figure 512.04- Spreading the HMWM sealer.

Traffic should not be permitted on the treated deck until it is tack free for a minimum of 6 hours.

There is a Qualified Product List (QPL) for this material which is maintained by the Office of Materials Management (OMM) located under 705.15.

Soluble Reactive Silicate (SRS) Concrete Treatment (512.05)

Proper surface preparation is essential for SRS to perform properly. The concrete surface must be swept, sand or water blasted and blown dry to remove all non-concrete material. The manufacturer must approve the use of any chemical to clean the deck surface.

The Contractor is required to perform a test section(s). This section(s) should incorporate all of the surface types to be treated, since test sections are to confirm application rates and appearance which will depend on the orientation and porosity of the concrete.

The temperature of the concrete surface to be treated must be above 35 °F.

After the treatment has cured, and prior to opening to traffic, the treated surfaces that experience vehicular or pedestrian traffic should be washed down with water. In some instances, the SRS treated surfaces have become very slick when first exposed to water. It is better to have this initial exposure in a controlled scenario versus allowing the first water exposure to the surface, such as rain, occur with traffic running on it.

There is a Qualified Product List (QPL) for this material which is maintained by the Office of Materials Management (OMM) located under 705.24.

Treating Concrete Bridge Decks with Gravity-Fed Resin (512.06)

Proper surface preparation is essential for Gravity Fed Resin to perform properly. The concrete surface must be swept, sand or water blasted and blown dry to remove all dirt and debris and all traces of asphalt or petroleum products from the deck to be treated. The contractor is required to remove existing pavement markings using a method specified in 614.11.G.1.a.

The temperatures of the concrete surface to be treated must be the range from 40 °F to 100 °F. Do not apply the Gravity Fed resin within 24 hours after rain or when rain is forecast within 12 hours of application. The application rate should be approximately 100 to 150 square feet per gallon.

Broadcast sand over the sealed areas of the bridge deck by mechanical means.

Figure 512.06- Spreading the resin and broadcasting sand

Traffic should not be permitted on the treated deck until it is tack free for a minimum of 6 hours.

There is a Qualified Product List (QPL) for this material which is maintained by the Office of Materials Management (OMM) located under 705.25.

Sealing Cracks by Epoxy Injection (512.07)

Epoxy Injection is a process to repair cracks or fractures in reinforced concrete that are 2 to 100 mils wide. Make sure the requirement for the presence of the manufacturer’s representative is enforced even if the Contractor has vast experience with this feature of work.

Note: the Contractor may refer to the injection ports as “straws.”

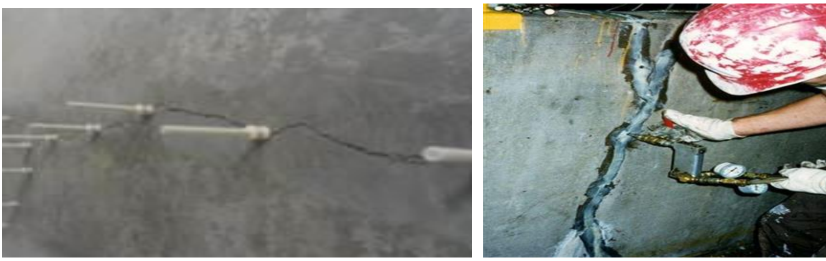


Figure 512.07- Ports and injecting epoxy for sealing cracks

The Contractor must establish injection procedures and the depths and spacing of holes at injection ports or tees. The Contractor must remove the injection ports or tees flush with the concrete surface after the fracture has been filled and the epoxy has cured. Take core samples as soon as the epoxy has cured. This is more critical on large jobs as the method of epoxy injection may have to be altered if it is not achieving adequate penetration. On small, one-day type jobs, this will not be possible.

There is a Qualified Product List (QPL) for this material which is maintained by the Office of Materials Management (OMM) located under 705.26.

Waterproofing (512.08)

Waterproofing material is applied on vertical and horizontal concrete surfaces. The waterproofing needs to be applied carefully to adhere to the concrete surfaces. Care should be taken while placing backfill or paving against and over areas that have received waterproofing. The waterproofing can be damaged by either direct contact of the equipment or by use of backfill materials which contain large sharp edged rocks. Do not apply waterproofing fabric or membranes over attachments and hardware. Seal the discontinuities with asphalt per C&MS 702.06 or hot applied joint sealer per C&MS 705.04.

Follow the manufacturer's recommendations for the application of prime coats, (rate of 0.10 to 0.20 gallon per square yard), prior to the application of fabric types, A, B, or E waterproofing. Follow the manufacturer's recommendations for the application of the types 2 and 3 membrane waterproofing.

Figure 512.08.A- Application of membrane waterproofing around appurtenances

If asphalt pavement is to be placed directly over the water proofing membrane, the Contractor must first apply tack coat as specified in C&MS 407 without damaging the membrane.

Figure 512.08.B- Paving over membrane waterproofing

There are Qualified Product Lists (QPL) for the membrane and fabric materials which are maintained by the Office of Materials Management (OMM) located under 711.24, 711.25, and 711.29.

513 Structural Steel Members

Description (513.01)

This work consists of preparing shop drawings, furnishing and fabricating structural steel members, nondestructive testing, fabricator performed quality control, documentation, cleaning, shop coating, and erecting structural steel and other structural metals. Prepare shop drawings and erect structural steel according to Item 501 and the additional requirements below. Shop painting shall conform to Item 514. The work also includes any work to move existing steel structures to the plan location, making necessary repairs and alterations, and connecting or joining new and old construction.

Fabricator Approval Procedure (513.02)

Fabricators are required to be prequalified according to Supplement 1078 as listed by the Department before the Contract letting date as evaluated by the Office of Materials Management.

Levels of Fabricator Qualification (513.03)

Each Fabricator will be classified by the Office of Materials Management at the highest level of the eight levels of fabrication it is qualified to perform according to Supplement 1078 .

Figure 513.03- Structural Steel beams in fabrication shop

General (513.04)

The Contractor is responsible for taking measurements of the existing structure as required to accurately join old and new work. The fabricator must include these measurements on shop drawings. Measurements shown on the plans that indicate the extent and nature of repair, alterations or extension shall not relieve the Contractor of this responsibility.

Figure 513.04- Surveyor taking measurements of existing structure

At least two weeks before starting shop fabrication, the fabricator shall notify the Office of Materials Management and furnish a proposed fabrication schedule for the work.

The Contractor is required to furnish the necessary access and area for inspection of all operations. The Inspector should not occupy the same float or suspended platform used by the workmen for safety reasons.

Fabricator Documentation Responsibility (513.05)

Fabricated steel should have a TE-24 with the shipment. If fabricated steel arrives without a TE-24, either the District Engineer of Tests or the Office of Material Management's structural steel section should be notified. A TE-24 in the project file provides verification that the structural steel is accepted material and fabrication has been properly performed.

Shop Drawing (513.06)

The Contractor is required to provide shop drawings conforming to 501.04 that include:

details, dimensions, size of materials, match mark diagrams for field connections, an overall layout with dimensions showing the relative unloaded vertical and horizontal position of beam or girder segments with respect to a full length base or work line, offsets for vertical and horizontal curvature at approximately each one-fourth of span length, at field splices, and at bearing points, the grade (ASTM designation), CVN, fracture critical, or any special testing requirements for each piece of steel, and the welding procedure by the WPS number at each joint.

Levels 1 through 6, Prefabrication Meeting (513.07)

After providing the notice and schedule required by 513.04 and at least 3 days after the Department receives shop drawings, the Contractor is required to

conduct a prefabrication meeting at the fabricator's facilities, or another location agreed to by all parties. The purpose of this meeting is to review any fabrication issues, including information on shop drawings, inspection, hold or witness points, unique fabrication items, special processes, and both the fabrication and project schedule.

Material Control (513.09)

The fabricator is responsible for marking each piece of steel with the ASTM A 6/A 6M specification identification color code and heat number. The fabrication quality control specialist shall provide the Engineer with a letter documenting that the fabricator performed material control according to this specification.

Care of Material (513.10)

The Contractor is required to store structural material at the shop or in the field, above the ground on platforms, skids, or other supports. Before using, clean all rusted or corroded material.

Workmanship and Straightening (513.11)

Structural steel is required to be fabricated to the dimensional tolerances specified by Section 3.5 of the AASHTO/AWS Bridge Welding Code and as specified below.

Sweep

The specified tolerance for sweep or horizontal curvature of a beam or girder is 1/8 inch (3 mm) in 10 feet (3.05 m). This can be applied to any 10 feet (3.05 m) length of the member or multiple 10 feet (3.05 m) lengths up to the total length of the fabricated section. A beam 100 feet (30.5 m) long, checked for its entire length, must not deviate more than ten 1/8 inches (3 mm) for a total of 1-1/4 inches (32 mm) from a taut line stretched between its ends.

Camber

The maximum camber tolerance at mid-span shall be 0 inch and the greater of + ¾ inch or the designated haunch height.

Finish (513.12)

The Contractor is required to remove fins, tears, slivers, and burred or sharp edges from steel members and provide a smooth surface, free from cracks and notches, and use a mechanical guide to provide an accurate profile.

Stiffeners (513.13)

Bearing stiffeners are required to be flush and square with the web and in a manner so at least 75 percent of the area of the bearing end is in contact with the inner surface of the flange and vertical after erection.

Fillers (513.14)

The fabricator is required to provide fill plates that compensate for the misalignment of abutting elements due to differences in thickness of flanges and webs at the splice locations.

Joints and Splices (513.16)

In bolted construction where tension or flexural members are spliced, the fabricator is required to produce connections that maintain a clearance of not more than 1/4 inch (6 mm) between the abutting surfaces of spliced members. For spliced compression members, the abutting surfaces are required to provide a uniform bearing when properly aligned and completely bolted.

Pin Holes (513.17)

Pin holes for up to 5-inch (127 mm) diameter pins shall not exceed the pin diameter by more than 0.020 inch (0.51 mm) and pin holes for larger pins shall not exceed the pin diameter by more than 0.031 inch (0.79 mm).

Holes for High-Strength Bolts and Bearing Bolts (513.19)

Finished holes shall not have a diameter larger than the nominal diameter of the bolt plus 1/16 inch (1.6 mm). The hole diameter shall not vary by more than 1/32 inch (0.8 mm) from a true circle for 85 percent of the holes in a contiguous group, and not more than 1/16 inch (1.6 mm) for the remainder. 85 percent of the holes in any contiguous groups shall have no offset greater than 1/32 inch (0.8 mm) between adjacent plies. The remainder of the holes shall not be offset more than 1/16 inch (1.6 mm) between adjacent plies.

Shipping, Storage and Erection (513.26)

Field Inspection

When the steel arrives on-site, and prior to erection, it should be inspected thoroughly for damages and for quality of fabrication as time and conditions permit.

Damage

The nature and extent of any damage that may have occurred because of loading, transit, or unloading should be noted along with the identifying piece mark or member. If corrective work is obvious, advise the Contractor immediately so the responsible party can be notified and correction can be performed in the most advantageous location.

Storage

Structural steel stored on-site shall be supported off the ground on blocking and stored in an upright position where it will not be affected by drainage. Many times the Contractor will secure angle iron across the top flanges of adjacent beams to prevent them from tipping over. If angle iron or other metal is secured across the top of the beams, it is important to ensure that the Contractor has not secured the angles or other metal by welding it to the beam.

Check of Bearing Seats

A final check shall be made of the elevation of bearing seats on the piers and abutments before erection of structural steel is scheduled to begin. If bearing seats are found that need to be corrected, it must be performed in the manner and to the tolerances described in 511, "Bearing Seats," of this manual.

The findings of this final check should be filed in the project records.

Required Erection Procedures

The specifications require the Contractor to submit an erection procedure for structural steel members. If there is railroad involvement, the PE stamped plan needs to be reviewed and approved by the appropriate railroad. For additional requirements refer to C&MS Item 501.05.Methods and equipment submitted for erection of members must be used in handling during transportation to the bridge site and unloading.

The erection drawings, usually the "E" sheets of the accepted shop drawings, must be used to locate the members on the bridge and may give special instructions for the Erector to follow.

Deviations from the submitted erection procedure, per C&MS 501.05, are not permitted. If the Erector proposes deviations in a procedure that appears to have merit, they must re-submit their modified erection procedure per C&MS 501.

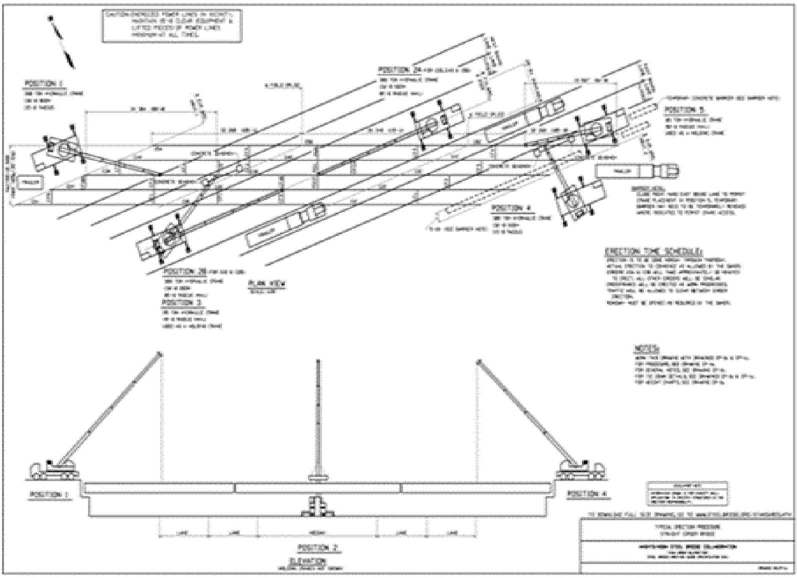


Figure 513.26.A- Erection procedure Engineered Drawing

Typical Erection Procedures Items

Typical items that should be included in the proposed erection procedure are as follows: (Reference C&MS 501.05.B.4. Use Erection Checklist Form CA-S-20.)

1. A drawing of the complete framing which shows each girder or beam section by "piece mark" and numbered in the order of proposed erection.
2. A print of the erection sheet of the shop drawings may be used.
3. The number of pieces and load capacity of erection equipment to be used and method of lifting members.

Figure 513.26.B- Erection of steel girders following the erection plan

4. Field splices to be made on the ground.

Figure 513.26.C- Lifting and performing field splice of girder

5. The number of field splice holes to be filled before erected members are released and allowed to deflect (50 percent required, preferably one-half with pins and one-half with bolts).

Figure 513.26.D- Use of drift pins to align plates

6. Methods and details for supporting the first beams or girders at the abutments and piers in each unit. Where some sort of attachment to the pier is used, it should be described as to size of members and method of attaching to the pier and steel. In addition to supporting the beams at the abutment and piers, there may also be additional bracing of the top flange at mid-span to prevent the beam from twisting or buckling under its own weight.

Bearing Adjustment (Also refer to Item 516 Bearing Device section of this manual.)

When steel beams or girders are first set on the bearing, and before sole plates are fastened, bearings may be set approximately plumb. After all beams or girders between expansion joints are in place and the overall length has been checked, make temperature corrections in the plumbness of the bearings. The length of bridge from the fixed bearing and the deviation in temperature of the steel from 60 °F (16 °C) must be used in calculating the tilt to the bearings when rockers are used.

The coefficient of expansion to multiply with the length and temperature difference is 0.000006 (0.0000117). For example, for a two-span length of 160 feet (49 m) at 40 °F (4 °C) for a difference of 20 °F degrees (-7 °C), the calculation is 160 x 20 x 0.000006 = 0.0192 feet or 1/4 inch (49 x 11 x 0.0000117 = 0.0060 m or 6 mm) that the rocker should be inclined from the vertical toward the fixed bearing to compensate for the existing temperature.

The same factors must be used to determine the offset in sliding plate bearings.

Adjustments should be made on a cloudy day when a temperature differential in the steel is not caused by the sun's rays.

A final check of correct bearing adjustment must be made after the deck has been completed.

Elastomeric bearings cannot be adjusted for temperature as there is no way to keep them in a deformed shape. Due to this, if it is necessary to correct for temperature due to excessive deformation or racking of the bearings, the beams will have to be jacked up and the bearings reset when the temperature is close to 60 °F.

High Strength Steel Bolts, Nuts and Washers (513.20)

The following described operations are intended to clarify some of the important requirements of the specifications.

Bolt Installation 513.20.C.

Joint Assembly

The beams or girders to be spliced must have their ends brought together at the correct relative elevation with respect to support points and be held at the elevation (and in correct alignment) so that heavy drifting is not necessary to align the holes.

Sufficient pins must be installed to obtain accurate alignment of parts and sufficient bolts to compact the joint. Before the beams or girders are released and allowed to deflect, at least 50 percent of the holes must be filled with pins and snug-tightened bolts. A minimum of 25 percent pins is desired. However, if less than 25 percent will carry the stress, and if additional pins cannot improve matching of holes, a lesser number will be satisfactory. If less than 25 percent pins are used, the remaining holes should be filled with snug-tightened bolts. Highly stressed joints will most likely require more than 50 percent of the holes to be filled with drift pins and snug-tightened bolts; note such cases

on the accepted erection procedure. Due to the possibility of damaging the threads on the bolts, any bolts installed prior to installing the drift pins shall be replaced.

On some beams and girders, it is possible for the initial bolts used to compact the joints to become loose when the remaining bolts are installed. After all the remaining holes have been filled with bolts and tightened to at least a snug tight condition, the initial bolts should be checked to assure that they are still snug tight.

When the splice is made on the ground, all operations to complete the splice shall be performed.

Pins shall be cylindrical and no more than 1/32 inch (1 mm) smaller than the diameter of the hole.

All holes not filled with pins shall be filled with bolts and bolt tightening operations completed on them before removal of any pins.

Figure 513.20.A- Example of Improper joining, uneven distribution of filled holes

Bolt Tightening

Tighten bolts by the turn-of-the-nut-method.

1. Tighten the bolt to a snug-tight condition.
2. Match mark the protruding end of the bolt and adjacent surface of the nut.
3. Tighten the nut to the additional specified rotation.

Greater variation in tension is usually obtained when the snug-tight condition is performed with power wrenches. More consistent tension is obtained with spud wrenches. When the steel surfaces are flat and compact, the snug-tight condition is obtained when bolt tension is between 5,000 and 10,000 pounds (22,222 and 44,444 newtons).

Snug-tight is accomplished by either an impact wrench or an ordinary spud wrench. If an impact wrench is used, snug-tight is achieved when the impact wrench begins to impact or hammer on the bolt. This will happen almost immediately after tightening with the impact wrench. When a spud wrench is used, snug-tight is achieved when the full effort of a man is applied to the spud wrench and the nut cannot be tightened any further.

Bolts must be match marked after the bolts have been tightened to a snug-tight condition. The purpose of the match mark is to measure the amount of rotation of the nut relative to the bolt. The match marks must be placed properly in order to measure this rotation.

The match marks must be placed on the end of the bolt and the adjacent surface of the nut. Contractors have placed match marks in several other locations; however, none of these locations allow the relative rotation of the nut to the bolt to be measured

(See Figures 513.20.B and 513.20.C - Match Marked Bolts).

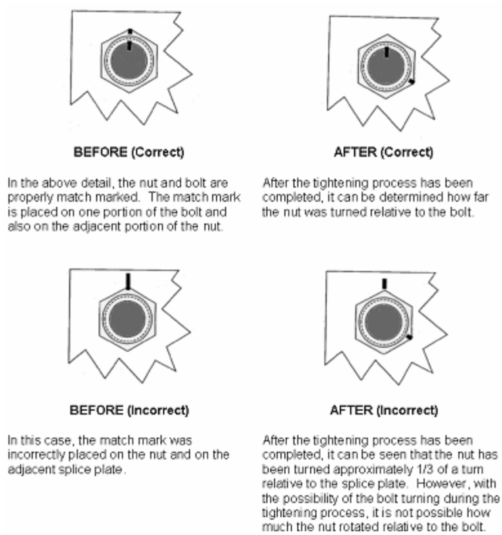


Figure 513.20.B - Match Marked Bolts

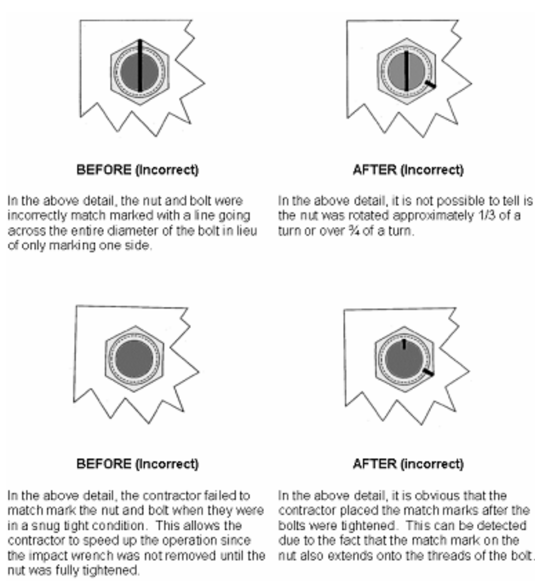


Figure 513.20.C - Match Marked Bolts

During final tightening, all of the specified rotation must be performed. Although the bolts may be over-tightened in the snug-tight condition by power wrenches, the full

specified rotation is still required. A maximum tension is not specified and excessive tension is not cause for rejection.

The first complete joint on a project must be tested. If certain conditions are met, inspection of subsequently-completed joints by testing may be waived by the Engineer. These conditions are:

1. The Engineer has accepted the compactness of the joint.
2. The snug-tight operations have been witnessed and accepted by the Engineer.
3. Match-marking of the protruding end of the bolt and nut have been performed and indicates the required rotation. The Engineer must be satisfied that these conditions have been met completely before the joint will be considered accepted and testing waived.
4. Galvanized A 325 (A 325 M) bolts, and bolts that were installed prior to inserting drift pins and subsequently replaced, shall not be reused. All other A 325 (A 325 M) black (un-galvanized) bolts may be reused if accepted by the Engineer. Re-tightening previously tightened bolts that may have been loosened by the tightening of adjacent bolts is not considered reuse.

Inspection of Bolted Joints (513.20.E)

Even though a joint may appear to have all the bolts in the joint properly match marked and tightened, there is still the possibility that these bolts were not properly tightened. Therefore, it is necessary for the Contractor to provide a torque wrench and a recently calibrated tension testing device.

The minimum torque required must be determined prior to inspecting the bolts with the torque wrench. This is accomplished with the aid of the tension testing device. A bolt is first placed in the tension testing device and tightened to the required tension as given by Table 513.20-2 in the C&MS. The torque wrench is then used to determine how much torque is required to turn the nut on the bolt after the minimum tension has been achieved. When calibrating the torque wrench, the Engineer should hold his hand on the nut being tightened in order to detect movement or rotation of the nut on the bolt. The required torque is based on the average torque of three bolts.

The torque wrench should be calibrated at the beginning of each day it is used and for each diameter or length of bolt being tested. Also, if the coating varies (i.e. galvanized bolts as opposed to un-coated bolts), the torque wrench should be calibrated.

Torque wrenches must have the capacity of the maximum job inspection torque required for any bridge.

The Contractor applying the torque should perform the inspection only up to the job inspection torque.

Figure 513.20.E – Ironworkers tightening match marked bolts

Figure 513.20.E – Determination of job inspection torque

Calibration Devices (513.20.F)

The Erector must furnish the Engineer with evidence that the manufacturer or a laboratory has checked the tension-testing device within one year.

Figure 513.20.F – Calibration device with torque wrench

Figure 513.20.F – Checking torque on installed bolts

Welding (513.21)

Welding requirements must be according to the current ANSI/AASHSTO/AWS "Bridge Welding Code" except as modified by Supplement 1011 and the Construction and Material Specifications.

No attachments, other than specified by the plans, shall be made by welding to any main structural members such as beams, girders, cross bracing, truss members, etc., unless accepted by the Office of Structural Engineering.

Approval of Welders

All welds must be performed by welders qualified for the specific welding method to be used according to Supplement 1011. A welder may obtain prequalification to perform welding in the field on a Department project by one of the following methods:

1. American Welding Society (AWS) Certified Welder Program

A field welder qualified as an AWS Certified Welder is acceptable to weld on Department projects. The field welder must show their current AWS Certified Welder card, showing qualification to the AWS D1.5 Bridge Welding Code, to prove their current certified status. Employment records with AWS are the responsibility of the individual welder. No submittals are required to be sent to the Office of Materials Management.

2. Ohio Department of Transportation Certified Welder Program

. A list of qualified welders is maintained by the Office of Materials Management. Welders must have been tested in the last 5 years.

Electrodes and Welding Procedures

Electrodes used to make all permanent welds to steel must be of the low hydrogen type and must be on the list of accepted electrodes maintained by the Office of Material Management.

In order to prevent moisture in the atmosphere from being absorbed by the electrodes, which can cause potential cracking of the weld, all stick electrodes must be purchased in a hermetically-sealed container or must be dried in an oven at 450 °F to 500 °F (232 °C

to 260 °C) for 2 hours and stored in a suitable container that will maintain a temperature of no less than 250 °F (121 °C). After removal for use, stick electrodes exposed to the atmosphere for more than 4 hours for E70XX electrodes and 2 hours for E80XX electrodes must be re-dried at a temperature of 450 °F to 500 °F (232 °C to 260 °C) before use.

When electrodes have become wet, the coating on the electrode is altered. Drying the electrodes does not restore the electrode coating to the original manufactured condition. Therefore, electrodes that become wet shall not be used.

Figure 513.21.A – Proper storage of electrodes in a hot box

The welding procedure which uses shielded metal arc electrodes (stick welding) is the only pre-accepted procedure. If the Contractor proposes to use Flux Core Arc Welding (FCAW), Submerged Arc Welding (SAW), or Gas Metal Arc Welding (GMAW), he must first have a welding procedure qualification test accepted and then submit a welding procedure specification for approval. Questions on welding procedure qualification tests and welding procedure specifications can be answered by the Office of Material Management's structural steel section.

Weather Restrictions

When the base metal is below the temperature listed in Table 513.A for the thickness of the material being welded, it must be preheated in such a manner that surfaces being welded are at or above the specified minimum temperature for a distance equal to the thickness of the part being welded, but not less than 3 inches (76 mm) both laterally and in advance of the welding.

Thickness of Thickest Part at Point of Welding – Inches (mm)	Minimum Temperature	
	A709 70W	All Other Steel
To ¾ (19), incl.	50 °F (10 °C)	50 °F (10 °C)
Over ¾ to 1 ½ (19 to 38), incl.	125 °F (50 °C)	70 °F (20 °C)
Over 1 ½ to 2 ½ (38 63.5), incl.	175 °F (80 °C)	150 °F (65 °C)
Over 2 ½ (63.5)	225 °F (110 °C)	225 °F (110 °C)

Table 513.21.A – Minimum Preheat Interpass Temperatures

When the base metal temperature is below 32 °F (0 °C), the above specified should be preheated to minimum temperature of at least 70 °F (20 °C). Preheating is only necessary where the welding begins. Continued welding will make further preheating unnecessary. Welding shall not be done when the ambient temperature is below 0 °F (-18 °C).

Welding Inspection

The welding operations should be observed and complete welds inspected for conformance to the plans and shop drawings. Fillet welds must be measured with the use of a weld gage or other method that will show the length of the sides in contact with the steel. Deficient welds must be built up to the required size. Poorly shaped welds or welds containing defects such as cracks, pits, craters, and undercutting must be corrected to the satisfaction of the Engineer.

When radiographic examination of welds is required, the report and film must be submitted to the Office of Materials Management, Structural Steel section, for review and approval. This must be done before any work is performed that would interfere with any necessary corrective work.

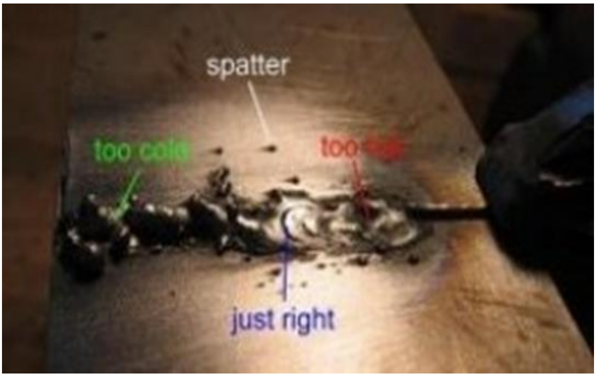


Figure 513.21.B – Example of weld quality

Arc Strikes

Occasionally during the welding operation, the electrode will come in contact with an area of steel that is not to be welded. This contact will result in a small burnt spot or arc strike in the steel. If not properly removed, an arc strike has the potential of propagating fatigue cracks.

Arc strikes located must be removed by grinding. They can result in unacceptable hard spots or small cracks. Therefore, after the arc strikes are removed, the Contractor must check every location where they occur where the steel is in tension. The Contractor must perform a magnetic-particle test on all arc strikes to assure that no cracks are present. Hardness tests must be run on all locations to assure that no unacceptable hard areas are present. Hardness values shall not exceed the higher of Rockwell C30 or the hardness value measured in the steel outside the location of the arc strike. If the above testing reveals unacceptable results, the flaw can be removed by grinding and the steel be retested to assure that the flaw has been completely removed.

Normally the Contractor is not equipped nor has the knowledge to perform the above test. He will typically make arrangements for a private testing laboratory to perform the required testing.

Figure 513.21.C – Example of an Improper arc strike on a beam web

Cleaning Of Welds

The finished weld must have all slag removed and be neutralized by vigorous wire brushing to remove any film that will affect the proper adherence of paint.

Stud Shear Connectors (513.22)

Shear studs are short rods that have been welded to a piece of steel for the purpose of anchoring that steel to concrete. There are additional requirements to inspect the weld joining the shear stud to a piece of steel.

Qualified Stud Welder Operator

Prior to allowing any production welding, it is first necessary to assure that the stud welder operator is qualified. This is accomplished at the project site since there is no list of qualified stud weld operators.

To be qualified, one must successfully weld two studs of the same type and size that will be used during the production welding. The studs must be welded to a piece of steel that is similar to the production member in thickness and property or they may be welded to the production member.

The studs should be visually examined after they have been welded. If they were welded properly there should be weld metal completely around the base of the stud (360 degree flash).

In addition to a visual examination, the studs must be bent to an angle of approximately 30 degrees from their original axis. Bend the studs by either striking them with a hammer or bending the stud by use of a pipe.

If the visual examination does not reveal a 360-degree flash or if the weld fails when the studs are bent over, the Contractor must make corrections to his procedure and two more studs must be welded and tested. This should continue until two consecutive studs are tested and found to be satisfactory.

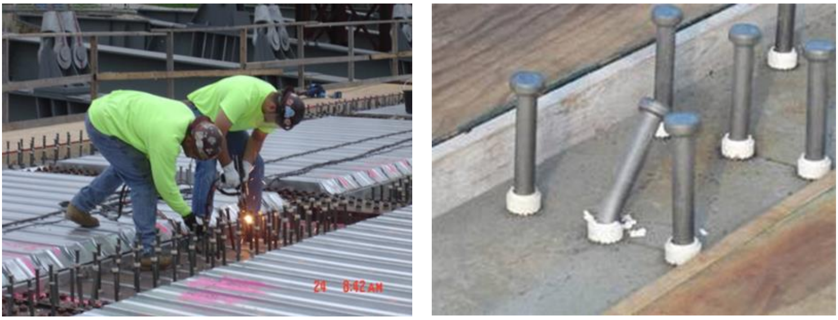


Figure 513.22 – Shear stud connector installation and testing

Qualifying the Stud Welding Procedure

Prior to production welding, it is necessary to qualify the stud welding procedure. This should be performed at the beginning of each day's shift when welding has been interrupted for an hour or more; when attaching the welding cable to a different ground; when changing weld settings; when changing loops in the cable; or when 500 studs have been welded after testing.

The actual testing shall be the same as required for qualifying the stud welding operator.

Post Testing of Stud Welds

After the studs have been welded, it is necessary to test the studs to ensure that they have been installed correctly. Test the studs by giving each one a light blow with a hammer. When the studs are tapped, they should emit a ringing sound. Any stud that does not emit a ringing sound should be bent approximately 15 degrees from its original axis.

In addition to tapping the studs with a hammer, a visual inspection must be performed. Any stud that does not show a 360 degree flash may be repaired by the Contractor by fillet welding the missing flash. Any stud the Contractor elects not to repair, or any stud that the Contractor has not repaired properly, must be bent to an angle of approximately 15° from its original axis.

Any stud that does not pass the bend test must be replaced. All studs that have been bent and have not failed should not be straightened.

Nondestructive Testing (513.25)

Nondestructive testing shall conform to the AASHTO/AWS *Bridge Welding Code,* as amended by Supplement 1011 and as specified below.

As the Engineer directs, the Contractor is required to perform ultrasonic or radiographic inspection of field welded repairs in main members for thick scabs, deep kerfs or nicks, and similar gross flaws.

The Contractor is required to submit radiographs, field sketches showing specific locations, lengths and depths of the repair, and two copies of the radiographic or ultrasonic technical reports to the Office of Materials Management for acceptance. Receive the Office of Materials Management's acceptance before performing construction activities making welds inaccessible for repair.

The Contractor or fabricator shall notify the Department at least 48 hours before performing nondestructive testing. Provide this notice even if specific hold or witness point inspections are not required by Supplement 1078.

The Office of Materials Management has the final authority to accept welds and will resolve controversies regarding the interpretation of radiographs, magnetic particle indications, or the acceptability of welds.

A. Radiograph Inspection of Welds.

Figure 513.25.A – Example of radiograph equipment

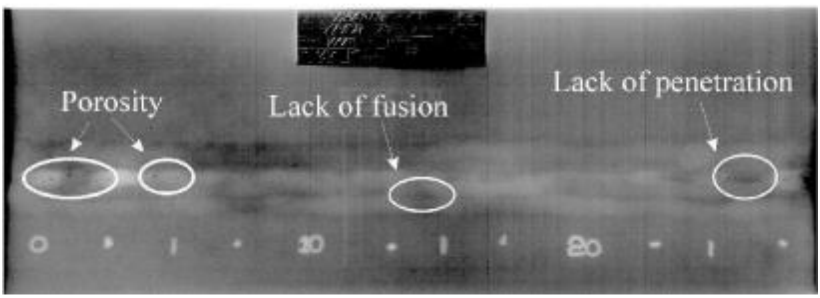


Figure 513.25.A – Example of radiograph film

B. Magnetic Particle Inspection of Welds

Figure 513.25.B – Example of magnetic particle testing of weld

C. Ultrasonic Testing of Welds

Figure 513.25.C – Example of ultrasonic testing of weld

Shop Coatings (513.27)

Any members where thickness appears questionable from a visual examination shall be checked in the field, preferably prior to erection.

514 Painting of Structural Steel

Description (514.01)

In order to protect structural steel from corroding, it is necessary to apply a protective coating system. This work consists of cleaning and painting all steel surfaces as shown in the plans.

Materials (514.02)

The coating system consists of three coats. On existing steel, all three coats, organic zinc prime coat, epoxy intermediate coat and urethane finish coat, according to 708.02, are applied in the field. On new steel, inorganic zinc primer, according to 708.01, is normally applied in the fabrication shop and the remaining two coats are applied in the field.

Caulk is required to be a single pack moisture cured polyurethane based material, which will not shrink or sag, capable of filling voids greater than 1/8 inch (3mm) and up to 1 inch (25 mm) wide, that is listed on the OMM Qualified Product List.

Superintendent (514.03)

The Superintendent must present a Bridge Painting pre-qualification training certificate offered by the Department to the Engineer prior to commencing work. No work is permitted unless the Superintendent provides a valid course certificate.


Ohio Department of Transportation

Certificate of Completion

[Enter Name]

Of

[Enter Company]

For

Work Type 26, Structural Steel Painting Course

I understand that this one day course is a prequalification requirement for any contractor applying for Work Type 26. This certificate is also required for the quality control specialist(s), superintendent or foreman assigned to supervise the contractor's bridge painting work on an ODOT Construction Project. This includes contractors who are not prequalified with ODOT.

This certificate will expire in 4 years on [Enter Date].

Gary E. Angles
Administrator, Construction Administration

[Enter Name]

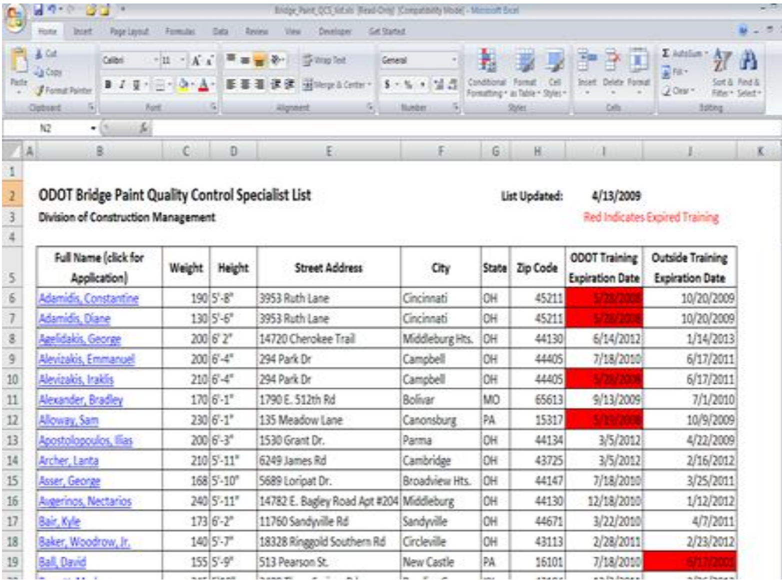
By my signature on this certificate, I certify that I have attended and understand the requirements of structural steel painting.

Figure 514.03 – Example of required bridge painting certificate

Quality Control (514.04)

Quality Control Specialist (514.04.A)

When applying coating systems, it is very important for the Contractor to constantly monitor the quality of the work. Due to his many duties and responsibilities, the foreman is not able to properly monitor the quality of the work. Therefore, the Contractor is required to assign one person the duties of a Quality Control Specialist (QCS). If there is no QCS on the project, the Contractor is not allowed to proceed with any production work. This person must be formally trained as a QCS. Prior to allowing the QCS to begin work, the Engineer should confirm that the QCS appears on the approved list maintained by the Office of Construction Administration (OCA). This list can be viewed on their website.



ODOT Bridge Paint Quality Control Specialist List — List Updated: 4/13/2009

Division of Construction Management — Red Indicates Expired Training

Full Name (click for Application)	Weight	Height	Street Address	City	State	Zip Code	ODOT Training Expiration Date	Outside Training Expiration Date
Adamidis, Constantine	190	5'-8"	3953 Ruth Lane	Cincinnati	OH	45211	[illegible]	10/20/2009
Adamidis, Diane	130	5'-6"	3953 Ruth Lane	Cincinnati	OH	45211	[illegible]	10/20/2009
Agelidakis, George	200	6' 2"	14720 Cherokee Trail	Middleburg Hts.	OH	44130	6/14/2012	1/14/2013
Alevizakis, Emmanuel	200	6'-4"	294 Park Dr	Campbell	OH	44405	7/18/2010	6/17/2011
Alevizakis, Iraklis	210	6'-4"	294 Park Dr	Campbell	OH	44405	[illegible]	6/17/2011
Alexander, Bradley	170	6'-1"	1790 E. 512th Rd	Bolivar	MO	65613	9/13/2009	7/1/2010
Alloway, Sam	230	6'-1"	135 Meadow Lane	Canonsburg	PA	15317	[illegible]	10/9/2009
Apostolopoulos, Ilias	200	6'-3"	1530 Grant Dr.	Parma	OH	44134	3/5/2012	4/22/2009
Archer, Lanta	210	5'-11"	6249 James Rd	Cambridge	OH	43725	3/5/2012	2/16/2012
Asser, George	168	5'-10"	5689 Loripat Dr.	Broadview Hts.	OH	44147	7/18/2010	3/25/2011
Augerinos, Nectarios	240	5'-11"	14782 E. Bagley Road Apt #204	Middleburg	OH	44130	12/18/2010	1/12/2012
Bair, Kyle	173	6'-2"	11760 Sandyville Rd	Sandyville	OH	44671	3/22/2010	4/7/2011
Baker, Woodrow, Jr.	140	5'-7"	18328 Ringgold Southern Rd	Circleville	OH	43113	2/28/2011	2/23/2012
Ball, David	155	5'-9"	513 Pearson St.	New Castle	PA	16101	7/18/2010	[illegible]

Figure 514.04.A – Example of bridge paint Quality Control Specialist list

The QCS is only to be involved in quality control work while production work is going on. The QCS is required to document the conditions during surface preparation and painting operations. The QCS is required to document the proper materials such as abrasive, paint, thinners and caulk are used to complete this work. The QCS is required to take readings and document the results concerning the profile of the blasted surface, condition of the surfaces to be painted, and the dry film thickness of the coatings. He is not to be a foreman or a member of the Contractor's production staff. He is not allowed to abrasive blast, apply coating, recover spent abrasive, mix paint, run errands, set up or maintain the traffic control, run or work on the equipment, etc. It is imperative that the QCS does not perform supervisory duties on the production staff. If the QCS is not performing his duties or is involved in any work other than quality control while production work is proceeding, the violation should be documented and remedied. It should then be determined, based on the disqualification guidelines in the specification, if the violation(s) warrants disqualification of the QCS. If the project staff feels that the

criteria for disqualification have been met, all documentation of the violation(s) is then sent to the Office of Construction Administration for review. The QCS should be allowed to continue work during this review process. If the Office of Construction Administration determines violations are substantiated, the QCS will be permanently disqualified from their duties as the QCS. The Office of Construction Administration will inform the project staff of the disqualification and the QCS should then be relieved of his duties as the QCS.

Figure 514.04. –Examples of improper surface preparation and painting over improper surface preparation

The Quality Control Specialist must be properly equipped with all the necessary testing equipment and be able to climb to all parts of the structural steel. He has the authority to stop the Contractor's work if necessary and to inform the foreman of all work that does not meet the requirement of the specifications.

Quality Control Points (QCP) (514.04.B)

The purpose of the quality control points is to mandate points in the surface preparation and painting process where the work can be inspected to ensure compliance with the specifications. It is important that the QCS signs off at all QCPs to verify that the work being inspected has been checked and is in complete compliance with the specifications. This sign-off puts the accountability for quality on the QCS. Only after receiving the QCS sign-off should the formal joint inspection begin. The Contractor's Quality Control Specialist (QCS) and the owners' Inspector (QA) must make independent checks and document the work at the Quality Control Points.

Testing Equipment (514.05)

The testing equipment listed in the specification must always be available for use by the Inspector. If the equipment is not available or not in good working order, all production work should be halted. Electric equipment must have batteries and bulbs to be considered in good working order. The tables and visual standards must be legible. There must also be film or photographic printing equipment available.

The list in the specification indicates the testing equipment that must be supplied by the Contractor, but it in no way limits the means by which the Inspector may inspect the work. This may include, but is not limited to, mirrors and larger lights. Note: magnification is not allowed to be used for the determination of SSPC-SP10 blast condition.

Figure 514.05. –Examples of bridge painting testing equipment, micrometer, sling psychrometer, Type 2 Non-Destructive Coating Thickness Gage, Recording Thermometer, Coating Thickness Calibration Plates

Work Limitations (514.06)

Abrasive blasting and painting is to be done between April 1 and October 31. The Contractor should plan his work to ensure that he is at an acceptable stopping point on October 31. This date is not to be waived without concurrence from the Office of Construction Administration.

Temperature (514.06.A)

Paint, except for inorganic zinc, must be applied when the temperature of the air within the enclosure, steel surface, or paint is 50 °F (10 °C) or higher and is expected to remain above 50 °F (10 °C) for the times noted in the table shown in 514.06.A. It should be noted that the times shown in the table are not recoat times. Recoat times are dictated by the manufacturer's written instructions, as a minimum and by the fact that applying the next coat can not have a detrimental effect on the paint system. They simply dictate the required time a particular temperature must be maintained after the coating is applied. At lower temperatures the paint will not cure, and in some cases, the paint may not resume curing when the temperatures warm up. It is important to pay close attention to the temperature in the early spring and the late fall. During the early spring and the late fall, the temperatures will be above 50 °F (10 °C) during the day, but the temperature will drop during the early evening hours before the paint has had enough time to properly cure.

The surface temperature of the steel should be taken in the area that is the coldest. This is not always the same on every structure (i.e., the fascia beam bottom flange). If you cannot tell where the coldest area is by running your hand over the steel, then it may be necessary to take readings in multiple areas.

For inorganic zinc, apply when the air, steel surface, and paint is 40 °F (4 °C) or higher.

Paint must be applied when the temperature of the steel is at least 5 °F (3 °C) above the dew point. Applying paint to steel at temperatures below 5 °F (3 °C) above the dew point could result in condensation on the surface of the steel. The dew point is to be determined by using the psychrometer and the psychrometric tables or comparable electronic or digital equipment for the measurement of dew point, accurate within 2 °F and within one percent relative humidity. The psychrometer should be used in the area to be painted or blasted (i.e., in containment near the beams). Note: if the barometric pressure is unknown when using the psychrometric tables, it is acceptable to assume a barometric pressure equal to 30 inches.

Abrasive blasting must be performed when the steel is at least 5 °F (3 °C) above the dew point. This is due to the possibility of condensation. The Contractor will be required to re-blast the steel if this requirement is not met.

Heated enclosures may be used to maintain the temperatures above the minimum specified temperatures. If combustion type heating units are used, the exhaust fumes must not be permitted in the enclosure, but should be vented away from the enclosure. If exhaust fumes are not properly vented, they can leave a deposit on the surface that could affect the ability of remaining coats of paint to properly bond to the steel or the previous coats of paint. These exhaust deposits could contaminate the freshly applied paint.

A recording thermometer should be used to ensure that the minimum temperature is maintained until the coating has cured. The thermometer should be placed close to the perimeter of the enclosure since this is the area subject to cooler temperatures. The paper graph generated by the recording thermometer should be copied and filed as part of the QCP documentation.

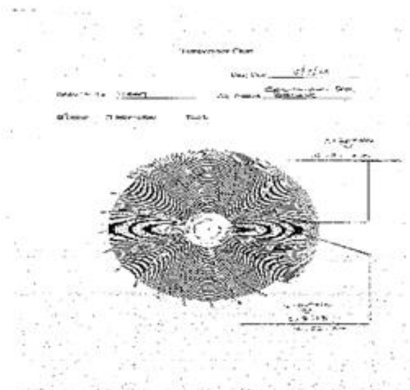


Figure 514.06. –Example of temperature record over 12 hour period

Pollution Control (514.08)

Special note should be made to address the handling storage and disposal of hazardous materials used during construction. Handling, storage, and disposal of any volatile products are of particular concern. These would normally include thinners, reducers, and solvents. Common types of volatile used in a painting operation may include methyl ethyl ketone (MEK), xylene, and toluene based materials.

When these types of items are on-site, it is important that the Contractor (1) submit MSDS sheets for each product, (2) maintain a current inventory sheet as to the quantity of each product (3) properly label usable product and hazardous waste created by the use of these products, (4) properly containerize and store these products and wastes so as to not create a health and safety hazard or exposure to the environment, and (5) waste containers must be managed in such a way that hazardous waste and non-hazardous waste are properly stored and kept separate.

The Contractor is required to take the necessary precautions to comply with pollution control laws, rules, or regulations of Federal, State, or local agencies and requirements of this specification. C&MS 107.19 Environmental Protection states to avoid polluting streams, lakes, ponds …. and avoid polluting the atmosphere with particulate and gaseous matter. The Contractor is required to comply with all current provisions of the Ohio Water Pollution Control Act and control the fugitive dust generated by the Work.

Figure 514.08. –Examples of pollution control measures

Safety Requirements and Precautions (514.09)

The Contractor is required to comply with all applicable safety requirements of the Ohio Industrial Commission and OSHA. The Contractor is responsible for taking the proper safety precautions to ensure workers in this environment are properly protected, (provide PPE, respirators, etc.). OSHA is enforcement agency for 29 CFR. The Contractor is required to provide material safety Data Sheets for all paints, thinners and abrasives used on the Project.

Inspection Access and Lighting (514.10)

Proper inspection cannot be accomplished unless the Inspector has access and proper lighting to see every surface to be painted.

To accomplish this, the Contractor is required to provide artificial lighting as necessary to supplement natural light with a minimum of 30 foot candles (325 Lux) at the surface of the steel for inspection, cleaning and painting. Prevent glare that interferes with traffic, workers and inspection. The Contractor is required to erect, and move scaffolding and all other equipment necessary to provide the Inspector access to closely inspect the work. On bridges with tall girders, placing scaffolding only under the girders is not adequate to provide proper access to the work. The Inspector should not climb around on the structural steel to inspect the work. If the Contractor fails to provide proper access to inspect the work, he should not be allowed to continue since proper inspection cannot be performed.

All scaffolding of any width, whether it is supported by a wire rope, mounted on the back of a truck, or supported by any other means, that is at least 21 inches (533 mm) or more below the surface to be painted, must have guard rail placed on all sides. It is not necessary for scaffolding that is less than 21 inches (533 mm) below the surface to be painted to have guardrail on the two sides bounded by the structural steel, but in this case, the scaffolding must be at least 28 inches (711 mm) wide.

One row of guardrail is required to be placed around the scaffolding when it is at least 21 inches (533 mm), but less than 43 inches (1092 mm) below the surface to be painted. Two rows of guardrail are required when the scaffolding is placed 43 inches (1092 mm) or more below the surface to be painted.

Remember you should never utilize a means of inspection access that you do not foresee as being safe.

Figure 514.10. –Examples of lighting and inspection access methods

Job Site Visual Standards (514.11)

Prior to production blasting, it is imperative that a test section be blasted and the job site visual standards be agreed upon and documented. A comparison to these standards will be utilized for the rest of the project to accept the surface preparation of the steel. The test section allows the Contractor to adjust his grit size/blast pressure combination to maximize his production while producing work that is within the specifications.

Note: in the event of a dispute, SSPC-VIS 1 will govern.

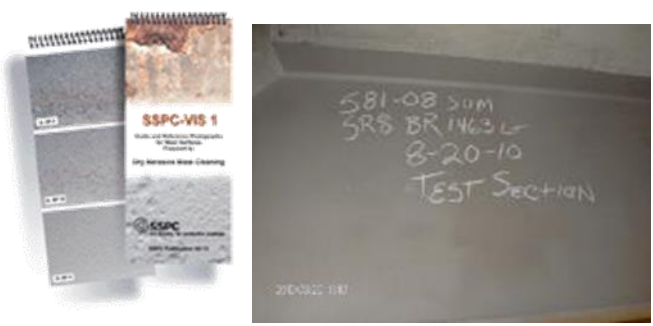


Figure 514.11. – SSPC-VIS 1 Standards and abrasive blast test section

Quality Control Point Photographic Verification and Documentation (514.12)

Document the work with photographs, especially at Quality Control Points 3, 4, and 11.

Surface Preparation (514.13)

One of the most important items of work is surface preparation. It is the most labor intensive and expensive phase of the work.

Solvent Cleaning (QCP #1) (514.13.A)

Prior to abrasive blasting, areas that contain asphalt cement, oil, grease, diesel fuel deposits, or other petroleum products and contaminants must be solvent cleaned. It is not necessary for the Contractor to solvent clean the entire surface of the steel to be coated, but only those areas that contain these contaminants.

Solvent cleaning per SSPC-SP1 requires the removal of foreign material prior to solvent cleaning. This can be done by one or a combination of the following: wire brushes, abrade, scrape, or clean with solutions of appropriate cleaners followed by a fresh water rinse.

Make sure that all solvent brought on-site are accompanied by a current MSDS for that product.

All solvent cleaning should be completed prior to the start of the abrasive blasting operation. If this is not accomplished, the abrasive blasting operation will not remove the asphalt cement, oil, grease, diesel fuel deposits or other petroleum products and contaminants but drive them into the steel.

In order to remove all residual solvent, asphalt cement, oil, grease, or diesel fuel deposits after the solvent cleaning, all solvent-cleaned areas are to be washed with water at a pressure of at least 1,000 psi (7 Mpa). In order to be effective, the nozzle must be held no further than 12 inches (300 mm) from the surface being washed.

Figure 514.13.A. –High pressure washing after solvent cleaning

Grinding Flange Edges (QCP #2) (514.13.B)

The specification requires that bottom flange edges of all beams are to be rounded to a radius of 1/8 ± 1/16 inch. This includes both rolled beams and girders. It is impossible

for an edge to be given a radius with one straight pass of a grinder. It requires multiple straight passes or the use rounding motion.

The radius is necessary to allow the application of the proper coating thickness. The sharp edge splits the spray of paint which results in only a thin coating of paint being deposited along that edge.

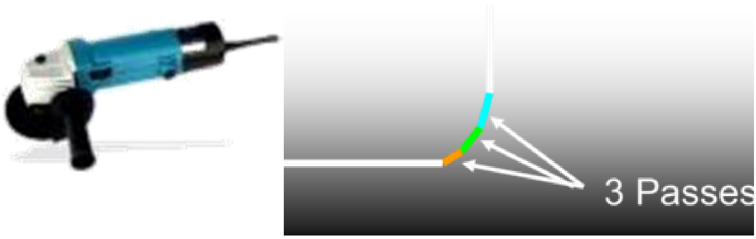


Figure 514.13.B. –Examples of grinder and ground flange edge

Abrasive Blasting (QCP #3) (514.13.C)

The prime coat contains zinc that protects the steel by reacting chemically with the surface of the steel. It is important to remove all foreign material from the surface of the steel to allow the zinc particles to come in contact with the bare steel. It is also important to roughen up or produce a profile on the surface of the steel. The profile aids the coating in adhering to the surface of the steel.

Steel surfaces to be painted are to be abrasively blasted to a near white metal, SSPC-SP10. SSPC-SP10 is generically defined as white metal with an allowable 5 percent staining. This allowable staining is a discoloration. It does not have any volume or noticeable thickness. It should be noted that SSPC-SP10 does not allow magnification for this determination. During inspection, pay special attention to areas that are more difficult to blast or areas that might be difficult to inspect. These areas include under cross-frames, around bolt heads and nuts, end dams, cross-frames next to or close to back walls, and any other areas of limited access. After the steel is blasted, it must be maintained in that condition until it is painted. The backside of cross-frame assemblies that are 3 inches (75 mm) or closer to backwalls may be commercial blast cleaned according to SSPC-SP6. SSPC-SP6 in generically defined as white metal with an allowable 33 percent staining. Again, this staining does not have any noticeable thickness. It is not a residue or film.

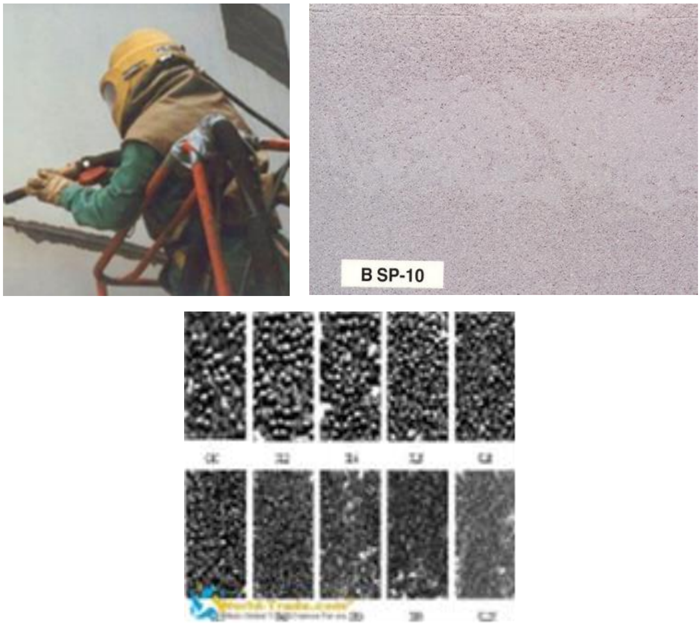


Figure 514.13.C. –Examples of abrasive blaster, SSPC SP-10 abrasively blasted surface and steel grit abrasives

The abrasive used in the field must be steel grit or a recyclable natural mineral, low dusting abrasive. Do not use silica sands, mineral slags, and other types of non-metallic abrasives that contain more than 0.5 percent free silica by weight, have a chloride content more than 25 ppm, and contain any organic material. The Contractor needs to supply material data sheets proofing that the mineral meets these requirements. The abrasive must be recycled to minimize the volume of waste material placed into landfills. The size or gradation of the grit is not specified, but must provide a profile of 1.5 mils to 3.5 mils. G40 and G50 size steel grits are commonly used by contractors for abrasive blasting in the field. The profile should be continuously monitored during the blasting operation since the size of the abrasive can be reduced due to being recycled, which can in turn reduce the size of the profile. The size of the profile can also be reduced if the air pressure at the blasting nozzle is reduced. The profile should be monitored by the use of extra-course replica tape and a spring micrometer. Make sure the replica tape is extra-course as this is the appropriate tape to measure our specified profile range of 1.5 mils to 3.5 mils. It is necessary to account for the 2.0 mil adjustment required for the thickness of the replica tape. This adjustment can be subtracted from every reading or the micrometer can be zeroed to -2.0 mils which results in a direct reading being taken from the micrometer.

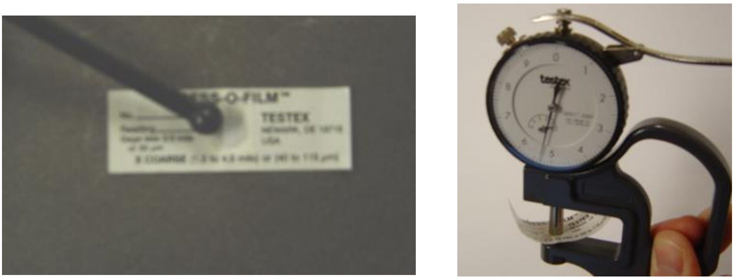


Figure 514.13.C. –Replica tape test and micrometer for determination of profile after abrasive blasting

Some abrasives, when received by the Contractor, can be contaminated with oil. Abrasives should be checked to ensure that they are free of oil. This check should be made by placing a small amount of abrasives in a jar with tap water. The abrasives and water should then be stirred or shook up. The top of the water should then be checked for signs of oil. If oil is detected, the abrasives should not be used.

Figure 514.13.C. –Example of jar for testing for steel grit abrasive oil contamination

Apply a prime coat to the steel that is blast cleaned in the field within 12 hours of the beginning of abrasive blasting. This requires that the time and location the blasting was started is accurately documented. This requirement is extended to 24 hours for shop blasted steel as it is a more controlled environment.

After abrasive blasting is complete, all abrasive and dust must be removed from the surface to be painted. Dust and abrasive must be removed from any adjacent painted surface or any adjacent structure. Dust and abrasive should be removed as soon as possible to prevent rust staining of adjacent surfaces. Rust stains can be very difficult to remove.

Figure 514.13.C. –Example of top of bottom flange where abrasive debris was not removed prior to paint application

Occasionally the compressed air used to propel the abrasive can become contaminated with oil or water from the compressor. This oil or water, if deposited on the surface of the steel to be painted, can be detrimental to the coating system. To prevent this problem, the Quality Control Specialist must blow air from a nozzle for 30 seconds onto a white cloth or blotter held in a rigid frame. This testing must be done at the start of each shift and at 4 hour intervals. If any oil, water, or other contaminates are present on the cloth or blotter, the blasting operation must be suspended until the problem is corrected. After the operation is corrected, and before the blasting operation is permitted to proceed, another test should be made to ensure that the problem has been corrected.

Figure 514.13.C. –Example of cloth blotter for testing oil contamination in air lines

Containment/Waste Disposal (QCP #4) (514.13.D)

The Contractor must comply with all federal, state, and local laws, rules, regulations, and ordinances.

Due to the possibility of the existing coating containing lead, chromium, cadmium, or arsenic, which are considered hazardous substances over regulatory concentrations, the Contractor is required to erect an enclosure to completely surround the area where the existing coating will be removed. Not only should the enclosure be placed vertically around the sides of the blasting operation, it should be placed on the ground under the blasting operation. In addition to containing potentially hazardous debris, the enclosure prevents fugitive dust from escaping into the environment.

Figure 514.13.D. –Enclosures for abrasive blasting and painting containment

The enclosure must be constructed of materials that are free of tears, cuts, or holes to prevent dust and lead from escaping into the environment. Holes, cuts, or tears that do occur should be repaired immediately. The perimeter of the enclosure should extend up between the beams to the bottom of the concrete deck. All seams should be fastened or lapped in a manner that ensures a seal and does not allow any openings between the screens or materials of the enclosure. The area where workers enter and exit the enclosure should be sealed.

In addition to placing an enclosure around the blasting operations, the Contractor must place ground covers under all equipment. This ground cover must be placed under the equipment for its entire length, not just a portion of its length. If the ground is not properly covered, there is the possibility that it could become contaminated. These ground covers are intended to reduce the impact of equipment leaking oil, fuel, or hydraulic fluid.

Figure 514.13.D. –Example of abrasive recycler improperly parked without ground covers

Figure 514.13.D. –Example of abrasive blasting equipment properly parked on ground covers

All abrasive blasting debris is to be picked up at the end of the day and must be stored in steel containers that have lids which lock. The Contractor will store the debris in 55 gallon drums with lids, not canvas bags. The lids have a ring around them that are capable of being locked. Normally, the Contractor will lock the lids by means of a bolt. This method is acceptable as long as there is a nut placed on the bolt and tightened by the use of a wrench. Many times the lids are not properly locked at the end of the day. They should be checked at the end of the day or the first thing in the morning to ensure that the Contractor is properly locking the lids. The use of tie wire, zip ties, or duct tape are not acceptable as a means for locking the lids. The locked drums must be stored at a location agreed to by the Engineer in a fenced enclosure or a dumpster that can be locked. If the Contractor chooses to use a large roll-off container to store abrasive blasting debris, the requirement for providing a means to lock the lid of the container must still be enforced. The blasting debris, whether it is determined to be hazardous or non-hazardous, must be stored in the locked drums while on the Project and when hauled from the storage location to the disposal site.

Figure 514.13.D. –Abrasive blasting debris stored in in locked drums in a fenced enclosure and a dumpster

Figure 514.13.D. –Example of abrasive debris sample being collected for determination if it is hazardous or non-hazardous material

Within the first week of production blasting, the Contractor must sample the abrasive blasting debris and have it sent out for testing. If the samples come back with lead, chromium, cadmium, or arsenic contents higher than the limits shown in the table in Section 514.13.D.1 of the Construction and Materials Specifications, the abrasive blasting debris is considered hazardous. If it is hazardous, contact the District Regulatory Waste Engineer and/or the Ohio Environmental Protection Agency Liaison in the Office of Construction Administration to get a Generator Number from the Ohio EPA that will be assigned to this hazardous waste. This generator number will need to be included with all manifests for this waste. Note that parts per million for these items is equivalent to mg/L. Blasting debris that is considered hazardous must be hauled away from the project site by a firm licensed to haul hazardous waste to a facility that is licensed to accept hazardous waste. Once the Project is completed, the Ohio EPA needs to be informed so that they may close the hazardous waste generator number. Non-hazardous waste must be hauled away from the project site by a firm licensed to haul solid waste to a facility that is licensed to accept solid waste. The Contractor must dispose of the abrasive blasting debris within 60 days after it is generated. The 60 days starts as soon as the Contractor generates the debris, not after the completion of the abrasive blasting operation. If the debris remains on the project site over 90 days, the state and the Contractor could be cited by the Environmental Protection Agency. On smaller structures, the debris can be removed in one operation. On larger structures where the abrasive blasting operation extends over a period of several months, it will be necessary to make several trips in order to comply with the 60 day limit. If after 60 days, the Contractor has not properly disposed of the debris, all abrasive blasting and painting of the structural steel on the project must immediately cease until the waste is properly disposed. At this time, the Department must cease processing all pay estimates and send notification to the Contractor’s surety that he has breached the Contract.

The Contractor is responsible for fines or liens assessed by any governmental agency that has jurisdiction over the disposal of this hazardous waste material and to decontaminate or dispose of all collection and containment equipment according to EPA guidelines.

Washing Shop Primer (514.14) **(QCP #7)**

For IZEU system with shop applied Inorganic Zinc, the Field Painting Contractor must wash shop primed structural steel after it is erected and the concrete deck is placed and within 30 days of applying the intermediate coat. Wash the steel with potable water. Use equipment capable of delivering the water at a nozzle pressure of at least 1000 pounds per square inch (7 MPa) and at a rate of not less than 4 gallons (15 L) per minute. The Contractor shall provide the Engineer with equipment specifications that verify both the delivery pressure and rate. The Contractor is required to provide gauges on the equipment to verify the pressure during operation. Hold the nozzle a maximum of 12 inches (300 mm) from the surface being washed. The surface is clean when clear rinse water runs off the structure. After rinsing the surface, inspect for remaining dirt and rewash dirty areas until clean. Do not pollute waters of the state with waste water.

Figure 514.14. –Containment for field washing of shop primed steel

Handling (514.15)

Note that the date of manufacture does not show up on all container labels. Some manufacturers show a code number in lieu of a date of manufacture. You will need to call the manufacturer and give them this code number and they will in turn give you the date of manufacture. All paint and thinner shall be delivered in original unopened containers with labels intact and provide the Engineer with shipping invoices for all painting materials used on the Project. Thinner containers shall be a maximum of 5 gallons (19 L). The labels should clearly show paint identification, component, color, lot number, stock number, date of manufacture, and information and warnings as may be required by Federal and State laws. The paint is required to be stored at the temperature recommended by the manufacturer and in a storage facility that prevents theft. Do not use paint that exceeded its shelf life, that has livered, gelled, or otherwise deteriorated during storage. Properly dispose of unused paint and paint containers.

Mixing and Thinning (514.16)

Prior to applying paint, it is necessary to thoroughly mix all the ingredients together. This is to be accomplished with a high shear mixer. Paddle mixers are not allowed since they will not adequately mix the different ingredients together. Do not use compressed

air to cause a stream of bubbles in the paint and paint shakers since it will not properly mix the ingredients.

During the application of the primer, it is important that it be continuously mixed. If it is not continuously mixed, the zinc particles in the primer will settle to the bottom of the container and will not be applied to the structural steel. To ensure that the mixing process is not interrupted, it is important that the mixer be an automated mixer, not a hand held mixer.

Thinning of the paint is typically not required. However, if the Contractor elects to thin the paint, it is important that it be thinned with the correct type and volume of thinner. To ensure that the Contractor is using the proper type of thinner, only use thinner recommended and supplied by the paint manufacturer. The maximum rate of thinner is to be as per the manufacture's printed instructions. If the paint manufacturer's printed instructions do not list a maximum proportion of thinner, the manufacturer should be contacted to obtain their recommendation. Note: the manufacturer may recommend different thinners based on humidity or temperature. All thinning should be done in the presence of the Engineer or Inspector.

In an effort to ensure that the thinner the Contractor is using is the thinner recommended and supplied by the manufacturer, only use thinner that has been supplied to the project in unopened containers with the labels intact. The amount of thinner used from each container should be monitored to prevent refilling of the container with other types of thinner.

The above restrictions do not apply to the thinners that the Contractor uses to clean his equipment. Be aware that methyl ethyl ketone (MEK) is sometimes used as both a reducer and a cleaner.

Use the mixture within the pot life specified by the manufacturer and dispose of unused portions at the end of each workday.

Figure 514.16.A –Example of high shear mixer equipment

Figure 514.16.B –Paint being mixed in project paint truck

Coating Application (514.17)

Paint is applied to provide the specified coating thickness by the use of brush and spray methods. Rollers can cause bubbling and other irregularities in the coating. Use daubers, small diameter rollers, or sheepskins to paint the following areas of difficult access: (1) where cross-frame angles are located within 2 inches (50 mm) of the bottom flanges, (2) where end cross-frames are within 6 inches (150 mm) of the backwall, (3) where there is less than 6 inches (150 mm) between the bottom of the bottom flange and the beam seat, and (4) other areas as determined by the Engineer. Apply primer and intermediate paint per 708.01 and 708.02 to cover all visible steel surfaces. If gaps or crevices remain between adjacent coated steel surfaces after applying the intermediate coat, caulk according to 514.19.

Figure 514.17.A –Example of paint rollers, and daubers

Figure 514.17. –Example of area of difficult access, between bottom of cross frame angle and top of bottom flange

Application Approval (513.17.B)

The specification states that each spray operator shall demonstrate to the Engineer or Inspector the ability to apply the paint as specified. This allows the project staff to remove a painter that is unable or unwilling to produce work within the specification requirements.

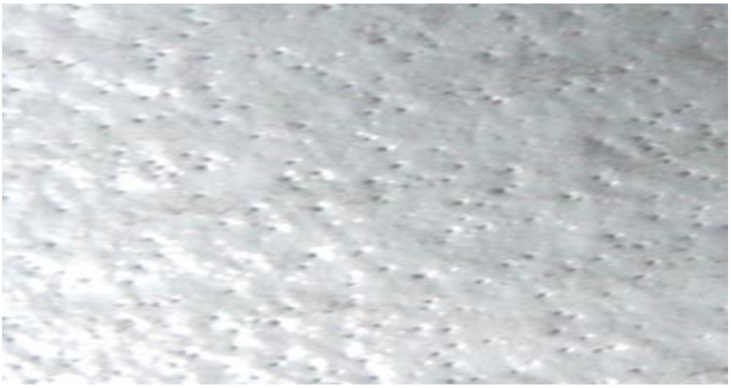


Figure 514.17.B –Example of paint application defect, pin holes

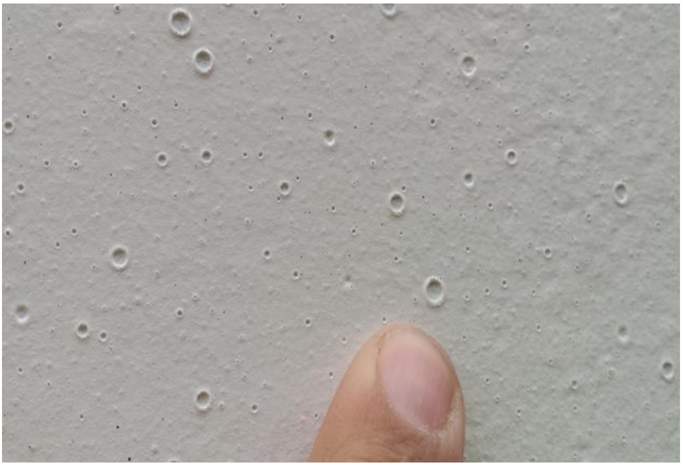


Figure 514.17.B–Example of paint application defect, outgassing

Additional Information Pertaining to Shop Applied Paint (514.17.C)

In the shop, the fabricator is required to apply a prime coat to all structural steel surfaces by brush or spray methods, including insides of holes, behind stiffener clips and contact surfaces of connection, and splice material that is to be fastened with bolts in the shop or field. If there are thick films of inorganic zinc primer, they are to be reduced by screening, sanding, or sweep blasting. If the primer paint cured longer than 24 hours, apply a re-coating of primer paint according to the paint manufacturer's printed instructions. Abrasive blast and re-apply the primer to the affected area if "mud cracking"

occurs. If "checking" occurs, abrasive blast and reapply the primer or remove the "checking" by screening and evaluate the area by adhesion testing.

Figure 514.17.C–Example of shop applied paint application defect, mud cracking

Figure 514.17.C–Example of shop abrasive blasting operation

If specified in the plans, the fabricator is to furnish all necessary labor, materials and equipment to apply a three - coat paint system to Item 513 Structural Steel in the shop and the field painter touch up areas in the field.

If there is any damage to the paint system caused during storage, transportation, erection, bolting, welding, forming, concrete placement, and form removal operation, it is to be repaired according to C&MS 514.22. Repair damage to the galvanized coating on the nuts, bolts and washers, in the field due to the bolt tightening or welding operations. Exercise extreme care while handling the steel during erection, and during subsequent construction of the bridge. Insulate the steel from the binding chains by softeners and pad all hooks and slings that are used to hoist/erect the steel members.

For bolted connections, the fabricator is to coat the faying surfaces of bolted splices with inorganic zinc primer in the shop. After erection is complete, field apply the final coatings of epoxy intermediate coat and urethane protective coats to overlap the shop coatings shown in Figure 1 with the field coats shown in Figure 2. For bolted crossframes, leave a minimum of one inch step back from faying surfaces, for epoxy intermediate and an additional one inch for urethane top coat.

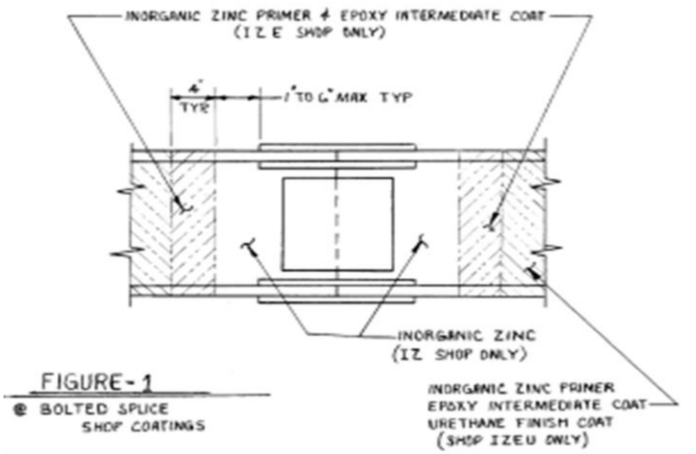


Figure 514.17.C–Example of shop painted Inorganic zinc faying surfaces with step backs

After installation, solvent clean all galvanized nuts, bolts, and washers. Remove any contaminants on the nuts, bolts and washers, prior to the application of paint. Repair any damaged galvanized coating and remove any corrosion prior to the application of organic zinc by brush. Then apply the epoxy coat and the urethane coats. Remove any oil, grease, asphalt cement, concrete or other contaminants from the surface of the IZEU system painted structural steel.

Figure 514.17.C–Example of nuts and bolts to be cleaned before field painting

Surface Cleanliness (513.17.D)

All surfaces to be painted shall be free of dust, dirt, and moisture. If these or other contaminants are left on the surface they can cause multiple types of defects, including adhesion failures and accelerated rusting. Simply blowing down with compressed air is not always sufficient. It is sometimes necessary to wipe the surface down, use a vacuum

system, or some other means to adequately prepare the surface to receive paint. This cleanliness requirement includes both the blasted steel surface as well as previously applied coats of paint.

Time Limitations

Apply a prime coat to steel that is blast cleaned in the field within 12 hours of beginning abrasive blasting. This requires that the time and location the blasting started is accurately documented. This requirement is extended to 24 hours for shop blasted steel as it is a more controlled environment.

The maximum elapsed time allowed between the application of any portion of the prime coat and the application of the intermediate coat is 30 days. The maximum elapsed time allowed between the application of any portion of the intermediate coat and the application of the finish coat is 13 days. The maximum recoat times shall not exceed the maximum recommended times by the manufacturer. Extending the time beyond the above mentioned time could adversely affect the bond of the coating. No additional time is allowed due to weather related delays. Any coat that has been allowed to cure more than the above listed time is to be removed and the steel re-blasted to SSPC S-P10.

Brush Application (513.17.E)

The painter is required to apply the paint to produce a smooth coat. To ensure coverage, apply wet stripe coats using brushes, daubers, small diameter rollers or sheepskins to all edges, outside corners, crevices, welds, rivets, bolts, nuts, and washers, in addition to the spray application of each individual coating. Apply stripe coats of primer after spray application of primer. Apply stripe coats of intermediate and finish coats before spray application of the respective coats. Apply additional paint as necessary to produce the required coating thickness.

Figure 514.17.E–Example of brush and surfaces, (edges and bolts), for brush application

Spray Application General (513.17.F)

The painter is required to Keep spray equipment clean so that dirt, dried paint, solvents, and other foreign materials are not deposited in the paint film. Apply paint in a uniform layer with overlapping at the edges of the spray pattern. Within a spray pattern area, hold the gun perpendicular to the surface and at a distance that will ensure a wet layer of paint is deposited on the surface. Release the trigger of the gun at the end of each stroke.

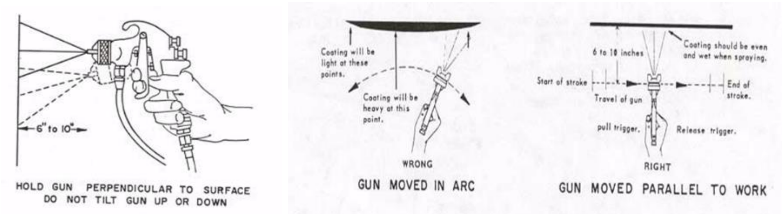


Figure 514.17.F–Examples of spray application techniques

Conventional Air Spray- Coating atomized by a stream of compressed air and carried to the surface on a current of air. Both air and paint enter the gun through separate hoses, are mixed and driven through the air cap in a controlled spray pattern.(Adjustable spray pattern, high quality finish, but slow and a lot of overspray) **Production up to 8000 square feet per shift per painter.

Figure 514.17.F–Examples of Airless and Conventional spray applicators

Airless Spray- Coating atomized without the use of compressed air and carried to the surface by the power of the fluid pressure passing through the spray gun. Coating is pumped under high pressure to the airless spray gun where it is forced through a precisely shaped and sized orifice or spray tip. (Little overspray, heavier film builds, higher production rates, no pressure pot, but need to change tips to adjust spray). **Production up to 12,000 square feet shift per painter.

Enclosure

During spray application of the paint, the operation is to be totally enclosed. The enclosure must be identical to the enclosure used during the abrasive blasting operation. Failure to properly utilize the enclosure could result in overspray damage to private property, including automobiles, the ground, public property, vegetation, streams, lakes, etc. The enclosure is not required if the paint is being applied by brush or roller.

Figure 514.17.F–Example of enclosure for blasting and painting of truss structure

Prime, Intermediate, and Finish Coat Application (QCP #5, # 8, and # 10) 514.17.G.

Each coat of paint is to be applied as a continuous film of uniform thickness. It is to be free of all defects, such as holidays, pinholes, mud cracking, checking, runs, sags, etc. Runs and sags are normally prevalent around bolts and areas of limited access. This is sometimes due to the fact the Contractor tries to paint these areas using only a spray gun (i.e., without the use of a brush). These defects should be corrected after each coat is applied. If not, the defect will just translate into the next coat and the repair will be more extensive.

Figure 514.17.G–Example of application defects, runs and drips

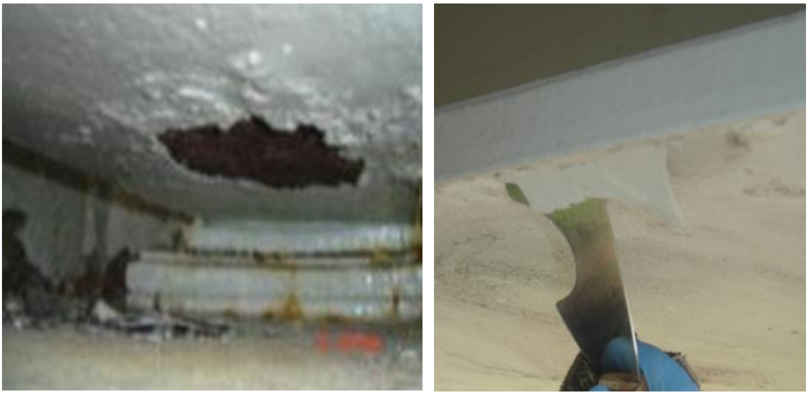


Figure 514.17.G–Examples of application defects, flaking paint

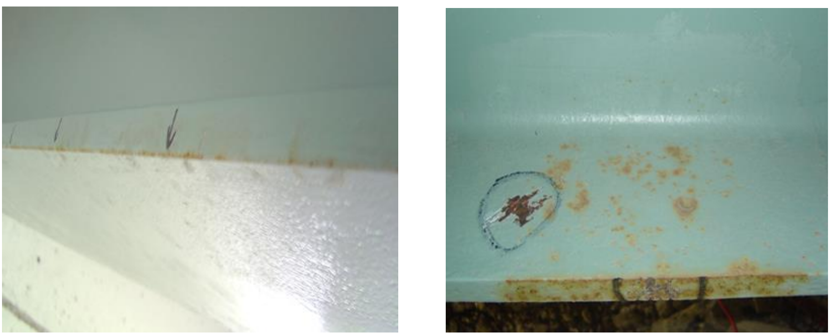


Figure 514.17.G–Examples of application defects, edges and bulk heads not painted properly

Do not exceed the following time intervals.

1. If the prime coat is organic zinc, the maximum time between the prime and intermediate coats is 30 days.
2. There is no maximum time between the prime and intermediate coats for an inorganic zinc primer.
3. The maximum time interval between intermediate and finish coats is 13 days.

Many time holidays in the form of pinholes are difficult to detect. The best way to view pinholes is with the aid of a flashlight. The flashlight should be placed to shine a beam of light parallel to the painted surface. If pinholes are present in the top coat, they will appear as small white specs about the size of the end of a needle. If they are present in the intermediate coat, they will appear as small dark specs.

If you are painting over an inorganic zinc primer, you should play close attention to pinholes appearing in the intermediate coat. The inorganic zinc has an inherent characteristic of "outgassing" due to its porous nature. The released gas pushes up through the intermediate coat and causes the pinholes. To avoid the majority of pinholes

in this situation, the Contractor should properly apply one or multiple mist coats of intermediate paint prior to the remaining full application.

Repairing pinholes can be very difficult. Applying another coat of paint over the pinholes will only result in the pinhole reflecting through the additional coat of paint. It is the Contractor’s responsibility to repair the pinholes. The best way to correct pinholes is by removing the coating down to at least the prime coat of paint. If the prime coat is not removed, measurements should be taken to ensure that the required minimum thickness of prime paint is still present. If the Contractor elects to leave the prime coat, he will probably remove the topcoats with sand paper. If a large area needs to be repaired, it will probably be more prudent for the Contractor to abrasively blast the coating down to bare metal and reapply it.

If there are some concerns about the quality of and individual coat or the paint system, the Engineer may request that the Contractor perform one or both of the following test to determine the hardness and or the adhesion of an individual coating or the coating system:

1. Determine the hardness of an individual coat or the coating system by performing a Pencil Hardness Test according to ASTM D 3363. Meet or exceed scale of hardness HB for the coating.

2. Perform Adhesion Testing according to ASTM D 4541, Type 4. Meet or exceed 400 psi adhesion between coats or between the paint system and the substrate.

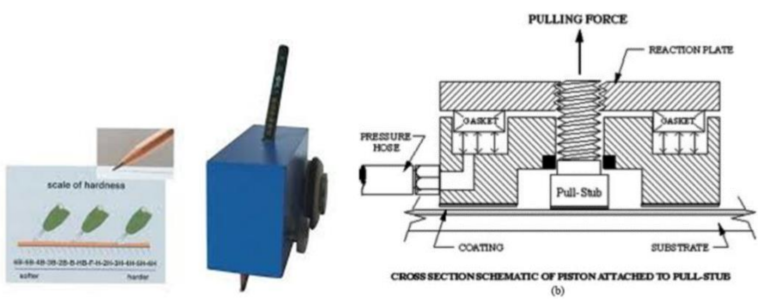


Figure 514.17.G–Pencil Hardness tester and adhesion tester illustration

The Contractor is required to stencil the Completion Date (month and year) of the finish coat and the letters of the applied paint system on the steel in 4-inch (100 mm) letters.

Figure 514.17.G–Stencil of type and completion date of painting of structure

Removing Fins, Tears, or Slivers (514.18)(QCP #6)

This item is paid for by the man-hour. The quantity of man-hours eligible for payment should not include the superintendent or the QCS, but only the personnel who actually perform the work. Use a grinder to remove all fins, tears, slivers, or any other burred or sharp edges that become evident after applying the prime coat. Retexture ground surfaces to produce a profile from 1.5 to 3.5 mils (40 to 90 μm) and reprime ground surfaces before applying the intermediate coat.

Figure 514.18.–Example of grinder and fins, tears and slivers

Caulking (514.19)(QCP #9)

After the intermediate coat cures and before applying the finish coat, caulk gaps or crevices up to ½ inch wide. Caulking is used to seal gaps around the perimeter of adjacent steel plates and angles. This void is caused by rust forming between the plates or angles and forcing them apart to the extent that it is not possible to seal the void with paint Allow for the cure of the caulk, per the Manufacturer's recommendations prior to the application of the finish coat.

Figure 514.19–Example of caulk and locations required to be caulked

Dry Film Thickness (514.20) (QCP #5, # 8, and # 10)

Prior to measuring coating thickness, using a Type 2 magnetic gage, it is necessary to determine the effect of the blasted surface of the steel on the paint gage. Since the steel receives a profile of 1.5 to 3.5 mils (40 to 90 μm), the paint gauge will read high. To compensate for this additional height, it will first be necessary to take a reading on the blasted surface immediately prior to applying the prime coat. Preferably three or more readings should be taken and averaged out. This average reading should then be subtracted from all paint film thickness readings. This reading is telling you how the gage is interpreting the uneven surface of the blasted steel.**This IS NOT the anchor profile. Remember the anchor profile is determined by the use of replica tape and a micrometer.**This substrate correction factor is needed to adjust the gage to compensate for the uneven surface when the blasted surface is not accessible. This will occur once the first coat of paint is applied. Use shims to adjust gage for blasted surface if it is exposed. Take reading through shim. Adjust readout with “+/-” to match shim thickness. As an alternate to subtracting the thickness attributed to the surface profile from the paint film thickness, recalibrating the paint gage to read 0 mils on the blasted steel is also acceptable. The Contractor must provide include a Certificate of Calibration for the gag

Figure 514.20.A–Calibration Certificate, taking reading of blasted surface, and using known thickness shim to adjust Type 2 Magnetic Dry Film Thickness gauge for blasted surface prior to taking measurements of coating thicknesses

It is important to determine the coating thickness by taking the average thickness in the manner specified in the specifications. This involves taking five spot readings for each type of member (e.g., webs, bottom of top flange, top of bottom flange, bottom of bottom flange, cross-frames, stiffeners, etc.) over an area of 100 square feet. A spot reading is comprised of the average of three closely-spaced, individual readings. The average reading for this 100 square foot area may be used to represent up to 1,000 square feet of painted steel surface. The number of 100 square foot areas to be measured is determined by the area of steel painted. Form CA-S-2 should be used to tabulate the results.

Bridge Area = 0 - 300		

Bridge Area = 301 - 1000		

Bridge Area = 1001 to Infinity							
301 - 1000			1001	2001	3001	4001	5001
6001	7001	8001	9001	10001	11001	12001	13001
14001	15001	16001	17001	18001	19001	20001	21001

Inspection Location (see above)					
Span /Beam Line					
Reading #1					
Reading #2					
Reading #3					
Total of 3 Readings:					
Spot Average (Total / 3):					
	Sum of Spot Averages =				
	Area Average (Sum of Spot Averages / 5) =				

Figure 514.20.B–Excerpts from CA-S-2 form for determining number of tests to take and for recording dry film thickness readings and determining spot and area averages of these readings.

The spot averages are to be within 80 percent to 150 percent of specified minimum and maximum thicknesses, respectively. The area averages must fall within the actual specified minimum and maximum values.

There are provisions in the specification for addressing areas with a film thickness greater than the maximum specified. If a Contractor chooses to have the certified testing done as described in the specification, make sure the preparation of the panels mirrors the actual field installation of the paint in question. This includes paint thickness, multiple or mist coats, as well as type and quantity of thinner used. The Painting Contractor and Paint Manufacturer must submit certified test data and a written statement from the paint manufacturer stating that the excessive thickness will not be detrimental to the overall coating system to the Office of Construction Administration. If they don't submit this information, or the Office of Construction Administration does not accept the excessive coating thickness, the painting contractor must remove the coatings down to the bare steel per C&MS 514.22.

Figure 514.20.C–Inspector taking dry film thickness reading

Final Inspection (514.21)(QCP #11)

The purpose of the final inspection is to ensure that the quality of surface preparation and coating thickness are witnessed by a third party. This third party could be the project engineer, area engineer, or other District personnel.

The Engineer will select the locations and take the dry film thickness (DFT) readings. The Contractor will then perform the removals. The 9 square inches required by the specification is the minimum "clean" area of steel. It normally takes about a 6 inch by 6 inch square to get 9 square inches of "clean" steel. The Contractor will use Methylene Chloride and MEK as a chemical stripper/solvent. These chemicals are both corrosive and the safety precautions found on the MSDS sheets and manufacturer's literature need to be followed.

A common stripping procedure is as follows:

1. Spray surface with stripper.
2. Wait 5 to10 minutes to allow the stripper to work.
3. Use a scraper or putty knife to remove top coat and intermediate coat. It may take multiple applications of the stripper to accomplish this.
4. Spray the exposed primer with stripper and allow time to work.
5. Scrape off majority of primer. Be careful not to damage the substrate.
6. Repeatedly apply solvent or stripper and rub with a rag until steel substrate is clean.

This process takes about 15 minutes for each stripped area. Work on other areas while the stripper sits. It is imperative that the Engineer observe the removal process as the stripper and a scraper can remove lead paint as well as new paint.

The engineer will evaluate stripped area and document his findings on Form CA-S-18.

If the surface of the stripped area is not found to be in complete conformance with the Contract documents, additional locations may be tested. Note: the Contractor is only paid for stripped areas that are found to be in conformance with the Contract documents.

Once all the required tests have been performed, and the progressive project data has been reviewed, the Engineer should complete Form CA-S-19.

Destructive test locations shall be repaired per 514.22.

Figure 514.21–Example of scrapers and stripped area for Final Inspection of surface preparation and dry film thickness

Repair Procedures (514.22)

If it is necessary to make repairs, the repair should blend in with the surrounding area so that it is not evident that a repair was made.

If the area to be repaired does not cover a large area, abrasively blasting the surface may not be advisable since it will damage the surrounding coating that does not need to be removed. In place of using abrasives, the Engineer may allow alternate methods of preparing the surface. This might include the use of power tools with abrasive bits or hand tools. Whatever method is used, it is still necessary to prepare the surface in a manner that will give a surface profile of 1.5 to 3.5 mils (40 to 90 μm).

In order to produce a smooth transition, it is necessary to feather the adjacent coatings. This cannot be accomplished through the use of abrasives. The new coat of paint should only be applied to the same coat that was feathered (i.e., the prime coat should only be applied to the feathered prime coat, the intermediate coat should only be applied to the feathered intermediate coat, and the finish coat should only be applied to the feathered finish coat). Applying the finish coat to an existing finish coat that has not been feathered, or in any other way abraded, will result in finish with a dull, frosty appearance instead of a bright, glossy finish.

All work limitation and documentation requirements are in effect when surface preparation is performed and paint is applied.

515 Prestressed Concrete Bridge Members

Description (515.01)

This work consists of preparing shop drawings, furnishing and manufacturing prestressed concrete bridge members, testing, fabricator performed quality control, documentation, shop coating, and handling, transporting, storing, and erecting prestressed concrete bridge members. Prepare shop drawings and erect prestressed concrete bridge members, according to Item 501 and the additional requirements specified below. Shop coating shall conform to Item 512.

Fabricator Approval Procedure (515.02)

Fabricators are required to be prequalified according to Supplement 1079 as listed by the Department before the Contract letting date as evaluated by the Office of Materials Management.

Levels of Fabricator Qualification (515.03)

Each Fabricator will be classified by the Office of Materials Management at the highest level of the three levels of fabrication it is qualified to perform according to Supplement 1079 .

Figure 515.03–Precast Concrete Beam Bed at fabricators facility

General (515.04)

The Fabricator is required to produce all members according to Item 511, Bridge Standard Drawings PSID and PSBD except as otherwise modified within 513.

Fabricator Documentation Responsibility (515.05)

Fabricated concerete beams should have a TE-24 with the shipment. If fabricated concrete beam arrives without a TE-24, either the District Engineer of Tests or the Office of Material Management’s concrete section should be notified. A TE-24 in the project file provides verification that the concrete beam is accepted material and fabrication has been properly performed.

Shop Drawing (515.06)

The Contractor is required to provide shop drawings conforming to 501.04 that include: details, dimensions, dimensional tolerances, size of materials, lifting devices, inserts, reinforcing steel supports, fabricator incorporated reinforcing, piece mark diagrams for field connection and erection of any steel and all prestress members, and all other information necessary for the complete fabrication and erection of the prestressed

members. Show all items that will be incorporated into each prestressed member. Provide the detensioning procedure and pattern conforming to 515.16.

Prefabrication Meeting (515.07)

At least 3 days after the Department receives shop drawings, the Contractor is required to conduct a prefabrication meeting at the fabricator's facilities, or another location agreed to by all parties. The purpose of this meeting is to review any fabrication issues, including information on shop drawings, inspection, hold or witness points, unique fabrication items, special processes, and both the fabrication and project schedule.

Materials Approval (515.09)

The fabricator shall control, test, and validate material requirements for all materials either incorporated into the prestressed fabricated item or supplied under Item 515 as component parts to the fabricated items. The fabricator shall provide S 1079 documentation to the inspector at the time of final inspection.

Construction Methods (515.14)

The two bottom edges shall be beveled 3/4 inch (19 mm). Reinforcing steel and strands shall be installed according to the approved shop drawings. Strands shall be tensioned uniformly to the stress indicated on the shop drawings. Unless otherwise shown in the plans, do not install inserts or holes in the beam web within a distance of 1.5 times the beam height from the end of the beam .

Concrete (515.15)

Non-composite members' surface shall be finished with a burlap drag or other means to provide a uniform surface with a gritty texture suitable for waterproofing.

Composite members' surface shall be finished with a wire broom, in a transverse direction and penetrating the finished surface approximately 1/4 inch (6 mm) + 1/16 inch (1.5 mm) – 1/8 inch (3 mm) at a maximum spacing of 1 -1/2 inches (38 mm).

Fabrication Tolerances (515.17)

Sweep

Specified tolerances for sweep or horizontal curvature of a prestressed box beam or I - beam are listed in the Office of Structural Engineering's standard drawing for I beams. I-beams are 1/8 inch every 10 feet with a maximum of 1 inch.

Box beam tolerances are 3/8 inch maximum for box beams 40 feet or less; ½ inch maximum for box beams 40 to 60 feet; and 5/8 inch maximum for box beams greater than 60 feet.

Figure 515.17.A – Illustration of beam sweep and stored concrete beams

Camber

Camber is based on the design plan requirements and are generally within a tolerance of 1-inch maximum. Box beams also have a maximum side-by-side differential camber of 1/2 inch. The side-by-side differential may override the 1-inch maximum camber tolerance for an individual member. The side by side differential camber is not checked by Laboratory prestressed inspectors as the beams are not installed in their final position.

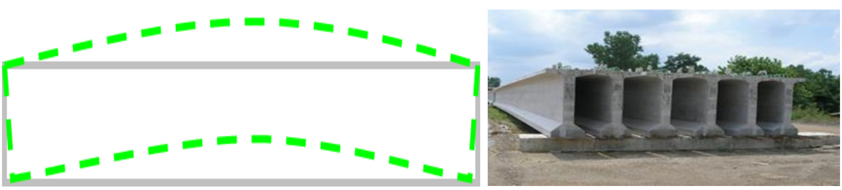


Figure 515.17.B - Illustration of beam camber and stored concrete beams

Phased construction can cause unique problems with camber. Camber is time dependent: as the members get older they will gain camber. If all beams are manufactured for a bridge at the same time but only half are shipped for an initial phase of construction there is a good probability that the second phase beams will have a higher camber than the first-phase beams. For box and I beam structures this additional camber may be able to be absorbed by thinning the haunch or variable depth deck. Field loading of the field-installed beams to reduce the camber is a method some Contractor's have used to deal with the camber growth. The best methods are for the Contractor to one, order the beams early enough so none of the beams are erected and loaded before they are six months or older, or two, coordinate their and the fabricator's schedules so that the fabricated age of the beams at time of erection is within 30 days of each other for all phases.

The Department will not accept for shipping, prestressed members with measured camber exceeding the Design Camber (Dt), used to establish the seat elevations, according to 511.07, by more than the Sacrificial Haunch thickness, until a corrective work plan has been approved by the Engineer. The plan shall be signed, sealed and dated by an Ohio Registered Engineer and shall include all revised plan information necessary to place the deck to the plan thickness. If the prestressed members are acceptable,

exclusive of the deviation from Design Camber, the Department will pay for all costs incurred resulting from measured camber exceeding Design Camber calculated for the actual beam age at the time of deck placement, as Extra Work, 109.05.

Handling, Storage, Transportation, and Erection (515.19)

Field Inspection

When prestressed members arrive on the site, they should be inspected for damage and quality of fabrication as thoroughly as time and conditions permit. Inspection should include areas that look like they were patched and cracking. Fine cracking at the ends of the beams, whether box beams or I beams, is not unusual and will tighten under erection and dead loading of the members. Cracking in other locations is not usual or acceptable. Any prestressed members should have a certification document (TE-24) with the shipment. Do not accept un-documented members. Notify the District Engineer of Tests or the Office of Materials Management Cement and Concrete Inspection Section.

Erection components for prestressed box beam members (i.e. tie rods, splices, nuts, etc) will be considered included under and covered by the fabricator's certification document. For I-beams the embedded components will be covered under the fabricator's certification document. If galvanized crossframes are used for prestressed I-beams, the prestressed fabricator will probably not supply a certification document; they will be provided by a steel fabricator with separate certification documentation (TE-24).

Damage

The nature and extent of any damage which may have occurred because of loading, transit, or unloading should be noted and reported to the Director along with the identifying piece mark or member. If corrective work is obvious, the Contractor should be advised immediately so that the responsible party will be notified and correction can be performed in the most advantageous location. For help on possible corrections, patching repairs, etc. contact the Cement and Concrete section of the Office of Material Management.

Special care should be taken when cutting shipping tendons which are sometimes necessary to allow transport of AASHTO Type 4 modified beams. The location of these tendons as well as the sequence and means of removal are determined by the fabricator. The relaxation in the beam that occurs when the tendons are "released" can induce stress cracking in the beam.


Figure 515.19.A - Example of precast beams damaged during transportation and erection

Storage

Prestressed members, if stored on the site, will be supported off the ground on blocking at their design bearing points. Assure that members are stored in a true vertical position.

Shop Coatings

Box beams should have had a silane treatment on the exterior beams or they also may be delivered with a colored coating (generally epoxy urethane) on the exterior members. I-beams do not require a silane sealer and will generally not be coated at the fabricator's yard

Check of Bearing Seats

A final check must be made of the elevation of bearing seats on the piers and abutments before erection of prestressed members is scheduled to begin. If bearing seats are found that need correction, it must be performed in the manner and to the tolerances described in the section entitled "Bearing Seats" in the 511 section of this manual.


Figure 515.19.B - Elastomeric bearing for precast concrete beams

Erection

The erection plan submitted by the Contractor should be reviewed with his representative in charge. The purpose of this review is to ensure that ODOT's interpretation of the plan is concurrent with the Contractor's intended course of action. Methods and equipment approved for erection of members must be used in handling during transportation to the bridge site and unloading.

The erection drawings, usually the "E" sheets of the approved shop drawings, will typically be used to locate the members on the bridge and may give special instructions for the erector to follow.

Deviations from the submitted erection procedure will not be permitted. If the erector proposes deviations in procedure that appear to have merit, they must resubmit their modified erection procedure per C&MS 501.

Required Erection Procedures

The specifications require that the Contractor submit an erection procedure for structural concrete members. If there is railroad involvement, the PE stamped plan needs to be reviewed and approved by the appropriate railroad. . For additional requirements refer to C&MS Item 501.05.


Figure 515.19.C – Setting precast concrete beams and cross bracing between concrete beams

Typical Erection Procedures Items

Typical items that should be included in the submitted erection procedure are:

1. A drawing of the complete framing plan showing each girder or beam section by "piece mark" and numbered in the order of proposed erection. A print of the erection sheet of the shop drawings may be used.
2. The number of pieces and load capacity of erection equipment to be used and method of lifting members.
3. Methods and details for supporting the first beams or girders at the abutments and piers in each unit.
4. Crossframe installation

Use Erection Checklist Form CA-S-20

Box Beam Grout Installation

Keyways should be grouted after erection of box beams. Generally, plastic rope or jute is installed into the bottom of the keyway to block the grout from flowing out. Assure that the installation is done properly. Box beam keys have failed because of improper jute installation. Grout should meet the material requirements of the Office of Structural Engineering's standard box beam drawings. OMM has an approved list of grout materials. The manufacturer's mixing instructions are required and it should be assured that the grout is properly mixed; vibrated into the joints; cured; and sampled for testing. Grouting should not be allowed if there is construction traffic or erection still going on.

The grout can be cracked by the vibration and deflection movements and make the keyways worthless. The design of the structure counts on the grout in the shear keys.

Do not allow traffic on the deck before the grout has obtained the required strength. This includes construction traffic.

Figure 515.19.D- Tie Rod ducts and grout keys and placing grout into key for precast concrete box beams

Galvanized Cross Frame Installation

Galvanized cross frame for prestressed I-beams should not be tightened down until the adjacent beams are set. While bolts are high-strength the connections are not friction type. The bolts should be well tightened but the turn of the nut method of installation is not required. If there are crossframe alignment problems do not allow I-beam field drilling until the Contractor has a method approved by the Engineer to determine where the reinforcing and the prestressing strands are and how to avoid drilling into it.

Do not allow the Contractor to elongate or enlarge slots in the steel cross frames.

516 Expansion and Contraction Joints, Joint Sealers and Bearing Devices

Description (516.01)

This work consists of fabricating, assembling, constructing, coating, and installing expansion and contraction joints, vertical extension of structural expansion joints, joint sealers, or bearing devices of the type and size specified.

Fabrication (516.02)

The Fabricator must be prequalified at least level SF for metal joint armor and metal bearings according to Item 513. The Contractor is required to submit mill test reports for structural steel, steel castings, bronze, and sheet lead certified according to 501.06.

Coating (516.03)

Steel bearings that are to be attached to structural steel are required to be coated according to Items 513 and 514. Steel bearings that are to be attached to concrete beams are required to be galvanized according to 711.02.

Coat metal parts of expansion joints with metalized 100 percent zinc wire. Prepare the surface to be coated and apply coating as required by The Society of Protective Coatings SSPC-CS-23.00(1). Apply coating to a minimum thickness of 6 mils.

Figure 516.03 – Painted pot bearing and metalized steel expansion joint armor

The allowable procedures for the repair of metalized and galvanized surfaces are described in C&MS Item 711.02, which refers to ASTM-A-780. The use of a galvanizing spray with zinc dust is not allowed. These unacceptable products go by the name of Spray Galv or Cold Galv. The main problem with these products is that they don't provide the galvanic protection that is required. Most of them are made out of tin and lead in place of zinc. When zinc and carbon steel are in contact, the zinc sacrifices itself to protect the steel. Conversely, when tin or lead are in contact with the steel, the steel sacrifices itself for the tin and lead.

Materials (516.04)

Structural steel is required to conform to 513, bearing bolts, anchor rods, swedged anchor bolts or bars to conform to 711.10, steel castings to 711.07, sheet copper to 711.15, bronze to 711.16, 711.17 and 711.18, sheet lead to 711.19, preformed elastomeric compression joint seal to 705.11, hot applied joint sealer to 705.04, neoprene sheeting to 705.13, preformed bearing pads to 711.21, elastomeric bearings to 711.23, preformed fillers to 705.03, and non-shrink, non-metallic grout to 705.20

Expansion and Contraction Joints (516.05)

It is important that the gap set between the armor plates of the joint be consistent along the entire length of the joint. The gap determined for the joint must be adjusted for temperature. The joint manufacturer will supply a table to help calculate this adjustment. This is especially true for more complex joints.

Figure 516.05.A –Steel armor for strip seal expansion joint

The characteristics of the structure (e.g., skew, crown, super elevation, sidewalk, etc.) can lead to a complicated installation of the joints. The Contractor should not weld anything to the joint or the reinforcing steel.

Joints like strip seal, compression, and modular, which incorporate a rubber seal into their design, need to have the seals installed per the manufacturer's written instructions. They should utilize tools that will not cut or puncture the seals. It is not acceptable to elongate or stretch the seal in order to make it narrow enough to fit in the joint gap.

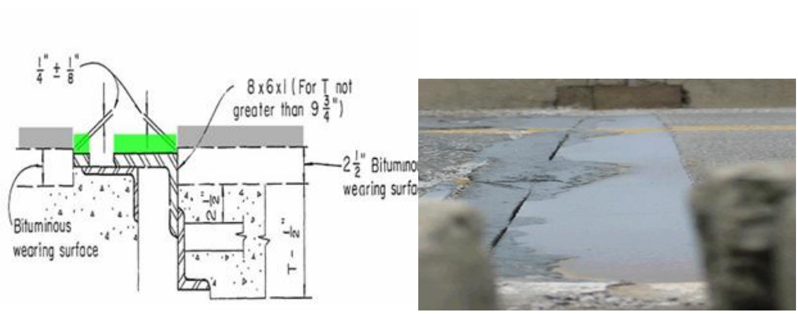


Figure 516.05.B – Illustration and example of sliding plate expansion joint

Figure 516.05.C Finger Joint and Modular Expansion Joint for large bridge movement

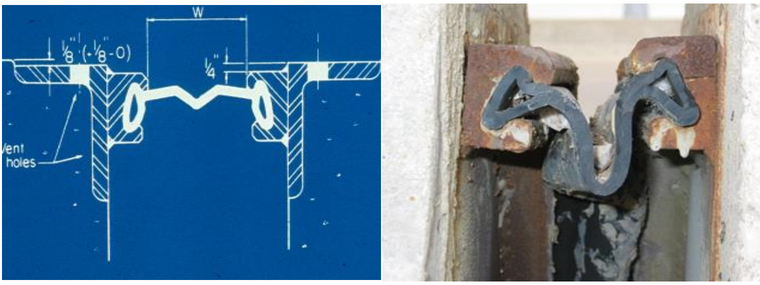


Figure 516.05.D–Illustration and example of strip seal expansion joint

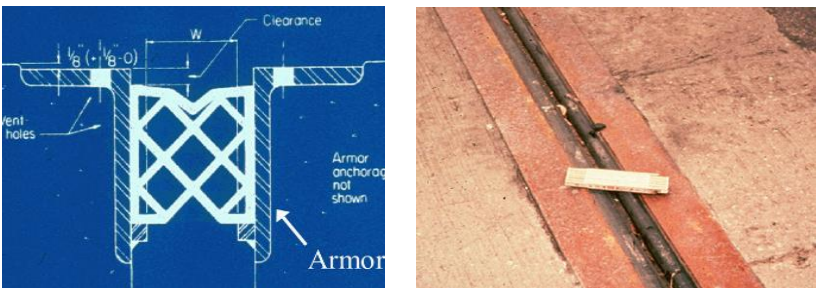


Figure 516.05.E – Illustration and example of compression seal expansion joint

For Integral and Semi-Integral Abutment Expansion Joint Seals, the Contractor must install a 3 foot wide neoprene sheet for waterproofing of the backside of the joint between the integral backwall and the bridge seat at locations shown in the plans. The neoprene sheeting is secured to the concrete with 1 1/4 inch by #10 gage (length × shank diameter) galvanized button head spikes through a 1 inch outside diameter, #10 gage galvanized washer. Maximum fastener spacing is 9 inches. Use of other similar galvanized devices, which will not damage either the neoprene or the concrete, will be subject to the approval of the Engineer. The neoprene sheeting shall be 3/32 inch thick general purpose, heavy-duty neoprene sheet with nylon fabric reinforcement.

There are listings on the Qualified Product List (QPL) for items covered in C&MS Items 705.11 and 705.03. This list is maintained by the Office of Materials Management.

Joint Sealers (516.06)

In addition to the protection required in the specification, the Contractor must ensure that the sawcut is not exposed to traffic prior to receiving the sealer without protecting the sawcut. If the sawcuts are not protected, rocks or other hard debris can get lodged in the top of the sawcut, and when driven over the rock, will spall the edges of the sawcut. For poured joint sealants, the Contractor is required to saw groove within four days of paving, not allow traffic on groove prior to sealing, and the groove should be clean and dry before applying sealant

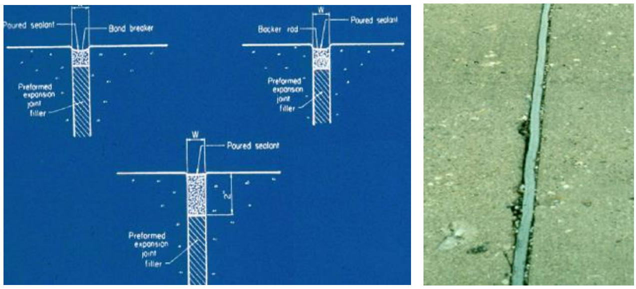


Figure 516.06 – Illustration and example of poured joint seal

Bearing Devices (516.07)

Note: if the beam seats are low and elastomeric bearings are utilized, it is not acceptable to use steel shims under the bearing to make up the elevation difference. Elastomeric bearing pads are to set directly on the concrete surface. If the beams seats are sealed with an epoxy or non-epoxy sealer prior to setting the bearings, do not apply sealer to the concrete surfaces under the proposed bearing locations. If these locations are sealed, the Contractor must remove the sealer to the satisfaction of the Engineer before setting the bearings. Contact the Office of Structural Engineering for guidance. Many of the bearings have beveled load plates. This is done to account for the grade in the structure. Make sure the beveled bearings are oriented correctly. Sometimes it is difficult to tell simply by looking at the bearing, as the difference may only be a 1/4 inch. If the short side of the bearing is not already marked by the fabricator, measure the bearing and mark it in the field. The Contractor is required to install each bridge bearing to within ± 0.125 in. of its marked centerlines in the horizontal plane and oriented to within an angular tolerance of 0.20 rad.(1 degree).

Accurately set, the level and alignment of elastomeric bearings, bearing plates, and bolsters. Set bearing plates and bolsters on 1/8-inch (3 mm) thick sheet lead, conforming to 711.19

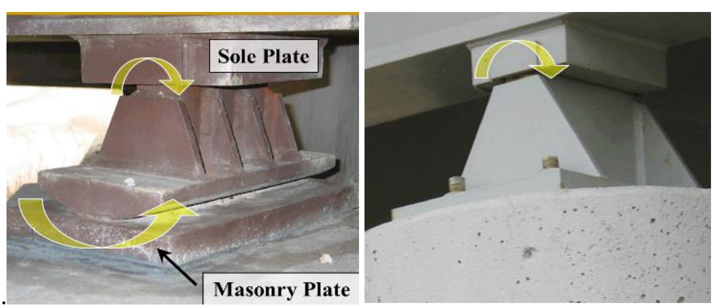


Figure 516.07.A–Rocker (expansion) bearing and Bolster (fixed) bearing

Figure 516.07.B – Fixed Pin (fixed) bearing and Sliding Plate (expansion) bearing

The Contractor must position rockers, elastomeric bearings, and rollers so that, when the completed bridge is at 60 °F (16 °C), the rockers and elastomeric bearings are vertical and the rollers are centered on the base. If the steel is erected at an ambient temperature higher than 80 °F or lower than 40 ºF and the bearing shear deflection exceeds 1/6 of the bearing height at 60 ºF ± 10 ºF, the Contractor must raise the beams or girders to allow the elastomeric bearings to return to their un-deformed shape at 60 ºF ± 10 ºF.

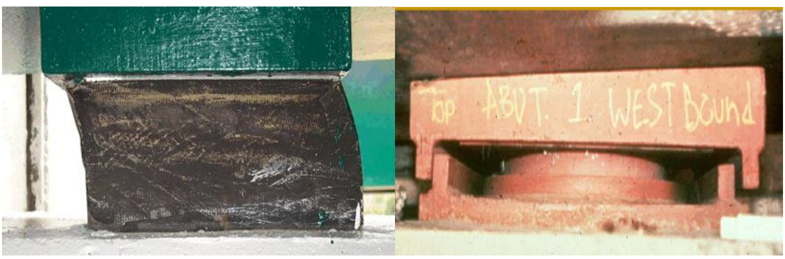


Figure 516.07.C- Elastomeric (expansion) bearing and Pot (expansion) bearing

The Contractor must set anchor bolts for bearing devices that are clear of the beam or girder flanges, in the concrete after erecting the main structural steel, except as specified below for bearing devices at abutments. Place reinforcing steel in the bridge seat to not interfere with the drilling of anchor holes. Accurately set anchor bolts in the holes and embed the anchor bolts in non-shrink, non-metallic grout. Until the anchors' are installed, prevent water from entering and or freezing in the anchor bolt holes. Permanently fasten bearing devices to the abutments, steel beams, or girders after backfilling the abutments to within 2 feet (0.6 m) of the top of the bridge seat.

Where the load plate of an elastomeric bearing is to be connected to the structure by welding, the Contractor must control the welding so that the plate temperature at the elastomer bonded surface does not exceed 300 °F as determined by use of pyrometric sticks or other temperature monitoring devices.

Figure 516.07.D – Weld of Elastomeric Load plate and use of Thermperature stick for monitoring temperature of weld

When galvanized bearings are welded to the embedded load plates on prestressed beams, the weld area must be repaired according to C&MS Item 516.03.

There is a listing on the Qualified Product List (QPL) for items covered in C&MS Item 711.21. This list is maintained by the Office of Materials Management.

Bearings-Rest or Refurbish

Contractor is required to submit Jacking Plan per C&MS 501.05.B.5. Use temporary supports. Do not use jacks alone to support the structure except during the actual jacking operation. The Contractor needs to provide Temporary Lateral Supports, maintain a maximum differential jacking of ¼” between adjacent beams and maintain a maximum differential jacking height of 1” between any adjacent abutments or piers. The Contractor needs to place jacks and load plates at least 2” from the edges of any concrete substructure seats.

Do not weld temporary members to permanent steel members or damage permanent structural concrete.

Figure 516.07.E - Use of jacking pump, and bracing

Figure 516.07.F - Example of use of multiple jacks

Figure 516.07.G - Example of Improper welding to permanent steel and drilling of abutments

517 Railings

Description (517.01)

This work consists of furnishing, constructing, coating, and erecting the concrete, steel tube or aluminum deep beam railing as specified in the plans. This work also consists of providing and galvanizing structural posts, anchors, and connections.

Fabrication (517.02)

The Fabricator must be prequalified at least level SF for steel railing according to Item 513. The Contractor is required to submit mill test reports for steel certified according to 501.06.

Materials (517.03)

Structural steel is required to conform to 513, reinforcing steel according to 509, steel tubing according to 707.10, stainless steel fasteners according to 730.10, metal deep beam rail according to 710.06, ductile iron castings according to 711.13, aluminum according to 711.20, pipe according to 748.06, preformed fillers according to 705.03 and 711.28, and concrete, Class QC 2 or QC 5 according to 499 and 511.

Construction Methods, General (517.04)

Construct railings as shown on the plans. Install posts for metal railings normal to the grade line. Install the tops of railings parallel to the grade line.

Remove or release shoring or falsework supporting the superstructure before placing railing that has no expansion joints or that is on the concrete parapet. The 2” x 13” aesthetic “Bumpout” on the fascia side of the barrier has been eliminated in new Bridge Standard Drawings BR and SBR. The 1¼” deep sawcut control joint has been replaced with a 4” deep contraction joint. The horizontal epoxy coated reinforcing steel is to be stopped 6 inches on each side of the plan specified joints, with glass fiber reinforced polymer lapping the ends of the epoxy coated reinforcing steel.

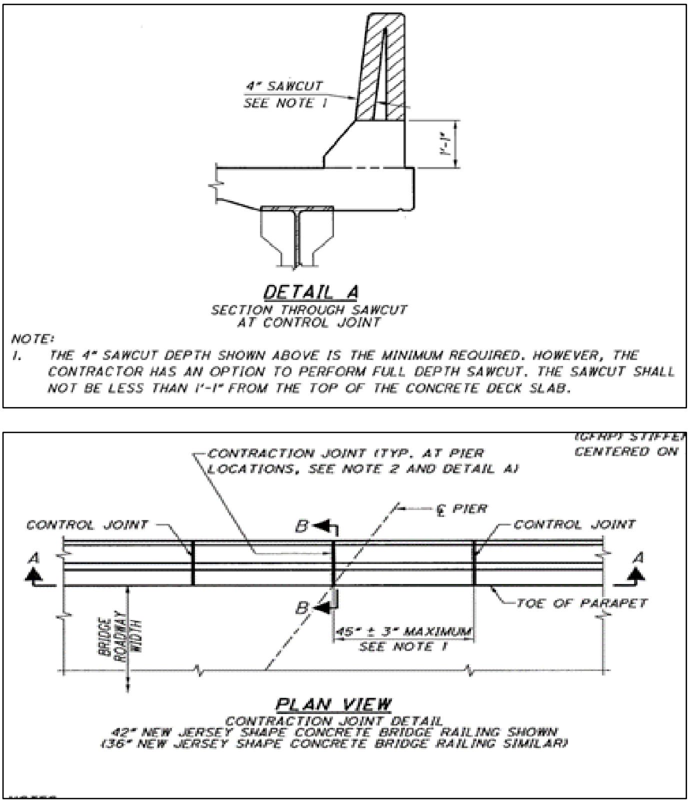


Figure 517.04.A – Details for sawcut control joints in bridge parapet from Bridge Standard drawings BR and SBR

Figure 517.04.B - Parapet slip forming operation

For slipformed concrete parapets, the Contractor must not add water as the concrete travels down the chute, or sprinkle water on the concrete to aid in hand finishing. This

will cause spalling at the concrete surface. After the concrete initially sets, but before any shrinkage cracks develop, the Contractor is required to saw control joints 1 1/4 inches (32 mm) deep into the perimeter of the parapet. Generally, initial set is within 6 hours of batching of the concrete. Ensure that all joints are sawed within 24 hours of placement. Saw control joints using an edge guide, fence, or jig to ensure that the joint is straight, true, and aligned on all faces of the parapet. The joint width shall be the width of the saw blade, a nominal 1/4 inch (6 mm). Because slipformed concrete has a low water-cement ratio, timely application of the water cure is critical in helping control shrinkage cracks.

The anchor bolts should be cast into the structure versus drilled and grouted into place after concrete placement. This will alleviate drilling into the epoxy coated reinforcing steel. Hold anchor bolts in place with the use of a template. When the anchors are cast into the concrete, the threads should be protected from getting filled with concrete paste.

Failure to release falsework prior to installing railings could cause the railings to deform as the structure experiences the additional dead load deflections associated with the falsework release.

Any preformed PVC fillers or paint coatings used should be listed on the Qualified Product Lists (QPL) for Items 711.28 and 708.

Steel and Iron Railings (517.05)

If field welding is required on galvanized members, repairs should be made similar to C&MS Item 516.03. Cold Galv or Spray Galv should not be used.

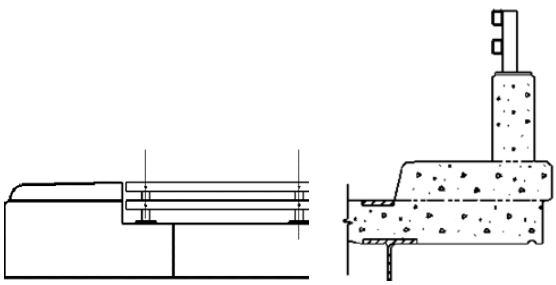


Figure 517.05.A –Detail for sidewalk barrier with railing

Figure 517.05.B–Details for Twin Steel Tube Railing with over the side drainage

Aluminum Railings (517.06)

Where aluminum or aluminum shims contacts different metal, thoroughly coat the contact surface with an aluminum-impregnated caulking compound or place a synthetic rubber impregnated fabric gasket between the metals.

Weld only where shown on the plans using inert gas shielded metal-arc or tungsten-arc method without flux, or by other approved methods.

518 Drainage of Structures

Description (518.01)

This work consists of constructing drainage systems for structures.

Fabrication (518.02)

The Fabricator must be prequalified at least level SF for scuppers according to Item 513. Submit mill test reports for structural steel, steel castings, according to 501.06.

Materials (518.03)

Scuppers, structural steel and cast steel are required to conform to 513, metal pipe according to 707, plastic pipe according to 707.33 and 707.45, other metal according to 711, reinforced thermosetting resin pipe according to 707.80, geotextile fabric , Type A according to 712.09. Furnish porous backfill consisting of gravel, stone, or air-cooled blast furnace slag, with a NO. 57 size gradation according to Table 703.01-1. The sodium sulfate soundness loss shall not exceed 15 percent. Furnish ACBF slag conforming to Supplement 1027.

General (518.04)

When installing to superstructure, the Contractor is required to take into account the deflection of spans under full dead load.

Porous Backfill (518.05)

Unless otherwise shown in the contract drawings, the Contractor is to provide a minimum of 24 inches of porous backfill behind the full length of abutments, wing walls, and retaining walls. The placement width is normally erratic due to construction means and methods. Make sure the minimum width is maintained. If the underdrain is at the footing elevation, the 24 inch dimension is measured from the edge of the footing, not the back face of the wall. If there are weep holes in the concrete, the Contractor must place 2 cubic feet of bagged No. 3 aggregate at each weep hole to retain the porous backfill. Place the porous backfill for the full width of the trench and extend it to the bottom of the approach slab or base, as shown in the plans.

Porous backfill is No. 57 size gradation. Place porous backfill in loose lifts not to exceed 12 inches. Run a plate compactor or tamper over the top of each lift for consolidation of approximately 85% of original layer thickness. If placed in loose lifts greater than 12 inches, flood the porous backfill at the appropriate moisture content for consolidation of approximately 85% of original layer thickness.

It is imperative that the filter fabric used to encapsulate the porous backfill is continuous and properly overlapped. The fabric gets flipped back and forth as the Contractor alternates from porous backfill to Type B granular. Working of the fabric in this manner can cause misplacement or tearing. A non-continuous or misplaced layer of filter fabric allows the fine material to “pipe” into the porous backfill, which can lead to settlement and lack of drainage.

Backfill elements as soon as all criteria are met to avoid ponding of surface water and accumulation of debris. Carefully backfill against waterproofed surfaces to avoid damage to the waterproofing material.

Figure 518.05 – Backfill at abutment and wall with waterproofing membrane

Pipe (518.06)

For drain pipe leading down from the superstructure, the Contractor is required to provide specials, elbows, tees, wyes, and other fittings essential for a complete and satisfactory installation of the same material and quality as the pipe with watertight joints.

The Contractor is required to place subsurface pipe as shown in the plans.

Figure 518.06 - Drainage pipe systems

Scuppers (518.07)

The Contractor is required to construct secure and watertight connections, including the connections to adjacent concrete. Provide castings, true to form and dimension. Weld the joints of structural steel scuppers. Galvanize scuppers according to 711.02.

Figure 518.07 - Scupper inlet and outlet

All drains should be free flowing. They need to have a positive fall. Special care needs to be taken when the drainage hangers, anchors, or pipes are attached to a structure prior to final dead load deflection. As the bridge deflects, the grade of the pipes may be affected and cause stagnant or pooling sections of pipe.

Excavation (518.08)

The Contractor is required to excavate all material encountered to the dimensions necessary to provide ample space at least to install pipe or other drainage facility behind abutments and for outlets.

519 Patching of Concrete Structures

Description (519.01)

This work consists of removing all loose and disintegrated concrete; preparing the surface; furnishing and placing reinforcing steel including welded steel wire fabric, dowels, and expansion bolts; placing forms; and placing concrete patches, including curing of same.

Materials (519.02)

Concrete is to be Class QC 2 or QC 5 according to 499 and 511, , reinforcing steel is to conform to 509, dowels to 709.01, 709.03 or 709.05, welded wire fabric to 709.10 or 709.12.

Removal of Disintegrated Concrete (519.03)

It is essential that all unsound concrete be removed. The use of a hammer will be necessary to sound tight areas, and the use of a sounding chain will speed up deck sounding. The practice of removing additional sound concrete after the deteriorated material is removed helps to ensure a stable surface to pour against.

Pay special attention to the locations at the edges of the patch where the reinforcing steel enters the sound concrete. In many cases, during the removal process, the reinforcing steel is vibrated or impacted, which causes cracking around the reinforcing steel penetration point. If this occurs, the Contractor will have to "chase" the cracks to make sure all fractured concrete is removed.

Figure 519.03–Removal of disintegrated concrete

Preparation of Surface (519.04)

The Contractor is required to shape the area to be patched, thoroughly clean the surface of the area to be patched and all exposed reinforcing steel of all dirt, dust, or other foreign materials with water, air under pressure, or any other method that produces satisfactory results. Thoroughly drench the surface with clean water. Before placing the concrete, allow the surface to dry to a damp condition.

Figure 519.04 - Preparation of concrete for patch

Placing of Reinforcing Steel (519.05)

The reinforcement for vertical patches is required to be welded steel wire fabric either 2 × 2 inch (50 × 50 mm) using wire size number W 0.9, or 3 × 3 inch (75 × 75 mm) using wire size number W 1.4. The entire area of the patch must be reinforced and a 1 inch cover retained to the surface of the patch.

Placing, Finishing, and Curing of Concrete (519.06)

It is very difficult to get proper consolidation of a vertical patch. It may be necessary for the Contractor to utilize a "pencil" vibrator and/or externally vibrate the forms to assist in consolidation. In all cases, the Contractor is responsible to provide a well consolidated patch.

Make sure all form ties and form attachment points in both the new concrete and the existing sound concrete are repaired after formwork removal.

Remove the forms within 24 hours after placing the concrete, and finish all exposed surfaces by rubbing to match the surrounding concrete. Apply membrane curing according to 511.17, Method B, immediately after rubbing the surfaces.

After curing and before final acceptance, sound all patched areas. Remove and replace all unsound or visibly cracked areas.

Figure 519.06 – Forming for pier patch and finishing patch after removing forms

520 Pneumatically Placed Mortar

Description (520.01)

This item of work consists of repairing concrete structures by spraying the area to be repaired with dry, premixed sand and cement that is blended with water in a mixing nozzle. The pneumatically placed mortar is then finished and cured. This type of procedure is often referred to as "shotcrete" by the industry.

Materials (520.02)

Portland cement is required to meet 701.01 through 701.05 and 701.09, reinforcing steel is to conform to 509, dowels to 709.01, 709.03 or 709.05, welded wire fabric to 709.10 or 709.12, fine aggregate is to conform to 703.02 and 703.03.

Removal of Concrete (520.03)

The Contractor is required to remove all loose, soft, honeycombed, and disintegrated concrete, plus a 1/4-inch (6 mm) depth of sound concrete. Remove additional concrete as necessary to permit the placement of the minimum specified mortar thickness of not less than 1 1/2 inches (38 mm), except on top horizontal surfaces where it shall not be less than 3/4 inch (19 mm). Perform all work in such a manner as not to damage or shatter the concrete that is to remain in place. Make square or, preferably, slightly undercut shoulders at the edge of all repair areas.

Reinforcement (520.04)

All existing reinforcing steel bars must have a minimum cover of 1 inch (25 mm). If the existing location of the reinforcing bars would result in less than 1 inch (25 mm) of cover, they are to be driven back into recesses cut into the existing concrete to achieve that coverage. If this is not practical due to the large number of reinforcing bars, the coverage must be obtained by modifying the finished surface. If the reinforcing steel is epoxy coated, care should be taken to minimize the damage to the existing coating.

Where the depth of the patch exceeds 1-1/2 inch (38 mm), in addition to any existing reinforcing steel, wire fabric is required. Where the depth of the patch exceeds 4 inches (100 mm), a layer of fabric is to be placed for each 4 inch (100 mm) thickness of patch or fraction thereof.

Preparation of Repair Area (520.05)

Prior to placement of pneumatically placed concrete, the area to be repaired must be properly prepared. All soft, loose, and disintegrated concrete, plus an additional depth of 1/4 inch (6 mm) of sound concrete, must be removed. Failure to remove soft, loose,

and disintegrated concrete will adversely affect the bond of the mortar and shorten the life of the repair.

The edges or shoulders of the repair areas must be square or slightly undercut. If this is not accomplished, the mortar placed at the edges of the repaired area will be feathered. These feathered areas will not have adequate strength and will scale off.

After all concrete has been removed from the repair area, all dowels and expansion hooks placed, all steel areas restored, and no more than 24 hours prior to placement of mortar, the area to be repaired must be abrasive blast cleaned. The abrasive blast cleaning must be done to remove spalls, laitance, and any other foreign material that might be detrimental to achieving a bond with the pneumatically placed mortar. The Contractor should select an abrasive blast method that will control or minimize the amount of fugitive dust escaping into the atmosphere. Suitable blast methods may include high-pressure water blasting with abrasives in the water, abrasive blasting with containment, or vacuum abrasive blasting. The Contractor must ensure that all wastes generated by the surface preparation operation are managed in accordance with 107.19.

Unless otherwise specified, the Contractor shall wet the area to be repaired with water for at least 2 hours prior to placing the mortar. The area must be kept wet until the mortar is placed. At the time of placement of the mortar, all free water must be removed.

Preconstruction Testing (520.09)

Due to past experiences with pneumatically placed mortar that was improperly placed and prematurely failed, each operator must demonstrate their ability to construct a sound, durable repair prior to being allowed to place mortar on the structure. This is accomplished by gunning the mortar onto a test panel. The mortar on this test panel is then tested for strength and examined for hollow areas, sand pockets, and bond to the reinforcement. The cores taken for compressive strength samples cannot contain any reinforcing steel. If the reinforcing steel spacing is too tight to retrieve a non-reinforced core, it may be necessary to construct a portion of the test panel without reinforcing. The easiest means to examine the test panel for mixing and consolidation issues is to pull a core at the intersection of the reinforcing steel or to simply saw the test panel in half. It is important to look at the cross-section of the reinforcing steel, as the backside of the reinforcing steel is usually the most suspect area. The test panel should be water cured for 7 days and handled in the same manner as a cylinder. The sample should not be cored for at least 7 days and the cores should be handled in the same manner as a cylinder.

Placing (520.10)

Place the premixed dry cement and sand by pneumatic equipment with the proper amount of water applied in the mixing nozzle for the correct placement consistency. Apply the mortar as dry as practical to prevent shrinkage cracking. Use shooting strips to ensure square corners, straight lines, and a plane surface of mortar, except as otherwise permitted by the plans or approved by the Engineer. Place shooting strips so as to keep the trapping of rebound at a minimum. At the end of each day's work, or similar stopping periods requiring construction joints, slope the mortar off to a thin edge. In shooting all surfaces, ensure that the stream of flowing material from the nozzle impinges as nearly as possible at right angles to the surface being covered, and hold the nozzle 2 to 4 feet (0.6 to 1.2 m) from the working surface.

Figure 520.10 - Placing pneumatic mortar

Curing

After the mortar is placed, it must be cured. Curing shall consist of covering the patch with burlap or cotton mats and keeping them wet for 7 days. If it is not practicable to use mats, the surface of the patch must be kept wet by sprinkling the surface with water for 7 days. If it is determined that the above methods are impracticable due to isolated areas being inaccessible, they must be cured according to the requirements of 511.14, Method B.

Inspection and Testing (520.11)

After the curing of the patched areas is completed and before they are accepted, they must be sounded, and every 200 square feet (20 m²) cored. All unsound areas, or areas that exhibit cracking, must be removed and replaced. The cores must be inspected for hollow areas, sand pockets, voids around reinforcing steel, and lack of bond to the underlying concrete. The cores are to be tested for compressive strength. Any defective patches, as determined by the cores, must be removed and replaced at the Contractor's expense.

Figure 520.11 - Example of cracks in pneumatic mortar requiring replacement

522 Structural Plate Corrugated Metal Structures on Footings

Description (522.01)

This work consists of the sectional corrugated metal arch described in 522. Excavation and concrete for structures are covered in 503 and 511.

Materials (522.02)

The Contractor is required to furnish plates and bolts conforming to 707.03 or 707.23, steel bearing angles or channels conforming to 707.03 or 711.01and aluminum bearing angles or channels conforming to 707.23.

General (522.03) Quality Control

The quality of galvanizing should be examined. Some added thickness occurs at the bolt holes and may appear to be stripping when the bolts are installed. Peeling, which is evidence of separation of galvanizing around bolts or near the edges of the plates, when pried with a knife or impacted with a hammer, is cause for rejection.

Corrugated metal arch structure plates, high strength bolts, ribs, and anchor angles should only be accepted from certified suppliers listed on the Office of Materials Management's website. The shipments should be accompanied by a certification document (TE-24).

Assembly

Properly support the metal bearing angle or channel in the position shown on the plans before placing footing concrete.

Certified suppliers must provide assembly and installation procedures with the shipment. Shipments that do not include the assembly and installation procedures should not be accepted.

523 Dynamic Load Test

Description (523.01)

This work consists of establishing a driving criteria for all the piles of a specified shape, cross-section, and ultimate bearing capacity or as specified on the plans to be installed in the structure. This shall be accomplished by applying dynamic loads with a pile hammer during driving of production piles to determine driving requirements. Apply the dynamic load to the piles using a pile hammer that is operating at its normal operating level. Perform restrike tests when specified in the plans.

Except for H-piles driven to bedrock, bearing piles are driven to a required blow count to ensure that they have the ultimate bearing value shown on the plans. The relationship between the blow count and ultimate bearing value is dependent on many variables, including the pile type, material, and length; pile hammer energy and performance; and soil properties. The simple formulas used in the past considered only one of these variables: pile hammer energy. Dynamic load testing measures the energy going into the pile from the hammer and accounts for many of the different variables to estimate the capacity of the pile with each blow of the pile hammer. The Department uses dynamic load testing to determine the required blow count for the ultimate bearing value on every project that includes driving bearing piles.

The methods used in dynamic load testing, also called PDA testing (named after the equipment: Pile Driving Analyzer), were developed in Ohio beginning in the 1960's. The Ohio Department of Transportation was involved early in its development and began to apply the results of the research in their construction projects around 1968. Since 2002, the Department has used dynamic load testing for all pile driving (except piles driven to bedrock) and discontinued the use of the simple formula used previously.

General (523.02)

Each dynamic load test consists of dynamically testing a minimum of two piles. If there are piles of different size, shape, or capacity, it will be necessary to perform dynamic load testing for each of these differing sizes, shapes, or capacities, and there should be additional pay items in the Contract to reimburse the Contractor for performing these tests.

Equipment (523.03)

Dynamic load testing is accomplished by connecting two sets of gauges to a pile. One set of gauges measures the strain in the pile at the top, while the other gauge measures the acceleration of the pile at the top. These gauges are then connected to a computer called a Pile Driving Analyzer (PDA). The PDA converts the measured strain and acceleration into force and velocity. By analyzing the way the force and velocity change with time, the PDA estimates the pile capacity for each blow of the pile hammer. After the PDA is connected to the pile, the Contractor begins driving the pile.

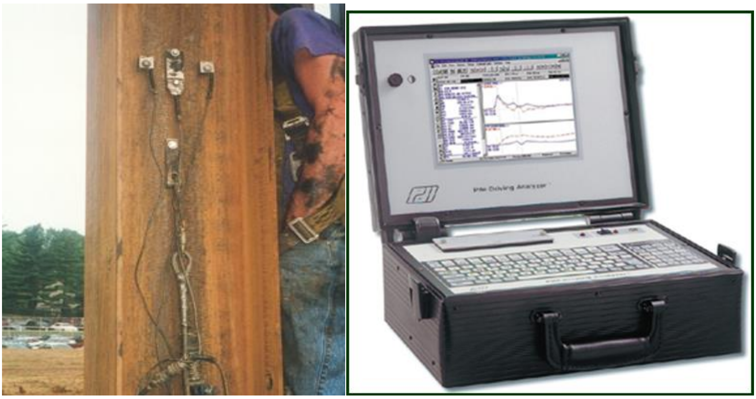


Figure 523.03.A – Dynamic load testing transducers placement and Pile Driving Analyzer

Once the dynamic load testing begins, the driving of the pile continues until the required ultimate bearing capacity is achieved. At this time, the blow count, blows/ft (blows/meter), is noted. It is necessary to record the stroke height of the hammer. In addition to performing dynamic load testing, the Contractor is required to perform signal matching analysis of the dynamic test data on at least one of the piles tested. The Contractor must perform the test according to ASTM D 4945. The signal matching analysis is a more refined analysis method that takes into account the properties of the different soil layers. The results of the dynamic load testing and signal matching analysis are then used to establish the driving criteria required to achieve the ultimate bearing capacity for the remaining piles represented by this test. Immediately after the dynamic load test has been completed, the personnel performing the testing must inform the Engineer of the required driving criteria. This will include both the blow count and the stroke height.

Prior to allowing the test to begin, the personnel performing the test must supply the Engineer with a copy of a certificate showing that they have an Advanced Master or Expert Level Certification in High Strain Dynamic Pile Testing (HSDPT) from either the Pile Driving Contractors Association (PDCA) or Foundation QA. The Foundation QA examination was the original certification program, but the Department is changing to the PDCA certification program. Both certification programs are currently acceptable. A sample certificate is shown below. The Engineer can also check a person's certification status on the following website:

www.pdaproficiencytest.com.

PDCA
PILE DRIVING CONTRACTORS ASSOCIATION

Pile Dynamics, Inc.

This documents that

Thomas Tester
Company Name

has on January 1, 2015 achieved the rank of

ADVANCED

on the **Dynamic Measurement and Analysis Proficiency Test.**

The individual identified on this document demonstrated to the degree granted above an understanding of theory, data quality evaluation, interpretation and signal matching for high strain dynamic testing of deep foundations. ***It is recommended*** **that Individuals at the Advanced level seek Master or Expert levels through additional study within four years of the date of this document.**

The ability of the individual named to provide appropriate knowledge and advice on a specific project is not implied or warranted by the Pile Driving Contractors Association or Pile Dynamics, Inc. **This certificate can be verified at www.PDAproficiencytest.com.** The Pile Driving Contractors Association or Pile Dynamics, Inc. assumes no liability for foundation testing and analysis work performed by the bearer of this certificate.

Steven A. Hall, Executive Director
Pile Driving Contractors Association

Garland Likins, President
Pile Dynamics, Inc

No. XXX

SAMPLE

Figure 523.B – Example PDA testing certificate

If the designers suspect that the capacity of the pile could increase or decrease after it has been in the ground for some period of time, an additional test called a restrike could be specified. If a restrike is specified, the plans specify the minimum elapsed time from when the pile was driven until the time of the restrike. This waiting period could be anywhere from a day to a week or more. Each restrike test consists of dynamically testing a minimum of two piles, the same as the dynamic load test.

When a restrike is specified, it is very important that during the waiting period, the pile to be tested should not be disturbed in any manner until the PDA is properly hooked up and the test is ready to begin. Disturbing the pile can cause the pile to partially or completely lose any change in capacity it has acquired during the waiting period.

The pile hammer used to restrike must be the same hammer used to perform the initial dynamic load test on the pile and must be thoroughly warmed up by applying at least 20 blows to another pile, other than the pile being tested, immediately before the test begins. When the test begins, the first few blows are used to determine the capacity of the pile. Any results obtained after the first few blows will result in the pile returning to the capacity it obtained prior to the required waiting period.

Test Report (523.04)

Within 48 hours after completing the test, the Engineer is to be given a written report with the results.

Include in the report, the required blow count for:

A. The different strokes of the ram at 6-inch (150 mm) intervals within the expected range of operation as determined by a wave equation analysis, when open ended diesel hammers and drop hammers are used.

B. The selected bounce pressures when closed end diesel hammers are used.

C. The operating air pressure and stroke when an air operated hammer is used.

D. The selected output energy or stroke when a hydraulic hammer is used.

Also include in the report a minimum depth of penetration if applicable.

Submit an electronic version of the report and data files from the testing and analysis to the Office of Geotechnical Engineering and the Office of Construction Administration.

524 Drilled Shafts

Description (524.01)

Drilled shafts are reinforced concrete columns, which, for the most part, are built below the surface of the ground. They are designed to provide a foundation for structures and carry the entire load of the structure. They are sometimes referred to in the field as caissons.

Materials (524.02)

Concrete for drilled shafts is required to be Class QC 4 for mass concrete , over 7 foot diameter shaft, or QC 5 according to 499 and 511, and epoxy coated reinforcing steel according to 509.

Contractor's Installation Plan (524.03)

Prior to installing drilled shafts, the Contractor is required to submit a written installation plan to the Engineer. This plan should be closely reviewed for conformance with the specifications. Among other things, the plan should describe how the Contractor proposes to excavate the hole, clean out the hole, and place the concrete. The plan needs to include procedures for maintaining correct horizontal and vertical alignment of the excavation. The plan should also include procedures and the proposed equipment required to deal with the possible presence of and subsequent removal of underground obstructions within the hole excavations.

If a permanent casing is specified, the casing should be installed to the prescribed depth before excavation begins. In some cases, the Contractor may not have the required equipment to completely install the casing prior to excavation. If the Contractor is not able to completely install the casing prior to excavation, he is allowed to either excavate the material within the casing, or excavate a pilot hole ahead of the casing. If the Contractor proposes to excavate the material within the casing to aid in the installation, it is important that the excavation does not proceed beyond the casing.

If the Contractor proposes to either pump or tremie the concrete under water while utilizing a temporary casing, his plan should describe how he proposes to remove the casing while not disconnecting or breaking apart the tremie or pump hose. In order to ensure that the end of the pump or tremie hose is always embedded into the concrete, his plan should detail how he proposes to monitor the level of the top of the concrete and the bottom of the pump or tremie hose. If the Contractor does not include these provisions in his plan, and encounters water in the field, he should be required to stop and resubmit a plan containing the necessary information. He should not proceed with verbal approval as it is too difficult to document what was said versus what may have been intended.

Drilled shaft installation can be very complicated since a large amount of work is performed in an area with very little access. The plan should be very detailed and site specific. A generic or “canned” plan should not be accepted.

The Contractor’s Installation Plan must include:

1. Sequence of operation
2. Procedures for maintaining correct horizontal and vertical alignment of the excavation.
3. Method to advance the casing
4. Methods to extract the temporary casing and to maintain the concrete slump to keep concrete workable by adding admixtures such as retarders or superplasticizers.
5. If using slurry, details of the methods to mix, circulate, and de-sand the slurry. For polymer slurry, submit the manufacturer's recommendations for use of the slurry.
6. Methods to clean the shaft excavation
7. Reinforcement placement including support and centralization methods.
8. Method of concrete placement including proposed operational procedures for free fall, tremie, or pumping methods
9. List of proposed equipment to be used such as cranes, drills, augers, bailing buckets, final cleaning equipment, de-sanding equipment, slurry pumps, tremies, concrete pumps, casings, etc.

Types of Drilled Shafts

There are two types of drilled shafts:

1. End bearing.
2. Friction.

End bearing drilled shafts derive most of their capacity through end bearing on a hard substrate, such as bedrock.

Friction type drilled shafts derive most of their capacity through a combination skin friction with the soil along the perimeter of the drilled shaft and end bearing on the substrate immediately below the drilled shaft. To obtain the required skin friction, it is important that the integrity of the soil be maintained during the drilling operation and prior to placing the concrete.

Figure 524.03–Drilled shaft equipment

Hole Excavation (524.04)

There are several different methods used to stabilize the sides of the excavation during the construction of the drilled shaft. Factors that impact the method chosen are types of soil, the elevation of the ground water, types of drilled shafts, plan requirements, and equipment utilized by the Contractor.

Figure 524.04.A. – Drill rig with auger and core barrel for shaft excavation

Dry Construction Method (524.04.A)

The dry construction method is accomplished by excavating the hole without the use of steel casing. The sides and bottom of the excavation should remain stable and should

not experience any caving, sloughing, or swelling. It should be possible to visually inspect the excavation prior to the placement of concrete.

The excavation should be done in a relatively dry condition with very little ground water present. The flow rate of any water that might enter the excavation should be such that the elevation does not change by more than 12 inches (300 mm) per hour. At the time of concrete placement, there should be no more than 3 inches (75 mm) of water in the bottom of the excavation. Both the flow rate test and the amount water in the bottom of the hole should be documented.

Wet Construction Method (524.04.B)

The wet construction method should be used at sites with or without casing and where a dry excavation cannot be maintained. This method consists of using either water or slurry to contain or prevent the seepage of ground water into the drilled shaft. With the use of slurry, this method may be used in place of a temporary casing to maintain the stability of the perimeter of the hole while advancing the hole to its final elevation.

If this method is used to excavate a hole for a friction-type drilled shaft, it is important to not compromise the integrity of the soil along the perimeter of the drilled shaft through the seepage of ground water. It is not only important to prevent the seepage of ground water into the excavation after it is complete, but it is important to prevent ground water from seeping into the excavation during the drilling process. To prevent this, it will be necessary to continually pump either water or slurry into the hole during the drilling operation to maintain an elevation slightly higher than the elevation of the static water table.

Either a tremie or a concrete pump will be used to place the concrete when the wet construction method is used.

Unless waived by the Engineer, it is required for the Contractor to use a temporary surface casing to prevent soil at the top of the casing from sloughing and falling into the excavation. This casing should never be shorter than 10 feet (3.0 m) long. The temporary casing aids in the proper alignment and positioning of the drilled shaft.

Figure 524.04.B - Wet construction technique

Temporary Casing Construction Method (524.04.C)

Temporary casing may be used at sites where dry excavation cannot be maintained and the Contractor elects not to use slurry.

It is important that the Contractor begins removal of the temporary casing while the concrete remains workable. Failure to remove the casing could result in a drilled shaft that is not capable of supporting the design load.

When the casing is withdrawn, there is a possibility that fluid trapped behind the casing will contaminate the concrete. To prevent this, it is important to maintain a head of concrete at least 5 feet (1.5 meter) in the casing. This minimum head may need to be increased to counteract any ground head that might be in the casing at the time it is withdrawn. Casing should be removed by pulling at a slow uniform rate. However, if the casing gets stuck, the Contractor may rotate, vibrate, or tap the casing to facilitate extraction. Rotating the casing may twist the reinforcing cage, so only rotate the casing enough to get it unstuck.

Figure 524.04.C -Temporary casing being pulled from drilled shaft

Friction Type Drilled Shafts (524.05)

Friction-type drilled shafts derive much of their capacity through the adhesion of concrete with the surrounding soil. If the Contractor elects to use a temporary steel casing and fails to remove it, or he fails to protect the integrity of the soil adjacent to the drilled shaft, much of the capacity of the drilled shaft could be lost.

When drilled shafts extend below the top of the water table, it is important that the water or slurry fluid inside the shaft excavation be maintained higher than the top elevation of the water table at all times. To accomplish this, it is not only important for the Contractor to add water or slurry fluid after the excavation is complete, but it is also important for him to add water or slurry fluid during the drilling operation. If this is not done, the surrounding ground water will begin to enter the excavation and erode the soil. This will result in the reduced capacity of the drilled shaft.

The dry construction method can be used in construction of friction-type drilled shafts. It should be used when the bottom of the drilled shaft is above the water table and the excavation can be made without the sides or bottom of the excavation experiencing any caving, sloughing, or swelling. If the dry construction method results in the sidewall becoming softened or swelling, the Contractor shall over ream the sidewall to sound material.

If the Contractor elects to use slurry, a delay in placing the concrete could result in the sidewalls degrading due to slurry cake buildup. Any slurry cake buildup shall be corrected by reaming the sidewalls to sound material.

If a temporary casing is not used, and concrete is not placed the same day that the excavation is complete, the excavation shall be re-drilled 6 inches (150 mm) larger in diameter immediately prior to the placement of the concrete.

Casings (524.06)

If a temporary casing is used, it should be smooth and free of dried concrete and other foreign materials that might contaminate the fresh concrete. While the strength and thickness of the steel casing is not specified, it should be strong enough to withstand handling, installation, and extraction stresses as well as the pressures exerted on it by the fresh concrete and surrounding earth.

The outside diameter of the casing should be at least equal to the plan diameter of the drilled shaft. Many times the Contractor will elect to use a casing larger than the specified casing. Oversized casings are acceptable; however, all additional costs associated with the oversized casings should be borne by the Contractor.

Typically, the diameter of the bedrock socket will be less than the diameter of the remainder of the drilled shaft. When the diameter of the bedrock socket is the same as the remainder of the drilled shaft, the diameter of the drilled shaft may need to be increased to permit the excavation of the bedrock socket. Again, increasing the diameter of the drilled shaft should be done at no additional cost to the state.

Slurry (524.07)

One potential method of excavating a hole through unstable or caving soils is through the use of slurry. The slurry should be added to the excavation during the drilling process and replace the material that is being removed. This is accomplished by mixing the slurry with the material to be removed. The combination of slurry and soil is then pumped from the hole while clean slurry is added. The slurry that was pumped from the hole is then cleaned of foreign material and placed back into the hole. This process is continued until the original soil has been removed.

There are two different types of materials used to produce slurries. One type of material produces mineral slurry and the other type of material produces polymer slurry.

If the Contractor elects to use polymer slurry, he must first demonstrate the slurry's ability to prevent caving of the hole. If the slurry is not capable of stabilizing the perimeter of the hole while the hole is being excavated, it should not be allowed. This should be accomplished by the use of a separate trial hole. This trial hole should not be one of the production shafts and no separate payment should be made for the trial hole. The trial hole should be the same size and diameter as the largest production drilled shaft except the depth of the hole need not be more than 40 feet (12 meters). The slurry used in the trial hole should be the same as that used in the production shafts.

Excavation Inspection (524.08)

An important factor in the performance of the drilled shaft is the cleanliness of the hole excavation prior to the placement of the reinforcing steel and the concrete. The Contractor must provide equipment to check the dimensions, alignment and cleanliness of the hole excavation.

Reinforcing Steel for Drilled Shafts (524.09)

Reinforcing should be placed just prior to concrete placement. It should be placed as one continuous cage. If a casing is not used, care should be taken when lowering the reinforcing steel cage into the shaft so it does not drag down the face of the shaft and compromise the integrity of the exposed soil surface.

Spacing devices, commonly referred to as “donuts,” need to be installed at quarter points around the shaft to ensure that the required concrete cover is obtained. On the bottom of the shaft, the Contractor can use plastic “shoes” to keep the reinforcing cage at the proper elevation. These shoes are normally 6 inches (152 mm) to 8 inches (203 mm) tall and about as big around as a soda can. In the past, mortar blocks were wired to the end of longitudinal steel to accomplish this task, but were unstable and the cage often fell off the blocks.

Figure 524.09 – Reinforcing steel cage being lifted to be set in drilled shaft

Concrete for Drilled Shafts (524.10)

The concrete used in the drilled shaft is Class QC 2. In order to aid the consolidation of the concrete without vibration, it is necessary to increase the slump to 6 inches (150 mm) ± 1 inch (25 mm). If the concrete is placed using a tremie, the slump should be increased to 8 inches (200 mm) ± 1 inch (25 mm). The accepted JMF’s maximum water-

cementitious ratio shall not be exceeded. It may be necessary to achieve the additional slump through the use of a super-plasticizer.

If the Contractor uses the wet method or places concrete under water or slurry, increase the cement content by 10 percent and place the concrete by either tremie or concrete pump.

If a temporary casing is used, it should be removed slowly and carefully. As the casing is removed, concrete that has been previously placed will fill the void left by the casing thus causing the top level of the concrete in the excavation to lower. As the level of the concrete drops, the concrete will tend to pull down on the reinforcing steel. If the casing is removed too quickly, the downward force of the concrete on the reinforcing steel will cause the reinforcing steel to be displaced.

Figure 524.10 – Concrete being placed by pump into drilled shaft

Tremie (524.12)

A tremie may be used to place concrete in a wet hole. If concrete is placed in a wet hole, it is important that the concrete not be placed into moving water. If concrete is placed into moving water, the water will have a tendency to wash the cement off of the sand and aggregate. To prevent moving water in the excavation, the level of water or slurry in the excavation must be equal to or higher than the level of the ground water.

The tremie must not contain aluminum parts that will come into contact with the concrete. In order for the concrete to pass freely through the tremie, the minimum diameter of the tremie shall be at least 10 inches (250 mm). It is important that the tremie be clean, smooth, and free of built-up concrete and other foreign material.

Prior to placing the tremie tube into the water, it is important to plug the end of the tremie to prevent the intrusion of water into the tremie. The tremie can be placed into the excavation after the plug is in place. After the tremie is filled with concrete, it should be raised up no more than one diameter of the tube. This allows the plug to be displaced and the concrete to begin flowing into the excavation. If the tremie is not plugged, the

tube will fill with water. When the concrete is dropped through the tube, it would drop through the water which separates the cement from the sand and gravel.

During the placement of the concrete, the end of the tremie should always be at least 10 feet (3 meters) below the surface of the concrete to prevent the water from contaminating the fresh concrete. It is important to devise a method to determine elevation of the top of the concrete and the bottom of the tremie since the concrete will be under water and not visible. This method should be determined and agreed upon with the Contractor prior to the concrete's delivery.

In order to prevent air voids in the concrete when a tremie or pump is used, place the concrete in one continuous operation. If the Contractor is allowed to break apart the tremie tube or pump hose to facilitate the removal of temporary casing, the tremie tube or pump hose could get air voids in them that will be forced down into the drilled shaft concrete. If the end of the tremie is pulled out of the concrete prior to completely placing all the concrete, the drilled shaft will contain concrete that will be contaminated by water. As a result, the drilled shaft may not have the required strength and should be considered defective.

After the concrete placement has been completed, there will be a layer of concrete at the top of the drilled shaft called, "laitance," that has been contaminated with water. This concrete should be removed either by overfilling the drilled shaft and causing the contaminated concrete to flow out of the drilled shaft or by shoveling off the concrete. If the contaminated concrete is shoveled off, the Contractor must place additional concrete to replace the concrete that was shoveled off.

Figure 524.12 – Concrete tremie

Pumped Concrete (524.13)

A pump may be used to place concrete in a wet hole. If concrete is placed in a wet hole, it is important that the concrete not be placed into moving water. If concrete is placed into moving water, the water will have a tendency to wash the cement off of the sand and aggregate. To prevent moving water in the excavation, the level of water or slurry in the excavation shall be equal to, or higher than, the level of the ground water.

Due to the adverse reaction of concrete with aluminum, the pump must not contain aluminum parts that will come into contact with the concrete.

In order to allow the concrete to pass freely through the pump, the minimum diameter of the pump pipe must be at least 4 inches (100 mm).

During the pumping operation, the pipe used to convey the concrete to the bottom of the drilled shaft must be anchored to the steel casing or other suitable stationary object to prevent the pipe from undulating. Otherwise, the tendency of the pipe to undulate could cause it to pull out of the concrete that was previously placed.

In order to lubricate the pump equipment, grout should be first pumped through the hose prior to pumping the concrete. The grout should not be placed in the drilled shaft. This process does not need to be repeated as long as the process is continuous.

Prior to placing the pump pipe into the water, it is important to plug the end of the pipe to prevent the intrusion of water into the pipe. After the plug is in place, the pipe can be placed into the excavation. When the pipe is filled with concrete, the pressure of the concrete will dislodge the plug. If the pipe is not plugged, and the concrete drops through the water, the water would separate the cement from the sand and aggregate.

During the placement of the concrete, the end of the pump pipe should always be at least 10 feet (3 meters) below the surface of the concrete to prevent the water from contaminating the fresh concrete. It is important to devise a method to determine elevation of the top of the concrete and the bottom of the pipe since the concrete will be under water and not visible. This method should be determined and agreed upon with the Contractor prior to the concrete's delivery to the project.

In order to prevent air voids in the concrete when a tremie or pump is used, place the concrete in one continuous operation. If the Contractor is allowed to break apart the tremie tube or pump hose to facilitate the removal of temporary casing, the tremie tube or pump hose could get air voids in them that will be forced down into the drilled shaft concrete.

If the end of the pipe is pulled out of the concrete prior to completely placing all the concrete, the drilled shaft will contain concrete that will be contaminated by water. As a result, the drilled shaft may not have the required strength, and should be considered defective.

After the concrete placement has been completed, there will be a layer of concrete at the top of the drilled shaft called, "laitance," that has been contaminated with water. This concrete should be removed either by overfilling the drilled shaft and causing the contaminated concrete to flow out of the drilled shaft or by shoveling off the concrete. If the contaminated concrete is shoveled off, the Contractor must place additional concrete to replace the concrete that was removed.

Inspection Records (524.15)

It is the Contractor's responsibility to provide the Engineer with all the necessary labor and equipment to obtain measurements of the drilled shaft. Since it is not possible to obtain these measurements after the concrete is placed, it is necessary to obtain these measurements prior to placing concrete.

Due to the risks involved, at no time should the Engineer ever go down into a drilled shaft for inspection or any other purpose.

A copy of form CA-S-1 should be filled out and submitted to the Office of Geotechnical Engineering.

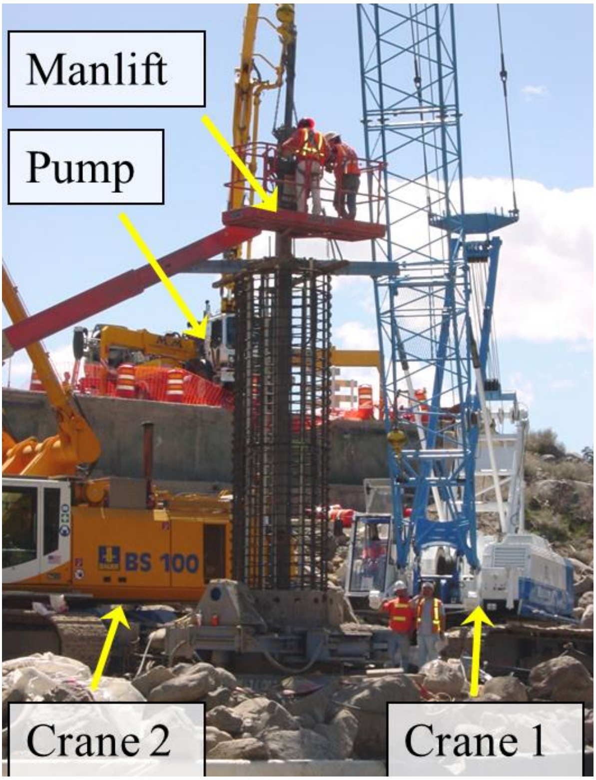


Figure 524.15 – Concrete placement and reinforcing steel supports for drilled shaft

Method of Measurement (524.16) and Basis of Payment (524.17)

The pay length of the drilled shaft is the required, accepted length measured along the axis of the shaft. It should be measured from the required bottom of the shaft to the proposed top plan elevation. Any over excavation below the required bottom of the shaft should not be measured for payment.

Drilled shafts that extend into bedrock should be divided into two sections. The lower section is the length of the drilled shaft that extends into the bedrock or the bedrock socket. The upper section is the length of drilled shaft above the bedrock. If the top elevation of the bedrock is lower than indicated on the plans, the additional upper section or length of drilled shaft above bedrock should be measurement for payment. The Contractor should not be paid for any over excavation of the bedrock unless he is ordered to do so by the Engineer.

526 Approach Slabs

Description (526.01)

This work consists of constructing reinforced portland cement concrete approach slabs for bridges on the completed and accepted subgrade or subbase.

An approach slab is designed to function as a bridge deck spanning the distance from the bridge abutment to beginning of the roadway pavement. As a result, it is designed and constructed similar to a bridge deck.

Materials (526.02)

The concrete used to construct the approach is the same class as the bridge deck and should be placed using the same specifications as the bridge deck concrete. If the project does not identify the class of concrete used for the superstructure, or if the deck is composed of prestressed box beams with an asphalt-wearing surface, Class QC-2 or QC-3 concrete, depending on the quantity required for the approach slab, should be used. Epoxy coated reinforcing steel shall conform to 509, preformed joint filler according to 705.03.

Forming, Furnishing and Placing Reinforcing Steel (526.03)

The Contractor is required to furnish true and straight steel or wooden side forms. Securely brace and hold forms to the line and grade shown on the plans. Do not allow forms to vary more than 1/8 inch (3 mm) from a 10-foot (3 m) straightedge. Do not remove forms for a minimum of 36 hours. Clean and oil forms after each use.

Figure 526.03 – Placing concrete in approach slab with wooden side forms

Setting Grades

It is important that the approach slab be constructed parallel to the surface of the bridge deck to provide a smooth ride from the approach pavement to the bridge deck. To accommodate the actual dead load deflection of the deck, which may vary from the anticipated dead load deflection, the approach slabs should not be placed until after the deck has been placed. However, in an attempt to achieve a smoother ride, District Bridge Engineers have allowed Contractors to place the approach slabs continuously with the bridge decks, especially for some semi-integral and integral abutment designs. Some things to consider if the approach slabs are placed continuously with the bridge deck:

1. Placing the deck and the approach slab together would not allow the installation of the Type A Waterproofing per Bridge Standard Drawing AS-1-81.

2. Adjacent spans with large deflections, over 1 inch, could cause the semi-integral or integral abutment diaphragm to rotate on the bearing, which could cause the D800 bar in the continuously placed approach slab to move and damage the approach slab where the concrete's initial set had already began. Therefore, concrete placement sequences may be required, such as starting at the rear abutment, placing concrete in the bridge deck and continuing across the forward approach slab, then coming back and placing concrete in the rear approach slab.

3. Approach slab concrete cannot be placed with bridge deck concrete if semi-integral or integral abutment diaphragm concrete placement for steel members or prestressed concrete members is not done prior to concrete deck placement.

4. Permit the placement of the approach slab with the bridge deck for integral or semi-integral designs if:

    a. The skew is less than 10 degrees for prestressed concrete beams.

    b. The skew is less than 30 degrees for steel beams.

    c. The deflection due to dead load of the adjacent span is less than 1 inch.

    d. There is no phased construction that requires the deck and abutment diaphragm to be placed together.

    e. The 1/2-inch joint for the preformed elastomeric compression joint seal between the deck and the approach slab is sawed as soon as possible for stress relief.

The final grade of the approach slab can then be established by using a string line. One end of the string line should be secured at a distance of approximately 10 feet (3 meters) back on the deck and stretched over the proposed approach slab with the other end attached to a grade stake marked with the proposed pavement grade. The final grade of the approach slab can then be determined.

Dimensions

The Contract plans will show the length of the approach slab. All other details are dictated by Standard Drawing AS-1-81. It will show the reinforcing and joint requirements as well as slab thickness and haunch details.

Placing and Sampling Concrete (526.04)

The Contractor is required to moisten the subgrade or subbase prior to the placement of the approach slab concrete. When the bridge superstructure and the approach slab require QC/QA, make at least one set of test cylinders for each 50 cubic yards (35 cubic meters) of concrete. Include the results of the cylinders into the LOT for the 511 superstructure item.

Finishing and Curing (526.05)

The Contractor is required to mechanically screed, at a vibration frequency of 1500 to 5000 pulses per minute, the concrete surface to the proper elevation in one complete pass with a minimum of hand finishing. If the approach slab is to serve as a base for an asphalt concrete wearing course, texture the approach slab according to Item 305. If the approach slab is to serve as a wearing surface, , test the surface according to 451.13, and diamond groove the surface according to 511.17. Cure approach slabs according to 511.14.A.

Open approach slabs to traffic according to Table 511.14-1A or Table 511.14-1B.

Figure 526.06 – Placing concrete in approach slab and finishing with surface with vibrating screed

600 Incidentals

601 Slope and Channel Protection

Because of the straightforward nature of this item of work, no detailed explanation of the item is required in this manual.

602 Masonry

Because of the straightforward nature of this item of work, no detailed explanation of the item is required in this manual.

605 Underdrains

Description (605.01)

The types of underdrains are specified in accordance with their application and intended usage. For a brief description of typical applications, see Section 605.02. If a more detailed description is required, see the ODOT Drainage Design Manual and the plans.

Materials (605.02)

Use approved granular material consisting of No. 8, 9, or 89 size Air-Cooled Blast Furnace slag, limestone, or gravel for underdrain backfill only, but not for underdrain outlet pipes.

Pipe for 605 Rock Cut Underdrains (605.02.A)

When the pay item description says Rock Cut Underdrains and the type of pipe is not specifically itemized in the Proposal, use one of the following:

1. Corrugated Polyethylene Drainage Tubing (Perforated) 707.31.
2. Polyvinyl Chloride Plastic Pipe 707.41.
3. Polyvinyl Chloride Corrugated Smooth Interior Pipe (Perforated per 707.31) 707.42.
4. Polyvinyl Chloride Solid Wall Pipe (Perforated per 707.31) 707.45.

Provide the pipe type on the appropriate construction inspection form.

Pipe for 605 Pipe Underdrains (605.02.B)

When the pay item description says Shallow Pipe Underdrains or Deep Pipe Underdrains, and the type of pipe is not specifically itemized in the Proposal, use one of the following:

1. Perforated Concrete Pipe 706.06.
2. Concrete Drain Pipe Extra Quality 706.07.
3. Perforated Vitrified Clay Pipe 706.08.
4. Clay Drain Tile Extra Quality 706.09.
5. Corrugated Steel Underdrains, Type III 707.01.
6. Corrugated Polyethylene Drainage Tubing (Perforated) 707.31.
7. Polyvinyl Chloride Plastic Pipe 707.41.
8. Corrugated Aluminum Alloy Pipe and Underdrains, Type III 707.21.

If the size and type of the underdrains required is a 6-inch (150 mm) Shallow Pipe Underdrain, and the type of pipe material is not specifically itemized, use 4-inch (100 mm) 707.31 Perforated Corrugated Polyethylene Drainage Tubing. An example would be 6-inch Shallow Pipe Underdrains listed in the description, and the Contractor can then furnish 4-inch 707.31 Underdrains placed at the same location as the 6-inch Shallow Pipe Underdrains. Provide the pipe type on the 605 CA-P-2 Structure Underdrain Form.

Pipe for 611 Conduit, Type F for Underdrain Outlets

The backfill requirements are as per 611. When the pay item description says, "611 Conduit, Type F for Underdrain Outlets," and the type of pipe is not specifically itemized in the Proposal, use one of the following:

1. Corrugated Polyethylene Smooth Lined Pipe 707.33.
2. Polyvinyl chloride plastic pipe (non-perforated) 707.41.
3. Polyvinyl chloride corrugated smooth interior pipe 707.42.
4. Polyvinyl chloride solid wall pipe 707.45.

Provide the pipe type on the appropriate construction inspection form.

Pipe for 605 Construction Underdrains (605.02.C)

Corrugated polyethylene drainage tubing (perforated) 707.31 is the only pipe type permitted.

Provide the pipe type on the appropriate construction inspection form.

Pipe for 605 Prefabricated Edge Underdrains (605.02.D)

Prefabricated edge underdrains 712.10 is the only pipe type permitted.

Provide the pipe type on the appropriate construction inspection form.

Pipe Underdrains Construction (605.03)

Construct underdrains as follows:

Excavation (605.03.A)

Underdrain ID	6 inches (150mm)	4 inches (100mm)
Trench Width	14 inches (350mm)	10 inches (250mm)

Provide the trench width on the appropriate construction inspection form.

If geotextile fabric is specified, note this on appropriate construction inspection form along with a sketch of how the fabric was placed and overlapped at the top of the trench.

Laying Underdrain (605.03.B)

Lay the underdrain true to line and grade with close fitting joints. Use locking bands or smooth sleeve type couplers, which match the underdrain material type, to join 707.01, 707.31, 707.41, and 707.21. When bell and spigot underdrain is used, lay it with the bell end facing up grade. Set the underdrain on a solid bed shaped to fit the underdrain throughout its entire length. Make all necessary connections with branches, wyes, tees, transitions, and bends that match the underdrain material type. Close the upper ends of underdrains with suitable plugs.

Lay perforated underdrain so that the perforations are in the bottom half of the underdrain.

Provide the pipe joint type on the appropriate construction inspection form.

Backfilling (605.03.C)

Inspect the underdrains before placing any granular material. Place the granular material for the full-width of the trench around the underdrain, and extend it to the bottom of the pavement or base as shown on the plans. If underdrains are placed outside of the pavement or base area, extend the granular material to within 4 inches (100 mm) of the finished grade. Fill the remaining depth of the trench with 203 embankment material. Provide the pipe backfill material type on the appropriate construction inspection form.

Protection (605.03.D)

Place the pavement over the underdrain trench within 90 days after placing the trench backfill. If the trench remains open for longer than 90 days, remove and replace backfill contaminated by soil. Provide the dates when the underdrains were placed and the date the pavement was placed over the underdrain trench on the appropriate construction inspection form.

Construction Underdrains (605.04)

Excavation (605.04.A)

Construction Underdrain	4 inches (100mm)	Trench Width	10 inches (250mm)
Construction Underdrain	6 inches (150mm)	Trench Width	14 inches (350mm)

Provide the trench width on the appropriate construction inspection form.

Trench Depth and Backfill (605.04.B)

Construct the trench depth to that shown on the plans or 30 inches (750 mm). Backfill the full width and height of the trench with granular material. Provide the pipe backfill material type and trench depth on the appropriate construction inspection form.

Outlet (605.04.C)

Outlet the construction underdrains into the ditch or drainage structures. There is no change in pipe types for the outlet. Provide the trench outlet location on the appropriate construction inspection form.

Removal (605.04.D)

Do not remove construction underdrains at any time. If a construction practice requires the construction underdrains to be removed, then install replacements as soon as possible. For example, if trenching for a culvert would cut the construction underdrains.

Provide the dates when the construction underdrains were placed on the appropriate construction inspection form.

Prefabricated Edge Underdrains (605.05)

Install the prefabricated edge underdrains against the outside wall of a 4 inch (100 mm) trench, and backfill the trench adjacent to the pavement with granular material. Place the granular material in one or more lifts with a vibratory compactor run over the final lift to compact the granular material before placing the asphalt plug. Place the first layer of granular material simultaneously with the trenching operation to hold the edge underdrains flush against the trench wall.

Before placing into the trench, splice the prefabricated edge underdrains, as required, using material furnished by the manufacturer and according to the manufacturer's directions. The manufacturer must furnish all material required for the splices and furnish any equipment required for splicing. Construct splices to prevent adjoining sections of the prefabricated edge underdrain panels from separating. Provide the dates when the prefabricated edge underdrains were placed on the appropriate construction inspection form.

Underdrain Outlets (605.06)

Construct outlets per 611 and document this work as required in 611. The manufacturer must supply outlet fittings that transition between the underdrains and the outlet pipe. These are included in the 605 pay items. Place underdrains and outlets on fractured slab projects, such as crack and seat, rubblized, or break and seat projects before fracturing the existing pavement.

Mark all underdrain outlets with a wooden lath prior to final seeding. Clean all debris from the outlets after final seeding. These are included in the 605 pay items.

Aggregate Drains (605.07)

Construct the aggregate drains after the completion of pavement.

Excavation (605.07.A)

Excavate trenches for aggregate drains to a minimum width of 12 inches (0.3 m) and to the depth shown on the plans. Slope the bottom of the trench to drain and to keep it free

from loose particles of soil. Excavate the trench to provide a clean exposure of the granular pavement courses to be drained. Provide the dates of when the aggregate drains were placed on the appropriate construction inspection form along with a sketch.

Placing and Backfilling (605.07.B)

Use granular material for the drains. Place the aggregate to a minimum depth of 8 inches (200 mm) above the bottom of the trench. According to Item 203, backfill the remaining depth of the trench with suitable embankment material. Provide how the aggregate drains were backfilled on the appropriate construction inspection form.

Method of Measurement (605.08)

Provide the method used to measure the underdrains on the appropriate construction inspection form , e.g. station-to-station, by wheel, or other standard method of field measurement.

Basis of Payment (605.09)

Note the length paid per day. Provide this on the appropriate construction inspection form.

606 Guardrail

Description (606.01)

This work consists of constructing or reconstructing guardrail, guardrail posts, bridge terminal assemblies, end terminals, and impact attenuators, including the furnishing, assembling, and erecting of all component parts and materials.

Guardrail shall be deep beam rail Type 5, 5A, 8 or MGS. Appurtenances shall include bridge terminal assemblies, end terminals, and impact attenuators. Construction of the various types of guardrail include the furnishing, assembling, and erecting of all component parts and materials, complete in place at the location shown on the plans, or as directed, and according to the manufacturer’s recommendations where applicable.

Setting Posts (606.03)

The posts shall be set or driven plumb in a manner that prevents battering or distorting of the posts. The posts that are set or driven more than 1inch above grade shall be trimmed. The trimmed posts shall be treated with a preservative material specified in 712.06.

Erecting Rail Elements (606.04)

The plans shall show how to erect either a standard design (single-faced) guardrail or a barrier design (double-faced) guardrail.

Erect rail elements in a manner resulting in a smooth, continuous installation. Shop-curved rail shall be used on curves with radii from 5 to 70 feet (1.5 to 22.4 m). Do not allow straight elements to be bent or curved to fit a radius.

The bolts shall be tightened through expansion joints, as tight as possible, to prevent the rail elements from sliding past one another longitudinally. Ensure that the bolts are long enough to extend at least 1/4 inch (6 mm) beyond the nuts.

Splice bolts that extend more than 1/2 inch (13 mm) beyond the nuts shall not be used. For double-faced guardrail, the bolts shall extend from 1/4 inch to 1 inch (6 to 25 mm) beyond the nuts.

Do not allow burning or welding in the field. The Engineer may approve making holes in the field, but only for special details in exceptional cases. The Engineer may approve field punching, cutting, and drilling if the Contractor demonstrates that its methods do not damage the surrounding metal.

The galvanized surfaces shall be repaired that have been abraded such that the base metal is exposed, including threaded portions of all fittings and fasteners and cut ends of bolts as specified by ASTM A 780.

The guardrail shall be erected so that the bolts at expansion joints are located at the centers of the slotted holes. The rail elements shall be lapped in the direction of traffic. The plates at each splice shall make contact throughout the area of the splice.

Guardrail Rebuilt (606.05)

Unless otherwise shown on the plans, the rebuilt guardrail shall be of the same type and spacing of members as the existing guardrail.

The following materials shall be new: posts, blockouts, bolts, washers, and incidental hardware, as necessary, to complete the guardrail, except: (1) existing steel posts and blockouts that are not damaged and have a good galvanized coating may be reused, and (2) guardrail splice bolts that are undamaged and were not removed during salvage may be reused.

Impact Attenuators (606.06)

Before installation of the attenuator, all corresponding shop drawings, installation drawings, and instructions from the manufacturer shall be made available for the Engineer's inspection. Ensure the attenuator is installed as per manufacturer's shop drawings.

The top of each foundation shall be graded at the same elevation as the adjacent travel lane and/or paved shoulder. The anchors for the attenuator shall be adjusted to avoid pavement joints.

Method of Measurement (606.07)

The Department will measure Guardrail, new or rebuilt, of the type specified, by the number of feet from center-to-center of end posts, excluding anchor assemblies. If, however, end connections are made to masonry or steel structures, the Department will measure to the center of the normal post bolt slot. If rail element is used across a bridge, the Department will measure to the first post off the bridge.

The Department will measure Anchor Assembly, of the type specified, by the number of each assembly furnished and erected complete.

The Department will measure Bridge Terminal Assembly, of the type specified, by the number of each assembly furnished and erected complete.

The Department will measure Impact Attenuator, of the type specified, by the number of each attenuator furnished and erected complete.

The Department will measure Guardrail Post, of the kind specified, by the number of each post furnished and erected complete.

Basis of Payment (606.08)

The additional costs associated with furnishing and installing extra-length posts instead of standard-length guardrail posts are incidental to Guardrail Post, 8 foot (2.44 m) or Guardrail Post, 9 foot (2.75 m).

For the extra costs associated with furnishing and installing extra-length posts in lieu of standard-length guardrail posts, payment for 9 foot (2.75 m) guardrail posts is considered full compensation.

607 Fence

Clearing and Grading (607.03)

Clearing and grading shall be performed to construct the fence to the required alignment and to provide a reasonably smooth ground profile at the fence line. The contractor shall perform 607 Fenceline Seeding and Mulching according to Item 659 Seeding and Mulching on all areas disturbed by the clearing and grading for the fence within 8 months of the activity. The Department will deduct the area paid for under Item 607 Fenceline Seedng and Mulching from Item 659 Seeding and Mulching quantities as described in the plan, if applicable.

Post Assemblies (607.04)

During the curing period of the concrete encasement, the brace end, corner, gate, and pull or intermediate anchor posts shall be secured in final position. Do not require forms for post encasement.

For Type 47 and Type CLT fence, the maximum spacing between intermediate anchor post assemblies, or between end post assemblies and intermediate anchor post assemblies, are 660 feet (200 m).

Horizontal Deflection (607.05)

At points of horizontal deflection, the fence shall be constructed as follows:

1. **Type 47 Fence.** If the fence changes alignment by more than 1 degree, but not more than 4 degrees, either steel line posts encased in concrete, or wood posts without encasement, shall be installed at all horizontal deflection points. If the change in alignment is more than 4 degrees and less than 30 degrees, an intermediate anchor post assembly shall be installed at the deflection point. If the change in alignment is 30 degrees or more, a corner post assembly shall be installed at the deflection point.
2. **Type CLT Fence.** If the fence changes alignment by more than 1 degree, but not more than 4 degrees, line posts encased in concrete shall be installed at all horizontal deflection points. If the change in alignment exceeds 5 degrees, a post brace and truss rod in each fence panel adjacent to the post located shall be installed at the angle point. If the change in alignment exceeds 5 degrees, the footings for all posts located at deflection points shall be constructed as specified for end posts.

Line Posts (607.06)

Line posts shall be set according to the following:

1. **Type 47 Fence.** The spacing of line posts is not to exceed 12 foot (3.6 m) intervals. Line posts at the bottom of dips or depressions in the ground surface are to be anchored in concrete.

2. On tangents, line posts shall be placed so that the fabric, when installed on the side toward the highway, is 2 feet (0.6 m) from the Right-of-Way line. If adjacent to Right-of-Way lines with less than 5,740 feet (1750 m) radius (in excess of 1 degree curvature), line posts shall be constructed on chords so that the fabric, when installed on the side toward the highway, is not less than 2 feet (0.6 m) or more than 8 feet (2.4 m) from the Right-of-Way line.
3. **Type CLT Fence.** The tops of driven line posts shall be protected by drive caps or other method to prevent distortion of the exposed end. Line posts are to be spaced at no more than 10 foot (3 m) centers, and placed so that, when the wire is fastened on the side toward the highway, it is 1 foot (0.3 m) from the Right-of-Way line.

Fabric (607.07)

The fabric shall not be erected until after 5 days from the time of setting the posts, when using regular cement, or until after 3 days, when using high early strength cement.

Type 47 fabric shall be stretched and fastened to line posts using galvanized ties. At a minimum, one tie shall be used for each of the top and bottom horizontal wires and one tie for each alternate horizontal wire below the top horizontal wire.

Chain-link fabric shall be fastened to the line posts using clips or bands spaced approximately 14 inches (0.4 m) apart, and to the top tension wire using bands or tie wires at approximately 24-inch (0.6 m) intervals or less. Successive rolls of fabric shall be joined by weaving a single picket into the ends of the rolls to form a continuous mesh.

Method of Measurement (607.09)

The Department will measure Fence, Type ___ by the number of feet (meters), complete in place. The Department will measure along the top of the fence from outside-to-outside of end posts, exclusive of gates and other openings.

The Department will count Gate, Type ___ by the number of complete units of the size and type specified.

608 Walks, Curb Ramps, and Steps

Description (608.01)

This work consists of constructing walks, curb ramps, and steps.

Concrete Walks (608.03)

Subgrade should be prepared and compacted to the elevations and locations as shown on the plans. Forms should be checked for any bulges and for proper cross slope. Ensure subgrade is wetted prior to placement of concrete for walk. Do not allow concrete finishers to apply water to the surface of pavement to aid in finishing of concrete. Any additional water added to the surface of the fresh concrete increases the water/cement ratio of mortar and adversely affects air content. This results in a less durable matrix and the concrete surface is more prone to early scaling and general surface deterioration. Prior to acceptance the walk should be checked again for cross-slope, surface defects, cracking outside of joints.

Curb Ramps (608.07)

The same practices outlined above for Concrete Walks should apply to curb ramps. Additional attention should be given to this operation to ensure that the ramps conform to the slopes, elevations and dimensions given in the plans and applicable standard drawings. It is critical to ensure that minimum dimensions are adhered to and that slope tolerances are not exceeded to ensure compliance with ADA standards.

Manufacturers are required to provide written installation instructions and a 5 year warranty for the detectable warning devices to the Engineer at or before the pre-construction meeting.

Method of Measurement (608.08)

Concrete Walk, Asphalt Concrete Walk, Aggregate Walk, Curb Ramp, and Detectable Warning are to be paid by the number of square feet of finished surface complete in place. Concrete Steps are to be paid by the lineal foot. Measure the completed in place length of each tread width, along the front edge, and add together for the total length.

609 Curbing, Concrete Medians, and Traffic Islands

Description (609.01)

This work consists of furnishing and constructing curb, combination curb and gutter, medians, and traffic islands. This work also consists of excavating, backfilling, furnishing and installing joint materials, and disposing of surplus excavation and discarded materials according to Item 203.

Cast-in-Place Concrete Curb and Combination Curb and Gutter. (609.04)

A. Forms and Joints. Use only approved steel forms for curbs. The Contractor may use approved flexible forms of steel or wood to construct curved curb with a radius of 200 feet (60 m) or less. Immediately before placing concrete, clean the inner surface of the forms, and coat this surface with a form release agent.

Where curb and combination curb and gutter is not constructed integral with, or tied to, the base or pavement, construct 1/4-inch (6 mm) wide contraction joints at 10-feet (3 m) intervals using steel separator plates, a grooving tool, or a saw according to Item 451. For combination curb and gutter, construct the joint to an average depth of 2 inches (50 mm) or more. For curb, construct the joint to an average depth of one-fifth or more of the curb height. Where expansion joints occur in the abutting pavement, separate the section being placed with 1-inch (25 mm) thick 705.03 preformed filler.

Where the curb is integral with, or tied to, the base or pavement, construct the same type of joints as used in the pavement. Space joints identically with the joints in the base or pavement to prevent the pavement movement from cracking the curb sections.

Leave curb forms in place until their removal will not damage the concrete. Do not seal transverse joints in cast-in-place concrete curb and combination curb and gutter.

B. Placing. Place concrete in forms and vibrate the concrete to eliminate all voids.

Place concrete for curb that is integral with the concrete base or pavement while the base or pavement concrete is plastic. Where the presence of the finishing equipment on the forms at the end of the day's run prevents completing the curb, install No. 5 (No. 16M) tie bars vertically in the pavement at 1-foot (0.3 m) intervals and in a line 3 inches (75 mm) inside of and parallel to the pavement edge. Install these tie bars to within 1 1/2 inches (38 mm) of the subgrade or subbase and 2 inches (50 mm) above the concrete base or pavement surface. Water cure this horizontal construction joint between the concrete base or pavement and the curb, or membrane cure the concrete base or pavement and remove the membrane before placing the curb. Immediately before placing the concrete curb, brush mortar (consisting of one part cement to two parts sand with enough water to form a workable mortar) into the surface area of the hardened concrete pavement or base where the curb is to be placed. Do not allow the mortar to dry before placing the curb on top of it.

C. Slip-Form Placement. The Contractor may use a self-propelled machine to place concrete curb or curb and gutter. Ensure that the concrete is extruded without excessive voids or slumping to maintain the desired shape and to the lines and grades given in the plan.

D. Finishing. Concrete should be finished without adding extra mortar or water to the surface to produce a smooth and even surface. Round the edges of the curb using a tool specially designed for this purpose. Immediately after removing the forms, rub the exposed face of the curb with a float to eliminate unnecessary tool marks. Provide a finished surface free of irregularities and waves, and uniform in texture.

E. Protection. Cure concrete according to Item 451. Ensure that curing is maintained and the concrete is protected from freezing.

Asphalt Concrete Curb. (609.05)

Asphalt curb may be placed using two methods. The mixture should be monitored to ensure that temperatures are consistent and allowing for proper workability of the material.

Method A. After completing the surface course, place tack coat material conforming to 407.02 at the rate of 0.15 gallon per square yard (0.7 L/m2). Place the curb with a hand-operated or self-propelled machine consisting of a hopper and power-driven screw, which forces the material through an extrusion tube. Force the material through a die attached to the end of the extrusion tube to obtain the proper density and cross-section.

Method B. As an independent operation preceding the final rolling of the asphalt concrete surface course on which the curb is placed, place loose asphalt concrete of sufficient height. Shape the loose asphalt concrete by hand methods using suitable templates or by other means to produce the specified cross section.

Compact the loose asphalt concrete using a hand-operated mechanical vibrating tamper equipped with a compacting shoe of such shape that will produce the specified final cross-section dimensions of the curb.

Concrete Median and Traffic Island. (609.06)

A. Forms and Joints. The Contractor must use steel forms that are stable to maintain line and grade. The Contractor may use approved flexible forms of steel or wood to construct curves with a radius of 200 feet (60 m) or less.

Immediately before placing concrete, clean the inner surface of the forms, and coat this surface with a form release agent.

Where medians and traffic islands are not anchored to the pavement, construct contraction joints at 10-foot (3 m) intervals using steel separator plates, a grooving tool, or saw according to Item 451. Construct joints to a minimum depth of 2 inches (50 mm).

Where the medians or traffic islands are anchored to the pavement, construct the same type of joints in the median or traffic island as used in the pavement. Construct joints to a minimum depth of 2 inches (50 mm) using steel separator plates, a grooving tool, or saw according to Item 451. Space the joints identically with the joints in the pavement.

Leave forms in place until their removal will not damage the concrete.

B. Placing. Ensure the subgrade is moistened before placing concrete. Place the concrete in forms and vibrate the concrete to eliminate all voids.

C. Slip-Form Placement. The Contractor may use a self-propelled machine to place medians and traffic islands. Ensure the concrete provides the desired shape and remains as placed without slumping of the faces.

D. Finishing. Finish the concrete per the specification without adding additional water or mortar to the surface.

E. Protection. Cure concrete according to Item 451.

Method of Measurement. (609.07)

Measure Sandstone Curb, Curb, Combination Curb and Gutter, and Asphalt Concrete Curb by the number of feet (meters) complete in place, measured along the front face of the curb section.

Measure Concrete Traffic Island and Concrete Median by the number of square yards (square meters) or the number of cubic yards (cubic meters) complete in place.

610 Cellular Retaining Walls

This specification covers general types of retaining walls. The first are walls made up of layered and tiered precast reinforced blocks. The second are constructed with metal columns and front and rear metal filler panels. Both of these wall types are specialized and require Director's approval. Acceptable manufacturers are sometimes indicated in the plan notes.

Materials(610.03) /Manufactured Units (610.04) /Wall Construction (610.07)

A. Concrete Cellular Wall. Concrete according to 499 and reinforcing steel according to 509.02. Reject reinforced concrete units if:

1. Reinforcing Steel is exposed
2. Honeycombs
3. Fractures and cracks

Interlock headers perpendicular to sills at proper grade and alignment. Do not shim.

B. Metal Cellular Wall. Galvanized metal sheets according to AASSHTO M 218 with a minimum thickness of 0.057 inches. Reject units with improperly drilled holes.

Place in proper position and batter by the use of templates.

611 Pipe Culverts, Sewers, Drains, and Drainage Structures

Description (611.01)

This specification states requirements in terms of the required results and includes criteria for verifying compliance without stating the methods for achieving the required results. The types of pipe are specified in accordance with their application and intended usage. For a brief description of typical applications, refer to “Materials,” Section 611.02. For a more detailed description, refer to the Location Design Manual, Volume 2, Drainage Design, and the plans.

The Inspector will monitor the materials and the installation plan. The Contractor will install the materials as well as monitor and document the installation while providing third party inspection/evaluation and certification of performance based on contract criteria.

Materials (611.02)

Materials selected as part of the installation plan will be inspected and approved by the Inspector prior to use.

Type A Conduits

Type A conduits are sealed culvert cross drains under pavements, paved shoulders, and embankments. These culvert cross drains are used to convey water from one side of the roadway to the other. These culverts can be either smooth lined or corrugated. Type A conduits are under pavement and open at both ends.

Type B Conduits

Type B conduits are storm sewers under pavement, paved shoulders, and commercial or industrial drives. Storm sewers are used to convey water from one manhole or catch basin to the other. Storm sewers are always smooth lined. Type B conduits have one or both ends closed with a drainage structure.

Type C Conduits

Type C conduits are storm sewers which are not under pavement, paved shoulders, or commercial and industrial drives. Like Type B conduits, these conduits are connected to a manhole or catch basin and are always smooth lined. Type C conduits have one or both ends closed with a drainage structure.

Type D Conduits

Type D conduits are culverts placed under residential driveways or bikeways. These conduits can be either smooth lined or corrugated.

Type E Conduits

Type E conduits are farm drain headers in or outside the right-of-way or used for ditch elimination beyond the paved shoulder. These conduits can be either smooth lined or corrugated.

Type F Conduits

Type F conduits are other miscellaneous pipe where a butt joint or a short length jointed pipe would be undesirable. Outlets for underdrain or farm drains, house drain connections, pull box drains, or steep portions of a median outlet under an embankment are examples of Type F applications. These conduits can be either smooth lined or corrugated.

Bedding and Backfill

The materials used for bedding and backfill are approved by the manufacturer prior to use and are listed in the Installation Plan. Bedding, Initial Backfill and Final Backfill materials are to be consistent with 611.02 H. The Bedding, Initial Backfill and Final Backfill materials, lift thickness and compaction requirements are all to be included in the Installation Plan.

Given that this is a performance specification, mostly focused on the performance measures of the conduit, it was determined that the manufacturers are more particularly concerned with the quality of the backfill material adjacent to the conduit or drainage structure and less concerned with the remainder of the trench backfill material. However, the performance of other items of work (roadways, embankment) are dependent on the entire trench backfill material. Poor quality backfill material or compaction efforts, not adjacent to the conduit, may not be observed during the performance inspection of the conduit. Therefore, Backfill material was further defined as Initial Backfill and Final Backfill. Initial Backfill represents the envelope of backfill above the bedding to 12 inches above the conduit or as necessary for the conduit material. Final Backfill extends from the Initial Backfill to the remainder of the trench. Final Backfill shall meet or exceed the requirements of C&MS 203. The definitions of Bedding, Initial Backfill and Final Backfill are described in 611.03 Definitions. Figure 611-1 is a graphic representation of the bedding and backfill definitions.

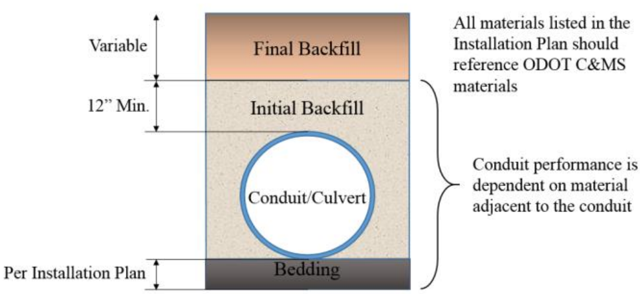


Figure 611.1 - Backfill definitions

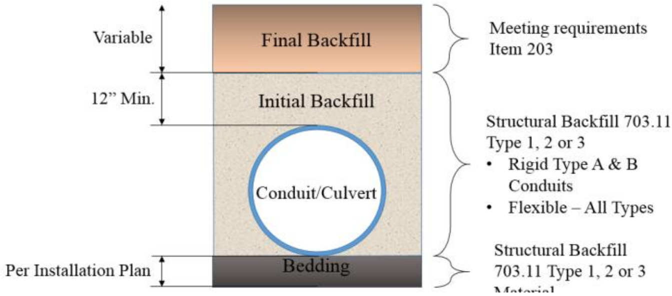


Figure 611.2 - Backfill definitions

Low Strength Mortar Backfill (LSM)

In some cases, the plans designate the use of LSM as bedding and/or backfill material. The requirements for LSM can be found in C&MS 613. There are three Types of mixes. Type 1 is a mixture of cement, fly ash, sand, and water. The Type 2 mixture substitutes an entrained air additive for the fly ash. The Type 3 mixture is a mixture of fly ash and water. All three mixes may be used, or an alternative mix, submitted for approval by the Contractor, may be used if the plans do not call out a mix. The alternate mixes shall meet the criteria in C&MS 613. Changes in the material type, amount, or sand gradation are allowed, as long as the final mix has the required strength, fills the voids, and sets up. The use of LSM backfill shall be identified on the Installation Plan.

Submittals (611.04)

Shop Drawings and Calculations

Shop Drawings and structural calculations are required to be submitted to the Engineer for certain precast concrete structures as described in 611.04 A. and reinforced concrete circular conduits as described in 611.04. A. 1.

Shop Drawings and calculations are sealed by a Registered Engineer as described in 611.04 A. Only one Registered Engineer is required to seal the shop drawings and calculations. Ensure the preparer and checker are listed on the shop drawings. .

The Project personnel will ensure Shop Drawings and calculations for Reinforced Concrete Circular Pipe, which require a special design, are submitted to the Office of Structural Engineering and a copy is filed in the project records.

The Project personnel will ensure Shop Drawings and calculations for Precast Reinforced Concrete three-sided flat topped culverts, precast reinforced concrete arch culverts, or precast reinforced concrete round sections, (706.051, 706.052, or 706.053) are submitted to the Office of Structural Engineering, and a copy is filed in the project records.

Load Rating calculations are required to be submitted to the Engineer for all structures with a 10-foot or greater span. The Project personnel will forward the calculations to the District Bridge Engineer and Office of Structural Engineering, Bridge Management Section. A copy is filed in the project records.

The Project personnel will ensure that if the Contractor substitutes one structure for another, they also submit hydraulic calculations to the Office of Hydraulic Engineering.

Installation Plan

Each run of conduit (A, B, C, D, E, F, etc.) to be installed will require a CA-P-1A Installation Plan. The conduit manufacturer will confirm that the material provided is appropriate for the proposed installation materials and method of the Contractor. The conduit manufacturer shall sign the submitted Installation Plan CA-P-1A. CA-P-3A Installation Plan is required for each drainage structure. Project personnel will review and accept the installation plan if it includes all the requirements listed in 611.04.B. Per C&MS 101.03 Working Drawings consist of installation plans and once accepted, become part of the contract requirements.

1. The Project personnel will monitor the installation process to ensure compliance with the Installation Plan. Each installation plan should be filed in the project records in the appropriate reference file. Deviation from the Installation Plan constitutes a revised Installation Plan and must be resubmitted to the Project for acceptance. The conduit manufacturer must sign off on all modified Installation Plans. For minor changes to the Installation Plan, the Contractor may continue to work while in the process of having a modified Installation Plan signed by the manufacturer. However, this work is done at the risk of the Contractor. If the manufacturer will not approve the modified Installation Plan, the Project personnel should not accept the modification.

For further detail on the Material Certification Program, contact the District Testing Engineer or refer to Materials Management Sampling and Testing Program Manual.

Construction Inspection

Each day the Contractor will submit to the Project personnel a properly completed construction inspection form, CA-P-1, for conduit and form, CA-P-3, for drainage structures. Inspection form CA-P-3 is not required for precast reinforced concrete outlet structures 706.15. The project personnel will review the forms to ensure the information on the construction inspection form is complete and accurate. The forms should document the installation procedure described in the accepted Installation Plan.

The forms should include trench and bedding measurements every 50 feet with a minimum of two per run. Measurements should be recorded to the nearest 0.1 foot (30 mm).

All items regarding the conduits and drainage structure should be included on the daily inspection reports, including:

1. Pipe joint sealer application.
2. Coupling band installation.
3. Field paving of conduits, materials, and installation process.
4. Concrete curing applied.
5. Waterproofing materials and installation process.

Performance Report

The Performance Report will consist of a performance inspection, a performance survey, a surface settlement evaluation, and an independent evaluation. A Performance Report

will be created for each performance inspection performed. Requirements for the Performance Report are listed in C&MS 611.04 D.

Bedding and Backfill (611.06)

Placement of bedding and backfill will be recorded by the Contractor's personnel in the construction inspection forms. Ensure that the Contractor is installing the bedding and backfill with the same lift thickness and density as shown on the Installation Plan. Modification of materials or installation method will require a new Installation Plan be submitted.

The Contractor is responsible for all density testing of the entire bedding and trench backfill material. The density and lift thickness results are recorded according to Supplement 1015.

Structural Backfill Type 3 in C&MS 703.11 is considered open graded material and the material density cannot accurately be verified through testing. Therefore, no density testing is required for Structural Backfill Type 3 material. The manufacturer shall indicate compaction effort of the open graded material for the Bedding and Initial Backfill in the Installation Plan. Open graded material used for Final Backfill shall be placed and vibratory compacted per C&MS 203.

Migration of fines into open graded aggregate is probable for trench bedding and backfill materials. Water is necessary to transport fines into the open graded material. Therefore, geotextile fabric should be used as a separation barrier when water has the potential to transport fines into open graded aggregate layers. Geotextile fabric Type A is required above open graded aggregate courses (703.11 Type 3) to prevent migration of the fines from above. The fabric is required for the entire width of the trench. Geotextile fabric Type A is also required to wrap the trench when groundwater is present. Place the fabric up to the level of groundwater elevation. If the groundwater condition was not identified in the contract documents and is present at the time of construction, direct the contractor to install the geotextile fabric up to the groundwater elevation and compensate per C&MS 109.05. Figure 611-3 graphically represents the locations of the geotextile fabric if required.

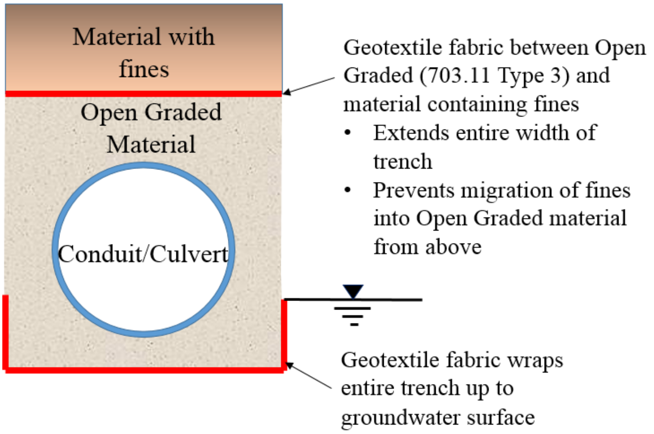


Figure 611.3 – Geotextile placement

Inspection (611.12)The Project personnel will witness the performance inspection, as performed by the Contractor. At a minimum, the Project personnel should be present at the initial inspections to ensure, early that the Contractor is performing the inspections per the Contract requirements. The conduits and structures should be cleaned of all debris to allow for proper inspection. The performance inspection should be 30 days after the completion of the finish grade or rough subgrade. The Engineer may adjust the minimum 30 day waiting period if access to the conduit will be an issue. However, the Contractor should make attempts to adjust their methods of construction to allow access after the 30 day waiting period. Contact the Office of Construction Administration to discuss an allowance from the minimum 30 day waiting period. A reduction in the maximum allowable deflection or cracking width may be appropriate for inspections occurring prior to the 30 day waiting period.

Ensure remote inspection equipment meets Supplemental Specification 902. Typically, this information is missing in the Performance Report. It may be beneficial to remind the Contractor of the requirements of SS902 at the time of the performance inspections to prevent the need to re-perform the inspections.

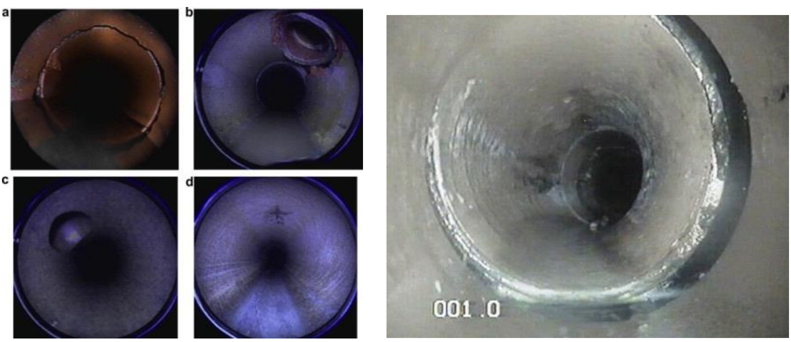


Figure 611.4 – Internal Conduit

(a) Defective and open joint – VC pipe, (b) Defective connection – VC pipe, (c) Perfect connection – VC pipe, and (d) Exposed reinforcement – RC pipe.

Figure 611.5 – You Never Know What you Will Find

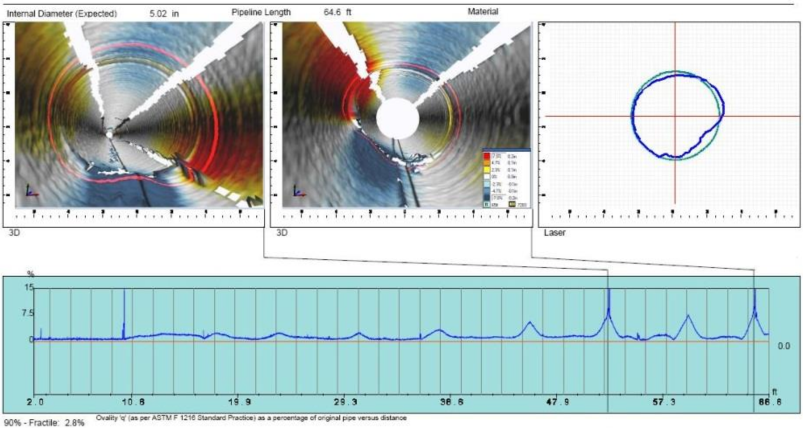


Figure 611.6 – Sample Pipe Inspection Report including Ovality Observations

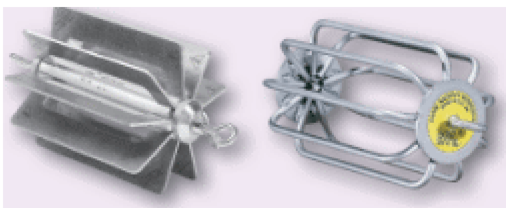


Figure 611.7 – Example Mandrel Gauges

Conduit Evaluation and Drainage Structure Evaluation (611.13 & 611.14)

Conduit and drainage structure elevations are verified by the Contractor and are now recorded on the construction inspection forms. This identifies to the Project personnel early that the as-built conditions are or are not in relative close conformity to the design. The Project personnel will note all non-conformity with the Contract Documents (Plans). The independent Registered Engineer may be required to provide additional hydraulic analysis if constructed at an out of tolerance vertical alignment or if sagging is present. Do not accept the Work unless proper documentation from the Contractor is provided.

An evaluation of surface settlements within 4 feet of the trench limits or drainage structure should be included in the performance inspection.

After the performance inspection, a survey and settlement evaluation is completed, and an independent registered engineer will provide a review of the conduits and structures. This independent registered engineer will provide a statement indicating that no repairs are required, or that repairs are required, and the repair plan meets the design requirements.

All defects or imperfections with the installation shall be noted as a defect in the inspection report and be evaluated by the independent registered engineer. Table 611.13 and 611.14 identifies the minimum items that need evaluation and when a repair is

required to be performed. It does not list when a defect shall be noted. (i.e. all cracks exceeding 0.01-inch in concrete are to be noted as a defect and evaluated. Cracks exceeding 0.1-inch require a repair.) The independent registered engineer shall evaluate all cracks of 0.01-inch and determine if the defect will impact the design service life of the conduit or drainage structure. Similarly, vertical sags, deflection less than 7.5% and non-uniform deflection are all examples of defects that require an evaluation.

All manual and remote performance inspections are to be video recorded.

Defect Repairs

The independent registered engineer's report should include all defects and whether a repair is necessary or not. Table 611.13 and Table 611.14 in the C&MS book identify certain thresholds for common defects when repairs are necessary. For plastic conduit, a repair or replacement is required when deflection exceeds 7.5%. Further, a repair is only allowed if the deflection is less than 12%. The recommendation provided by the independent registered engineer must include written confirmation from the manufacturer that the repair is appropriate. The repair plan must be signed and sealed by the independent registered engineer.

A follow-up performance inspection and evaluation is required on all repaired or reinstalled conduit or drainage structures.

Project File Requirements - 611 Pipe Culverts, Sewers, Drains and Drainage Structures

1. File the Contractor supplied Shop Drawings with each applicable reference.
2. File the Contractor supplied Installation Plan in the project records with each applicable reference.
3. File Contractor supplied form CA-P-1 or CA-P-3 as appropriate in the project records with each applicable reference. Make sure all waterproofing and field paving is noted in the comments section of the forms.
4. Enter the daily amounts installed into SiteManager as appropriate.
5. File the Contractor supplied Performance Inspection, Performance Survey, and Surface Settlement Evaluation in the project records with each applicable reference.
6. File the Conduit Evaluation and Drainage Structure Evaluation as provided by an independent registered engineer in the project records with each appropriate reference.

613 Low Strength Mortar Backfill

Method of Measurement Requirements

This section recommends minimum documentation and critical inspection requirements for Item 613 used as conduit backfill. The following documentation requirements must be recorded in the appropriate sections of the conduit construction inspection form and in the project daily reports. Specifications or other requirements waived by the Project Engineer shall be noted in the daily diaries.

A comparison needs to be made between the quantity installed and the quantity computed from the plans (take-off quantity). Record both the installed and take-off quantities Measure and pay the computed amount of cubic yards (cubic meters) unless it is determined by the Engineer that the amount used is reasonable for pay. Documentation of the take-off and installed quantities is an important part of the record, particularly when paying less than the quantity delivered.

614 Maintaining Traffic

Description (614.01)

This work consists of maintaining and protecting vehicular and pedestrian traffic according to these provisions. For through traffic, the Special Provisions or the plans will designate whether the highway will be closed with detours, roads, and run-arounds provided or whether traffic will be maintained through all or portions of the project.

Traffic Facilities (614.02)

Vehicular and pedestrian ingress and egress for all property adjacent to any improvement shall be provided at all times.

Contractor maintenance responsibilities, including pothole patching, begins for a section of highway when the Contractor begins the work in that section and ends with the acceptance of the work under 109.11 or 109.12. The two directions of a divided highway are considered separate highway sections and the start of work on one direction does not begin maintenance responsibilities on the other direction.

Traffic Control General (614.03)

The traffic control shall conform to the requirements of the plan, standard construction drawings shown on the plans, and the OMUTCD for Streets and Highways, hereinafter called the Ohio Manual, for the installation, maintenance, and operation of all traffic controls and traffic control devices. When the plans or standard construction drawings do not cover a specific traffic control situation, the necessary traffic control devices shall be placed according to the Ohio Manual and procedures required by the Ohio Manual shall be implemented.

The OMUTCD (Ohio Manual on Uniform Traffic Control Devices) has three levels of compliance to indicate the type of standard and whether it is mandatory, recommended, or optional:

- All mandatory conditions are listed under the section heading “Standard.”
- All recommended conditions are listed under the section heading “Guideline.”
- All allowed conditions are listed under the section heading “Option.”
- A fourth grouping, “Support,” was added to include statements that were not mandatory, recommended, or optional, but rather general information.

Supplement 1061 prequalifies the portable changeable message boards. Only two panel of information shall be allowed.

Cones, drums, signs, portable sign supports, barricades, impact attenuators, and other traffic control devices that are certified to meet NCHRP 350 safe-crash standards, or as modified by Contract Documents, shall be used. Do not allow heavy, non-yielding devices or supports that do not conform to the current standards of NCHRP 350, unless allowed by Contract Documents.

Ensure the drums are furnished with reboundable reflective sheeting, which complies with the requirements of 730.191 and in conformance with the OMUTCD. Ensure that

owner identification markings on construction drums are no more than 1 inch (25 mm) in character height and are located at least 2 inches (50 mm) below the reflectorized bands or on the top or bottom horizontal surfaces of the drum. Ensure the drums are ballasted according to the manufacturer's recommendations.

Object markers shall be a minimum size of 6 x 12 inches and that consists of reflective sheeting adhered to an aluminum or plastic plate.

614.035 Storage of Equipment, Vehicles and Material on Highway Rights-of-Way.

Unless otherwise permitted by the Engineer, locate all equipment, vehicles, and material stored or parked on highway rights-of-way:

A. At least 6 feet behind the face of Existing Barrier and not within the 75 foot long by 20 foot wide Recovery Area behind the Existing Barrier run, or;

B. Not less than 30 feet from the nearest edge of the traveled way, or;

C. At least 6 feet behind raised curbs.

Additionally, at night, encompass any such equipment, vehicles or material with drums, equipped with Type A warning lights, spaced at 5 feet on center.

For locations with traffic approaching from more than one direction or side (e.g., medians, between mainline and ramps, etc.), ensure the requirements are met for all traffic approaches.

Existing Barrier, for purposes of 614.035 only, includes and is limited to: existing permanent guardrail, existing concrete barrier, temporary or new permanent guardrail installed in accordance with the plans, temporary portable barrier installed in accordance with the plans, or new permanent concrete barrier installed in accordance with the plans. Other types of barrier not listed, such as cable barrier, are excluded as a means of protecting drivers from stored equipment, vehicles and material on highway rights-of-way.

Recovery Area, for purposes of 614.035, shall have slopes 3:1 or flatter and be free of workers, hazards, equipment, vehicles, drop-offs, and material storage. The Recovery Area length is to begin at the terminus of the Existing Barrier run. Any gating impact attenuator length shall not be included as part of the Recovery Area length.

Flaggers (614.08)

Whenever one-way traffic is established, at least two flaggers shall be used, unless the Engineer authorizes otherwise, and signs, cones, barricades, and other traffic control devices shall be erected according to the Ohio Manual. Flaggers shall maintain positive and quick means of communication at the opposite ends of the restricted area.

Asphalt Concrete for Maintaining Traffic (614.13)

The Contractor may use either a Type 1 or Type 2 mix of Item 448 asphalt concrete PG 64-22, or an asphalt concrete surface course the Engineer approves. Surface course materials shall be placed where the Engineer directs for maintenance of the existing pavement, shoulders, or structures.

Where materials are placed in small quantities or under adverse conditions, the Engineer may waive specification requirements for placing and finishing if, in the judgment of the Engineer, it is determined that the Contractor can obtain satisfactory results in providing a smooth and durable pavement surface.

Performance (614.14)

If, in the opinion of the Engineer, the Contractor is not furnishing proper maintenance of traffic facilities and proper provisions for traffic control, the Department may take the necessary steps to place them in proper condition. The Department will deduct the cost of such services from any money that may be due or become due the Contractor.

Method of Measurement (614.15)

The Department will measure Work Zone Marking Signs as the number of sign installations, including the sign, necessary supports, and all attachment hardware. The Department will include all other work zone signs under Maintaining Traffic unless separately itemized.

The Department will measure Work Zone Pavement Markings complete in place, by class and material, in the units designated.

The Department will measure line quantities as the length of the completed stripe, including gaps, intersections, and other sections of pavement not normally marked.

Basis of Payment (614.16)

Unless separately itemized, the lump sum price bid for Maintaining Traffic shall include the cost of removing conflicting pavement markings and layout, application and removal of pavement markings, maintaining the existing highway in a safe condition for public use, and removing abrasive and salt residue remaining from snow and ice control performed by the Department or local governments. The lump sum price bid for Maintaining Traffic shall also include the cost of providing flaggers and their equipment, while maintaining the equipment in an acceptable condition, and subsequently removing the following work zone traffic control items, as required by the Contract Documents:

1. Signs, supports, and warning lights.
2. Drums, cones, gates, barricades, and vertical panels.
3. Flashing arrow panels.
4. Work zone traffic signals.
5. Lighting for work zone signals and flaggers.

If traffic permanently damages beyond use, any of the following items, the Department will compensate the Contractor for the fair market value of the damaged item according

to 109.05, provided the Contractor has pursued, but failed to obtain compensation from the motorist. Follow the procedures given in 107.15 for traffic damage compensation to completed permanent items of work. Obtain compensation from the motorist before requesting compensation from the Department.

1. Flashing arrow panel.
2. Work zone signal, pole, or controller.
3. Lighting unit or pole.
4. Changeable message sign.
5. Work Zone Impact Attenuator.

The lump sum price bid for Detour Signing includes the cost of the Contractor furnishing, installing, maintaining, and removing the detour signing shown on the plans and their necessary supports.

The Department will pay for the following items under their associated item numbers: 502, "Bridges"; 615, "Roads and Pavement"; 622, "Portable Concrete Barrier." The Department will pay for aggregate and calcium chloride authorized by the Engineer and used for Maintaining Traffic under Items 410 and 616.

Project File Requirements – 614 Maintaining Traffic

Use the ODOT Long Term Inspection form for long-term projects that are under temporary traffic control twenty-four hours a day, seven days a week.

The ODOT Short-Term form is for projects that are typically set up and torn down daily such as for projects where the MOT is set up new each day, such as mill and fill operation.

615 Roads and Pavements for Maintaining Traffic

Description (615.01)

This work consists of providing, maintaining, and subsequently removing roads and appurtenances, and pavements for maintaining traffic.

Document any work as if it were being performed as its own item (203, 442, 452, 616, etc.).

Method of Measurement (615.09)

Measure the quantity of Pavement by the number of square yards (square meters) of pavement surface placed, maintained, and removed as directed, measured complete in place. Measure areas of soft subgrade, undercut and replaced, according to 204.08.

Payment for Roads for Maintaining Traffic includes the installation, maintenance, and removal of all fencing, earthwork, guardrail, sidewalk, and all other items as necessary to provide a complete, functional, and safe installation for public use.

616 Dust Control

Ohio Administrative Code references, as seen in Section 107.19, address the regulatory requirements of controls required to address the discharge of fugitive dust during construction. These Administrative Code sections are summarized in an Ohio EPA guidance document entitled, "Engineering Guide # 57."

www.epa.state.oh.us/portals/27/engineer/eguides/guide57.pdf

The guide describes, in a straightforward nature, Reasonably Available Control Methods (RACM) are required to comply with the law.

617 Reconditioning Shoulders

Description (615.01)

This work consists of preparing the shoulder, and furnishing and compacting additional aggregate on the existing or prepared shoulder.

Use removed or excavated materials in the Work when the material conforms to the specifications; if not, then recycle or dispose of the material according to 105.16 and 105.17.

Prosecution. (615.03)

Complete all shoulder reconditioning within four days following the placement of the surface course or any course that results in a dropoff of 2.0 inches (50 mm) or greater.

618 Rumble Strips on Shoulders

Because of the simplicity of this item of work, no detailed explanation of the item is required in this manual.

619 Field Office

Because of the simplicity of this item of work, no detailed explanation of the item is required in this manual.

620 Delineators

General

This information is intended to serve as a guide for construction personnel where the Contractor furnishes and installs delineators. However, it may be useful for maintenance personnel performing the same functions. Inspection procedures are outlined. This information points out the various important features and references the applicable specification or standard drawing.

Materials (620.02)

Make sure that all delineator materials used on a project are approved and listed on the Qualified Product List at the following website:

Item 720.01 Rectangular Reflectors

www.odotonline.org/materialsmanagement/qpl.asp?specref=720.01

Item 720.03 Flexible Posts

www.odotonline.org/materialsmanagement/qpl.asp?specref=720.03

Layout (620.03)

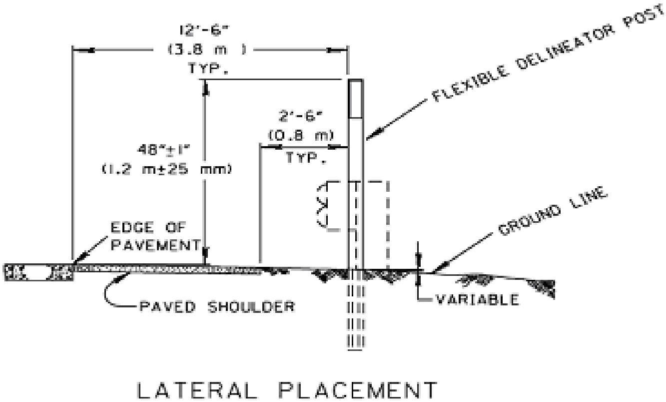


Figure 620.A – Delineator lateral placement, SCD TC 61.10

The top of the delineator post shall be 48 inches above the edge of the pavement.

The delineator post shall be placed 12 feet and 6 inches outside the outer edge of the pavement or the delineator post shall be placed 2 feet and 6 inches outside the outer edge of the shoulder.

Placement of delineator on curves and tangent sections.

Delineators shall be spaced 400 feet apart on the tangent sections.

Delineators on the horizontal curves shall be spaced according to the table in the SCD TC-61.10.

Delineators should be provided on the outside of horizontal curves on interchange ramps.

The color of the delineator reflector and flexible post shall conform to the color of the pavement markings nearest the delineator.

Installation (620.05)

Delineators shall be installed facing traffic, except for red reflectors facing wrong-way traffic, if used.

Protective paper covering the face of flexible post-mounted reflectors shall not be removed until after installation.

Ensure that delineator posts are no more than 1:50 out of plumb. If soil conditions may cause the post to be out of plumb, the Contractor may drive a pilot shaft before installation.

Install the flexible posts using methods and equipment that conforms to the post manufacturer's recommendations.

621 Raised Pavement Markers (RPM)

General

This information is intended to serve as a guide for construction personnel where the Contractor furnishes and installs raised pavement markers. However, it may be useful for maintenance personnel performing the same functions. Inspection procedures are outlined. This information points out the various important features and references the applicable specification or standard drawing.

Conduct 25 percent to 75 percent inspection during the installation activities, which include daily start-up, intermittent, and end of day inspection. Additionally, conduct 80 percent to 100 percent inspection of all installed RPMs prior to final acceptance.

Materials (621.02)

Make sure that all RPM materials used on projects are approved and listed on the Qualified Product List at the following website:

Item 721.01 Raised Pavement Marker Castings

www.odotonline.org/materialsmanagement/qpl.asp?specref=721.01

Item 721.02 Prismatic Reflectors

www.odotonline.org/materialsmanagement/qpl.asp?specref=721.02

Item 721.03 Raised Pavement Marker Castings Adhesive

www.odotonline.org/materialsmanagement/qpl.asp?specref=721.03

Item 721.04 Prismatic Reflectors Adhesive

www.odotonline.org/materialsmanagement/qpl.asp?specref=721.04

Installation RPM Casting (621.04)

References:

1. Brochure for RPM Installation Procedure.
2. See Traffic Engineering Manual, Section 350-3 at the following website:

   www.dot.state.oh.us/Divisions/HighwayOps/Traffic/publications2/TEM/Documents/Part_03_071808_bookmarked.pdf

RPMs shall be placed when the pavement surface temperature and the ambient air temperature is at least 40 °F (5 °C) and the pavement is dry.

RPMs shall not be placed under the following conditions:

1. On pavement surfaces with cracking, spalling, or failure of underlying base material.
2. Within 1 foot (0.3 m) of active signal detector loop wires.
3. Over pavement markings, except with the Engineer's approval.

4. Closer than 2 inches (50mm) to a pavement construction (transverse or longitudinal) joint or within an intersection.
5. Within 3 feet (1 m) of a bridge expansion joint.

Procedure for RPM Casting Installation:

1. Casting installation.

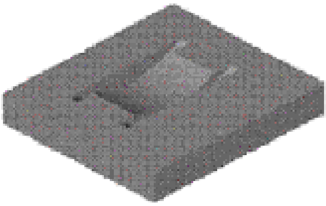


Figure 621.A – Typical saw cut

   a. Pavement must be cut to the dimensions for the casting being used.

2. Casting in saw cut without epoxy.

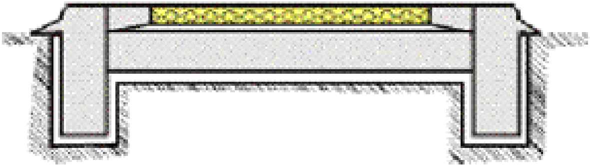


Figure 621.B – RPM cross section in saw cut

   a. Each pavement cut must be inspected prior to adding epoxy.
   b. When a casting is inserted in the cut without epoxy, all four leveling lugs/tabs must contact the pavement surface.

   All four keel-ends of castings must be below the surrounding pavement surface.

3. Casting centered in saw cut lengthwise.

Figure 621.C – Proper saw depth

   a. Each casting must be centered lengthwise and should have 1/8-inch (3 mm) clearance between pavement cut and casting for epoxy to bond properly.
   b. Only the leveling lugs/tabs should be in contact with pavement surface after insertion of casting in pavement so that a minimum of

1/8 inch (3 mm) of epoxy is the bonding adhesive between casting and pavement.

c. The pavement cut must be completely dry and free of dust, dirt, or any other material that will interfere with the adhesive bond.
d. Epoxy on the active reflector face must be removed immediately.
e. Saw cut – casting fit must be periodically checked as saw blades wear to ensure correct dimensions are maintained.

4. Properly installed RPM with epoxy around casting.

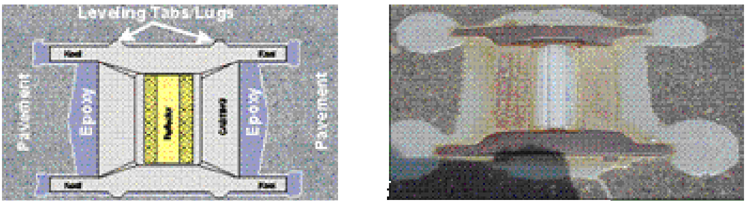


Figure 621.D – Proper adhesive placement

a. Two component epoxy adhesive approved (must be on QPL) is to be used to fill the pavement cut to within 3/8 inch of top of pavement cut prior to placing casting.
b. After placing casting:

The four leveling lugs/tabs must be in contact with pavement surface.

The epoxy should ooze out from under the casting of all sides, filling all voids around the casting, and be level with pavement surface.

Reflector Replacement (621.06)

References:

1. Brochure for RPM Installation Procedure.
2. See Traffic Engineering Manual Section 350-3 at the following website:

http://www.dot.state.oh.us/Divisions/Operations/Traffic/publications2/TEM/Documents/Part_03_Complete_042012Revision_bookmarked_042012.pdf

Procedure for Reflector Replacement:

1. Remove reflector.

Figure 621.E – Reflector removal

a. Pry old reflector out of casting.
b. Use eye protection when replacing reflector.

2. Clean the casting.

Figure 621.F – Adhesive removal

a. Scrape old pad material and adhesive out of reflector pocket, using an air hammer or wire brush.
b. Sandblast the casting pocket to remove all residual adhesive, rust, and other contaminants from the casting.
c. It is important that the casting is clean to ensure long-lasting performance.

3. Apply adhesive.

Figure 621.G – Reflector adhesive application

a. Peel the release liner from the back of the reflector.
b. Apply a wide bead, approximately 3/8 inch, of an adhesive (as approved ODOT QPL) in the center of the adhesive pad on the back of the reflector.

4. Install reflector into casting.

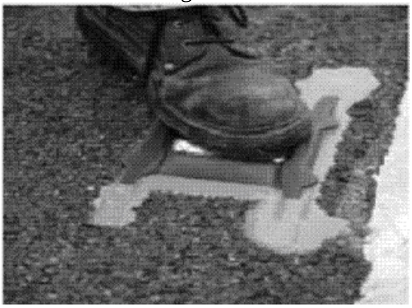


Figure 621.H – Reflector placement

a. Place the reflector into the casting pocket.
b. Apply foot pressure on the reflector for 1 to 3 seconds.
c. Adhesive must flow out around all edges of the reflector to indicate that the adhesive completely covers the entire bottom of the reflector and provides a uniform adhesive layer between the reflector and the casting.

Remedial Actions for Poorly Installed RPM Castings

This information is intended to serve as a guide for construction and/or maintenance personnel where the RPM castings are poorly installed. It provides a guide to the necessary remedial action to fix the problem.

The RPM casting shall be installed properly according to the following references:

1. Item 621.03, “Layout.”
2. Item 621.04, “Installation of RPM Casting.”
3. Standard Construction Drawings TC-65.10 and TC-65.11.

The following information provides examples of defectively installed RPM castings and describes remedial action to fix the problem.

Defective Installation: The RPM is installed with all four lugs/tabs not resting on the pavement as shown in Figure 1 below:

Figure 621.I – Improper casting placement

Remedial Action:

Remove and reinstall the RPM casting at a new location.

New RPM location shall not exceed 25 percent of the specified RPM spacing.

If necessary to relocate the RPM to a distance greater than 25 percent of the RPM spacing, do not install the affected RPM.

Fill the old cavity on the roadway surface with epoxy or asphalt concrete from where the RPM casting is removed.

Defective installation: The RPM is installed, but does not fill the voids with epoxy around the casting or the RPM is installed, but the epoxy is not around the casting to the surface of the pavement as shown in Figure 2.

Figure 621.J– Improper casting placement

Remedial Action:

Blow out dirt from around casting with compressed air.

Fill the voids and seal the RPM casting all around with epoxy as shown in Figure 3.

Figure 621.K– Improper casting placement

Defective installation: The RPM casting is installed near or on a longitudinal joint or crack on the roadway surface as shown in Figure 4.

Figure 621.L– Improper casting placement

Remedial Action:

Seal all the cracks with epoxy up to 9 inches from the RPM casting as shown in Figures 5, 6, and 7.

Figure 621.M– Improper casting placement

Figure 621.N– Improper casting placement

Figure 621.O– Improper casting placement

Defective installation: The RPM is installed, but the epoxy adhesive is not hardened, or the epoxy adhesive is not uniform gray in color as shown in Figure 8.

Figure 621.P– Improper casting placement

Remedial Action:

Remove and reinstall the RPM casting at a new location.

New RPM location shall not exceed 25 percent of the specified RPM spacing.

If necessary to relocate the RPM to a distance greater than 25 percent of the RPM spacing, do not install the affected RPM.

Fill the old cavity on the roadway surface with epoxy or asphalt concrete from where the RPM casting is removed.

Defective installation: The RPM is installed on construction joints which have extensive failure as shown in Figure 9.

Figure 621.Q– Improper casting placement

Remedial Action:

Remove and reinstall the RPM casting at a new location.

New RPM location shall not exceed 25 percent of the specified RPM spacing.

If necessary to relocate the RPM to a distance greater than 25 percent of the RPM spacing, do not install the affected RPM.

Fill the old cavity on the roadway surface with epoxy or asphalt concrete from where the RPM casting is removed.

Raised Pavement Markers Removed

Remove raised pavement markers in concurrence with the maintenance of traffic phases so that their existence or removal will not conflict with the temporary pavement markings or snow and ice removal.

Remove all standing water and fill with asphalt concrete. By the end of the next workday, depressions will be caused by removing the castings. Compact the asphalt concrete flush with the pavement.

622 Concrete Barrier

Description (622.01)

This work consists of furnishing and placing Portland cement concrete barrier on the accepted and prepared subgrade, subbase course, or existing pavement. This item consists of furnishing, placing, maintaining, and removing portable concrete barrier.

Placing Concrete (622.03)

The concrete barrier will be constructed by either cast-in-place, precast, or slip-form methods. For slip-form construction, conform to 609.04.C. For cast-in-place construction, conform to the proper SCD.

1. RM- 4.3 Single Slope Barriers.
2. RM- 4.4 Single Slope Barrier Transitions.
3. RM- 4.5 Single Slope Barrier, Type D.
4. RM- 4.6 Concrete Barrier End Sections.

Portable Barrier (622.04)

The individual sections of PCB shall be no less than 10 feet (3 m) long. See SCD RM-4.2, 32-inch Portable Concrete Barriers for details. If intending to use the barrier at one location on the project, the Contractor may slip-form barriers in place without joints or with grooved or sawed joints to facilitate removal. Any barrier sections damaged during handling or by traffic shall be either repaired or replaced for the life of the project.

Joints (622.05)

The joints for cast-in-place or slip-formed barriers shall be constructed of the type and dimensions and at the locations specified in the plans.

Contraction Joints

The Contractor may construct unsealed contraction joints by sawing using metal inserts inside the forms, using a grooving tool, or using full-width, 3/4 inch (19 mm) thick, preformed joint filler conforming to 705.03. Joints shall be sawed, tooled, or formed by inserts a minimum of 1/8 inch (3 mm) wide and 3 inches (75 mm) deep. The joints should be sawed to the required depth with minimal spalling of the concrete surface as soon as curing allows.

Expansion Joints

The 3/4-inch (19 mm) thick, preformed joint filler shall conform to 705.03 to construct expansion joints.

Horizontal Construction Joints

If, and as shown on the plans, the Contractor may place horizontal construction joints.

Finish (622.06)

Check the surface of the barrier with a straightedge for irregularities of more than 1/4 inch in 10 feet (6 mm in 3 m) after the Contractor has checked and made corrections. Document any findings on CA-D-3.

Curing (622.07)

Concrete curing shall be according to 511.17, Method B, and the following additional requirements. Ensure that the curing compound is approved. For small areas, allow the use of other acceptable methods.

Do not allow any load or any work that will damage newly placed concrete. A minimum of 36 hours of cure time is required on any concrete placed first at a horizontal construction joint. The Contractor may cure precast sections according to 515.15. The Contractor may use radiant heated forms for curing.

The Contractor may use 511.17, Method A for curing of short sections of barrier (leave-outs); however, before the curing is completed for any leave-outs, material conforming to 705.07, Type 2 at the normal rate specified in 511.17, Method B shall be applied.

The Contractor may cure horizontal construction joints between the foundation and the upper portion of the barrier, and between portions of the upper barrier placed separately according to 511.17, Method A or B. The membrane should not be removed before placing the next portion of the concrete barrier.

623 Construction Layout Stakes and Survey Monuments

Description (623.01)

All surveying work related to locating and setting reference monuments, Right-of-Way monuments, and setting steel rods in monument assemblies must be performed under the direction of a Registered Surveyor. According to the Ohio Revised Code, a Registered Surveyor must perform the work associated with property boundaries. Either a Registered Surveyor or Registered Engineer can supervise other surveying work to set project control and construction layout stakes.

Verification (623.04)

Before beginning any construction activities that might disturb existing survey monuments, the Contractor must have a Registered Surveyor verify the location of existing survey monuments that are listed in the Contract Documents. The Registered Surveyor must prepare a report and submit it to the Engineer and District Survey Operations Manager. If the Contractor submits the verification report to only the Engineer, then send a copy to the District Survey Operations Manager. If the Surveyor finds any survey monuments not listed on the Contract Documents, the surveyor must survey their location and include them in the verification report.

Placement, Protection and Restoration of Survey Monuments (623.05)

The Right-of-Way designer will include quantities for proposed monument assemblies and reference monuments in the Right-of-Way plans. Also, the Right-of-Way designer will include quantities to replace any survey monuments that are located within a temporary easement and that they expect the Contractor to destroy during the work. The Contract Documents should include pay items to replace any survey monuments that the Contractor can't help but destroy during the progress of the work. However, the Contractor may also destroy or damage survey monuments due to carelessness or inattention. The Contractor must replace these survey monuments at no cost to the Department. If the Department ends up having to replace survey monuments that are damaged by the Contractor, then deduct all costs incurred by the Department from the Contractor's estimate.

In some cases, the Contractor will not have to replace an existing survey monument when it is destroyed as a result of the work. For example, when the Department is acquiring additional Right-of-Way, the old Right-of-Way monuments will be abandoned and do not need to be replaced. This is why the phrase, "unless directed otherwise by the Engineer," is included in the sentence, "Restore survey monuments damaged or destroyed by construction activities, unless directed otherwise by the Engineer." Contact the District Survey Operations Manager if there are any questions.

When the Contractor sets new survey monuments, a Registered Surveyor must prepare a report similar to the verification report (623.04). The Contractor submits this report to

the Engineer and District Survey Operations Manager. If the Contractor submits the report to only the Engineer, then send a copy to the District Survey Operations Manager. Refer to Standard Construction Drawing RM-1.1 for details about the different types of survey monuments.

Providing Electronic Instrumentation (623.09)

Contractors use global positioning methods to perform construction control on many projects. If a pay item for providing electronic instrumentation is provided in the Contract Documents, then the Contractor provides one GNSS receiver for the project staff to use for verifying locations and elevations. GNSS stands for Global Navigation Satellite System. It is like the Global Positioning System (GPS) but includes satellites run by countries other than the United States. For large projects, the Contract Documents may include an, "as per plan," item that requires the Contractor to provide two or more GNSS receivers. The Contractor must also provide training to use the equipment and provide technical assistance throughout the project duration. At the end of the work, the equipment is returned to the Contractor.

If the District decides to use its own GNSS receivers to inspect the work, the Contractor must still provide the model files that the Contractor is using to perform the project control. However, in this case, there is no guarantee that the model files will work with the District's equipment. The District may have to convert or translate the files.

624 Mobilization

Because of the simplicity of this item of work, no detailed explanation of the item is required in this manual.

625 Highway Lighting

General 625.01

Highway lighting construction work must adhere to the Contract Documents. In addition, there may be building or electrical codes (e.g., NEC) or change orders that must be followed.

When there is a question regarding the intent of the plan, the Engineer should:

1. Define the discrepancy or ambiguity.
2. Determine if more than the highway lighting is affected.
3. Identify the standard drawings and specification pertinent to the situation.
4. Determine potential solutions.
5. If the issue involves the location of the luminaires or light poles, the mounting height of the luminaries above the pavement, the luminaire to be used or the lamp to be used, the Engineer should consult ODOT's design office and the Designer to ensure that the performance goals for the lighting system will still be met by the solution under consideration.
6. Consider the maintenance of the installation if the solution is implemented. Will parts not normally stocked by the maintaining agency be required, or will tools and equipment not normally at the disposal of the maintenance crews be required, or will special training of the workers be required?
7. Evaluate potential solutions for safety. Consider measures needed to keep errant vehicles from striking the item, the danger to those who must maintain the installation, and the danger to traffic from the maintenance activities.
8. Determine if applicable codes and regulations will be met. Commonly involved will be the National Electric Code, The National Electric Safety Code, and Utility Company requirements. There may also be state and local building codes.

Materials (625.05)

In general, all material furnished shall be new and of first quality, unless otherwise noted in the plans, and shall be identified either by a permanently attached name plate or by an indelible marking.

Before installation, all material shall be checked to determine that it is indeed the material that has been specified, the appropriate material process has been completed, and all paperwork is in hand.

The following procedures are used to ensure that the correct materials are installed.

1. Qualified Products List (QPL).
2. Approved Products List (Approved List).
3. ODOT Plant Sampling and Testing Plan (TE-24 Certification).
4. Working Drawings, with Certification and Catalog Cuts.
5. Project Inspection of Material.

Qualified Products List / Approved List

The Office of Materials Management maintains the Qualified Product List and Approved List. The Engineer can verify that the material is on a Qualified Products List (QPL) through ODOT's SiteManager. After verifying that the material being supplied is that specified by the Contract and on such a list, the project may accept the material.

Plant Sampling / TE-24

The ODOT Plant Sampling and Testing Plan (TE-24 system) is administered by the Office of Materials Management. This system was designed to allow certain material to be sampled, tested, approved, and stocked for future use on ODOT projects. The material is inspected at the manufacturing or distribution site. Each approved lot of material is assigned a certification number and documented on Form TE-24. Material from the approved lot may then be transferred directly to an ODOT project or it can be transferred to other warehouses, such as a Contractor's storage facility, and then transferred to a project at a later date.

Lighting material for which TE-24 Certification may be obtained:

1. Pull box.
2. Junction box.
3. Anchor bolt.

Project Inspection of Material

The following materials are normally manufactured to standards that meet ODOT criteria and therefore do not have a QPL, do not normally have a TE-24, and shop drawings or catalog cuts are normally not required:

1. Exothermic welds.
2. Insulating varnish.
3. Split bolt connector.
4. Expansion fittings.
5. Connector kits.
6. Splice kits.
7. Copper crimps and compression connectors.
8. Light pole decals.
9. Circuit identification tags.
10. Cable grips.
11. Wood service poles.
12. Fuses for control center and connector kits.
13. Photoelectric cell and bracket.
14. Secondary lightning arrestor.
15. Guy anchors and anchor rods.
16. Weather heads.
17. Watertight hubs.
18. Remote ballast enclosures and mounting brackets.

Project inspection of material is used to verify that the material at hand is listed on a QPL or described on a TE-24 for which certified shop drawings or catalog cuts have been received and that the material complies with the requirements of the Contract Documents. For material not on a QPL, which does not have a TE-24, and for which

shop drawings or catalog cuts are not required, the project inspection of material is limited to comparing the material at hand with the requirements of the Contract Documents.

Shop Drawings (625.06)

Lighting material requiring Certified Drawings or Catalog Cuts:

1. Luminaires.
2. Luminaire supports (towers, lowering devices, poles, bracket arms).
3. Power service equipment.
4. Portable power units.
5. Temporary lighting systems.

The Contractor shall submit two copies of shop drawings or catalog cuts prior to the installation of the material. The submittal ensures that the state has a good record of the material installed should there be any question about the material meeting criteria or should additional or replacement units be required.

Each submittal shall identify the project and the bid reference number under which the item is being provided. Drawings or catalog cuts shall be clearly marked by circling or underlining to indicate the exact item and options being supplied. If a given item is to be supplied under multiple bid item reference numbers, separate and complete documentation packages shall be submitted for each bid item reference number. If multiple items are to be supplied under a single bid reference number, all the items to be supplied under said reference number shall be submitted as a package. The Contractor's cover letter for each package is to certify in writing that each manufactured item in the package conforms to all contract requirements for that item.

The submittal of certified drawings or catalog cuts does not relieve the Contractor from furnishing additional information concerning the material deemed necessary by the state.

Luminaires (625.08)

A luminaire consists of a housing which contains a light source and associated electrical components. The housing may have optional components, such as fuses or a photocell when they are specified in the Plans. The housing is fitted with the necessary clamps or other provisions for attaching the luminaire to its support and terminal block for the incoming power.

Verify that the luminaire installed at each location is one of the luminaires listed in the plan for that location. Verify that the distribution, light source (HPS lamp or LEDs), and wattage are as specified in the plans. Instructions packed with the luminaire will explain the distributions that the luminaire is capable of producing and how to set any adjustments in the luminaire to provide each distribution.

Conventional Luminaire

The conventional luminaire used by ODOT is also known in the trade as an "Ovate" or "Cobra Head" fixture. It may be equipped with a flat or a dropped style refractor as specified.

Verify that the luminaire is properly leveled according to the instructions packed with the luminaire.

Side-Mount Roadway Luminaire

This luminaire reminds one of a floodlight. These are rarely used on ODOT projects as permanent fixtures.

Verify that the "tilt" has been set as specified in the plan according to instructions packed with the luminaire. Verify that the luminaire is oriented "normal" to the line of survey for the roadway being lighted unless the plans stipulate otherwise.

High Mast Luminaire

These luminaires are mounted on tall structures equipped with devices to bring the luminaires to ground level for servicing.

Verify that the luminaire is not "twisted" with regard to its bracket arm. There are three distributions commonly used. If the luminaire has a rotatable refractor, verify that it has been aligned properly.

Low Mast Luminaire

Low mast luminaires are the same luminaire as a high mast luminaire, but installed as a fixed unit on a pole of more traditional height.

Verify that the luminaire is not "twisted" with regard to its bracket arm. There are three distributions commonly used. If the luminaire has a rotatable refractor, verify that it has been aligned properly.

Underpass Luminaire

Underpass luminaires are used to light roadways beneath bridge decks and longer, tunnel-like structures. Commonly they are wall mounted on a pier cap or abutment. Sometimes they may be ceiling mounted on the underside of the deck or to a panel attached to the deck supporting beams or pendant mounted on suspension pipes attached to the structure. Occasionally they will be post top mounted on short poles.

Verify that the luminaire has been attached to the structure at the location and in the manner specified.

Lamps

The use of lamps is decreasing as ODOT moves toward the use of solid-state (LED) lighting as the default standard construction item (see below). However, some HPS luminaires will continue to be deployed, so the following lamp inspection items should be noted. Verify that the lamp is one of the brands listed in the plan. Verify that the lamp type and wattage is compatible with the luminaire and its ballast. Unless otherwise specified, for a particular installation, the lamps are to have clear envelopes. Do not substitute lamps with "frosted" envelopes. Verify that the installation date has been properly marked on the base of the lamp. Instructions packaged with the lamp explain how to use the dating provision built into the base.

Solid-State (LED) Luminaires (General)

Verify that the luminaire is on the Supplemental Specification 813 Approved List or is a model called for in the plans. Verify that a Surge Protective Device is present inside the luminaire housing between the incoming power connection point and the LED driver(s), and that the SPD has a UL 1449 marking. Verify that a black-on-white LED label is applied to the bottom of the luminaire housing. Verify that leveling devices (spirit levels, etc.) are present to assist the installer in properly leveling the luminaire.

Luminaire Supports (625.09)

The inspection of the supports (poles, arms, towers, lowering devices, brackets, etc.) consists of two phases: (1) inspection of the components and (2) inspection of the completed assembly. While these may be done together, it is better if the components are inspected upon arrival at the project since there is more time to obtain replacements or correct faults.

Inspection of Support Components

Three areas are examined in this phase: welding, galvanizing, and compliance with shop drawings.

Inspection of Welds (Steel and Aluminum Supports)

Examine each weld for the following:

1. Each of the welds called for by the certified shop drawings is present and there is no weld present that is not shown on said drawings.
2. There is no misalignment of the parent material being joined by the weld.
3. There has been no warping of the parent material by the weld.
4. Each weld is of the type, size, and continuity shown on the shop drawings.
5. Each weld is of full cross-section without excessive concavity or convexity.
6. There is no over filling or cratering at either the beginning or end of the weld.
7. There is no undercutting (a shallow groove melted into the base metal adjacent to a weld and left unfilled by weld metal) along any weld.
8. There is no porosity (pitting or pinholes) in any weld.
9. There is no crack or discontinuity in either the base metal or weld material along any weld.

Inspection of Galvanizing (Steel Supports only)

Examine the galvanizing for the following:

1. There are to be no spots where the galvanizing is missing or loose and can be flaked off with a penknife.
2. There should be no ash that has been picked up from the top of the bath which usually appears as coarse lumps.
3. There should be no pimples from entrapped bath scum particles.
4. There should be no blisters from hydrogen gas absorbed during pickling being released and rupturing the surface of the galvanizing.
5. There should be no flux inclusions from flux picked up from the top of the bath during dipping and burned on during immersion.

6. There should be no lumps or runs of excess zinc from delayed run-off of molten metal trapped near surface discontinuities, such as joints, seams, or holes as the part was lifted from the bath.
7. There should be no rust stains from impurities from the pickling process weeping at seams and folds.
8. There should be no general overall roughness from over pickling or of excess zinc bath temperature and/or immersion time.
9. There should be no patches of dull, gray coating from slow cooling of heavier cross-sections of the part after immersion.
10. The galvanizing should have a uniform appearance.

Excessive galvanizing faults, gross imperfections, or overall poor workmanship may be cause for rejection of the support. Minor scratches in galvanized surfaces can be accepted.

Compliance with Shop Drawings

Supports are frequently shipped to the job site and stored prior to assembly and erection as components which give opportunity for the components to get mixed up leading to improper assemblies since the basic design often does not prevent errors. Therefore, prior to beginning the assembly of a given support, it is necessary to check the major dimensions of the various components against the shop drawing for the support to verify that this has not occurred.

Verify that each support base has the required identification information, per the SCDs.

On poles, verify the length, base diameter, top diameter, and wall thickness of each pole, or section of the pole, for poles shipped in multiple sections that are field assembled. Verify the length, width, and thickness of the base plate along with the bolt circle diameter, bolt hole size, and number of anchor bolt holes provided.

On bracket arms for conventional supports, verify the arm length and arm rise.

On lowering devices, verify the diameter of the luminaire mounting ring and number of luminaire arms on the ring. Also, verify the length of the power cord along with the wire size and number of conductors in the cord. Verify the diameter and length of each piece of hoisting cable.

Assembly of Supports

Support components stored in the field should be kept off the ground to prevent finish blemishes where the component lay in contact with a damp surface earth or water. Support components and assembled supports should be loaded, transported, unloaded, stored, and erected in a manner avoiding damage to the factory applied surface finishes.

On multi-piece poles, verify that the sections to be assembled are the correct pieces for the pole at hand. Before tightening each telescopic joint between the sections, verify that the sections are properly oriented and that the male section has been marked to indicate when full insertion has been achieved. Verify that the process used for tightening the joint between sections is approved by the pole manufacturer and that the pole is not bent during the tightening process.

On each steel light pole used with an aluminum transformer base, verify that both the bottom of the pole base plate and the top of the transformer base were given a coat of zinc rich paint prior to assembly.

On each light pole, verify that the cable grip in the light pole is properly installed as shown in SCD HL-10.12 to prevent damage to the pole and bracket cable.

On each light tower, verify that the luminaire ring has the correct number of mounting arms and that each arm is attached such that when the tower is erected, the arms will be in the positions relative to the roadway as shown on SCD HL-10.31. If the lowering device is equipped with top laches, verify that when the luminaire mounting ring is fully raised and latched, the latch indicator on each latch will be in the “extended” or “visible” position. Verify that all moving parts on the head frame assembly and hoist mechanism have been lubricated in accordance with the manufacturer’s instructions.

Verify that all parts are in place and all fasteners have been properly installed according to the manufacturer’s instructions.

Verify that each hand hole door or cover closes with no excessive gaps.

Verify that anti-seize lubricant has been worked into the threads of each fastener which hold each removable cover in place.

Erection of Supports

Prior to erection, verify that nuts can be easily turned by hand onto the threads of each anchor bolt. This is to assure they are undamaged and free of concrete.

When leveling nuts are to be used, verify that the leveling nuts are level before beginning the lift to set the support.

Each support should be lifted and set by crane with the hoist line attached at a point as far above the support’s center of gravity as possible, with a tethering cable from the lifting point to the base of the pole. The lifting point on poles made up of sections slip fitted together should be above the uppermost joint. Hoisting should be smooth and continuous without abrupt jerks. Light tension should be maintained in the hoist lines until an anchor nut has been threaded onto each anchor bolt far enough that the bolt is projecting though the nut by a full thread.

Verify that each support with a transformer base has been plumbed using leveling shims approved by the base manufacturer, installed between the base and the foundation according to the base manufacturer’s instructions and limitations and that the anchor nut on each anchor bolt has been properly tightened.

Verify that each support with an anchor base installed directly on a foundation, without leveling nuts, has been plumbed using leveling shims approved by the pole manufacturer. Each support is installed between the base and the foundation, according to the pole manufacturer’s instructions and limitations, and the anchor nut on each anchor bolt has been properly tightened.

Verify that each support with leveling nuts is plumbed by adjusting the leveling nuts. Verify that both the anchor nut and the leveling nut on each anchor bolt are properly tightened by the Turn-of-the-Nut method. The Turn-of-the-Nut method requires the contractor to use match marks that provide visual evidence of proper bolt pre-tensioning

and facilitate inspection. Refer to C&MS and MOP sections 630 and 513 for additional details on the Turn-of-the-Nut method of pre-tensioning.

Verify that a light tower has been plumbed early in the morning when the heat effect from the sun is at a minimum.

Verify that each support has been plumbed when there is no appreciable wind.

Verify that the space between the top of the foundation and the base of the support has not been grouted.

When a high mast support (light tower) is equipped with a lowering device that has top latches, verify that the ring engages all latches simultaneously. This is often referred to as "leveling" the ring. It should be done following the manufacturer's directions. Generally the procedure is to place a block on each hoisting cable which is attached to the ring a few inches above the ring in such a manner that the block will slide along the cable when the block contacts the portion of the mechanism at the top of the tower. The ring is then raised until all blocks have made contact, but not fully raised. The ring is lowered and the distance between each block and ring is measured. Hoisting cables are adjusted to make the measurements equal. The process is repeated until no further adjustments are required. The blocks are removed and the lowering device operated several times through its full cycle watching all latches for proper operation.

Verify that support identification decals have the proper legend and the decals are located approximately 7 feet above the base of the pole facing oncoming traffic. Verify that the pole base plate identification is present, per the SCD.

Foundations (625.10)

Foundation inspection normally consists of three parts: location, excavation and concrete placement.

Foundation Location, Possible Utility Conflicts, Clearances and Worker Safety

After the location of each foundation is staked, verify that the location is specified in the plan and that Ohio Utility Protection Service and all utilities in the area have been allowed at least 48 hours to mark their utility locations relative to the proposed foundation. Verify that the location appears logical. Be alert for the following:

1. Installing the lighting item at the staked location will require removal of vegetation that shields adjacent property owners from the highway.
2. Installing the lighting item at the staked location will locate the item at the top of the back slope, in a cut cross-section, or at the bottom of the fill in a filled cross-section where guardrail is to be used to keep errant vehicles from going down the slope.
3. Installing the lighting item at the staked location will place the item under an overhead utility line or over an underground utility line. It is the contracting firm's responsibility to assure the safety of its workers, but some general information appears below for the benefit of ODOT construction inspectors.
    a. **Overhead.** Clearance to overhead electric lines is covered by IEEE Standard C2, The National Electrical Safety Code (NESC), and

depends upon the voltage of the open conductor and its calculated movement in the wind. Rule 234B of the NESC should be used. In addition, construction clearance (cranes, bucket trucks, etc.) is covered by OSHA regulations under 29 CFR 1910 Subpart S. Note that there is a distinction made between "qualified" and "unqualified" persons working near exposed energized conductors. For light poles (not towers), signal supports and mast arms, all of which are generally 40 feet or less in height, a rule-of-thumb to be used only in the absence of other data is that absolute clearance of no less than 10 feet should be maintained [29 CFR 1910.333(c)(3)(i)(A)(2)]. However, the contractor and inspector should always consult with the utility company for their required clearances.

b. **Underground.** Clearance to underground utilities is often specified under municipal codes, but NESC Rule 320B provides clearance information as well.

4. Installing the lighting item at the staked location will require a graded access drive for the construction that has not been addressed in the plan.

The Designer should be consulted prior to relocating any light support more than 10 feet or if two or more adjacent supports need to be relocated.

Excavation

Foundations are to be placed only in undisturbed soil or compacted embankment.

If a minor cave-in should occur, the Contractor may, with the approval of the Engineer, continue to excavate using sleeving or casing. When bedrock is encountered, the Engineer may reduce the specified foundation depth.

If construction crews must leave the job site with a hole unfilled, it shall be covered and marked with cones, barrels, or warning tape.

Placement of Concrete

Verify that the top of the foundation will be at the proper elevation.

Verify that construction joints are not used except at locations indicated in the Standard Drawings.

Tops of foundations shall be finished smooth and level to enable proper plumbing of the light pole.

Verify that the anchor bolts are of the correct size and number and that each bolt is securely held in the correct position. The use of an anchor bolt setting template is encouraged. Verify that each anchor bolt will project the proper distance from the foundation.

Verify that conduit ells are present and that each ell is of the correct size and material and properly oriented.

Verify that all reinforcing bars are present and that each is of the correct size and shape.

Verify that all items to be cast into the foundation, along with any forming aids, are secured in such a manner that they will not move out of position during the placement of concrete.

Verify that water encountered in the foundation excavation is pumped out before concrete placement. If this is not feasible, verify that the concrete is placed by the tremi-tube method.

Verify that the concrete is of the proper design, has been properly mixed, has the correct slump, and is properly handled during placement. Verify that the concrete is vibrated to eliminate voids.

Verify that the top of the foundation is properly finished and that the concrete is properly cured.

Assure that no support is placed on the foundation until it is fully cured.

Junction Boxes (Handholes) & Pull Boxes (Manholes) (625.11)

Junction Boxes (Handholes)

Verify that each junction box is of the correct size and material and securely fastened in the correct location. Verify that a light amount of anti-seize or grease lubricant has been worked into the threads of each fastener holding the cover in place.

Pull Boxes (Manholes)

Verify that each pull box is of the size and material specified.

Verify that each pull box is at the planned location unless the planned location puts the box in a low spot with respect to the surrounding surface. In such cases, notify the Engineer so that the Engineer, in consultation with the designer, may attempt to move the box to a location where it will be less likely to hold water.

Verify that a light amount of anti-seize or grease lubricant has been worked into the threads of each fastener holding the cover in place.

Raceways and Conduits (625.12)

Verify that each conduit run is of the correct size and material.

Verify that each cut end on each piece of conduit is reamed to remove rough edges. Verify that conduit bushings or hubs have been installed where each conduit enters a box or enclosure; bushings and hubs must be installed prior to pulling any through-conductors.

Verify that all field cut threads on galvanized conduit have been coated with zinc rich paint.

Verify that each expansion or deflection fitting has a bonding strap for ground continuity when used with metal conduit.

Verify that each conduit run has been properly fastened in place.

Verify that the Contractor checks each run of conduit by rodding (pushing a mandrel through the empty conduit) or pulling a cleaning puck through the conduit.

Verify that each run of conduit being left empty for future use contains a No. 10 AWG pull wire or equivalent.

Verify that each end of each conduit run is terminated either in a box connector that contains an integral bushing or with a separate bushing to protect cable pulled into the conduit.

Trenching (625.13)

Verify that the trench did not deviate more than 6 inches from the designated line, unless such deviation has been approved by the Engineer. Verify that the sidewalls and bottom of the trench do not have any protruding sharp rocks.

When duct-cable is installed in the trench, verify that the backfill material within 2 inches of the duct-cable does not contain pieces larger than 1/2 inch.

Verify that the backfill is placed in compacted layers exceeding no more than 4 inches in thickness.

When caution tape is specified, verify that the tape is installed 6 inches to 8 inches below grade.

Power Service (625.15)

The Power Service construction item varies from site to site and includes all equipment from the connection point to the utility company to the beginning point of the individual lighting branch circuits.

Verify that the power service location will be readily accessible to both maintenance personnel and utility company personnel. There should be a safe parking area for service vehicles since the site will be visited regularly. The location should not be prone to standing or flowing water during rain events or to drifting snow. If the location appears unreasonable, involve the designer and utility company as soon as possible, since moving a power service often means redesigning the lighting circuits.

Verify that the Contractor has been in touch with the utility company and is aware of any utility company requirements which may differ from the requirements of the Contract Documents.

Verify that the photocell is facing the north sky, unless otherwise stipulated by the plan, and that no artificial lighting source is disrupting its proper operation.

Verify that the conduits are neatly routed and fastened securely in place.

Verify that enclosures are securely mounted.

Verify that enclosure covers are in place and fasteners for the covers have had anti-seize or grease worked into the threads.

Verify that moving parts of the electrical switch gear have been lubricated and operate smoothly.

Verify that no debris has been left in enclosures and that the wiring in each enclosure is neat, orderly, and tied into place where appropriate.

Confirm that no electrical connectors, even though they may be insulated, are laying directly on the bottom surface of the enclosure.

Grounding (625.16)

The conducting portions of those items which contain electrical conductors are to be connected to each other and to earth electrodes to decrease the chance of injury and damage from unwanted electrical currents. Connecting the various portions together to form a continuous path for the flow of stray electrical currents, often referred to as bonding in ODOT's projects, is generally incidental to the construction. Installation of the earth electrodes and the connection of the conducting portions to those electrodes is often referred to as grounding, and in ODOT's project's payment is somewhat related to the electrodes installed.

Ground Rods

Verify that the specified ground rods have been installed. When additional rods have been added to lower the resistance, verify that the installation of each rod was approved prior to its installation.

Verify that the connection between the ground rod and the grounding cable is an exothermic weld. When additional rods have been added to reduce the resistance, verify that the additional connections are exothermic welds.

The normal ground rod item is for one rod, driven into earth, and the lead between the rod and the first connection and associated connections. The earth resistance is then checked. When said resistance exceeds the specified limit, an additional rod is to be driven and connected to the first. The earth resistance of the pair is then checked. The process is repeated until the resistance of the group is lower than the specified limit. Payment is then made for each rod installed at the "per rod price."

ODOT has reserved the right to approve the use of each additional rod before it is installed and may decline to install additional rods, thereby stopping the process at any point. When ODOT stops the installation of additional rods, it may decide to take another course of action to lower the earth resistance. If no additional action is taken, then by default, the earth resistance becomes acceptable as it stands.

The Engineer may approve the use of soil ground enhancing material if the Contractor requests its use.

Exothermic Welds

An exothermic weld often has a rougher surface texture on the weld metal than one may be used to seeing, but the weld is not to have other signs of a poor quality weld, such as porosity, cratering, cracking, or undercutting.

Structure Grounding

Verify that each grounding electrode is acceptable before structure construction makes modification of the electrode, or the installation of additional electrodes, impractical. Remember, if some of the electrodes are driven rods that such rods are incidental to the structure grounding system, not separate items. However, if due to high resistance, additional rods are driven, those rods are not incidental to the structure grounding system.

Verify that the necessary bonding jumpers are in place and functioning correctly before structure construction makes the installation of additional jumpers impractical.

Structures present special needs. Not only is it impractical to have a separate ground rod for each light pole or similar item mounted upon the structure, but there are also elements of the structure itself that need grounding. The normal practice is to use bonding jumpers to connect all exposed metal items together and therefore to the several electrodes which frequently utilize the main conducting portions of the structure as the main grounding buss. This means that electrodes are often under footers and bonding jumpers are frequently embedded in the structure. If something is left out or does not function as intended, and it is not discovered until the final stages of construction, the grounding can become expensive, unsightly, and less than desired. Unfortunately, structure designers all too often include little in the way of specific details for the structure grounding. Therefore, it is imperative to constantly think ahead to fully understand where each electrode and jumper is to be located and to verify that it is in place and functions correctly at each stage.

Bonding along Circuits

Verify that all of the conducting items which contain the conductors of each circuit are bonded to form a continuous path back to the source of the circuit. (i.e., the Lighting Control Center or Power Service.

At light poles, verify that metal conduits entering the base of the pole are bonded to the pole.

At pull boxes, verify that the metal conduits entering the pull box are bonded together and the metal lid and lid frame are bonded to the metal conduits.

At junction boxes, verify that the metal conduits entering the junction box are bonded to the box.

At the expansion and deflection joints in conduits of conducting materials, verify that a bonding strap has been install across the joint.

When non-conducting conduit or duct is used, verify that a grounding conductor has been installed to provide for the continuous grounding path.

Wiring and Cabling (625.17)

Field wiring of highway lighting circuits is broken into three types.

Pole and Bracket Cable

Pole and bracket cable is the insulated, single conductor used in a light pole (but not in a light tower) to connect from the distribution cable, up the pole, and out the bracket arm

to the light fixture. In a tower, the electrical wiring from the base of the tower to the luminaires is a component of the lowering device.

Verify that each run of cable is of the size and type specified. The wire size and insulation are to be indelibly marked on the insulating jacket at frequent intervals along the length of the cable.

Verify that each run of cable is installed in a continuous piece without inline splices between the terminations shown on the plan.

Verify that the insulating jacket wasn't nicked, nor portions shaved away, as the cable was pulled into place.

Verify that the cable was not stretched as it was pulled into place. If the cable can be pulled back and forth by hand enough to move both ends, stretching probably did not occur.

Verify that a cable support was installed at the upper end of the vertical run of cable up the pole.

Verify that there is enough length on each end of the run for the cable to be routed properly to its termination and still remain slack.

Distribution Cable

Distribution cable is the insulated, single conductor used to construct lighting circuits from the control equipment of the power service to the disconnect kits of a light pole, the terminal block of a light tower, or the disconnect switch for underpass or sign lighting.

Verify that each run of distribution cable is of the size and type specified. The wire size and insulation are to be indelibly marked on the insulating jacket at frequent intervals along the length of the cable.

Verify that each run of cable is installed in a continuous piece without inline splices between the terminations shown on the plan.

Verify that the insulating jacket wasn't nicked, nor portions shaved away, as the cable was pulled into place.

Verify that the cable was not stretched as it was pulled into place. If the cable can be pulled back and forth by hand enough to move both ends, stretching probably did not occur. Unfortunately, for the larger wire sizes and the longer runs commonly encountered in highway lighting circuits, the cable cannot be pulled by hand. The most common indication of stretching is when the length of pulling lead exiting the raceway is greater than the length of cable entering the raceway, or the pulling forces are greater than normally encountered, both of which are not easily detected by anyone other than experienced installers.

Verify that there is enough length on each end of the run for the cable to be routed properly to its termination and still remain slack.

Verify that all cables arelabeled in accessible enclosures (pull boxes, hand holes, transformer base, device housing, etc.). A minimum of 5 feet of extra cable shall be provided for each conductor at all terminal points.

Duct-Cable

Duct-cable consists of insulated conductors, of the type used for distribution cable, installed into a duct and shipped as an assembly to the project. It is used in place of conduit and distribution cable to speed the installation of underground circuits.

Verify that the temperature of the duct-cable was above 32 °F (0 °C) throughout the installation process.

It is permissible to install duct-cable when the outdoor air temperature is actually below those temperatures, but the Contractor must obtain authorization from the Engineer. The Contractor shall submit, in writing, his method of heating the duct-cable and maintaining the duct-cable at a uniform temperature throughout the installation process. To ensure that the duct-cable is heated uniformly, the heating process shall keep the temperature of the duct-cable above 32 °F (0 °C) for a minimum of 24 hours prior to installation. Under conditions, such as the preceding, where the temperature of the duct-cable can be expected to vary widely during the installation process, the expansion and contraction of the duct-cable must be taken into consideration. Typically, the duct-cable length will decrease or increase 1 foot per 1,000 feet (0.3 m per 300 m) for each 10 °F (5.6 °C) decrease or increase in temperature.

Verify that the duct of the installed duct-cable extends out of any conduit sleeve through which it passes enough to allow for the expansion and contraction in the duct due to seasonal changes in temperature. Typically a projection of 2 to 3 inches (50 to 75 mm) is appropriate at the usual installation temperatures for the lengths of run typical in ODOT’s installations.

As received on the reel from the manufacturer, it will appear that the cables inside the duct and the duct are equal in length, but in reality the cables are shorter than the duct. In order to reel the assembly onto the shipping spool, both the cables and the duct were anchored to the spool. As the duct cable assembly is unrolled from the shipping spool, the cables will be drawn into the duct resulting in empty duct at the start of the run. For the assemblies typically used in ODOT’s projects, leaving 25 feet (7.6 m) of duct for each 1,000 feet (300 m) of run to be installed, in addition to that required as slack for connections at the start of the run, will compensate for this. At the end of the run, only the slack amount for connections is required.

Verify that the insulating jacket of each cable within the duct has not been damaged when the duct was stripped to allow the connections to be made. Often the length of duct to be stripped is such that no protection can be slid over the cables and into the end of the duct, which means that the cables within are saved from damage only by the skill of the person stripping the duct.

When a duct cable assembly has been passed through a conduit sleeve, verify that the duct has been sealed to each end of the sleeve by means of a molded boot or wrapped sealing pad.

Verify that the seal installed between the cables and the duct is installed in the same location and in the same manner as outlined under the installation of distribution cable into conduits.

Verify that there is enough length on each end of the run for each cable to be routed properly to its termination and still remain slack.

Conductor Identification

Verify that at each access point (pole base, pull box, junction box, switch gear enclosure, etc.) each conductor of each run of the field wiring (pole and bracket cable, distribution cable, duct-cable) of each circuit is identified by applying a tag to the conductor indelibly marked to indicate the circuit and the use of that conductor within the circuit.

Connections (625.18)

This covers the connection of the field installed wire and cable to other such wire and cable and to the various items of equipment.

Sizing Conductor to Device Terminal

Designers should strive to match conductors with device terminals. When the circuit conductor is unavoidably of a larger size than the device terminals can accommodate, verify that the connection has been made by splicing a short piece of smaller wire onto the end of the large wire and then connecting the smaller wire to the device terminal. This sometimes happens because the wire size for long circuit runs is determined by voltage drop restrictions and not the ampacity of the wire alone. The smaller wire is normally identical to the larger wire in all aspects except for size. The smaller wire must be large enough to carry the current that the circuit protection will allow. It is not acceptable to cut back some of the strands of a conductor, so that the remaining stranded will fit into the terminal.

Crimped Compression Connections

Verify that the die in the compression tool was correct for the connector applied. Verify that the connector is sized to match the wire to which it was applied and the tool used was of a type that did not release the connector from the die once compression started until full compression was achieved.

Pull-Apart and Bolted Connections

Verify that the internal connector is properly applied to the conductors.

Verify that the insulating cover was cut to proper step for a snug fit over the insulation on each entry to the housing.

Verify that the internal parts are all present in good condition and are fully seated into the housing.

Verify that the male half of the housing is a snug fit and fully inserted into the female half of the housing.

Verify that a coating of the kit manufacturer’s approved, non-conducting grease has been used at the joint between the two halves of the housing, between the housing and each cable entering the housing, and on other internal parts, as show in the manufacturer’s instruction, which allow the parts to slide smoothly into place and help seal out water.

Verify that there are no sharp bends in each cable where the cable enters the housing sufficient to cause the housing to pull away from the insulating jacket on the cable.

When the kit is to contain a fuse, verify that the fuse is of the proper ampacity.

Where the kit contains bolted connections, verify that the connections have been properly tightened before the housing was closed.

Verify that there is sufficient slack in the cables being connected to permit bringing connector kits outside of the pole, transformer base or junction box in which it is housed for servicing.

Unfused Permanent Connections

Verify that the internal connection is via a proper crimp compression connector.

Verify that the mold surrounding the connection is completely filled with resin.

Verify that the connection is positioned within the mold such that the resin properly surrounds the connection.

Verify that there are no voids in the resin.

Verify that no fillers have been used.

Verify that the resin has properly set.

Testing of Installation (625.19)

There are a number of tests normally utilized to ascertain that the lighting installation has been well constructed and is in good operational order. For a particular test to have meaning it must be properly conducted and the results properly interpreted.

Verify that the equipment used to conduct the test is in working order and has a certificate of calibration.

Grounding Electrodes and Grounding Systems (625.19.B)

Verify that each specific grounding electrode meets the requirements of the earth resistance test.

The first key to conducting a successful test of a grounding electrode is to understand what constitutes the electrode. A single driven rod is an electrode. When that rod fails the earth resistance test and another rod is added, the electrode then becomes both rods together. However, in the case of a light tower where two rods are typically specified, the initial electrode is the two rods together rather than each rod separately. In structure grounding, the cluster of driven piles at the end of a pier footer should be considered as a single electrode, with the cluster at the other end of that same footer considered as a separate electrode. A continuous grid of mesh, bars, or cables laid beneath a footer is one electrode, but separate grids under different portions of the same footer are separate electrodes. Wires buried in a radial pattern from a single pole constitute an electrode.

The second key to successful ground resistance is to understand the limitations of the various test instruments and procedures. The chosen procedure must be appropriate for

both the electrode under test and the conditions in which the electrode is installed and the instrument must be capable of producing valid results for the situation at hand.

Circuit Continuity (625.19.C)

The key to the proper checking of circuit continuity is to remember the objective and to test one conductor at a time. The objective is to see that the conductor is connected to the desired device point and the conductor has not been connected to any other devices. The difficulty is that the devices are scattered over a large area, thus, requiring the other conductors of the same circuit to be used as returns for the test signal. For the test to be of use, the testing must start at one node in the circuit and test all connections along an isolated link from that node. Additional nodes and links are then added one at a time and the continuity of the conductors rechecked until the entire circuit has been verified.

Cable Insulation (625.19.D)

This test is designed to verify that the insulation of each conductor in the circuit, and permanent and bolted connections in that conductor, are in good conditions to impress a much higher than normal voltage on the conductor using the change in leakage current over time. Care must be used not to impress the test voltage on devices normally connected by the circuit since the devices would probably be damaged. Since the other conductors in the circuit must often be used as the return path, it is necessary to use care to ensure that other conductors are not damaged while serving as signal returns and careful interpretation of the results to determine whether the leakage is from a conductor failing the test or from a failure in the return path.

Lowering Device Operation (625.19.E)

This test is simply repeated operation of the lowering device on a light tower to verify that is operates smoothly and correctly throughout its full range cycle of motions.

System Performance (625.19.F)

The test uses the concept, “infant mortality,” to determine if the equipment is likely to operate satisfactorily throughout the projected life of the installation. The concept is that the equipment is most likely to fail from manufacturing defects and installation in the first part of its service life, and once this “infant mortality” period is past, it is likely to run the rest of its life with only normal maintenance. In conducting the test, it is important to recognize the significance of each component malfunction encountered and to properly interpret whether the malfunction indicates a need to extend the test period.

Information to Maintaining Agency

Ensure that each maintaining agency receives the documents pertinent to the maintenance and operation of the lighting units for which it is responsible. Typically included are:

1. A copy of the plan marked to show any changes made during the construction.
2. A copy of each certified shop drawing or catalog cut.
3. A copy of each instruction or parts manual supplied by each manufacturer.

626 Barrier Reflectors

General

This information is intended to serve as a guide for construction personnel where the Contractor furnishes and installs barrier reflectors. It may also be useful for maintenance personnel performing the same functions. Inspection procedures are outlined. This information points out the various important features and references the applicable specification or standard drawing.

Materials (626.02)

Make sure that all barrier reflectors used on a project are approved and listed on the Qualified Product List at the following website:

Item 726.01 Barrier Reflector Type A & B

www.odotonline.org/materialsmanagement/qpl.asp?specref=726.01

Installation (626.04)

1. The color of the reflector shall match the color of the nearest edge line.
2. Install Type A and A2 reflectors on the guardrail blockout.
3. Install Type B and B2 with the top of the barrier reflector so its height is 26 inches above the near edge of pavement, except that the top of the barrier reflector is at least 3 inches below the top of the concrete barrier.
4. Type B and B2 barrier reflectors shall not extend further than 5 inches) in a horizontal direction towards the traffic lanes.
5. Apply adhesive to clean and moisture-free surface according to manufacturer's recommendations.

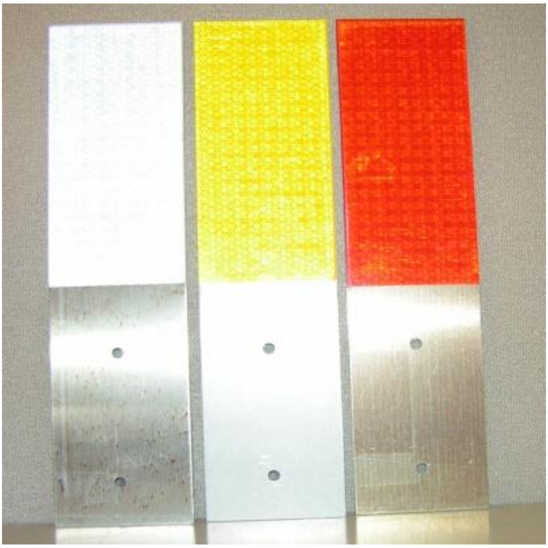


Figure 626.A – Barrier reflector Type A and A2

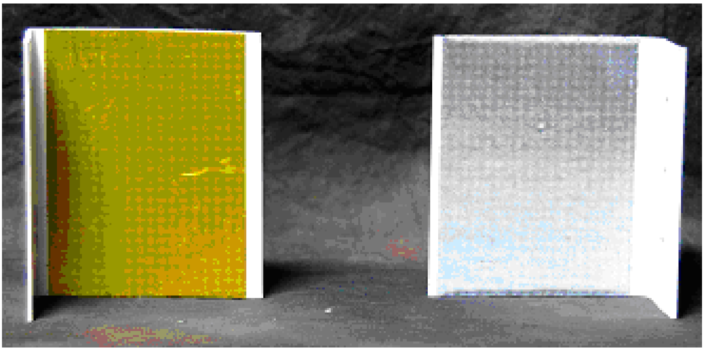


Figure 626.B – Barrier Reflector Type B and B2

630 Traffic Signs and Sign Supports

Description (630.01)

This information is intended to serve as a guide for construction personnel where the contractor furnishes and installs traffic control devices and appurtenances. However, it may also be useful for maintenance personnel performing the same functions. Inspection procedures for various types of traffic control devices are outlined, mainly in the form of checklists to assist project personnel in performing their duties. This information points out the various important features of each device and references the applicable specification or standard drawing. Illustrations are used for easy recognition of the device or feature being discussed.

Sign Service

Sign service shall comply with Traffic Plan Insert Sheets (PISs) 203210 and 203211 and the plans. Additional information is provided in TEM Section 240-7.2 and C&MS Item 631.04. Basically, sign service consists of cable and equipment to provide a complete electrical service from either an underground source or an overhead direct drop to a separately furnished disconnect switch with enclosure. The equipment could include a weatherhead, a conduit riser with necessary fittings, attachment clamps and cable.

A thorough review of the plans should be made to determine the specific requirements of the maintaining agency for sign service.

When required, an electric meter base will be furnished by the applicable utility and installed by the contractor as part of the sign service work.

The sign service shall terminate at the meter base, if used; otherwise termination shall be at the switch enclosure. Sign service may be by:

1. Direct drop by means of a weatherhead and conduit riser routed to the switch enclosure;
2. Underground conduit and the pole interior to the enclosure; or
3. Underground and structure-attached conduit to the enclosure (for overpass-mounted signs).

The conduit riser shall comply with C&MS Item 725 and the plans, and the weatherhead shall be threaded aluminum or galvanized ferrous metal (C&MS Item 732.16).

The disconnect switch shall be a single-throw safety switch meeting the voltage and capacity requirements of the plans. The enclosure shall be a NEMA Type 4 ICS 1-110.15 with sufficient volume to accommodate an internal transformer when specified. The enclosure shall contain a solid neutral bar.

A ground wire shall be used as shown on Traffic PISs 203210 and 203211 leading to a ground rod installed in accordance with Section 240-7.3.

Sign Fabrication (630.04)

General

Signs should be inspected when received on the job site if possible, but certainly prior to erection.

The signs should be inspected for conformance with the plans, certified shop drawings, catalog cuts, and material specifications.

Flatsheet signs are typically of aluminum sheet cut into geometric shapes of the size specified.

Dimensions and thickness are to be as shown on SCDs TC-52.10 and TC-52.20. Bolt holes are to be drilled or punched (630.04).

Extrusheet signs are fabricated of aluminum sheet and extrusions, joined by spot welding and assembled by bolts (SCD TC-51.11). As an alternative, panels extruded in a single operation may be used (SCD TC-51.12). Extruded panels and spot welded panels shall not be used in the same sign. There shall be no appreciable deviation from flatness on the face of an assembled sign.

Overlay signs are of aluminum sheet of the specified thickness and used to cover the legend of extrusheet signs. Signs with overlays should be checked for any loose rivets holding the overlay sign.

All signs shall be reflectorized by being covered with the appropriate grade of sheeting. The sheeting shall be of the correct color, firmly attached, and free of tears, wrinkles, blisters, or blemishes.

Sign legend shall be in accordance with the plans, certified shop drawings, and the OMUTCD.

The type of copy on extrusheet signs shall be as shown on the certified shop drawings. Available types of copy are listed in TEM Table 297-6.

All signs shall be identified on the reverse side by decals as described in 630.

Extrusheet signs shall also to be identified by information in a detachable form on the back (see Item 630.04).

Sign Copy

TEM Table 297-6 provides information about the sign copy used, type, material used, design features, etc.

Sign Identification Decals

All signs shall be identified on the reverse side by decals of Type F white reflective sheeting (730.18) with silk screened numerals. Information shall be coded by screened-on or punched-out numerals before decal application and shall include sheeting manufacturer and year of sign fabrication. At the time of erection, month and year of erection shall be scratched out by the Contractor. This procedure is described in 630.04, which also contains an illustration of the decal. Decals for overlay signs may be on the front surface.

The following codes shall be used on the decals to identify the manufacturer of the sheeting.

0 - Avery Dennison

1 - Minnesota Mining and Manufacturing Company (3-M)

2 - Sakai Trading-New York, Inc.

3 - Nippon Carbide Industries (USA)

4 - Morgan Adhesives Company

5 - American Decal and Manufacturing Company

6 - Stimsonite Corporation

7 - Reflexite North America

8 – Oracal USA, Inc.

Foundations (630.05)

Staking

Sign support foundations shall be located so the sign face is at a right angle to the roadway lanes served, unless the plans specify otherwise. An example of an exception is the W1-6 Large Arrow sign (black arrow on yellow background), which is located as shown in TEM Figure 298-24.

Foundations should be staked by the Contractor in accordance with the locations shown on the plans.

The stakeout locations should be checked for:

1. The presence of obstructions which could restrict motorists' proper visibility of the sign from the point where they are expected to read the sign. Curved roadway locations should especially be checked.
2. Obvious conflicts with overhead power lines or other utilities. There should be available a proper safe clearance from overhead lines for construction operations, in compliance with the National Electric Safety Code and any local codes.
3. Possible conflict with underground facilities.

Foundation locations may be adjusted when necessary to overcome difficulties such as those shown in TEM Figure 298-24 and discussed herein with the concurrence of the project engineer. Adjustment should not violate minimum clearance dimensions as shown on SCDs TC-42.10 and TC-42.20 and the OMUTCD.

Excavation

Foundations shall be placed only in undisturbed soil or compacted embankment, and excavation shall be by an earth auger of the specified diameter to the specified depth. See TEM Figure 298-25 for a diagram of a foundation excavation.

If a minor cave-in should occur, the Contractor may continue excavation using an increased diameter or using sleeving, casing, or other method approved by the Project Engineer. The foundation concrete will be measured as determined from plan dimensions. The Contractor shall remove all extraneous material from the excavation before concrete placement. When subsurface obstructions are encountered, permission may be granted by the Project Engineer to replace the excavated material and relocate the foundation. When bedrock is encountered, the portion of the specified foundation depth within the bedrock may be reduced as much as 50 percent.

Placement

Anchor bolts and conduit ells shall be of the correct size and furnished with the support. At least one 2 inch minimum conduit ell shall be furnished and capped if unused. Anchor bolts, conduit ells, and EMT (Electric Metallic Tubing) shall be oriented in the foundation according to the plans, conduit runs, and ground rod location. All anchor bolts shall be provided with standard steel hex nuts, leveling nuts, and plain washers. The nuts shall be capable of developing the full strength of the anchor bolts. Reinforcing bars, tie loops, and tie bars shall be of the correct size and arranged with the anchor bolts into cages according to the applicable SCD TC-21.10 or SCD TC-21.20. A special foundation design will be required when soil with a load bearing capacity of less than 2,000 pounds per square foot (9700 kg/m^2) is encountered.

Anchor bolts shall be vertical with their ends projecting the correct distance above the foundation surface in compliance with the plans. When the distance the anchor bolts project above the foundation surface is not specified, a rule of thumb is four times the bolt diameter. The anchor bolts shall be tied to the cage tie bars according to standard details.

The rebar cage shall be supported 3 to 4 inches above the bottom of the excavation by a piece of concrete block or similar material. The cage shall be positioned with a clearance of 3 inches from the excavation wall by similar blocking so that after concrete placement a full thickness cover is assured. A template and/or frame shall be used to rigidly hold the anchor bolts and conduit ells in the specified pattern during concrete placement. A form shall be oriented according to the plans to shape the foundation into a square from the surface or grade shown to a nominal 6 inches below ground line. The template and form may be combined. Gaps of 6 inches or less between the foundation and adjacent paved surfaces shall be eliminated by increasing the formed foundation.

Water encountered in the foundation excavation shall be pumped out before concrete placement.

If this is not feasible, concrete should be placed by the tremie-tube method.

Concrete conforming to Item 499 and Item 511 shall be placed and vibrated to eliminate voids. Care should be exercised during vibrating to avoid disturbing the anchor bolts, conduit ells, and reinforcing cage.

Forms may be removed as soon as the concrete has hardened sufficiently so as not to be susceptible to damage, 511.16.

Minor earth caving external to the hole, which may have occurred during excavation using sleeving or casing should be corrected after concrete placement by backfilling and tamping in accordance with 203.

Joint filler complying with 705.03 shall be placed between the formed foundation and adjacent paved surfaces.

Supports and poles may be erected, signs installed, and span wire load applied only after the concrete has aged sufficiently to be in compliance with 630.

Curing and Loading

Curing and loading of concrete for traffic control devices shall comply with 511.17.

Concrete for foundations of sign supports shall be cured, have bracing removed, and be loaded only when the concrete has achieved the age shown below:

	Age of Concrete in Days	
	Without Beam Test	**With Beam Test ****
Curing	7	5
Removing Bracing	7	3
Loading*	14	7

* No load shall be applied or other work done that will damage new concrete or interfere with its curing.

** Beam test specimens shall be poured from the same batch, immediately before, during, or after foundation pour. Specimen configuration shall be to ODOT requirements. Specimens when tested shall have at least an average modulus of rupture for two tests of no less than 650 pounds per square inch (4.5 MPa).

Sign Supports (630.06)

General

Various general aspects of overhead sign supports are addressed in this section. TEM Table 297-7 provides an overall summary of the structure types, allowable sign area on each, and the span or arm length.

Pole and Support Inspection

This inspection checklist covers the general features of strain poles, mast arm type signal supports, and overhead sign supports. Features pertaining only to specific pole or support types will be found in the sections of this manual covering exclusively those poles or supports.

1. When poles and supports of the combination type are specified, they are to provide extra length for a highway lighting function, and welded-on bracket arm plate(s) complying with SCD HL- 10.12 or SCD HL-10.11 for attachment of a separately furnished luminaire arm.

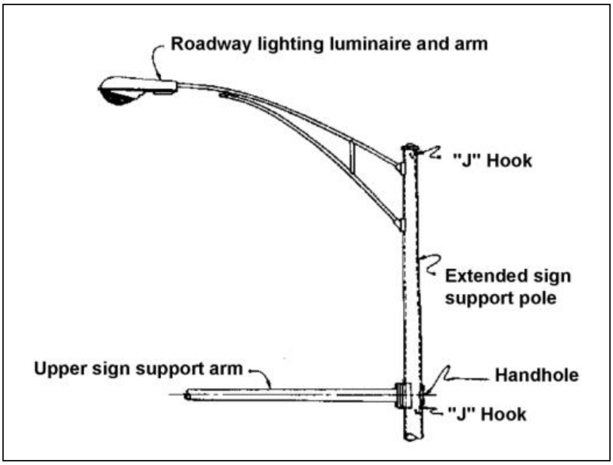


Figure 630.A – Typical lighting terminology

2. Supports may be of an alternate design utilizing all non-tapered tubing structural members.
3. If possible, poles and supports should be inspected when received, but certainly prior to erection.
4. General dimensions should be checked first, including pole length, base diameter, top diameter, and wall thickness. Similar mast arm dimensions should also be checked. Wall thickness is most easily measured with calipers at the end. Caps on poles may have to be removed.
5. Orientations of the various appurtenances should be checked against the plan's orientation diagram if such is available; otherwise, orientations may be determined from certified shop drawings and the intersection drawing.
6. Base plate dimensions should be checked including thickness, bolt circle diameter, and bolt hole size. Base plates may be plate or cast steel according to 730.04.
7. A handhole with ground lug is to be furnished, with a cover plate complying with 730.05 and a stainless steel chain complying with 730.10.
8. A pole cap conforming with 730.06 shall be furnished and in place before final inspection.
9. An arm cap conforming with 730.07 shall be furnished for chords or mast arms.
10. All strain poles and overhead sign and signal supports shall be grounded, even if no power is available.
11. Welding shall be inspected in accordance with 630.
12. Galvanizing shall be inspected in accordance with as detailed below.
13. Supports are to include sign brackets, U-bolts, and clamps.
14. The correct number and size of anchor bolts and conduit ells shall be furnished for placement in the foundation.
15. Anchor bolt diameter and length shall be according to the plans and SCD TC-21.10 or TC- 21.20. Anchor bolt ends may have an L-bend or be fitted with a tapped steel plate. Threaded ends shall not to be damaged and shall be galvanized at least 2 inches beyond the threads. The galvanizing should be in good condition, and absent or damaged galvanizing should be repaired by the application of two coats of zinc-rich paint. Galvanizing thickness should

permit the turning of nuts by a wrench without difficulty. Loose rust on anchor bolts should be removed.

16. All anchor bolts shall be provided with standard steel hex nuts, leveling nuts, and plain washers. The nuts are to be able to develop the full strength of the anchor bolts.

Inspection of Welds

All welds of supports shall be inspected visually, as soon as possible, following support delivery. Welds should be inspected for flaws and imperfections under good lighting conditions using a magnifying glass as necessary. Evidence of any of the following faults or other imperfections, such as warping and misalignment may be cause for rejection of the support. The following features of welds should be checked:

1. A check should be made for the actual presence of all welds called for by the certified shop drawings and standard drawings.
2. Welds on tapered tubes, pipe, or structural shapes shall be continuous around the joint. Welds requiring terminations shall be of the correct length.
3. Welds shall not exhibit cracks or discontinuities in base metal or weld material and shall not show evidence of porosity, which shows up as pitting or pinholes. The galvanizing layer may cover such flaws, but their existence should be checked.
4. Welds shall be full cross-sections without excessive concavity or convexity. Required weld terminations shall be filled to full section without depressions or craters.
5. There should be no evidence of undercut, a condition where a shallow groove is melted into the base metal adjacent to a weld and left unfilled by weld metal.
6. Base plates shall be welded to two ply poles with AWS prequalified welds in conformance with 730.04.
7. Arm attachment plates shall be welded inside and outside with fillet welds. Each fillet weld shall be equal to the wall thickness of the respective tubing.

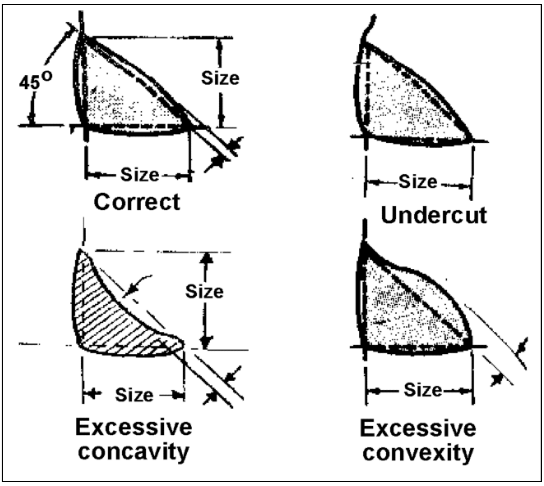


Figure 630.B – Weld profile

Inspection of Galvanizing

The galvanizing cover of supports shall be inspected visually, as soon as possible, following delivery. The galvanizing should be inspected externally and internally for flaws and imperfections in daylight or strong artificial light. In accordance with 513.26, supports shall be loaded, transported, unloaded, stored, and erected in a manner to avoid damage to any feature including the galvanizing. Supports stored in the field should be kept off the ground to prevent the galvanizing from contacting water, which may result in a premature oxidation condition. The galvanizing should have the appearance of a uniform application. Supports should be checked for assurance that the following flaws or imperfections do not exist:

1. Loose or bare spots in the galvanizing where improper preparation has prevented metal adherence in the molten zinc bath. Poles should be rejected if the point of a penknife can flake off the galvanizing layer.
2. General overall roughness, a symptom of over-pickling or of excess zinc bath temperature and/or immersion time.
3. Pimples, due to entrapped bath scum particles.
4. Blisters, due to hydrogen gas absorbed during pickling and coming out at the time of galvanizing.
5. Flux inclusions, picked up from the top of the bath when dipping and burnt-on during immersion.
6. Ash, usually in course lumps picked up from the top of the bath.
7. Patches of dull gray coating due to the slow cooling of heavier cross-sections of supports after immersion.
8. Excess zinc lumps or runs due to delayed molten metal run-off from surface discontinuities, such as joints, seams, or holes.
9. Rust stains due to the weeping of impurities from the pickling process at seams and folds.

Excessive galvanizing faults and imperfections combined with general poor workmanship may be cause for rejection of the support. Gross imperfections may lead to the suspicion of inadequate protective cover which may require inspection with a magnetic instrument. Items 1 through 6 may be cause for rejection. Items 7 through 9, if extreme, may be cause for rejection because of poor appearance, even if the protection of the support is not affected.

After erection, supports should be given a final inspection for any damage to the galvanizing due to improper handling in the erection process. Damage due to slings, etc., which is more serious than superficial brightening, is to be repaired by the Contractor with the application of two coats of zinc-rich paint.

Weight of Supports

TEM Tables 297-8a through 297-8f provide information on the weight of various overhead sign supports. For all structures, the weight of the pipe support has been given where pipe has been frequently used in place of tapered tubes. In general, the tapered tube support will be lighter than the pipe support. The support numbers listed may be preceded by I-129, 815, 844, or other designation instead of TC.

For estimating purposes, a 10 x 10 foot (3.0 x 3.0 meter) sign, excluding the sign lighting, weighs approximately 250 pounds (113 kilograms).

Assembly and Erection Procedure

Erection procedures pertaining to specific pole or support types will be found in the sections of this manual devoted exclusively to those poles or supports. In general, the following assembly and erection procedure applies:

1. To minimize erection time and the hazard to workers and road users where traffic is maintained, supports should be erected with mast arms attached, and horizontal sign support members (over the roadway) should be prewired for lighted signs or other traffic control devices. See the notes in plans for traffic maintenance requirements when span-type sign support members are erected.
2. Support components shall be assembled with their threaded fasteners tightened in accordance with 630.06. Fasteners 1/2 inch or greater shall have anaerobic adhesive applied to the threads according to the manufacturer's recommendations. Nuts shall be tightened by the turn-of-the-nut method.
3. The turn-of-the-nut method shall be in accordance with 513.20. Nuts shall be made snug tight by the effort of a person using an ordinary spud wrench followed by an additional 1/12 to 1/6 turn.
4. Leveling nuts shall be placed on the anchor bolts, initially clearing the foundation surface by at least 1/4 inch and forming a horizontal plane.

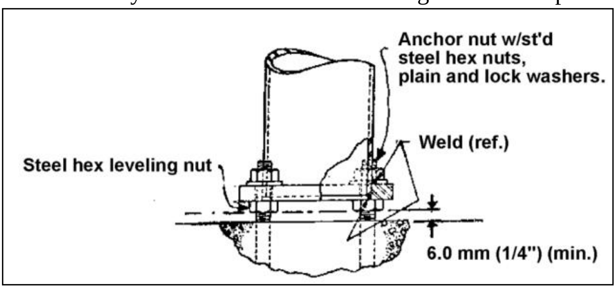


Figure 630.C – Pole base detail

5. Poles or supports shall be raised into position with equipment of adequate lifting capacity and used in a manner preventing damage to attached appurtenances (signs, brackets, luminaries, etc.) and to the galvanizing. The weight of poles or supports is given in TEM Tables 297-8a through 297-8f for the use of the Contractor in the erection procedure.
6. With the pole or support's base plate resting on the leveling nuts, the plain washers and anchor nuts shall be placed on the anchor bolts, the support plumbed in a vertical position or raked, and anchor nuts given a preliminary tightening.
7. After any necessary leveling, nut adjustments are made to ensure that supports are essentially vertical after attachment of signs, sign lighting equipment, or signals. The anchor nuts shall have anaerobic adhesive applied and be tightened in accordance with the instructions for assembling fasteners given in the foregoing paragraphs, 2 and 3.
8. Anchor nuts are not to be covered with bolt covers or a cover base regardless of support location (Item 630.06B).
9. Poles or supports which are prewired before erection should be checked to determine if the erection procedure has disturbed the wiring. Wire for lighted signs should be supported by looping wire over the J-hook in the vertical support member (Item 631.05). Cable supported by cable support assemblies

should be checked to determine if the sling is over the J-hook and if the adjustment is proper to eliminate strain on the cable jacket.

Overhead Sign Supports by Type

General

The previous section addressed general assembly and erection guidelines for strain poles and supports. The following sections provide additional information specific to various types of supports. For the most part, the information is provided in checklist format.

Ground-Mounted Sign Supports (630.06.A)

General

This section provides additional information, generally in the form of checklists, about various ground-mounted supports. TEM Section 221 addresses general guidelines about sign supports and TEM Section 240-5 provides additional design information about ground-mounted supports.

Posts

1. Ground-mounted sign supports of the post type shall be U-channels or square posts of the number specified and shown on SCD TC-41.20.
2. Post lengths appearing on the plans are approximate and the Contractor is responsible for determining the exact length of required posts before cutting to length (630.06A).
3. No. 4 U-channel posts consist of two No. 2 posts bolted back-to-back. No. 6 U-channel posts consist of two No. 3 posts bolted back-to-back. Back-to-back posts are assembled by 5/16-inch steel bolts, lock-washers, and nuts on 4-inch centers below the ground line and 16 inch centers above the ground line. No. 4 and No. 6 U-channel posts cannot be installed in exposed locations.
4. Posts should have a line of paint 48 inches (1.20 meters) from the end, which will be in the earth. The mark when driven to a distance of 6 inches above the ground indicates a post driven to the proper depth.
5. If it is necessary to cut posts to correct length in the field, the cut end should be covered with two coats of zinc-rich paint and the cut end driven in the earth or embedded when required (except for back-to-back posts).
6. Posts shall yield when hit and shall be driven to a depth of 42 inches (1.05 meters). Posts are typically not to be embedded in concrete unless specified in the plans or ordered by the Project Engineer to overcome problems, such as adverse soil conditions or prevalent bedrock close to the surface. The driven depth has been established to ensure best yielding characteristics. Deeper depths are not beneficial in this regard.
7. Caution shall be used when driving posts in areas of buried cable.
8. Posts shall not to be driven in drainage ditches.
9. Posts shall be installed vertically and at right angles to the edge of pavement, unless otherwise required. Exceptions may be NO PARKING signs and STOP signs located at intersections with curved approaches. In this situation, STOP signs should be placed perpendicular to a line from the viewing point where they are normally recognized and stopping action would begin.

10. Posts shall be driven without bending, distortion, or end mutilation. Mutilation may be prevented by the use of a driving cap. Posts should be checked to see if the paint mark is 6 inches out of the ground after driving.
11. Posts located in paved areas shall be driven through a hole provided by sleeving or core drilling. After driving, the hole shall be patched with asphalt concrete or approved bituminous material.
12. At locations where posts cannot be driven, the post may be moved at no additional cost to ODOT, when approved by the Project Engineer.
13. Typical vertical and horizontal clearances of signs are shown on SCDs TC-42.10 and TC- 42.20.

"One Way" Sign Supports

Square posts, which are capable of supporting signs at right angles to other signs on the post, are designated as "One-Way" sign supports for the most common application. This is shown on SCD TC-41.50.

Standard Beams

1. Ground-mounted sign supports of the non-breakaway beam type shall be rolled steel, wide flange sections of the size, and weight specified (from the list on SCD TC-41.10). Non-breakaway beams shall be protected by guardrail or concrete barrier installed for another purpose. Inspection of beams of the breakaway type is covered in 630.
2. Beam lengths appearing on the plans are approximate and the Contractor is responsible for determining the exact length of required beams before fabrication (630.06 A).
3. Galvanizing shall be inspected in accordance with 630.
4. Beams shall be embedded in a concrete foundation in accordance with SCD TC-41.10.
5. Beams shall be raised into position with equipment of adequate lifting capacity and in such a manner as to prevent damage to the galvanizing. The beams shall be braced in a plumb and square position until the concrete has cured. The age of the concrete before it is considered cured and before signs are permitted to be erected is to be in accordance with 630.

Breakaway Beams and Connections

1. Ground-mounted sign supports of the breakaway beam type shall be rolled steel, wide flange sections of the size, and weight specified (from the list on SCD TC-41.10).
2. Beam lengths appearing on the plans are approximate and the Contractor is responsible for determining the exact length of required beams before fabrication (630.06 A).
3. Beams shall use a slip base design. Alternate designs of breakaway connections are permitted.
4. Base plates shall be fabricated to standard details and welded-on with a bead equal to the beam flange and web thickness respectively, but not less than 1/4 inch.
5. Welding and Galvanizing shall be inspected in accordance with 630.

6. All portions of beams should be shop assembled in accordance with SCD TC-41.10.
7. The beam upper portions shall be joined by the bolts attaching the fuse and hinge plates. The plates shall be fabricated to standard details with the fuse plate having notched holes at the bottom and the hinge plate having unnotched holes. The steel hex head bolts, with washers under both head and nut, shall be tensioned in the shop to the final specified value. For S4x7.7 (S100x11.5) beams only, malleable iron beveled washers are used under bolt head and nuts.
8. The beam lower portions should be joined by steel hex head bolts inserted with their nuts uppermost. A galvanized bolt retainer plate shall be sandwiched between the base plates. Flat washers shall be used under both bolt head and nut as well as under the bolt retainer plate. Bolts shall be snug tightened for delivery to the site with final torqueing to be done after erection.
9. Base plate skewed notches should point toward the roadway along the path of typical vehicle collision. The skewed notches of both base plates should match.

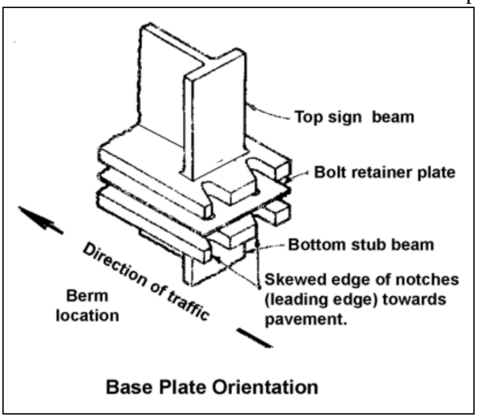


Figure 630.D – Slip base detail

10. For beams located in medians, the base plates should be welded-on upside down as compared with those of beams located on the right side of the roadway, so the base plate skewed notches will point toward each roadway along the path of vehicle collision from either direction of traffic.
11. For beams located in medians, fuse plates shall be used on both sides of the beam.
12. For beams located on the right side of the roadway, fuse plates shall be on the side of the beam facing traffic.

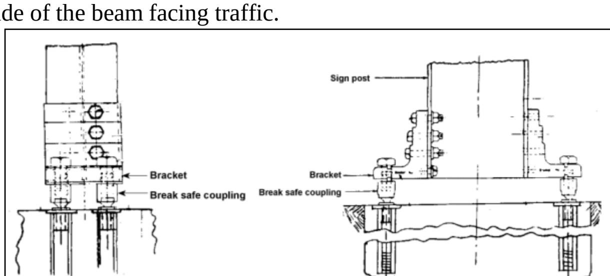


Figure 630.E – Base detail

13. For the alternate design, special foot brackets shall be bolted to the upper beam portion, and four couplings incorporating a breakable reduced section are connected between the foot brackets and threaded anchor inserts embedded in the foundation. The couplings permit use of the design in medians where collision can occur in either direction of traffic.
14. The alternate design uses four hinge/fuse plates incorporating a thinned section and bolted where the beam is cut through just under the sign. The pair of plates on the impact side of the beam and a pair on the opposite side bend severs upon impact to allow the beam to swing upward out of the path of the impacting vehicle.
15. Beams should be erected in a single unit because they are easier to plum, square, and brace when the entire assembly is raised and set in concrete.
16. Beams shall be erected in accordance with the procedure given for non-breakaway beams in 630.
17. A sloping concrete foundation top surface is required on the high ground side to prevent a water pooling pocket and permit drainage as per SCD TC-41.10. For the alternate design, the foundation top shall be level in the area of the breakable couplings.

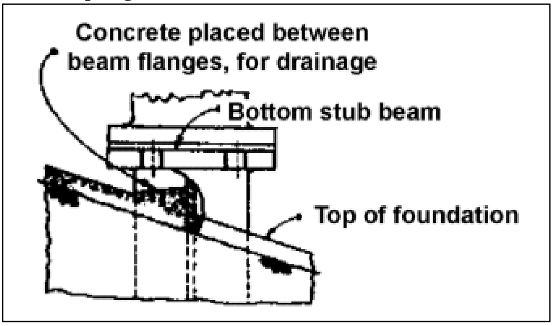


Figure 630.F – Slip base detail

18. When a supplemental panel is required below an extrusheet sign, the panel is fastened by sign backing assemblies to the parent sign. The panel shall be separated from the sign by the width of the fuse plate, plus 1 inch. This is to permit unhindered hinge plate bending in the event of a vehicle collision.
19. After the foundation concrete is cured, base plate nuts shall be loosened in turn and retightened with a torque wrench in a systematic manner to the specified maximum torque shown in the table on SCD TC-41.10, also shown in TEM Table 297-9. Torque wrenches used should be calibrated daily.
20. At least 4 weeks following the erection of signs on breakaway beams, the breakaway feature shall be inspected by the Contractor for evidence of shifting or loose fasteners.
21. All loose fasteners shall be re-torqued to specified values. Base plate fasteners shall be loosened and re-torqued even if no shifting or looseness is detected. If the base plate connection was made with torque limiting nuts, re-torqueing will only be required if looseness can be detected. Re-torqued conventional nuts shall have anaerobic adhesive applied, or as an alternate, new torque limiting nuts of the proper range may be used.

Rigid Overhead Supports (630.06.B)

Single Arm Support

1. Single arm supports shall comply with certified shop drawings, SCD TC-16.21, and the plans.
2. Welds, galvanizing, and general features of the support shall be inspected in accordance with 630.
3. For arms of two telescoping pieces, a 15 inch overlap is required. The overlapped arms shall be secured with a stainless or galvanized steel hex head through bolt with nut.
4. Arm caps shall cover at least 50 percent of the end area (Item 730.07).
5. A minimum of two brackets shall be provided for each sign, each attached to the arm by steel clamps with carriage bolts. The clamps should be able to be tightened in a manner to firmly grasp the arm so as to prevent sign rotation.
6. If signs are lighted, disconnect switch enclosure mounting brackets may be required on the support.
7. Erection shall be in accordance with the general procedure given in 630, except as hereafter noted.
    a. The Contractor may choose to attach the signs and any sign lighting items before erection.
    b. Signs are installed at the same elevation. For this purpose, adjustment is provided by two pairs of slotted holes in the sign bracket for attachment of the arm clamp.
    c. Contact between galvanized clamp flanges and aluminum sign brackets shall be prevented by the use of chloroprene gaskets.
    d. Initial rake shall be adjusted so that under the load of signs, the pole will assume an essentially vertical position and the arm rise will be within the limits specified on the standard drawing, 3 inches minimum and 12 inches maximum.

Cantilever Support

1. Cantilever supports shall comply with certified shop drawings, SCD TC-12.30, and the plans.
2. Welds, galvanizing, and general features of the support shall be inspected in accordance with 630.
3. Supports with arm lengths 18 feet (5.5 meters) and over shall have truss members. Truss members may be angles or pipe.

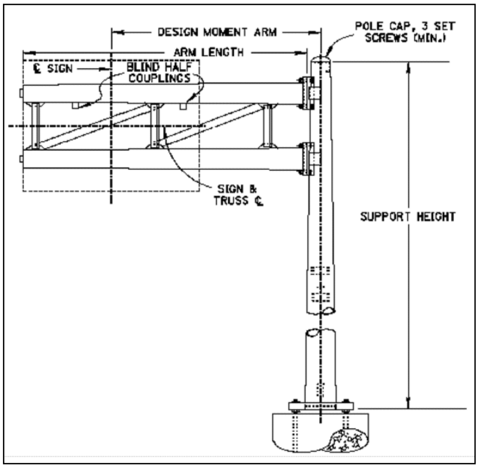


Figure 630.G – Cantilever detail

4. Erection shall be in accordance with the general procedure given in 630, except as hereafter noted.
    a. The Contractor may choose to attach the signs and any sign lighting items before erection.
    b. Signs are centered vertically on the chords.

Center-Mount Support

1. Center-mount supports shall comply with certified shop drawings, SCD TC-9.30, and the plans.
2. Welds, galvanizing, and general features of the support shall be inspected in accordance with 630.
3. Sign clearance above the roadway shall be a minimum of 17 feet (5.2 meters).
4. Arms may be either square or round tube. The arm attachment design shall be in accordance with standard details for either square arms or round arms with separate cradle.
5. Erection shall be in accordance with the general procedure given in 630, except as hereafter noted.
    a. Signs are centered vertically on the arms.
    b. Signs may be mounted laterally on the support in an eccentric position. However, a minimum of 2 feet (0.6 meter) of sign length shall remain to one side of the pole centerline.
    c. The Contractor may choose to attach the sign and any sign lighting items before erection.

Semi-Overhead Support

1. Semi-overhead supports shall comply with certified shop drawings, SCD TC-9.10, and the plans.
2. Welds, galvanizing, and general features of the support shall be inspected in accordance with 630.

3. Sign clearance above the ground shall be at least 10 feet (3.0 meters) unless a lower height is approved by the Project Engineer to provide sign visibility through preceding overpass structures.
4. Arms may be either square or round tube. The arm attachment design shall be in accordance with standard details for either square arms or round arms with separate cradle.
5. Erection shall be in accordance with the general procedure given in 630, except as hereafter noted.
    a. Signs are centered vertically on the arms.
    b. Signs may be mounted laterally on the support in an eccentric position. However, a minimum of 2 feet (0.6 meter) of sign length shall remain to one side of the pole centerline.
    c. The edge of the sign shall be back at least 2 feet (0.6 meter) from the edge of the curb.
    d. The Contractor may choose to attach the sign and any sign lighting items before erection.

Span Truss Support

1. End frames for span truss supports shall comply with certified shop drawings, the plans, and SCD TC-7.65 for aluminum trusses and SCD TC-15.115 for steel trusses.
2. Welds, galvanizing, and general features of the support shall be inspected in accordance with 630.
3. Handholes shall be oriented on the end frame downstream vertical member on the side away from the direction of traffic.
4. The size of truss members shall be in accordance with standard details. Truss member joints may be of two different designs.
5. An angle shall be furnished and welded onto the end frame, near the top, to support the lower chords of the span box. Stainless steel U-bolts shall be used with aluminum trusses and galvanized steel U-bolts with steel trusses.
6. End frame vertical members shall be furnished with steel clamps and a separate tee or angle (alternate) for supporting the upper chords of the span box. Stainless steel U-bolts shall be used with aluminum trusses and galvanized steel U-bolts with steel trusses.
7. When using an aluminum truss, the following shall apply:
    a. Aluminum trusses shall comply with certified shop drawings, SCD TC-7.65, and the plans.
    b. Welds shall be inspected according to 630.
    c. End caps shall be on each end of chords. The top front end caps shall be tapped for wiring.
    d. Span length shall be in accordance with shop drawings and the plans.
    e. Span box camber shall be in accordance with standard details.
    f. Flanges between span box sections may be cast or fabricated with forged flanges as an alternate.
    g. Flange attachment hardware shall be stainless steel bolts and nuts.
    h. Supports shall be furnished with necessary sign brackets, U-bolts, luminaire support arms, bracing rods and other necessary structural members
8. When using a steel truss, the following shall apply:

a. Steel trusses shall comply with certified shop drawings, SCD TC-15.115, and the plans.
b. Steel truss checking instructions are the same as those for aluminum trusses, except as hereafter listed.
    i. The galvanizing shall be inspected according to 630.
    ii. Flanges between span box sections shall be forged.
    iii. Flange attachment hardware shall be galvanized steel bolts and nuts.

9. See the notes in the plan for traffic maintenance requirements when span type sign support members are erected.
10. The base plates of end frames shall be placed on anchor bolt leveling nuts, plain washers and anchor nuts placed, the frames plumbed into a vertical position in both longitudinal and lateral directions, and nuts made tight in accordance with 630.
11. Truss camber shall be correct. The various truss sections shall be assembled in the arrangement and sequence shown on the shop drawing.
12. Trusses may be assembled into a total span while lying on blocks with wedges. Flanges on truss section ends may be aligned by driving in the wedges as necessary. All flange bolts are then assembled and made tight.
13. Two cranes may be necessary when lifting very long trusses or the heavier steel trusses. For reference, truss weights are given in 630.
14. Care should be taken in the attachment of slings. Trusses should be lifted at positions of a quarter to a third of the total span. Slings should be attached to the top chords and the horizontal diagonals.

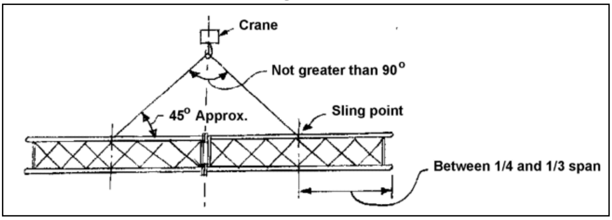


Figure 630.H – Truss lift

15. Trusses may be easily overstressed by poor handling, and care should be taken when moving assembled trusses for temporary storage, during transportation to the erection location, and in the erection procedure.
16. Trusses shall not be erected unless at least one sign is in place within 8 hours or the trusses are fitted within the same period with damping devices approved by the Project Engineer (630.06 B).
17. Attachment of the box truss to the end frames shall be by four U-bolts. Aluminum trusses shall be attached by 5/8-inch stainless steel bolts according to SCD TC-7.65 and steel trusses shall be attached by 3/4-inch galvanized steel bolts according to SCD TC-15.115.
18. The Contractor may choose to attach the signs and any sign lighting items before erection.
19. Signs are centered vertically on the chords (not considering the height of Exit Panels).

Span Wire Support (630.06.C)

Span Wire sign supports shall comply with SCD TC-17.10 and the plans. These sign supports consist of strain poles, messenger wire with accessories, and sign hangers. Strain pole size and type, anchor base, or embedded shall be as specified.

1. Strain poles shall be inspected in accordance with 632 and general features of the poles shall be inspected in accordance with 630. Welds shall be inspected according to 630 and the galvanizing shall be inspected according to 630.
2. Erection shall be in accordance with the general procedure given in 630, except as hereafter noted.
    a. For the initial rake of strain poles of the anchor base type or embedded type poles, see 632.
    b. The upper messenger wire shall be assembled with its accessories according to the standard drawing. Preformed guy grips are not permitted because wind loads on the signs can cause failure of the grips. Alternate methods of attaching messenger wire to strain poles may be used.
        i. Span wire clamp with clevis, anchor shackle and thimbles on the messenger wire, or
        ii. Messenger wire wrapped twice around the strain pole and secured with a 3 bolt clamp of the proper size.
    c. The upper messenger wire shall be fitted with its signs, furnished under other items of work, and the vertical clearance to sign bottoms adjusted within clearance limits over the roadway. The sag of the upper messenger wire shall be between 4 and 5 percent.
    d. It is essential that the lower messenger wire have more slack than the upper wire. The sag should be approximately 3 inches greater than the upper wire. This sag adjustment shall be made before the sign hangers are attached to the lower wire.
    e. Sign hangers shall be clamped snugly to the lower wire by U or J bolts. In the case of back-to-back signs, the lower messenger wire running in between the sign hangers is clamped between bolted spacers that are slightly thinner than the messenger wire (see SCD TC-17.10).

Overpass Structure Mounted Support (630.06.D)

1. Overpass structure-mounted supports shall comply with the plans and SCD TC-18.24 for flush type supports and SCD TC-18.26 for skewed type supports.
2. Overpass structure-mounted supports include sign brackets and two different kinds of steel Z-bars which are fastened to bridge concrete. For steel beam bridge mounting, aluminum angles at the bottom are to extend between sign brackets and short galvanized steel angles bolted to the bridge steel. For overpass structures essentially perpendicular to the roadway underneath, sign brackets are flush mounted to Z-bars for direct sign viewing. For overpass structures skewed to the roadway underneath, a wedge-shaped box structure is inserted between the sign brackets and Z-bars to provide for direct sign viewing.
3. The number of sign brackets will vary according to the bracket spacing as required by SCD TC-22.20. Bracket details are also shown on the standard drawing.

4. The number of aluminum frames in skewed supports shall equal the number of sign brackets. Frame details shall be in accordance with standard details and are to include two angles placed diagonally.
5. Front upper and lower members of skewed supports shall be aluminum angles with a length equal to the sign length.
6. The skewed support structure shall be internally braced by two aluminum angles extending diagonally and horizontally through the interior.
7. For bridge clearance above a roadway of less than 17 feet, the sign clearance above the bottom of the bridge shall be 3 inches minimum without or 15 inches minimum with sign lighting fixtures on the lower edge of the sign.
8. Supports shall be mounted on the overpass structure so the sign is horizontal regardless of bridge slope (630.06 D).
9. Expansion double wedge steel anchor bolts shall be used to fasten the support's Z-bars to the overpass structure concrete parapet. Intended locations of anchor bolts are to be approved by the Project Engineer before any field drilling. Z-bars "A" are used at the top and Z-bars "B" at the bottom of parapet concrete.

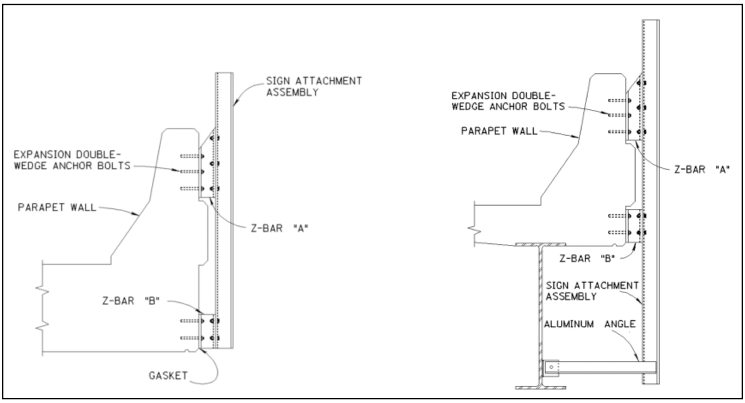


Figure 630.I – Bridge parapet support detail

10. For a steel beam bridge mounting, aluminum angles at the bottom shall be fastened to short galvanized steel angles bolted to the bridge steel.
11. Chloroprene gaskets shall be used to prevent contact between aluminum sign brackets or support frames and steel Z-bars or bolted-on angles.
12. If the sign extends more than 4 feet (1.2 meters) above or below the attaching Z-bars, intermediate sign brackets shall be provided.
13. For precast beam bridges, aluminum angles at the bottom shall be fastened to short steel angles and two expansion double wedge steel anchor bolts shall be used.
14. After sign erection, the sturdiness of the support to bridge attachment should be checked.

Sign Erection (630.07)

General

This section provides information on erection of the signs. Assembly and erection of various types of overhead sign supports are addressed in 630.04 and 630.05 and ground-mounted supports are addressed in Section 630.06.

Ground-Mounted Flatsheet Signs

When erecting ground-mounted flatsheet signs, the following provisions apply:

1. Typical vertical and lateral clearances of ground-mounted flatsheet signs are shown on SCD TC-42.20.
2. Flatsheet signs shall be fastened to posts by 5/16-inch hex head steel bolts with a 3/8-inch ID x 1-1/4-inch OD wide washer under the bolt head and using a lock washer and hex nut. For U-channel posts, at each bolt, a bearing plate shall be used behind the sign to reinforce the sign, as indicated on SCD TC-41.20. The hardware and bearing plates are furnished with the signs.
3. Posts supporting groupings of flatsheet signs in multiple arrangements will require the use of sign backing assemblies made up of bolted together short sections of posts. Sign backing assemblies are furnished with the signs unless separately itemized.
4. Flatsheet signs mounted so as to be read by motorists using bridges shall be erected on special steel posts in accordance with SCD TC-41.40.
5. Street Name signs shall be erected on square supports in accordance with SCD TC- 41.40.

Ground-Mounted Extrusheet Signs

When erecting ground-mounted extrusheet signs, the following provisions apply:

1. Typical vertical and lateral clearances of ground-mounted extrusheet signs are shown on SCD TC-42.10.
2. Mounting clips and other attachment hardware shall conform with SCD TC-51.11.
3. Supplemental panels erected underground-mounted extrusheet signs mounted on non-breakaway beams shall be fastened directly to the beams. The panel shall be separated from the parent sign by 1 inch to conform with SCD TC-42.10. When the panel is too short to reach between the beams, the panel may be fastened to the parent sign by sign backing assemblies.
4. Supplemental panels erected underground-mounted extrusheet signs mounted on breakaway beams shall be fastened to the parent sign by sign backing assemblies. The panel shall be separated from the parent sign by the width of the fuse plate plus 1 inch.
5. Exit Panels erected above extrusheet signs shall be attached by sign backing assemblies furnished with the Exit Panel.
6. The signs should be checked after erection to verify that the beams extend to the top of the signs and that the signs are horizontal and the clearances satisfactory.

Overhead Signs

When erecting overhead signs the following provisions apply:

1. The clearance above the roadway for the bottom of overhead signs shall be a minimum of 17 feet (5.2 meters) or as shown on the plans.
2. Overhead signs shall be vertical or horizontal regardless of the sag of supporting messenger wire, mast arm rise, chord camber, or overpass slope.
3. Signs erected on span wire supports shall be attached in accordance with SCD TC- 17.10.
4. Signs erected on single arm supports (SCD TC-16.20) shall be installed so their bottom edge is at the same elevation. Sufficient adjustment for this purpose is provided by the two pair of slotted holes in the sign brackets for the attachment of the arm clamps. The clamps shall be tightened sufficiently to prevent sign rotation about the arm.
5. Signs mounted on semi-overhead supports (SCD TC-9.10) shall be erected so that their edge clearance from the curb line is at least 2 feet (0.6 meter).
6. Extrusheet signs over 8 feet (2.4 meters) in height may be delivered in two pieces for assembly in the field (630.08).
7. Extrusheet signs erected on supports with two arms shall be centered vertically.
8. Mounting clips and other attachment hardware for extrusheet signs shall conform to SCD TC-51.11.
9. Signs mounted on center-mount supports (SCD TC-9.30) may be mounted laterally on the support in an eccentric position when required by the plans. However, a minimum of 2 feet (0.6 meter) of sign length shall remain to one side or the other of the vertical member centerline.
10. Overlay signs erected in the field over existing extrusheet signs shall be attached by blind rivets at spacings as required in 630.04.
11. Flatsheet signs used in connection with signals supported by span wire shall be fastened to the messenger wire by special attachments in accordance with SCD TC-41.41.
12. Flatsheet signs used in connection with signals supported in a swinging condition on mast arm supports shall be fastened to the arm by a special attachment in accordance with SCD TC-41.41.
13. Exit Panels erected above extrusheet signs shall be attached by sign backing assemblies furnished with the Exit Panel.
14. Extrusheet signs shall be attached to rigid overhead supports using sign brackets in accordance with SCD TC-22.20. Signs extending more than 4 feet (1.2 meters) above or below an attachment point require the use of intermediate sign brackets.

Sign Shipment and Storage (630.08)

Signs shall be suitably protected and identified for shipment and storage. Extrusheet signs shall be kept rigid by backbracing or crating and the sign face covered with protective material. The backbracing shall extend sufficiently below the sign lower edge to keep the sign off the ground.

Extrusheet and flatsheet signs shall be stored in a vertical position.

Signs must be stored in such a manner that the packaging paper or cardboard material does not get wet. If the packaging material or slip sheeting should become wet, the paper

should be removed immediately from contact with sign faces to prevent damage to reflective sheeting on the faces.

In the case of signs furnished by ODOT for erection by the Contractor, the Contractor shall be responsible for the storage and care of the signs after their transfer (630.08).

Sign Inspection (630.13)

After sign erection, the Contractor shall inspect all signs under both day and night conditions. Any necessary adjustments in lateral position or orientation to correct visibility deficiencies shall be made to the satisfaction of the Project Engineer (630.13).

Overhead Guide Signs should typically be centered over the lane(s) to which they apply. Down arrows on the signs should normally be centered over the proper lane as viewed by the road user.

The maximum displacement of a down arrow from the center of a lane should not be more than 2 feet (0.6 meter).

Overhead Guide Signs situated on curved roadways and incorporating down arrows may have the arrow(s) adjusted within the sign and/or the entire sign moved laterally so the arrows, when seen from a typical viewing distance on the curve, will appear to be over the proper lane(s).

Night conditions inspection is to assure that each sign has visible and uniform reflectivity. Any signs not having proper reflectivity should be noted and cleaned or replaced by the Contractor.

631 Sign Lighting and Electrical Signs

General (631.02)

Sign lighting is not necessary for overhead guide signs when Type H or J reflective sheeting is used for the reflective legends. Therefore, for new installations, sign lighting will normally not be used.

Guidelines and design information on sign lighting are addressed in TEM Sections 212 and 240-7.

This section provides additional information about what to look for when installing sign lighting.

1. Check certified shop drawings, catalog cuts, etc. for luminaires, ballasts, switches, and enclosures.

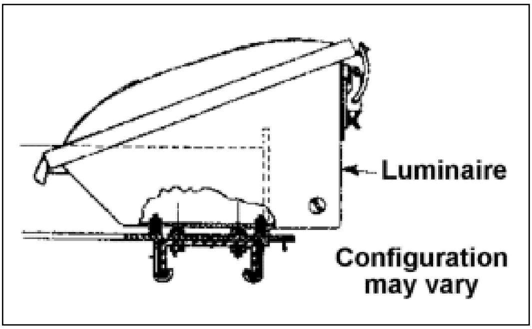


Figure 631.A – Luminaire detail

2. Luminaires for mercury vapor sign lighting shall comply with 731.01 and shall consist of a housing that contains a reflector, lamp socket, wiring, and a door containing a glass lens or refractor, which meet the following requirements:
    a. The housing shall be adequately reinforced cast aluminum with a natural finish or painted gray.
    b. The reflector shall be highly reflective aluminum.
    c. The lamp socket shall be a porcelain shrouded mogul screw with lamp grips and a large center spring, which provides firm contact with a lamp base.
    d. The door shall be an aluminum frame cast with either a natural finish or a formed extrusion with an anodized finish. The door shall be hinged securely to the housing and be provided with a spring loaded latch. Hinges shall be stainless steel and designed so that unintentional door separation is impossible. Latches shall be stainless steel and are not to require tools for opening.
    e. A flexible, readily removable gasket shall be attached to the housing or door so a waterproof seal is formed when the door is closed and the gasket compressed. The glass lens shall be mounted within the door and sealed with elastic cement or a gasket.

f. The glass lens shall be borosilicate or equivalent and able to withstand hail or the thermal shock of freezing rain.

g. Drainage weep holes shall be provided in the housing or the door depending upon the luminaire's bottom or top position on a sign.

3. Mercury vapor lamp sizes shall be as specified. Ballast type shall match the specified lamp wattage. Lamp watts and ANSI code are shown in TEM Table 297-11 and SCD TC-31.21.
4. Sign lighting shall be controlled by a disconnect switch within an enclosure. The switch shall be a two-pole minimum, single throw, fused safety disconnect type rated at 600 volts and 30 amperes (C&MS Item 631.06). The fuse size shall be as specified. A solid neutral bar shall be provided.
5. The enclosure shall be weatherproof and lockable, complying with NEMA standard Type 4 ICS 1-110.15. Enclosure size shall be as specified (See SCD TC-32.10).
6. Each enclosure shall be furnished with at least one padlock. Padlocks shall have a corrosion resistant body and a corrosion proof steel shackle. All padlocks for a project are to be keyed alike from an appropriate master key number obtained by the Contractor from the maintaining agency.
7. Sign service to the enclosure shall be in accordance with the plans. Service wiring cable size shall be as specified, single conductor rated at 600 volts and no less than Number 4 AWG (631.04). Sign service underground from a pull box to a foundation mounted support, or to a support mounted on a concrete median barrier, is shown on SCD TC-32.10. Sign service from a direct drop is shown on SCD TC-32.11.
8. Sign wiring from the disconnect to the luminaires shall be the size specified, single conductor rated at 600 volts and no less than Number 10 AWG (631.05). The wiring shall be fully protected within enclosures, support interiors, junction boxes, rigid or flexible conduit, and luminaire housings. Wiring shall be continuous from the disconnect switch to a junction box mounted on the sign support or overpass structure. The junction box shall permit disconnection of wiring when a sign and its lighting equipment are removed as a unit. A junction box shall be installed for each sign. Wiring shall be continuous from the junction box to the first luminaire on a sign and continuous between additional luminaires on the sign.
9. Luminaire ballast shall be located within the luminaire (integral) or in a weatherproof housing attached to or beside the luminaire (contiguous). Wiring to the ballast shall be continuous with permitted disconnection at the sign support junction box (see paragraph 8).
10. The wiring routing for wired signs shall be as shown on SCD TC-31.21.
11. Luminaire supports complying with SCD TC-31.21 are specified for new installations. Support arms are of welded tubular design incorporating an attachment flange and a luminaire support plate. The arms are bolted to a continuous rectangular galvanized steel tube forming the lower portion of the sign's glare shield. The face of the rectangular tube shall be covered with non-reflective sheeting, which complies with 730.20, so as to match the color of the glare shield sheeting. Support arms shall not be mounted upside down or in any other manner than that permitted by the SCD.
12. Luminaires shall be adjusted to a proper aiming angle according to the manufacturer's instructions and inspected at night to determine if they are providing uniform illumination to the sign face.

Inspection and Testing (631.11)

1. In accordance with 631.11, sign lighting and electrical signs shall meet the requirements of the following tests as required by 625.19 and performed by the Contractor:
    a. Ground rod resistance to ground (see 632).
    b. Cable insulation (Megger) test (see 632).
    c. Ten-day performance test (see 632).
2. During the 10-day performance test, failure of lamps, ballasts, and transformers may be corrected by replacement of the faulty component, but will not require restart of the entire test period.
3. The Contractor should perform a circuit test on all sign lighting cable and wire conductors to determine if there are any short circuits, cross circuits, or other improper connections. Circuit testing may be done in accordance with 632.
4. The test results shall be reported to the Project Engineer in the test information required by 625.19. The test results should be documented.
5. During the 10 day performance test, a night inspection shall be performed by the Contractor and final adjustments made to sign lateral positions and the aiming angle of luminaires to the satisfaction of the Project Engineer (631.11). The adjustments are to eliminate excessive brightness and glare and to obtain optimum sign face reflected brightness, uniformity of illumination, visibility, and legibility.
6. Following successful completion of a 10-day performance test and after there has been a partial or final acceptance of the project, the Contractor should turn over to the Project Engineer all manuals, diagrams, instructions, guarantees, and related material. The Project Engineer should transfer the material to the maintaining agency. For ODOT maintained signs, the material should be given to the appropriate ODOT District Office.
7. After the project has been accepted by ODOT, the Project Engineer should immediately notify the maintaining agency that as of a certain exact time and date, the agency is responsible for the maintenance.

632 Traffic Signals and 633 Signal Controllers

General

This information is intended to serve as a guide for construction personnel where the Contractor furnishes and installs traffic control devices and appurtenances. It may also be useful for maintenance personnel performing the same functions. Inspection procedures for the various type traffic control devices are outlined, mainly in the form of checklists, to assist project personnel in performing their duties. This information points out the various important features of each device and references the applicable specification or standard drawing. Illustrations are used for easy recognition of the device or feature being discussed.

Qualified Products List (QPL) and Other Lists

Check all 632 and 633 devices against the Qualified Products List, Approved List, and Traffic Authorized Products (TAP) list before they are incorporated into a project

Foundations (632.14)

See Item 630 for additional information relative to concerns regarding the installation of foundations for poles and controller cabinets.

Electrical Appurtenances

General

This section will be used to provide additional information about various electrical appurtenances involved in the traffic signal installations, such as pull boxes, conduit, and ground rods.

Pull Boxes

Pull boxes shall be of the specified sizes (see SCD HL-30.11 and the plans), typically 18 inches or 24 inches, and the specified material.

The word on the cover should be, *Traffic*, when the pull box is part of a traffic signal system unless the plans require the word, *Electric*, or other marking. The word shall be formed on the surface or displayed on an attached metal plate.

The location of pull boxes shall be as shown on the plans. However, pull boxes in low drainage areas may be adjusted to eliminate drainage problems, or feasible methods of positive drainage may be used in accordance with 611 and details on SCD HL-30.11 with the approval of the Engineer.

Pull boxes located in sidewalks, traffic islands, and curbed areas close to the roadway, where wide turning vehicles could drive over them, may be adjusted to eliminate the problem, or a concrete pull box with a heavy duty lid may be used with the approval of the Engineer.

Trench

Trenching shall be in accordance with 625. Any change in dimensions will require approval by the Engineer.

Trenching may be in earth or in paved areas according to plan details. Trenching and subsequent restoration of surfaces in paved areas shall be in accordance with SCD HL-30.22.

Trenching work in paved areas shall be divided into two pavement depths for payment: less than 6 inches and 6 inches or greater (625.20).

The trench in paved areas may be 4 inches wide when cut by a Vermeer type trencher. In this case, the trench shall be backfilled with concrete full-depth, except the bottom 4 inches above the conduit may be 625.13 tamped backfill.

Conduit

Metal conduit shall comply with 725, with sizes according to the plans. It shall be made from domestically produced steel, and the domestic steel content of the conduit shall be certified by the manufacturer or supplier before it is approved for installation.

The routing of loop detector wire in conduit through curb or under shoulder shall be as shown on SCD TC-82.10.

Conduit containing cable and/or wire shall have the terminal at the high end completely sealed in an approved manner, with removable sealing compound or a molded plastic or rubber device compatible with the conduit, cable jacket, and wire insulation according to 625.

After placement, a conduit which will not have cable or wire pulled into it during construction shall have a pull wire installed in it. The terminal at the high end shall be sealed with removable sealing compound, a molded plastic, or a rubber device according to 625.

Difficult pulling and possible jacket skinning may occur when an attempt is made to install too many cables or wires within a given conduit. The reason could be design error in new systems or attempts to insert an excess number or size of cable or wire in existing conduit.

ODOT 632/633 now require that the combined cross-section of all cables and wire within a conduit should be less than or equal to 25 percent of the conduit inside area:

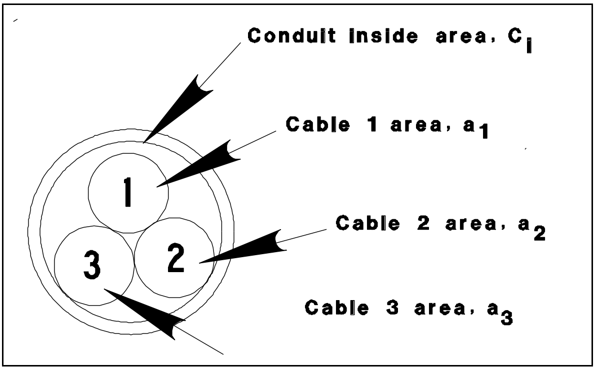


Figure 632.A – Cable and duct area calculation

$a1 + a2 + a3 + \text{etc.} \leq 0.40Ci$

a = Cable or wire across section area, sq. in. (mm²)

Ci = Conduit inside area, sq. in. (mm²)

A calculation can be made using the above formula. The cross-section area of conduit, cable, and wire is shown in TEM Table 497-1. The 25 percent limit is lower than the NEC requirement of 40 percent maximum fill. The requirement is ODOT-specific, designed to facilitate wire maintenance and provide space for additional wires.

Ground Rod

A ground rod shall be driven below surface near the foundation of every strain pole and overhead sign or signal support whether there is power in the vicinity or not, as shown on SCDs TC-21.20, TC-32.10, and TC-32.11.

Ground rods shall comply with 725 and be installed in accordance with 625. A ground wire of insulated 600 volt No. 4 AWG 7-strand soft drawn copper shall be attached by an exothermic weld. The typical exothermic weld procedure is described in 632.

Insulating varnish shall be applied to the weld and any exposed conductor.

Exothermic Weld

The following procedure is typical and may be used unless the manufacturer's instructions differ.

1. The end of the ground wire shall be in an un-flattened, unbent, clean, and dry condition to ensure a good weld.
    a. Bent and out-of-round conductor wire will hold the mold open causing weld material leakage. A cable cutter should be used to make un-deformed ends. If a hacksaw is used, the insulation should first be peeled, as the saw tends to coat the cable with plastic material, which must be cleaned off.
    b. Corroded cable shall be cleaned. Oily or greasy cable should be cleaned with a solvent that dries rapidly and leaves no residue. Very greasy cable can be cooked out by dipping into molten solder.

c. Wet cable can cause molten metal to blow out of the mold, and the cable should be dried by a hand torch or a quick drying solvent such as alcohol.

2. Ground rod ends which have been mutilated in driving can hold the mold open and should be cut off. Rod ends shall be clean and dry.
3. The weld mold shall be clean before use. Damp or wet molds can cause porous welds and should be dried by heating.
4. The cable shall be inserted into the side of the mold so the cable is 1/8 inch back from the center of the tap hole. The mold shall be placed on the ground rod so the cable sits on top of the rod. A clamp or locking pliers should be used on the rod to keep the mold from sliding down during the welding process. The conductor should be marked at the mold surface so it can be verified that the conductor has not shifted before the weld is made.
5. The steel disk shall be inserted into the crucible and the cartridge contents poured on top, being careful that the disk is not upset. The cartridge should be tapped when pouring to make sure the starting powder comes out and spreads evenly over the welding powder. A small amount of starting powder should be placed on the top edge of the mold under the cover opening for easy ignition.
    a. The proper cartridge size is marked on the mold tag and is the approximate weight of the powder in grams.
    b. If the proper cartridge size is not available, two or more small cartridges or part of a larger cartridge can be used.
6. The mold cover will be closed and the starting powder ignited with a flint gun. If it is necessary to hold down the cover during the flash of igniting powder, a long tool should be used and the hand should be kept away.

Pole and Support Inspection - General

See 630 for information about pole and support inspection.

Signal Support (632.15) and Strain Pole (632.16)

General

This section will be used to provide additional information about traffic signal supports. Various types of overhead signal supports are also depicted in TEM Table 497-4.

Strain Pole Type Support (632.16)

Strain poles shall comply with the certified drawings and the plans.

They shall be galvanized and the general features should be inspected in accordance with 630.

Strain poles used to support traffic signals or signs (SCD TC-17.10) shall be furnished with one or more span wire clamps with shackles for attachment of messenger wire (see SCD TC-84.20).

Only messenger wire may be attached by wrapping twice around the pole and securing with a three-bolt clamp, as shown in SCD TC-84.20, when used on round, tapered steel strain poles. Tether wire shall not use the alternate wrap method.

Erection of these poles shall be in accordance with the general procedure given in Section 630, except as noted in this section.

For the initial rake of strain poles of the anchor base type, leveling nuts shall be adjusted to provide a rake of 1/8 to 1/2 inch per foot of pole in the direction opposite to the contemplated span wires and are to be made snug tight. Further adjustment may be necessary to ensure that the strain poles are vertical after the application of span wire load.

Single Arm Support

Single arm supports shall comply with the certified drawings, SCD TC-81.21, and the plans. General features of the support shall be inspected in accordance with 630, and except as noted in this section, erection of the support shall be in accordance with the general procedure given in 630.

Welds shall be inspected according to 630 and the galvanizing inspected according to 630.

For arms of two telescoping pieces, a 15-inch overlap is required. The overlapped arms shall be secured with a stainless or galvanized steel through-bolt with hex head washer and nut(s).

An arm clamp with clevis shall be furnished at each signal position as well as a hole with a rubber grommet for the outlet of signal cable.

The installation of small signs and their attachment to the arms should be checked. Any possible interference between swinging signals and signs should also be checked.

Blind half couplings shall be located on the pole of the support for mounting pedestrian signal heads or controller cabinets when required by the plans.

Signal heads shall be installed so that their bottom surface is 16 to 18 feet (4.9 to 5.5 meters) above the roadway. The signals shall be installed at essentially the same elevation. Drop pipes should be used only when necessary to maintain the clearance between 16 to 18 feet (4.9 to 5.5 meters). If the clearance without a drop pipe is slightly over 18 feet (5.5 meters), it is permissible to omit the drop pipe, with the maintaining agency's approval.

Initial rake shall be adjusted so that under the load of signals, the pole will assume an essentially vertical position and the arm rise will be within the limits specified on SCD TC-81.21 (i.e., 3 inches minimum and 12 inches [maximum).

Verify that all fasteners are properly tightened. Verify that there is no visible gap between the arm attachment plate and the pole attachment plate; if daylight can be seen between the flanges when observing them carefully from ground level, the bolts should be tightened.

Direct Tension Indicating (DTI) Washers.

Some ODOT mast arms require DTI washers be used under the attachment bolt heads, as shown in the SCDs. Verify that the Contractor has properly pre-tensioned the bolts by compressing the DTI washer to the correct level. Feeler gages provided by the DTI manufacturer are typically used to indicate proper bolt tension.

Sag and Vertical Clearance

TEM Figure 498-13 illustrates sag guidelines and vertical clearance standards for traffic signals.

Cable Support Assemblies (632.21)

A cable support assembly makes use of a flexible, tubular, wire mesh device called a cable grip, which has a gentle holding action over its length and is used to eliminate strain or damage to the jacket of cable(s) hanging in the interior of poles.

The support assembly consists of the grip attached to a single "U" eye support bale and a sling when necessary. The grip may be used on an individual cable or a group of cables up to a maximum of four. The grip shall be the proper size and strength for the cable(s), of stainless steel or tin coated bronze, and may be either a "closed" or "split with rod" type. The split type is used when a cable end is not available. In this application, the grip mesh is not a continuous tubular weave, but is split for wrapping around the cable(s) and is secured by a rod which is inserted through alternate weaves at each side to form a tube.

The support's bale shall be hung over the pole J-hook if sufficient length is available; otherwise, a sling shall be made of messenger wire, clamps, and thimbles. The sling wire is to be passed through the bale eye, adjusted to the proper length, and hung on the J-hook.

Pole interiors should be checked by removing pole caps to verify that cable support assemblies are in place, hung on the J-hook, and properly adjusted to eliminate cable jacket strain.

Aerial Interconnect Cable

When aerial interconnect cable is used, the following standards and guidelines apply:

1. Aerial interconnect cable and accessories shall comply with SCD TC-84.20. Interconnect cable may be supported on separate messenger wire or be the integral messenger, self-supporting type, with a, "figure 8," cross-section, if specified on the plans.
2. Metal poles with messenger wire supported interconnect cable are to be furnished with pole clamps. The pole clamp may provide clevis(es) to which the messenger is attached and terminated or may provide a stud to which a clamp assembly can be bolted.
3. Messenger wire ends are to be looped and secured with three-bolt clamps or a messenger vise, or a preformed guy grip dead end may be used (see 632). If clamps or vises are used, the wire tail shall be served (see 632). Thimbles with a correct groove size for the messenger wire shall be used to connect to the clevis of the pole clamp.
4. When messenger wire is to be grounded to a metal pole, a ground clamp, an insulated ground wire, and a bolt tapped into the pole shall be used (also see item 10 in this section).
5. Wood poles with interconnect cable shall be fitted with through-bolts holding a clamp assembly or with a thimble eye-bolt to which the messenger may be attached and terminated.

6. The clamp assembly shall be suitable to the type of cable support, either messenger wire or self-supported cable with "figure 8" cross-section. Clamp assemblies for "figure 8" interconnect cable differ slightly from those intended for use with separate messenger, since the clamp used with "figure 8" must allow a small gap for the web of the "figure 8" cable which joins the messenger to the cable.
7. When messenger wire or "figure 8" cable is to be grounded on a wood pole, a ground clamp and an insulated ground wire, stapled to the pole and covered by a molding, shall be used (see Item 10 in this section). The ground clamp used with "figure 8" cable shall be a type with teeth to penetrate the jacket over the messenger. The ground wire shall be bonded to an existing ground wire or to a ground rod.
8. Standard interconnect cable shall conform to C&MS Table 732.19-1 and have the number of conductors and wire gauge specified. There is no difference between standard interconnect cable and signal cable, only in the application. Interconnect cable of the shielded type may be specified in the plans. The interconnect cable should be marked with the correct nomenclature. Solid conductors are not permitted (732), unless specified in the plans. Splices may be used on long lengths of interconnect cable (632) and shall be accomplished only in weather tight splice enclosures. Splice enclosures may be either aerially located on the messenger wire or be a pole-mounted box type (see SCD TC-84.20). Where the aerial enclosure is clamped to the span, it should be within 2 feet (0.6 meter) of a pole to improve accessibility. No measurement allowance is given for splices.
9. Aerial interconnect cable is to have a sag between three to five percent of pole spans or is to match existing utility lines.
10. Messenger wire supporting interconnect cable, and the integral messenger of self-supporting type cable, is to be grounded in cable runs at the first and last poles and on intermediate poles at intervals not to exceed 1,200 feet (366 meters). See Item 4 of this section for grounding on metal poles and Item 7 for grounding on wood poles.
11. As temperatures decrease, interconnect cable gets stiffer and harder, becoming brittle when below freezing. In very cold weather, the cable should be handled with care so as not to damage the jacket or insulation when unreeling, flexing, and installing.
12. Standard interconnect cable may be attached to supporting messenger wire by lengths of preformed lashing rod or by spinning wire. Lashing rods shall be of the proper internal diameter to snugly hold the cable, but not cut into its jacket (see 632).
13. Aerial interconnect cable of the integral messenger, self-supporting type (with a "figure 8" cross-section) shall have its wind stability increased by being twisted or spiraled once every15 feet (4.6 meters) of span. This is done by clamping the tensioned cable to every other pole and then going to intermediate poles and twisting the cable before tightening their attachment clamps.
14. When the interconnect cable is attached to a pole and continues in a relatively straight line past the pole, this is an intermediate support; however, if the interconnect cable turns at the pole, it is a corner or turning point. Certain types of clamps may be well suited for intermediate support applications, while other designs are required for corner clamps. The clamps shown on the left side in SCD TC-84.20 are usually not suitable for corner clamps if the change of

direction is more than 10 degrees. See SCD TC-84.21 when the change of direction is more than about 10 degrees.

Tether Wire and Appurtenances

Tether wire and accessories shall comply with **SCD TC-85.21 and TC-85.22.** S-hook wire diameter shall be in accordance with the strain pole Design Number, as shown in the SCD.

The tether span, as shown in the standard drawings, is designed to yield under either high wind loads or vehicle snags. The S-hooks are designed to yield in a wind event, allowing the signal span to revert to a free-swinging configuration. The breakaway tether anchors are attached to the signal heads and designed to release the tether in the event of a vehicle snag.

The use of a backplate and tethered span increase the frontal area of a 3-section signal head by a factor of approximately 2.5 times that of a free-swinging signal head without backplates. For this reason, it is important to provide a yielding element on the tether span that unloads the tether at the proper tether wire tension. <u>The S-hook must be galvanized, mild, low-carbon steel.</u> High-strength alloy steels, such as Grade 80, sometimes used for load-rated S-hooks in the rigging industry, are not acceptable. These are much too strong for the application and will overload the strain pole in a design wind.

The use of breakaway tether anchors to attach signal heads to tether wire is required. Designs which use an L-shaped clamp, as shown in **SCD TC-85.22**, are acceptable. These shall be properly installed, with the cable clamped below the pinch bolt and the opening facing downward. This allows the tether wire to slip out in the event of a vehicle snag. They should not be overtightened, a condition usually indicated visually by the strands being "smashed" underneath the clamp surfaces.

The turnbuckle used at the end of the tether span is a tensioning and leveling device used to bring the tether into its proper configuration after erection. On all spans, the tether wire must remain essentially horizontal. Verify that the proper tension per SCD TC-85.20 is measured in the tether wire. A typical wire rope tension gage is shown in Figure 632.A.

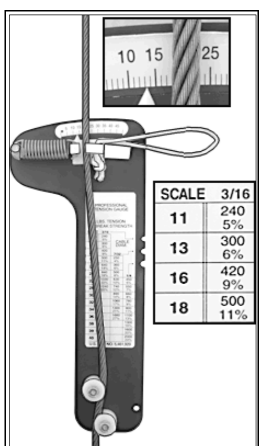


Figure 632.B – Cable tension measurement device

The guy grip end also serves as the anchor point for the safety tie. The safety tie is an accessory feature designed to prevent the loose end of a tether span from dropping into the roadway in the event of an S-hook yield. As such, the safety tie need not be particularly strong. In the event of a strong vehicle snag, the 1/8-inch safety tie is designed to yield at a lower load than the 1/4-inch tether wire. If a full-strength safety tie matching the tether wire diameter were used, the possibility would exist of a snagged tether wire overloading the pole. Since the safety tie is small-diameter wire rope, it is specified to be stainless steel, with stainless steel hardware, to minimize corrosion.

Messenger Wire (632.22)

General

This section will be used to provide additional information about signal span messenger wire and appurtenances.

Note that tether wire is distinct from messenger wire. Messenger wire supports a significant vertical load. Tether wire does not and is used to prevent:

Signal Messenger Wire and Cable

Messenger wire and accessories shall comply with SCD TC-84.20. Messenger wire diameter shall be in accordance with the plans.

The height at which the messenger wire is to be attached to the pole will, in some instances, be shown on the plans. In cases where this is not shown, the Contractor is responsible for determining the proper attachment height. This determination shall consider the relative elevation of pavement to pole foundation top, the desired clearance between pavement and the bottom of each signal (i.e., 16 to 18 feet [4.9 to 5.5 meters]), the sag in the messenger wire (3 to 5 percent), and the height of each signal.

Alternate methods of attaching messenger wire to strain poles may be used as follows:

1. Span wire clamp with clevis, anchor shackle, and thimbles on the messenger wire.
2. Messenger wire wrapped twice around the strain pole and secured with a three-bolt clamp of the proper size when used on round, tapered strain poles. This method shall not be used with tether wire.

If the messenger wire attachment to strain poles makes use of the alternative with pole clamps and anchor shackles, the wire is to be hooked through the shackle using a thimble and secured with a three-bolt clamp. A preformed guy grip shall not be used for messenger wire attachment at the pole. Guy grips of the proper size may be used at bull rings (aerial corners).

Thimbles with a correct groove size for the messenger wire (or the wire and eye of guy grips) are to be used at anchor shackles and bull rings. When three-bolt clamps are used, the wire tail is to be served as shown in the section on messenger wire. See the section, Messenger Wire, for the installation procedure for preformed guy grips.

Thimbles with a correct groove size for the messenger wire or the preformed guy grip shall be used to connect to anchor type shackles or bull rings at span wire aerial corners.

Messenger wire sag shall comply with 632 and the section, Sag and Vertical Clearance.

The signal cable shall be attached to the messenger wire by lengths of preformed lashing rod.

The lashing rod shall be the proper internal diameter to snugly hold the cable, but not cut into its jacket. See the section, Wire Lashing, for further information.

A drip loop shall be formed in the signal cable at each weatherhead and should extend at least 6 inches below the weatherhead.

Cables or groups of cables (up to a maximum of four), hanging within pole interiors, shall have their strain relieved by cable support assemblies.

Messenger Wire Served Ends

Messenger wire may be attached to various accessories by looping the wire to make an eye.

The wire end shall be secured by a three-bolt clamp, and the cut wire end or tail shall be served with construction wire or clamped with a sleeve device, as shown on SCD TC-84.20. The following illustrations show both serving methods for the wire tail:

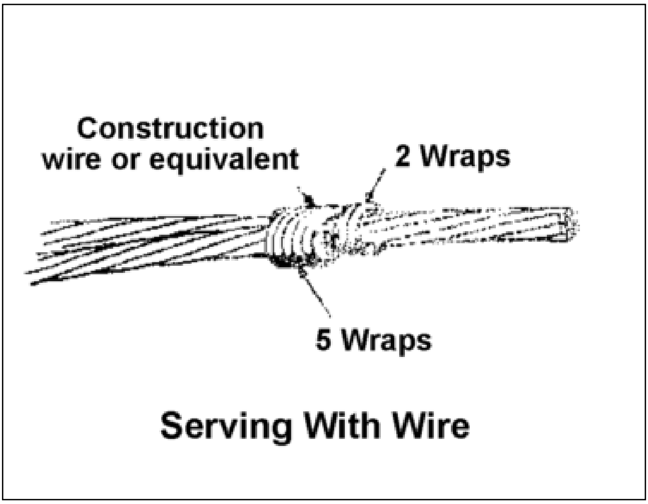


Figure 632.C – Wire connection

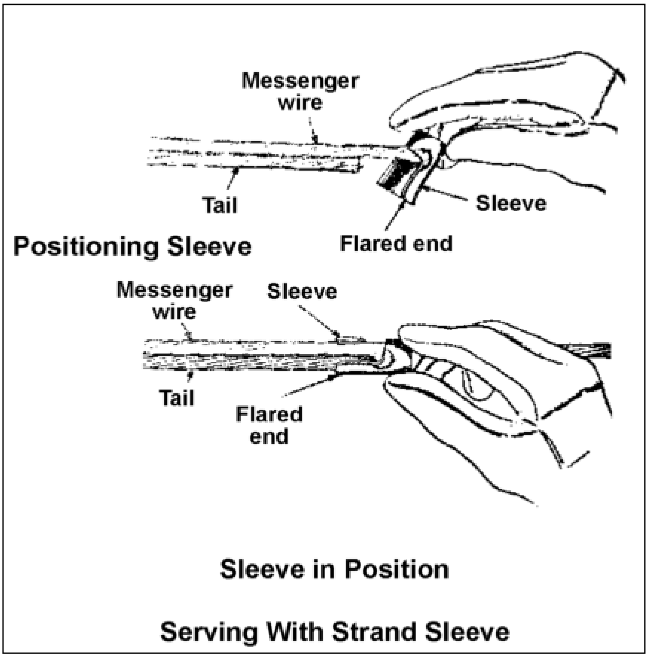


Figure 632.D – Wire connection

Preformed Guy Grips

Preformed guy grips are made of helically shaped, high-strength steel wire. They are available in sizes fitting the outside diameters of messenger wire and form an eye permitting attachment to various accessories.

As shown in SCD TC-84.20, they should be used at bull rings of span wire aerial corners (see the following illustration). Thimbles are used in the eye of grips in accordance with standard details in the SCD.

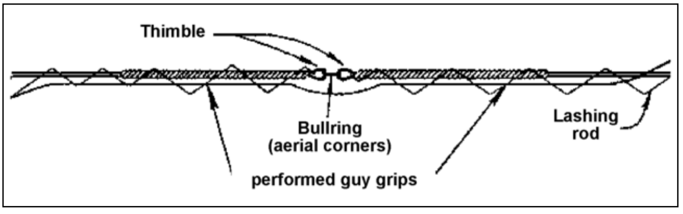


Figure 632.E – Wire lashing

Grips are installed on an end of the messenger wire by wrapping a first leg of the grip to the messenger wire. In most cases, the accessory to which the grip is to be attached must be inserted in the eye of the grip with a thimble before the second leg of the grip is wrapped. The second leg is then applied to the combined first leg and messenger wire. The following illustrations show the wrapping sequence.

Guy grips shall not be used on messenger wire used for span wire sign supports. In this application, wind load on the signs can cause failure of the grips (see SCD TC-17.10). Guy grips shall not be used for attachment to signal strain poles (SCD TC-84.20(5)).

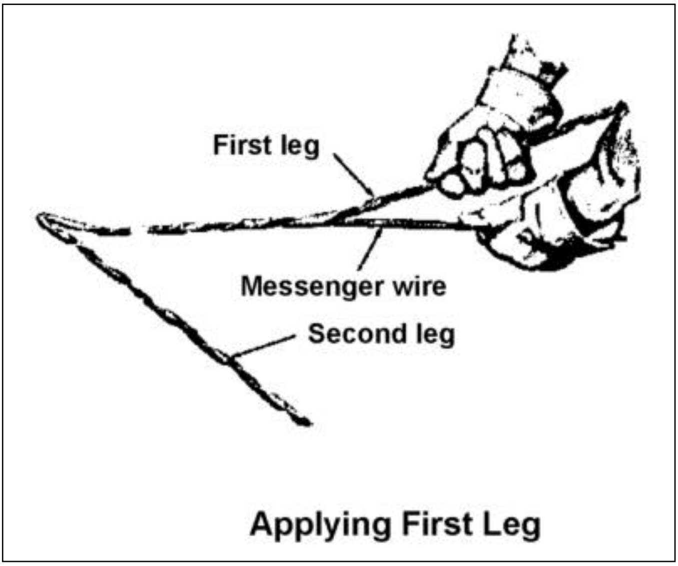


Figure 632.F - Braiding messenger wire

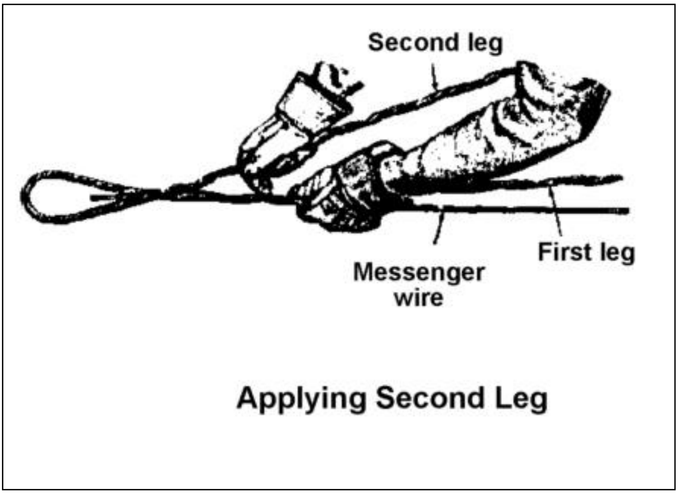


Figure 632.G - Braiding messenger wire

Cable and Wire (632.23)

In certain instances, the plans will assign a color code usage for each cable or a typical usage by color code. All connections should be made observing these assignments, and any deviations, if determined necessary, should be recorded. When a color code usage is not provided, good electrical wiring practice would still dictate that color code wiring on the project be consistent.

Typically, white is reserved for the neutral or common leg of a circuit. The following provides additional information about various types of cable and wire contained in Table 732.19-1:

1. Signal cable is used as the electrical connection between signal heads and the controller cabinet at an intersection. The cable may be either IMSA 19-1, which has a jacket of polyvinyl chloride, IMSA 20-1, which has a polyethylene jacket, or IPCEA S-61-402. The number of conductors and wire gauge shall be as specified on the plans. Conductors shall be of copper and stranded, and conductor insulation shall be color coded. Splices are not permitted in signal cable and the cable should be scanned to be sure that there are none.
    a. As temperatures decrease, signal cable gets stiffer and harder, becoming brittle when below freezing. In very cold weather, the cable should be handled with care so as not to damage the jacket or insulation when unreeling, flexing, and installing.
2. Interconnect cable is used as the connection between intersections for systems of signals. Spread-Spectrum Radio and Fiber Optic Cable are more commonly used for signal interconnection.
    a. The cable may be either IMSA 19-1, IMSA 20-1, or IPCEA S-61-402 as in signal cable, or twisted pair/shielded interconnect cable, conforming to RUS PE-39, may be required by the plans.
    b. Twisted pair/shielded cables are less prone to pick-up induced current as a result of nearby electrical devices or magnetic fields. Twisted pair/shielded cables are necessary for certain types of communication systems which may be used to interconnect signals. The number of conductors and wire gauge shall be as specified. It should be noted that in the case of twisted pair/shielded cable, the number of conductors is typically referred to as the number of pairs or pair count (i.e., six conductor cable would be referred to as a three-pair cable). Conductors shall be of copper and are usually solid.
3. Interconnect cable of the integral messenger type is aerial self-supporting cable with a, "figure 8," cross-section. The cable may be either IMSA 19-3, which has a jacket of polyvinyl chloride, or IMSA 20-3, which has a polyethylene jacket. Shielded versions, IMSA 19-4 and IMSA 20-4, may be required by the plans. The number of conductors and wire gauge shall be as specified. Conductors shall be of copper and stranded, and conductor insulation shall be color coded.
4. Loop detector wire is laid in turns in saw slots cut into the pavement and routed by the groove to the edge of pavement and to a pull box. The wire is single-conductor No. 14 AWG.
    a. The conductor shall be of copper and stranded. Loop detector wire consists of detector wire inserted into a flexible plastic tubing (732) that meets specifications, IMSA 51-5. The tubing shall encase the

wire completely from the splice at the lead-in cable through the entire loop turns and back to the splice.

b. Special pre-formed loops are sometimes used, especially for railroad preemption queue detectors and similar queue detectors. Often, these preformed loops have an extra loop of wire called a check loop, used for self-checking of the loop by the loop processor. Verify that the proper loop construction is performed, as called for in the Plans.

5. Lead-in cable for detector loops is spliced to loop wire and routed to detector units in the controller cabinet. The cable shall be two-conductor No. 14AWG with a jacket of 0.04 inch minimum black polyethylene and insulation of polyethylene. Each conductor shall be stranded copper. The conductor pair shall be twisted and shielded.
6. Power cable is used as the connection between the service pole or service drop and the controller cabinet. The cable normally is two-conductor and UL:RHH/RHW/USE type. The wire gauge shall be as specified. Conductors shall be color coded, made of aluminum, and stranded.
   a. Stranded copper may be substituted with an AWG one gauge higher (wire one size smaller).
   b. When specified, power cable may be three-conductor. Single conductor cables may be substituted for a two (or three) conductor cable, but color coding should still be provided.
7. Service cable is used to bring power to the vicinity of an isolated intersection. The cable is normally two-conductor (duplex) and XHHW type or cross-linked polyethylene with a 0.045 inch minimum jacket. The wire gauge shall be as specified. The cable is aerial self-supporting with one conductor being an uninsulated ACSR (aluminum conductor, steel reinforced) messenger wire. An insulated conductor of stranded aluminum is twisted around the messenger. Stranded copper with an AWG one gauge higher (wire one size smaller) may be substituted for the aluminum conductor. Three-conductor (triplex) may be specified where two insulated conductors are twisted around the messenger wire. The uninsulated messenger serves as the grounded neutral of the power supply.
8. Ground wire is used to connect signal or sign supports to ground rods. The wire shall be single-conductor No. 4 AWG made of seven-strand soft drawn copper with white insulation and rated at 600 volts. The wire is used as part of the 625.16 Ground Rod item.

Lashing of Overhead Cable

A preformed helical lashing rod shall be of the proper internal diameter to tightly secure overhead cable(s) to the messenger wire. A lashing rod should not be loose or so tight as to be impressed deeply or cut into the cable jacket. If either deficiency is observed, the proper internal diameter may be determined by the following formula: C approx. = (0.85)(D+m), where C is the lashing rod internal diameter, D is the cable jacket diameter, and m is the messenger wire gauge (all dimensions in inches).

For groups of several cables of varying diameter, the internal diameter of the lashing rod may be best determined by a graphic layout to scale.

Signal cable routed on messenger wire should neatly pass the bull rings in its path. Also, signal cable routed around an aerial corner formed in the span wire at a bull ring should have a radius in its routing small enough to form a tangency with the bull ring.

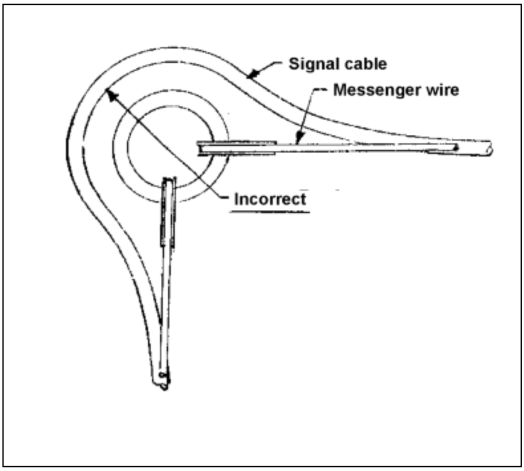


Figure 632.H

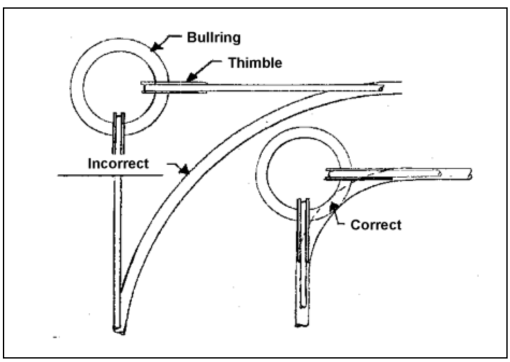


Figure 632.I – Signal wire placement around bullring

Power Service (632.24)

General

Power service for traffic signals shall comply with SCD TC-83.10 and the plans. It shall consist of the equipment needed to provide a pole-attached wiring raceway and disconnect switch for use with separately furnished power cable routed from the service point to the controller cabinet. Unless otherwise specified, the equipment includes a weatherhead, a conduit riser with necessary fittings, and attachment clamps as well as a disconnect switch with enclosure.

A thorough review of the plans should be made to determine that the specific requirements of the maintaining agency for power service have been satisfied.

A ground wire shall be used, as shown on SCD TC-83.10, leading to a ground rod installed in accordance with 632.

The LB type fitting under the controller cabinet may have to be installed before erecting the pole because of interference with the foundation.

Electric Meter Base

When required, an electric meter base may be furnished by the applicable utility and installed by the Contractor as part of the power service work.

Conduit Riser and Weatherhead

Power cable is the only type cable or wire permitted through the power service conduit riser.

If used, the conduit riser shall terminate at the meter base; otherwise, termination shall be at the switch enclosure. From there, the conduit connection to the controller cabinet is as shown on the plans. Conduit connection could be:

1. Immediately to the controller cabinet on the same pole.
2. Downward by underground conduit and possibly a pull box to a nearby foundation-based controller cabinet.
3. Upward by another riser on the pole to span wire and a remote cabinet location.

The conduit riser shall comply with 725 and the plans. The weatherhead shall be threaded aluminum or galvanized ferrous metal. Risers on painted poles shall be painted to match the poles.

Disconnect Switch

The disconnect switch shall be a UL listed, single-throw safety switch or circuit breaker which meets the voltage and capacity requirements of the specifications. The amperage rating of the fuse or circuit breaker shall be 5 to 10 amperes greater than the peak load rating of the equipment service. The enclosure shall be a UL listed, water tight, lockable, stainless steel NEMA Type 4, supplied with UL listed conduit hubs, and the enclosure shall contain a solid neutral bar normally grounded to the enclosure.

Signal Equipment and Wiring

General

This section will be used to provide additional information about other signal equipment and wiring.

Controller Cabinet (632.05)

While the layout of controller cabinets may vary, the following requirements and guidelines apply:

1. The prewired cabinet should be checked against certified drawings, the wiring diagram for the cabinet, and the plans.
2. The cabinet should be fitted with a small door-in-door (police door), unless otherwise specified. The cabinet should be in good condition, revealing no evidence of damage, with its material free of cracks and pinholes. The doors

and seals should fit properly. The cabinet exterior should appear as metallic aluminum, unless a color is specified. The cabinet interior may be similar to the exterior or may be flat white. The method of cabinet mounting should be as shown on the plans and the cabinet should be securely mounted.

3. Cabinets equipped with solid state controllers shall be provided with a suitable number of sturdy adjustable metal shelves to mount the specified equipment and to provide the required space for designated future equipment.
4. The equipment shall be arranged for easy withdrawal and replacement, without the necessity of disturbing adjacent equipment. The permanent location of equipment within the cabinet, as well as the shelves themselves, should allow free circulation of air and not restrict air flow from fan ducts or vents. Components on shelves and devices on the door shall be arranged so that a 1-inch minimum space separates them when the door is closed. This minimum space shall not be compromised by plugs, wires, controls, or similar items. Terminals and panel-mounted devices with exposed contact points located next to shelf mounted equipment shall be provided with spacers, shelf lips, or other means to assure that component units cannot be accidentally moved into contact with any exposed electrical terminal points. A minimum 4-inches clear area from the bottom of the cabinet should be reserved for the routing of cables. No shelf, component, or panel-mounted item shall be located in the bottom 6 inches of cabinets, with the exception that terminal blocks only in pedestal or pole mounted cabinets may be installed as close as 4 inches to the bottom.
5. Ready accessibility should be provided for items such as load switches, flasher, relays, terminal blocks, and fuses which are mounted on or plugged into panels on the cabinet back or sides. Switches, controls, and indicator lights should be easily operable and visible without having to move equipment from their positions.
6. Major equipment items should bear a name plate, brand, or indelible marking for identification as to type, model, catalog number, and manufacturer’s name or trademark.
7. The furnished controller unit should be checked for the correct type, number of phases, and available control functions required by the plans. Controller units should be furnished with all auxiliary equipment necessary to obtain the operation shown in the plans.
8. When specified, other equipment may be a part of the prewired cabinet, such as radar processors, spread-spectrum radios, an on-street master, interconnection equipment, preemption equipment, GPS time clock, and special relays.
9. Furnished detector units should be checked to see if the correct quantity is installed, and the proper type used with each loop and each detector phase. When multi-channel detector units are furnished, the plans may require the provision of special cabinet wiring and an adapter harness to allow single channel detector units to be readily substituted.
10. The prewired cabinet should also be checked for the following auxiliary equipment:
    a. A forced air ventilating fan automatically controlled by a thermostat shall be furnished.
    b. A conflict monitor shall be furnished. When the plans so specify, according to 733., an increased capability monitor shall be furnished. The minimum number of monitor channels, related to the number of phases for the intersection, should conform to 733.

c. Load switches should be provided in sufficient quantity for the interval sequence shown in the plans. The switches shall be solid state NEMA triple-signal type with input indicator lamps. The minimum number of load switch sockets furnished, related to the number of phases for the intersection, shall conform to 733.
d. A flasher or flashers shall be solid state NEMA type.
e. Relays required for the proper operation of the specified equipment shall be furnished.
f. Surge protection devices (SPDs) shall be furnished for the protection of solid state controllers, as required by 733. They should be located on the incoming power line and on loop detector leads where these connect to the terminal block.
g. A convenience outlet and cabinet internal illumination shall be furnished. The outlet should contain at least one standard three-wire plug receptacle of the ground-fault, circuit-interrupting type. The lamp should be an incandescent type, located in the upper part of the cabinet and controlled by a switch.
h. A main power breaker shall be furnished. The fan, convenience outlet, and lamp should be wired on a branch of the AC+ power line preceding the main breaker, so these may be operated independently of the main breaker control. This preceding branch should contain an auxiliary breaker rated at 15 amp.
i. A radio interference filter should be installed in the incoming AC+ power line between the main breaker and solid state equipment. It is sometimes integral to the SPD.
j. A manual control cord with push button should be furnished only when the plans so require (733). The cord should be at least 5 feet long.
k. Switches required for the proper operation of specified equipment should be furnished and labeled as to function and setting position. The following switches should be grouped behind the small door-in-door (police door): signal shutdown switch, flash control switch, and an automatic/manual transfer switch (when manual control is specified).
l. Terminal blocks should not be obstructed by other equipment. Terminal points should accept spade-type wiring terminals except for incoming power terminal points which may be either the type to accept bare wire or spade terminals. Contact between adjacent terminal points may be either by bus bar or by wire jumpers with spade terminals.

11. The incoming power bus should be fed from the line side of the incoming 120 VAC power line after the circuit has passed through the main power breaker. A signal bus relay should control power to the bus which supplies power for the signal load switches. The requirement for radio interference filters (733) should be adhered to, such as buses supplying load switches and flashers being filtered if load switches do not switch at the zero voltage point of the power line sinusoid wave form. A common terminal bus insulated from the cabinet should be furnished for the connection of the neutral wire of the incoming 120 VAC power line. This common bus should have sufficient terminal points to accommodate all potential cabinet wiring as well as field wiring. A separate

common terminal, insulated from the panel, should be used for the interconnect common (if interconnection is a part of the system).

12. The cabinet should include a ground bus bar with an adequate number (at least three) of ground terminal points (733). This bus bar should be grounded to the cabinet. The ground bus bar will normally be bonded to the common terminal bus using at least a No. 8 AWG copper wire.
13. Wiring bundles should be neatly arranged and grouped as to voltage and function and should be lashed or restrained so they do not interfere with the access to equipment, including terminal blocks or buses. The harnesses should be of sufficient length and should be easily traced through the cabinet. All conductors should be stranded, with labeled spade-type terminals or plug connectors. The wiring should be color coded, with solid white for the AC common, black for the AC line side power (AC+), and solid green or white with green stripes for the safety ground.
14. Incoming cable and wire should be identified by tags or bands (632). The size, material, and method of tag or band identification should be in accordance with 725, except that marking may be by indelible pen on plastic tags instead of embossed letters. The identification on the tags or bands should conform to the wiring diagram for the cabinet and its intersection, with typical abbreviations in accordance with the Table in 632.
15. Two copies of the schematic and wiring diagram for each cabinet and its intersection should be furnished by the Contractor. The diagrams are to be updated to reflect any changes made during construction. The diagrams should be neat and legible on durable paper and folded in a moisture-proof envelope fastened to the cabinet interior.

Cable and Wire Identification (632.05)

As noted in 632, cables and wires shall be identified as shown in TEM Table 497-2.

Vehicular Signal Head, Conventional (632.06)

1. Signal heads shall conform to the plans, 732 and applicable SCD. Signal heads shall be made up of the correct number of optical sections (one, three, four, or five, typically). Sections shall be of the correct lens size, color, and ball or arrow configuration.
2. Lenses shall be aligned properly in their frames so their optical configuration directs most of the light to the forward sector.
3. Signal heads shall have a yellow or black finish, unless otherwise specified in the plan.
4. Cutaway type visors shall be fastened to each optical section, unless open bottom tunnel visors or other types are specified, and the interior finish of the visors shall be flat black.
5. Signals should be clean and the assembly tight. Gaskets should be in good condition and lens door hinges and latches should be in good working order. All openings not used for mounting purposes shall be closed by waterproof caps.
6. Five-section faces, arranged in accordance with applicable SCD and the plans, are to use galvanized pipe, elbows, and tubular hardware painted to match the signal head.
7. Swinging signals shall be installed in a plumb condition. A balance adjustor should be used only when necessary to achieve plumb.

8. Swinging signals suspended from a mast arm shall be fitted with a universal hanger which permits swinging in both longitudinal and transverse directions.
9. When specified by the plans, disconnect hangers shall be used with signal heads.
10. Drop pipes, 1-1/2-inch diameter galvanized pipes, are a source of trouble and are aesthetically unattractive; therefore, they are intended to be used only when they are necessary to permit signals to be suspended above the roadway at the proper height Signals supported by span wire, with sag required between 3 and 5 percent, shall be brought to proper clearance by adjusting the attachment height of the span wire to the poles. Due to the 2 foot clearance tolerance, drop pipes should not be necessary in most cases.
11. Backplates shall be fitted to signal heads.
12. Signal cable shall be routed into the interior of heads through the entrance fitting using a grommet. The cable shall be routed to each face's terminal block, which is typically in the yellow indication section, but may be in the green section. Conductors shall be fitted with spade-type terminals and shall be fastened securely to the correct terminal points. Conductors shall be identified according to the wiring diagram. Signal cable shall not be spliced between signals or in signal face interiors.
13. External signal cable shall be fashioned into a drip loop extending at least 6 inches (150 millimeters) below the entrance fitting, but shall not chafe on the signal.
14. Lamps shall be LED only.
15. Each face of a signal head shall be oriented to its approach of traffic and its locking device securely tightened. Orientation or aiming of standard signals should be done so the maximum light intensity from a standard signal is directed slightly below the horizontal center; thus, on a level approach, the face of the signal should be essentially vertical. When an approach to a signal is on a grade, the signal may be tilted slightly to point the signal axis parallel to the grade of the approach. Horizontal aiming should orient the axis of signal display parallel to the centerline of the approach for straight approaches when the signal is over the roadway. When the approach roadway is curved, or when a signal is not over the roadway, the axis should be directed at a point on the approach which is 175 to 625 feet (54 to 191 meters) in advance of the intersection, the distance being dependent on the speed of approaching traffic.
16. When a vehicular traffic signal head has been erected and faces approaching traffic, it shall either be in operation as a stop-and-go signal or a flasher, or it shall be covered or bagged. This is an OMUTCD requirement and cannot be ignored. Typically, the plans will contain an item for "Covering of Vehicular Signal Heads," which will require the Contractor to cover, maintain the covering, and subsequently remove the covering when the signal is ready to commence operation. The backplates shall be covered as well.
17. Normally, the plans will provide the covering item for each new signal head, but will not provide them for any existing heads which are to be removed. The intent is that covering will be necessary for the new heads until they, and their associated controller and wiring, have been checked by circuit testing (see 632), while any existing signals at the intersection will continue to control traffic. When the new signals are uncovered and placed in operation, the existing signals can be quickly removed. Specific maintenance of traffic requirements in any plan may require a different means to assure the unused signals are not exposed to traffic.

Vehicular Signal Head, Optically Programmed (632.07)

Programmed heads shall conform to certified drawings and the plans. They are to have the correct number of optical sections making up each face. Programmed heads have many points of similarity to regular heads. For more detailed information, see publications by the manufacturer.

Programmed heads shall be mounted in a manner permitting little or no motion. If mounted on a mast arm, a rigid adapter shall be used. Heads of more than three vertical sections mounted on a mast arm shall be fitted with pipe backbracing, as shown on SCD TC-85.20. The pipe shall be a minimum of 17 inches behind the signal center axis so that adequate clearance is provided for the programming procedure. If heads are supported by span wire, a tether wire shall be attached to a fitting in the bottom of the signal's lower section.

Customarily the manufacturer's representative will program the signals, but in accordance with the plans, the Contractor is responsible for the correct aiming and masking of the signal so as to be visible to drivers or pedestrians only in the area indicated on the plans.

Pedestrian Signal Head (632.08)

Pedestrian signal heads shall conform to 732, certified drawings, the plans, and SCD TC-85.10. Signals shall have the correct type of light source and lettering height in accordance with the plans.

Housings shall have a black finish, unless otherwise specified. Visors shall be fitted over each message, except one type may have the entire face protected by a flat black sunshade fastened close to the lens. The interior surface of visors shall be flat black finish. Signals should be clean and the assembly tight. Gaskets should be in good condition and lens door hinges and latches in good working order.

Housings shall be positioned with a minimum set back of 2 feet from the curb and a height of 8 to 9 feet above the sidewalk for adequate clearance. The heads shall be oriented toward their crosswalk and locked securely in position.

Push button housings shall have a yellow finish, unless otherwise specified.

Push buttons on metal poles shall be installed over a 3/4-inch maximum field drilled hole with edge protected by two coats of zinc-rich paint and a rubber grommet inserted.

The push button housing curved back shall be positioned over the hole, wiring routed through to the electrical mechanism, and the housing secured by stainless steel screws. Unused holes in the housing shall be plugged. Push buttons on wooden poles shall have their wiring in conduit connected to a fitting of the signal support.

Pedestrian signal head supports (conduit and fittings) on wooden poles shall be grounded using a ground clamp and an insulated ground wire stapled to the pole and covered by a molding.

If specified in the plans, pedestrian signal heads may be covered in accordance with 632.

OMUTCD addresses standards for the signs used where push buttons are provided to actuate pedestrian signals. The sign legend shall conform to the plans.

Detector Loop (632.11)

1. Slots cut into the pavement which form rectangular detection loops shall be in accordance with the plans and SCD TC-82.10.
2. The slots shall be a minimum of 3/8 inch in width and shall have a minimum depth of 2 inches in concrete and 4 inches in asphalt concrete. SCD TC-82.10 requires that loop corners be made at a drilled or bored hole, about 1-1/4 inches in diameter, and with the same depth as the saw slot. Any sharp edges at the saw slots and the holes shall be chiseled out.
3. The slot depth shall accommodate the specified number of turns of wire laid so that the uppermost wire has a covering of at least 3/4 inch (19 millimeters). The number of wire turns shall comply with the plans and the table in SCD TC-82.10. A separate slot leading from the loop to the pavement edge is typically cut for each loop.
4. When permitted by the Engineer, loops installed in new asphalt concrete may be sawed, and the loop wire(s) embedded with sealant in a subsurface course with subsequent covering by the surface course.
5. Some plans may specify the use of preformed loops
6. If the problem of loop installations in brick streets is encountered, the Engineer should consult with the local traffic engineer for recommendations.
7. Loop locations may be adjusted to avoid manholes. Loops should not be placed across pavement joints. Instead, lateral and longitudinal adjustments should be considered with the approval of the Project Engineer. If joint crossing is unavoidable or major pavement cracks are encountered, the following techniques may be used.
    a. In Technique A, the loop wires are laid over the joint or crack within a 3-inch square or circular hole cut to slot depth. The wires are laid in an “S” shape and the hole filled with elastic joint material or asphalt concrete.
    b. In Technique B, the slot at the joint or crack is saw cut to twice-normal width and depth. The wires are laid so as to conform to the deepened slot, which is injected with soft setting butyl rubber up to the depth of the original slot. The original slot depth and the remaining perimeter of the slots are embedded with standard sealant cured to a flexible state.
    c. In Technique C, the slot at the joint or crack is enlarged. The wires are encased in a length of plastic tubing which should be large enough to loosely hold all wires and may be slit lengthwise to facilitate construction. Before placing it in the slot, the ends and the longitudinal slit are to be taped shut to prevent the entry of loop sealant. The enlarged slot is then filled with loop sealant.
8. Before loop wire is placed, all slots shall be brushed, blown clean of loose material, and completely dry.
9. Loop detector wire shall be single-conductor No. 14 AWG insulated wire, type IMSA 51-5 with stranded copper conductors, unless otherwise specified. The wire should be marked at intervals with the wire gauge, UL label and type. The detector wire is contained inside a flexible plastic tube, as required by IMSA 51-5.
10. The correct turns of loop wire shall be placed in the slots, to comply with 6323 and the plans. The wire shall be pushed to the bottom of the slots with a blunt wooden tool (or equivalent) to avoid damaging the insulation.

11. The wires with tubing at the pavement edge or curb shall be led into a conduit of the size shown in SCD TC 82.10. Care should be taken to prevent excessive slack at the point where the wires enter the conduit. The high end of the conduit shall be sealed in accordance with SCD TC 82.10.
12. The detector wire shall be twisted in the conduit leading from the pavement edge to the pull box. The flexible plastic tubing shall cover the wire completely from the splice at the lead-in cable, through the entire loop turns, and back to the splice. The tubing provides extra protection from abrasion and allows the wire to slide inside the tubing in case of pavement shift or cracks, thus minimizing the possibility of breakage. Since wire/tubing includes an air pocket, it will tend to float to the surface when sealant is applied to the slot. For this reason, it is usually necessary to wedge short lengths of the tubing, or similar devices, into the slot to wedge down the tubing/wire. These are usually needed at 1 to 2 foot intervals.
13. The slots shall be completely filled with approved sealant and left undisturbed until cured to a flexible state. Sealants on the ODOT prequalified list shall be used in accordance with the manufacturer's recommendations. Materials which set-up to a hard or brittle state are not acceptable.
14. Detector loops are measured as "each" loop installed and the item includes wire, pavement cutting, and sealant.

Loop Detector Lead-In Cable

Unless otherwise specified, loop detector lead-in cable shall be two conductor No. 14 AWG twisted pair shielded, with a jacket of black polyethylene 0.04 inch thick minimum, and polyethylene insulation with conductors of stranded copper.

Within the pull box, loop wire ends shall be joined to the conductors of the lead-in cable by soldering and covered with insulating material. An approved, poured epoxy waterproof splice kit shall be used. It is understood that epoxy splice kits are easily damaged by freezing temperatures encountered prior to mixing. Damaged epoxy components may sometimes be recognized if either of the components has turned or is streaked milky white.

Lead-in cable shall be routed to the controller cabinet, fitted with soldered spade-type terminals, and fastened to the correct points of the terminal block. The lead-in cable's shielding shall be grounded to the ground bus within the cabinet.

If a pull box is not specified on the plans, the splice between the loop wire and lead-in cable shall be made in the first entered pole or pedestal, except where the controller cabinet is mounted on the pole or pedestal. If the controller cabinet is mounted on the pole or pedestal, the loop wires may be routed directly into the cabinet and no lead-in cable is necessary.

Testing (632.28)

General

Traffic control signal components and the entire system shall be tested, as required by various specifications, to assure proper operation before acceptance. Ground rods shall be tested for satisfactory low resistance to ground. A circuit test should be performed on

all conductors to make sure there are no shorts, crosses and high resistance, or other improper connections. A cable insulation or Megger test shall be performed on all conductors to verify the integrity of the insulation covering. All traffic control equipment in the controller cabinet should be checked for correct settings and all controls manipulated for assurance of an operable system.

Finally, the traffic control system shall successfully pass a 10-day performance test, which will give an opportunity for any hidden flaws to reveal their presence. As a final "housekeeping" check, equipment should be observed for any evidence of unattached ground wire, unlatched or unbolted doors, etc.

The results of the various tests are to be entered by the Contractor on test report forms (TEM Form 496-6) as required by 632.

Ground Rod Test

All ground rods shall be tested by the Contractor for earth resistance to ground, as required by 632.

Short-Circuit Test

Before the performance of any cable insulation (Megger) test or the 10-day performance test, a short-circuit test shall be performed by the Contractor using a volt-ohmmeter or other approved instrument. Short-circuit tests shall be conducted with all electrical loads, power sources, equipment grounds, and earth grounds disconnected (see TEM Figure 498–28).

Signal cable routed to signal heads may be tested with connection made to the lamp sockets, but without the lamps being installed.

Each conductor shall be measured against every other conductor and ground to ensure that no short-circuits, cross-circuits, or other improper connections exist. Continuity should not exist between any conductor and any other conductor including ground.

Circuit Continuity Test

Each circuit branch shall be disconnected and tested by the Contractor for continuity by temporarily jumpering each branch at its termination and measuring the temporarily looped circuit for assurance that no open circuits exist (TEM Form 496-6). This testing is illustrated in the TEM. Each circuit branch should be according to plan, with no high resistance connections and with proper identification.

Lead-in cable for loop detector wire shall be tested before and after the cable is spliced to the loop wire.

Circuit continuity of signal cable may be done by applying 120 volts to each outgoing circuit and observing that only the specific lamps are lighted.

Cable Insulation Test (Megger Test)

This testing is illustrated in the TEM Figures.

1. Each conductor of cable or wire terminating at the controller cabinet shall be tested by the Contractor for insulation resistance measured to ground (TEM

Form 496-6). A listing of the resistance reading for each conductor is to be included in the test results furnished to the Engineer.

2. Cable and wire insulation can be faulty, but the imperfections can be easily overlooked, leading to eventual electrical failure of the wiring. Weakening of insulation properties may be caused by poor storage conditions and stress due to rough handling during installation. Dirt is especially troublesome since it is an electricity conductor and can penetrate small cracks in the insulation.
3. Insulation testing shall be performed with all conductors disconnected from their points on the terminal block in the cabinet. This will ensure that there is no voltage present and will prevent damage to any connected equipment. One Megger instrument terminal shall be attached to a termination of jumpered together ends of conductors or to the end of a single conductor cable or wire undergoing testing. The other Megger instrument terminal shall be attached to the cabinet ground bus bar.
4. Insulation resistance shall be measured for the wire of roadway loops after the embedding of the wire with sealant in slots.
5. The meter pointer of the Megger instrument (or equivalent indication) should be adjusted to zero and the test switch activated. Test duration should be as recommended by the instrument manufacturer.
6. The insulation resistance measured to ground for each conductor shall be no less than 10 megohms. Cable or wire not meeting this reading shall be replaced.
7. After completion of the cable insulation test, all cabinet wiring shall be connected in accordance with the wiring diagram. The Contractor shall demonstrate to the satisfaction of the Engineer that all circuits are continuous and operating correctly, free from shorts, crosses, and unintentional grounds.

Functional Test

Before energizing the traffic signals the following functional checks should be made:

1. The incoming AC voltage should be checked.
2. Operation of the following equipment should be checked: cabinet ventilating fan, fan thermostat, and convenience outlet with lamp (when furnished). The filter(s) used with the fan should be unobstructed.
3. Timing settings on solid state controllers should be varied over their ranges and all functions activated to verify that the controls are operable without fault.
4. Timing settings in accordance with the plans should now be entered on the controller, time clock, etc. and checked for corrections. On some projects, timing settings will be provided by the maintaining agency and not listed in the plans.
5. An agreement should be reached with the Contractor and the maintaining agency on the procedure which will be followed in the event of a signal failure prior to acceptance.
6. Before signals are energized to control traffic, the maintaining agency should be notified and given an opportunity to check the installation and timing settings.

After energizing the traffic signals the following functional checks should be made. In the event the signals are controlling traffic at the time, these checks should be made with caution to protect the safety of workers, pedestrians and drivers.

1. The function of all cabinet switches should be checked, including the power on/off switch and manual control (when furnished).
2. The traffic signals and controller indicator lights should be observed to verify that the controller is timing consistently the intervals and phases set into the controls. A stopwatch is suggested, especially to check critical short intervals. All controllers' functions should be activated to verify that operation is proper.
3. The detector units should be investigated to determine which pavement loop(s) or other type sensor is associated with which unit. The visual indication of units (light, meter, etc.) should be observed to determine that each vehicle (truck, car, motorcycle, etc. see TEM 420-5.2) entering sensor areas are properly detected on the associated unit and that no extraneous calls occur when the sensor area is vacant. When a detector unit is set for "presence," a detection call should continue as long as a vehicle is positioned over the associated sensor. Concurrent with detection, the appropriate controller indicator light should exhibit the detection.
4. The flasher switch should be activated to cause the signal heads to flash. Their indications should be checked to verify if they are correct. The flasher switch should then to be returned to the normal or signal mode and a check made of the resumption of normal stop-and-go operation.
5. The conflict monitor should not be activated by normal signal operation or by the manipulation of cabinet switches. If at any time the monitor is activated, the Contractor is required to determine the cause of the problem and make appropriate changes and adjustments before beginning the 10-day performance test. The Contractor should test the conflict monitor by artificially causing a number of different conflicting indications. The Contractor should check that at each test, the monitor causes the signals to flash and places the controller in a "stop timing" mode. Artificial conflict may be caused by touching a jumper wire between two load switch outputs that would signal a traffic conflict. Other methods of artificially caused conflicts may be used at the discretion of the Contractor.
6. Signals which are interconnected should be observed to determine if offset relationships are maintained in accordance with settings during all periods of the day.
7. When preemption equipment is furnished as part of the cabinet installation, the proper functioning of the equipment should be checked. The equipment should be activated and observations made to determine if the required sequence of intervals and phases is called for in a correct and safe manner.
8. On projects having equipment furnished for future use only, the equipment should be checked to verify that it is properly installed and operable in a correct manner.

Some signal control equipment is, intended to vary the timing patterns at different periods of the day or days of the week. To determine if these required changes are occurring at the proper times, it is necessary that observations be made to check the operation at transition times over a period of several days.

After successful completion of the 10-day performance test, and after a partial or final acceptance of a project, the Contractor should give the Engineer all manuals, diagrams, instructions, guarantees, and related material, as required by 632. It is recommended that the Engineer list this material in the project diary as a permanent record of the transfer.

The Engineer should transfer the material to the maintaining agency. For ODOT-maintained signals, the material should be given to the District Roadway Services Manager.

After a traffic control system project has been accepted by ODOT, the Engineer should immediately notify the maintaining agency to indicate that as of a specific time and date, the agency is responsible for the operation and maintenance of the system.

Performance Test

Before acceptance of the traffic control system, the Contractor shall furnish all personnel and equipment required to successfully operate the system continuously for 10 consecutive days without major malfunction or failure (632).

At least 7 days prior to the beginning of the performance test, the Contractor shall notify the Engineer of the starting date. The Engineer will notify the maintaining agency.

The Contractor shall arrange with the utility supplying the power for purchase of the energy required to conduct the test. All costs of personnel, equipment, electrical energy, and incidentals required to perform the test are to have been included in the contract unit prices for the respective items tested.

Minor failures, such as lamps, a single detector, or an individual signal head, etc. shall be immediately replaced or repaired and will not cause restart of the test.

A major malfunction or failure, such as a master or local controller, interconnect equipment, etc. will cause termination of the test, and after replacement or repair of the malfunctioning or failed equipment, the beginning of a new 10-day test.

Items which have been repaired or replaced are to be monitored by the Contractor for a period of 10 days to assure their reliability.

The complete test results are to be furnished to the Engineer on test reporting forms in accordance with 625. The Contractor is to record, in the test results, the beginning and end of the test and the method and date of the correction of each fault.

The Engineer should record the following events in the project diary: the date the 10-day performance test began, a day-by-day record of faults as they occur during the test, and the date of the successful completion of the performance test.

Final Signal Installation Check

After all wiring is completed, and all testing completed and accepted, a final inspection of the traffic control system should be performed to assure a neat and workman-like appearance.

1. All spare conductors should be connected to the ground bus bar in the controller cabinet.
2. All ground wires should be properly connected.
3. The spade type ends of conductors should be sound. After all testing is completed they should be reinstalled on their correct points of terminal blocks and tightened.
4. A visual check should be made for any signs of arcing, melted insulation, etc.
5. All debris from wiring work or packaging materials should be cleaned from the bottom of cabinets.

6. Cabinet vents should be checked to assure that they are unobstructed and all filters should be clean and in place.
7. Duct sealing material shall be used to seal the conduit entering the cabinet from the base.
8. All doors on the optical sections of vehicular and pedestrian signal heads shall be closed and latched.
9. No wires or cable should be visible under the base plates of poles and pedestals.
10. The handhole covers on poles and end-frames shall be securely fastened.
11. Pedestals with transformer type bases shall have the access door securely fastened.
12. The covers on pull boxes shall be securely bolted.
13. Verify that all traffic signal control items carrying a 5-year warranty (733.02) have the required label attached.

632/633 Supplemental Information

Please refer to the Traffic Engineering Manual (TEM) for a complete list of forms, supplementary information, and updates.

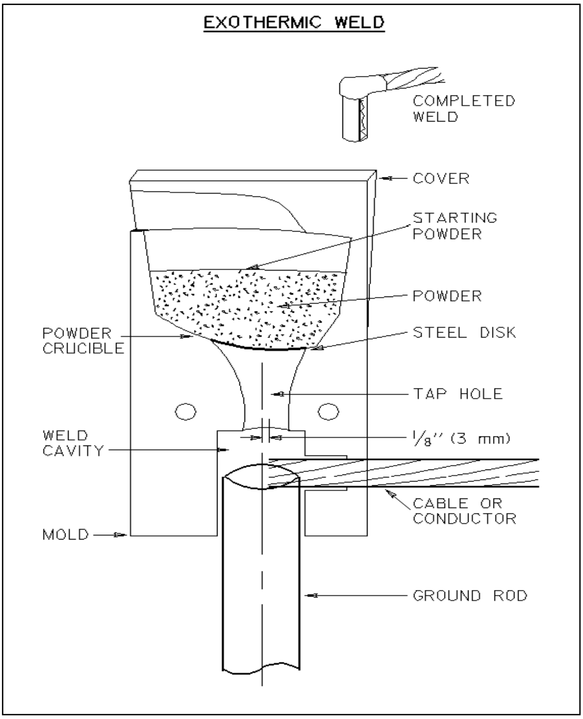


Figure 632.J – Exothermic weld

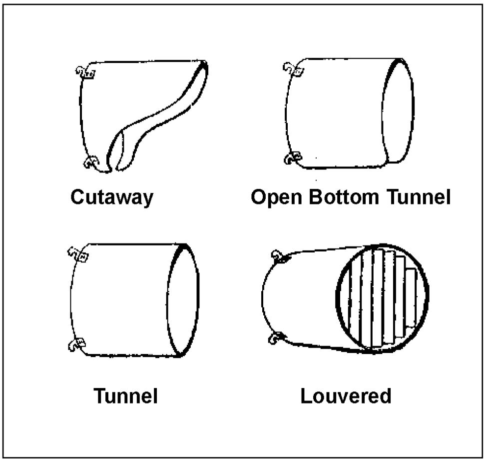


Figure 632.K – Vehicular signal head visors

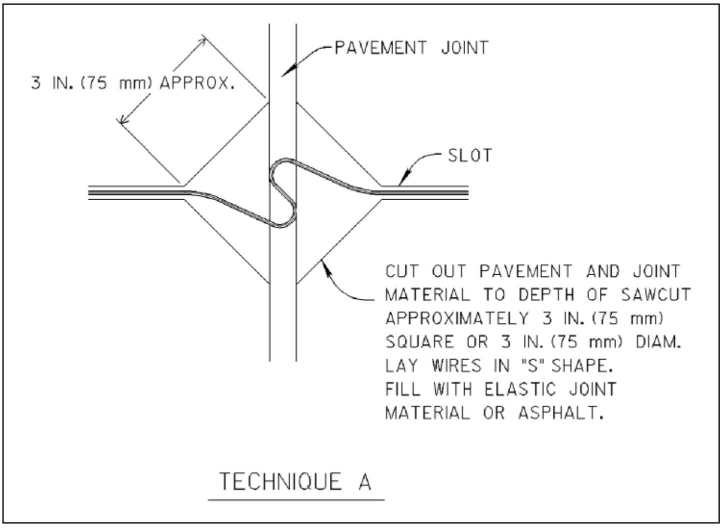


Figure 632.L – Loop construction

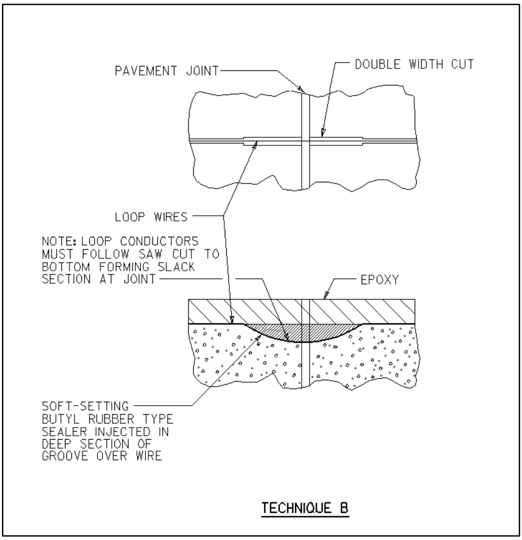


Figure 632.M – Loop detector slots and wiring

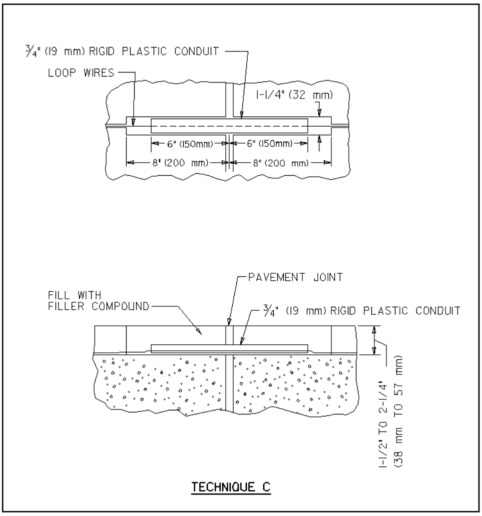
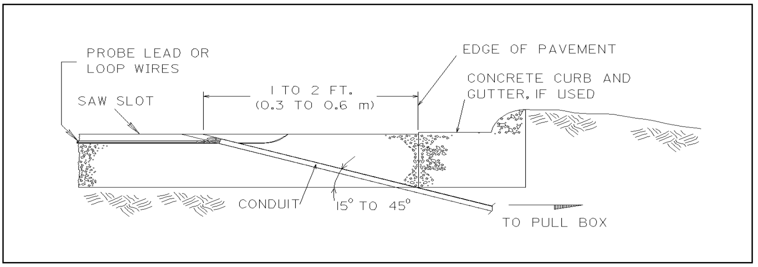
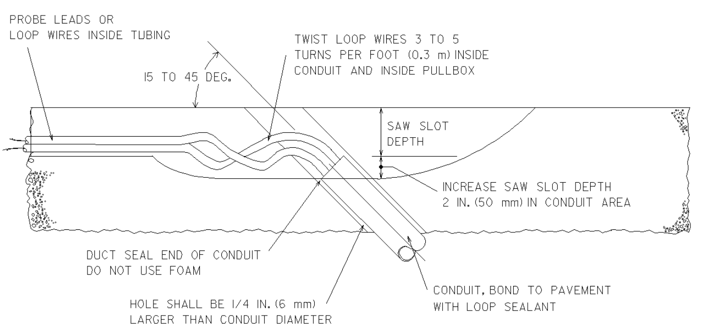
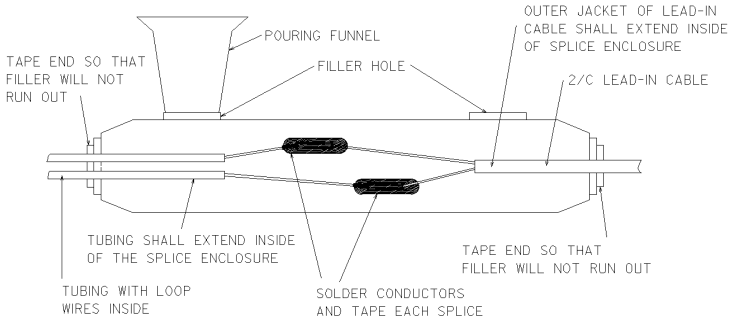


Figure 632.N – Loop detector slots and wiring





CONDUIT DRILLED HOLE DETAIL



SPLICE ENCLOSURE DETAIL

Figure 632.O – Loop detector wiring

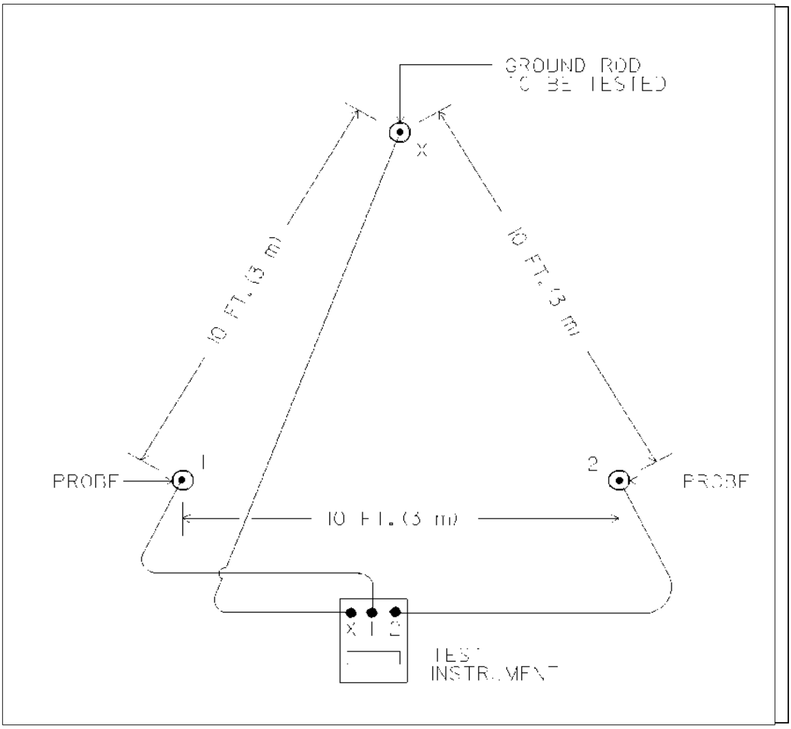


Figure 632.P – Ground rod testing

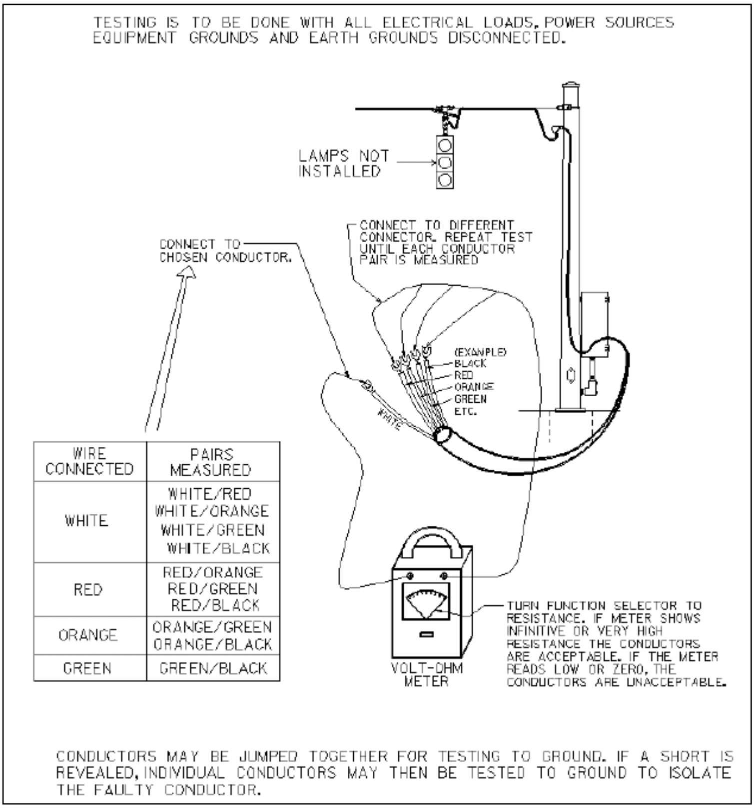


Figure 632.Q – Short-circuit test

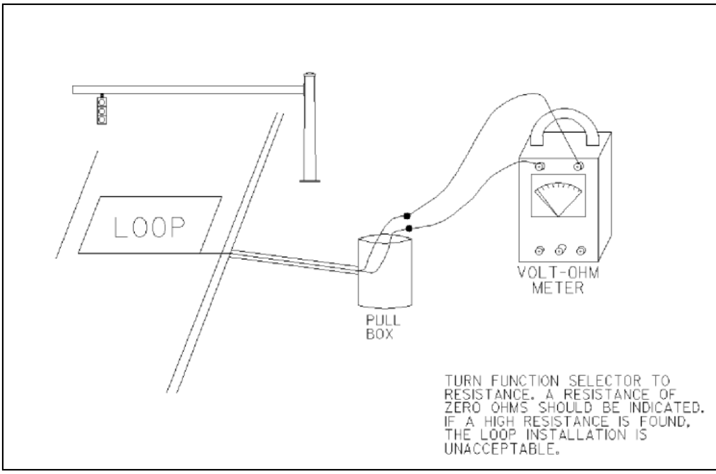


Figure 632.R – Circuit continuity test of loop wire (before splice to lead-in cable)

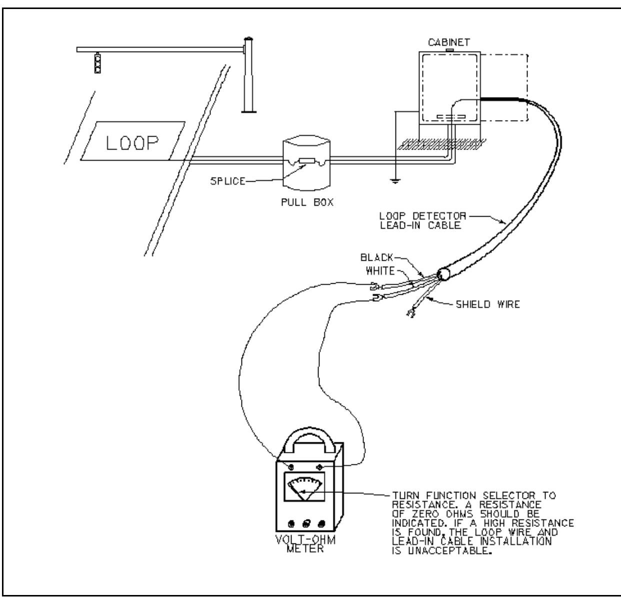


Figure 632.S – Circuit continuity test of loop wire and lead-in cable

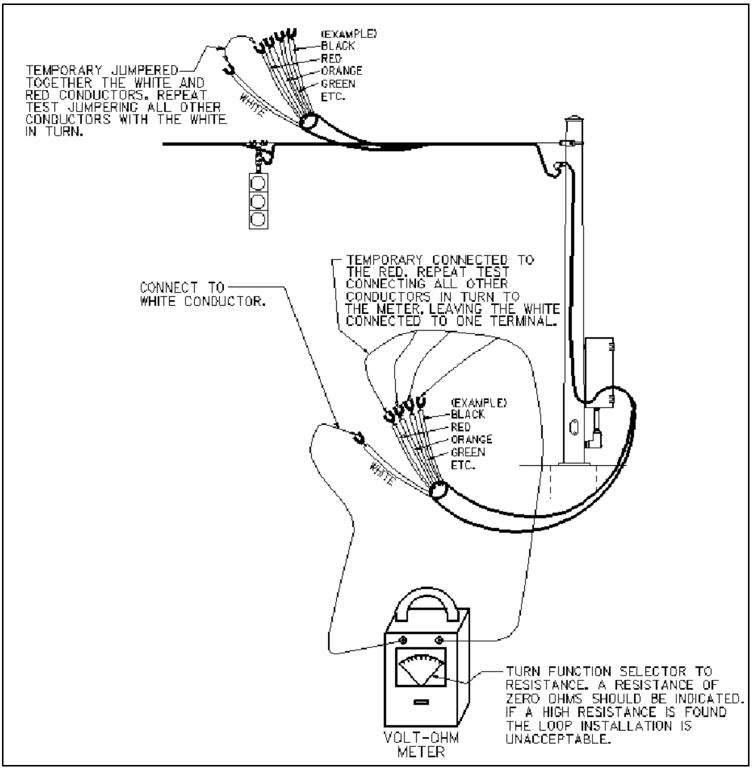


Figure 632.T – Circuit continuity test of signal cable disconnected from heads or other cables such as interconnect and loop or magnetometer lead-in

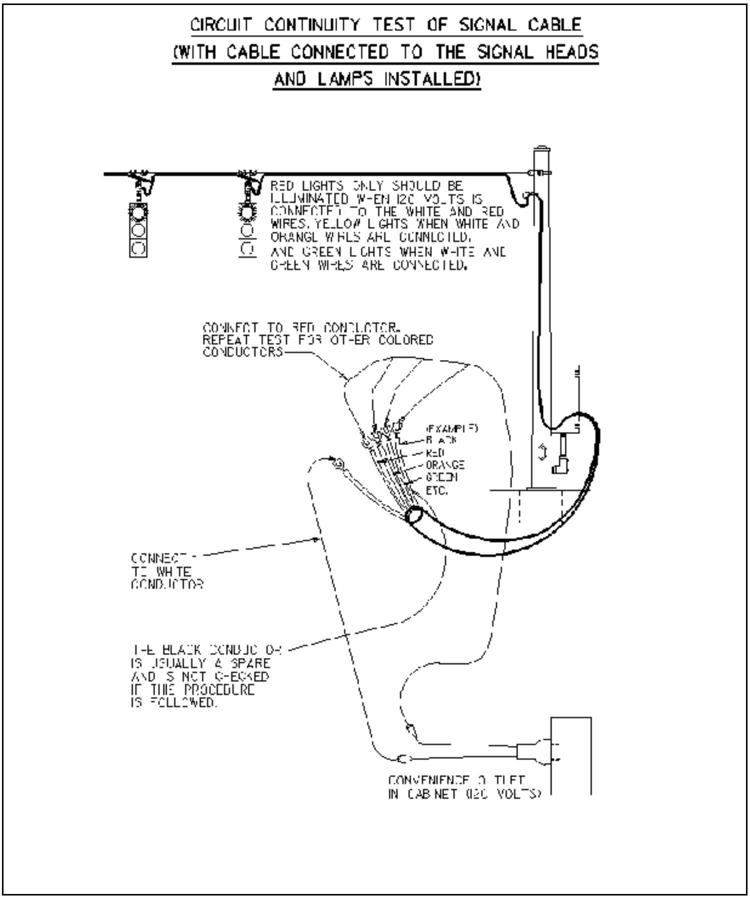


Figure 632.U – Circuit continuity test of signal cable with cable connected to the signal heads and lamps installed

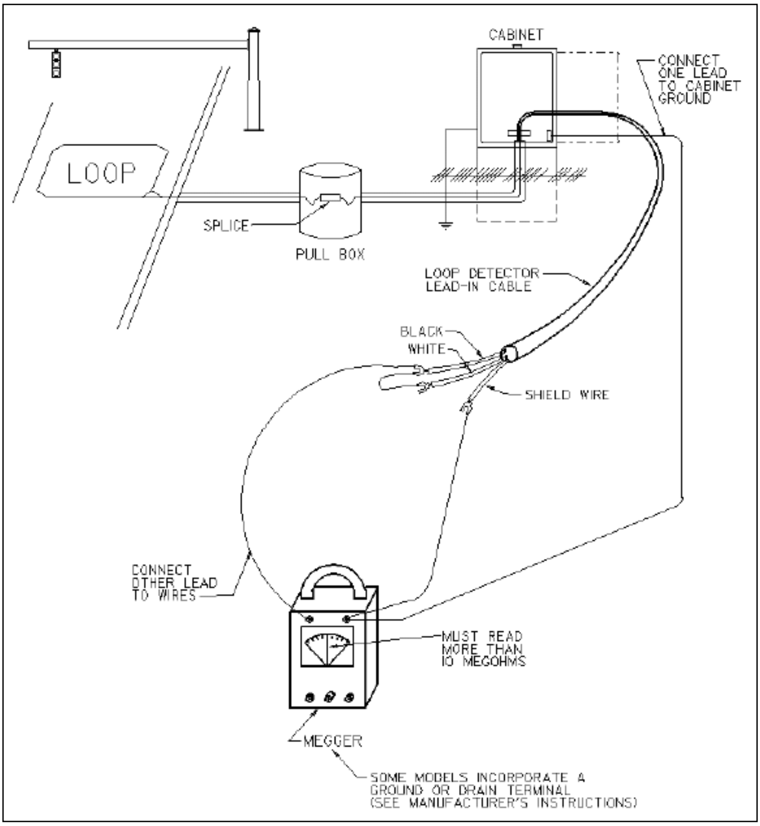


Figure 632.V – Cable insulation test (loop detector wire)

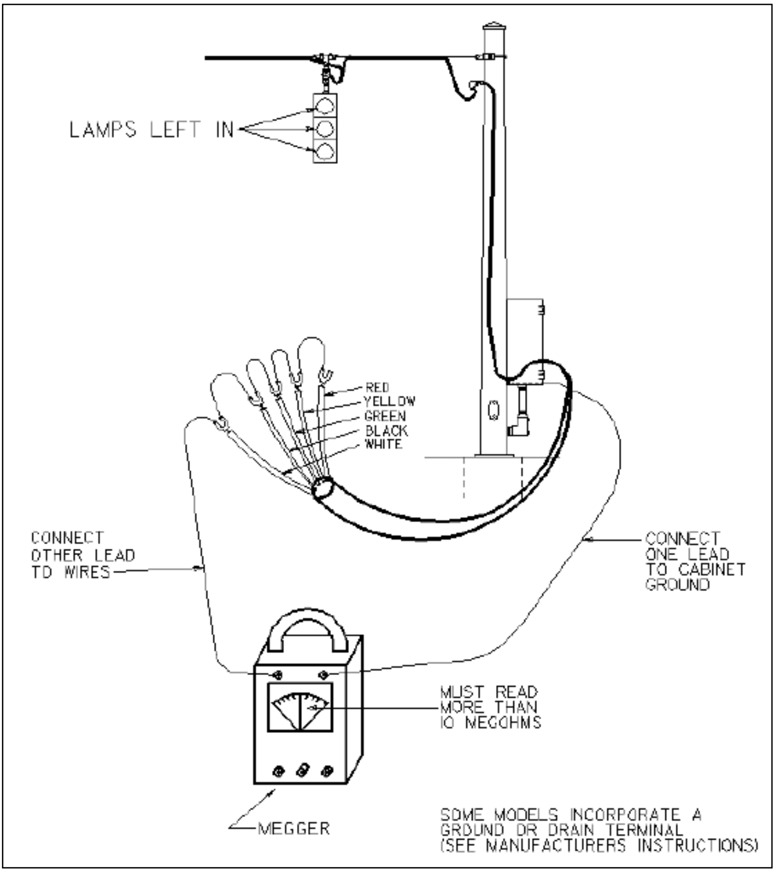


Figure 632.W – Cable insulation test (signal cable)

638 Water Mains and Service Branches

Project file Requirements - 638 Water Mains and Service Branches

Ensure written Installation Plans have been submitted per 611.04 B. Installation Plans may be eliminated if installation details are included in the contract documents.

640 Pavement Markings

641 Pavement Markings – General

This information is intended to serve as a guide for construction personnel where the Contractor furnishes and installs traffic control marking devices. This information may also be useful for maintenance personnel performing the same functions.

As per 641.06, the Contractor shall establish reference points to ensure proper placement of restored markings on projects where resurfacing or other operations will result in obliteration of the existing pavement markings.

Please refer to the Traffic Engineering Manual for a complete list of forms and supplementary information. Updates are available on the following ODOT website:

> *www.dot.state.oh.us/Divisions/Operations/Traffic/publications2/TEM/Documents/Part_03_Complete_042012Revision_bookmarked_042012.pdf*

Pavement Marking Materials (641.02)

Pavement marking materials used on the construction projects shall be as listed on the Approved List.

The Approved List for pavement marking materials is maintained by the Office of Material Management (OMM) and is available on the website.

> *www.dot.state.oh.us/Divisions/ConstructionMgt/Materials/Pages/PAVEMENT-MARKING-MATERIALS.aspx*

The appropriate type of glass beads shall be applied according to C&MS 740.09 for different types of pavement marking materials.

Application of Pavement Marking Materials (641.03)

Pavement marking materials shall be applied according to C&MS Items 640 and 740.

Data Logging System (DLS) (641.04)

The Data logger System can be verified in the field by using the following method:

DLS Verification Testing

This section provides information on the Data Logger System (DLS) for long-line striping trucks, the reports generated by DLS, and how to use the reports to verify compliance with specifications.

DLS Requirements

The requirements for DLS are contained in C&MS Section 641.04.

According to Item 641.04, long-line striping equipment for traffic paint, polyester, epoxy, and work zone markings (Item 642) shall be equipped with a computerized Data Logger System (DLS) to document long-line markings as follows:

1. Measure and record application vehicle speed to nearest 0.1 mph.
2. Measure and record weight and/or volume amount of material used by color.
3. Measure and record weight of glass beads.
4. Measure and record pavement surface temperature.
5. Measure and record air temperature.
6. Measure and record dew point.
7. Measure and record humidity.
8. Calculate and record average material application rates and film thickness over the section painted.
9. ODOT provides standard DLS spreadsheets which prescribe the correct DLS report format and content.

DLS are not required for any markings applied by hand, with push carts, for channelizing lines, or Class II work zone markings.

When the Striping Truck Arrives on the Project

- Each district should establish one individual as District DLS Contact to receive DLS Reports for all striping activities. Check with the District Construction Office for the email address of the District DLS Contact to provide to the Contractor.
- Make sure every vehicle in the striping train has the correct maintenance of traffic equipment and signs. See SCD MT-99.20 and plan notes.
- Check the driver’s door or the door of the DLS unit to confirm the presence of the DLS calibration sticker. It should be signed and carry a date no more than one-year-old. Every DLS must be calibrated once every year.
- Make sure that there are adequate TE-24s to cover all materials needed for the job.
- Make arrangements with the Contractor’s crew foreman to get DLS Short Reports for each day’s work. DLS Short Reports are to be provided to ODOT the next working day or, when requested by ODOT personnel, any time route sections are completed on any given day. ODOT should receive a report from the Contractor for each day worked. The DLS specification requires the Contractor to furnish ODOT with a paper copy of the DLS Short Report which should be retained to compare to the electronic file that will be received later.
- The Data Logger System shall be verified by field personnel. Field personnel shall randomly verify the components of the DLS. The purpose of this is to verify that the striping truck places the material shown on the DLS printout. Field personnel should try to verify the DLS of every paint contractor at least once per construction season. If field personnel believe that the DLS printouts are not accurate, then more field checks can be taken.

How to Field Verify the Data Logger System

Figure 640.A – Striping truck with DLS system

Figure 640.B – Electronic control box

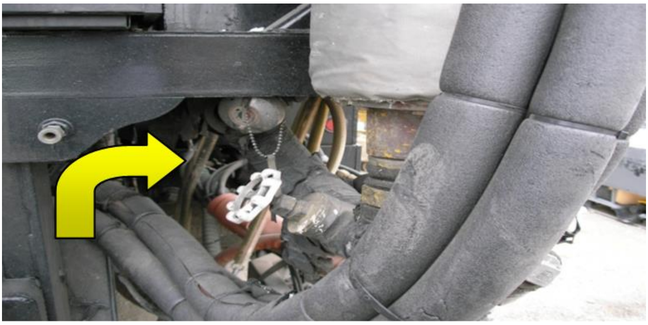


Figure 640.C – Sensors

Sensors such as temperature sensors, located at appropriate locations on the striping truck, provide temperature data.

Figure 640.D – Gauges

Gauges provide data and help monitor the temperatures of striping material in the tanks.

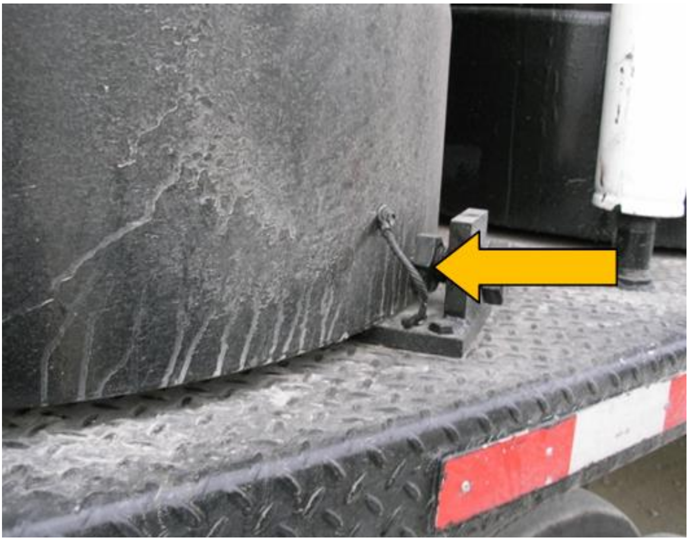


Figure 640.E – Glass bead tank load cells

Glass bead tanks are mounted on load cells. Load cells are the basis of bead weight calculations.

Figure 640.F – DLS electronic data sheet

1. DLS data is automatically recorded and stored electronically.
2. DLS data includes:
    a. Sensor data.
    b. Distance data.
    c. Ambient conditions.
    d. Material quantities.
3. Verification test results will be compared to the Contractor's electronic sheet data.

Calibration Sticker Check

Check for the presence of the annual calibration sticker.

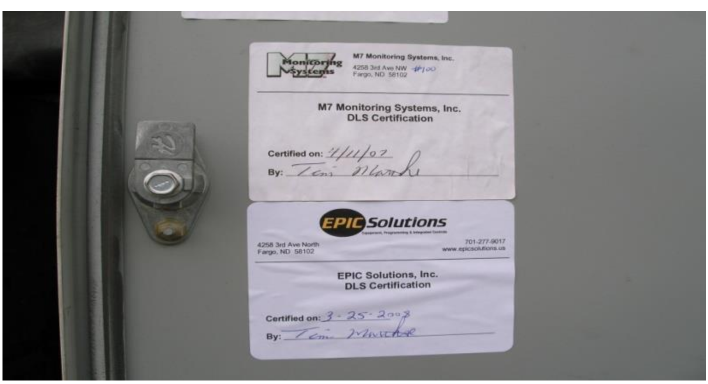


Figure 640.G – Calibration sticker

Evidence of the annual calibration shall be a signed and affixed sticker to the inside of the driver's door of each striping truck.

Yearly Calibration

1. As per C&MS 641.04, each DLS shall have an annual calibration.
2. Items to be calibrated include:
    a. All mechanical and electrical components.
    b. Software.
    c. Function and output.
3. Calibration will be confirmed by the manufacturer.

The Plate Test

Figure 640.H – Plate test equipment

1. Place an aluminum plate, approximately 24 inches by 8 inches under the paint gun of the striping truck. Aluminum plates are supplied through the Office of Materials Management (OMM), Chemical Section.
2. Allow the striping truck to stripe over the plate in order to get a stripe of the desired thickness on the plate.
3. Send the striped plate to the OMM, Chemical Section for film thickness testing. After converting dry film thickness to wet film thickness, the difference obtained from the plate should be no more than 5 percent from the DLS reading.
4. Send the Contractor’s DLS average mils applied data as comparison for the film thickness testing results. See picture below.
5. Note: Be careful not to damage the paint stripe on the plate.

Figure 640.I – Average mils applied

The Bead Weight Test

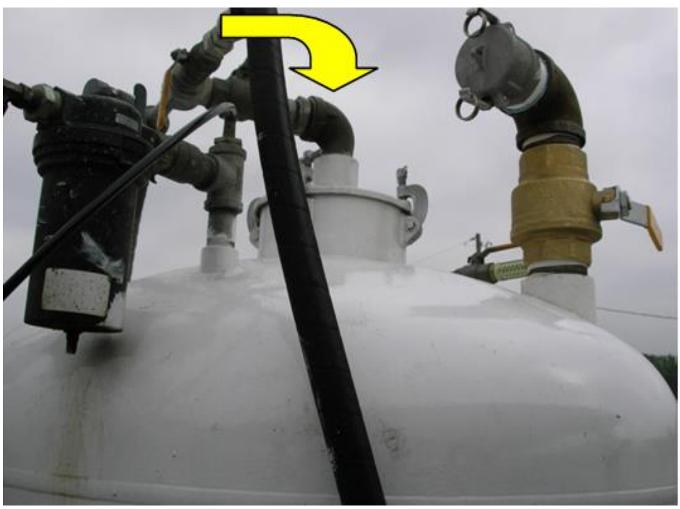


Figure 640.J –Bead weight test sampling location

1. Check and record the bead weight on the DLS electronic data sheet W1.
2. Obtain an object of known weight. Must be a minimum of 20 pounds (e.g., a 50 pound bag of glass beads).
3. Place the weight on top of the bead tank. Keep the weight in position on top of the tank and check and record the new weight, W2, on the DLS electronic data sheet.

Subtract W1 from W2 to get the known weight of the object used.

W2 – W1 = weight of the object of known weight used.

Correct test results confirm the proper operation of the bead tank load cells as well as the accuracy of the data on the spreadsheet. The difference should be no more than 5 percent.

Figure 640.K –Bead weight test screen

The Infrared Thermometer Test

Figure 640.L – Infrared thermometer test

Use a hand-held Infrared Thermometer to measure road surface temperature, air temperature, and/or striping material temperature.

1. To operate the infrared thermometer, follow the manufacturer’s operating procedures.
2. Compare temperature readings to the data on the appropriate DLS electronic screen.
3. Temperature readings on the DLS screen should be within ±5 percent of the thermometer readings.

Figure 640.M –Infrared thermometer test screen

The Humidity Test

Figure 640.N –Humidity tester

1. Measure the ambient humidity with the use of a sling hydrometer.
2. To operate the sling hydrometer, follow the manufacturer's operating procedures.
3. Compare humidity readings to the data on the appropriate DLS electronic screen.
4. Humidity readings on the DLS screen should be within ±5 percent of the hydrometer readings.

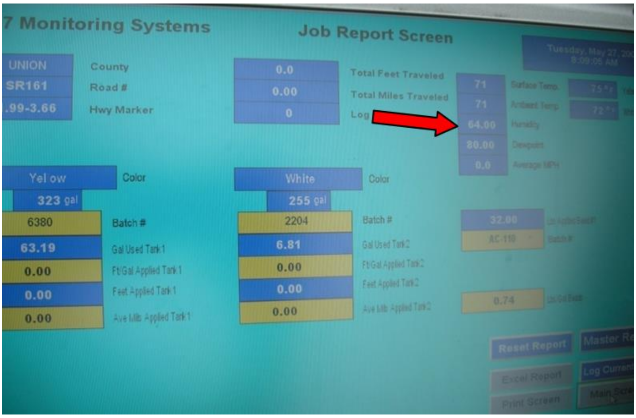


Figure 640.O –Humidity test screen

The Distance Traveled Test

Figure 640.P –Distance traveled measurement

1. Testing the distance traveled data on the DLS electronic data screen can be done using a distance wheel like the one shown in the picture.
2. To operate the distance wheel, follow the manufacturer's operating procedures.
3. Compare distance readings to the data on the appropriate DLS electronic screen.

4. Distance readings on the DLS screen should be within ±5 percent of the distance wheel readings.
5. DLS distance data can also be checked using mile markers and an accurate odometer.

Figure 640.Q –Distance traveled test screen

Summary

1. The specified annual calibration of the data logger system is the primary check of the operation of the systems.
2. The tests described above are meant to be done in a random fashion to:
    a. Verify proper operation after calibration.
    b. Verify correct millages are applied.
    c. Determine if the system is the cause of suspicious developments in the field application of striping material.
3. One or all of the tests may be used to check the DLS operation.

What to Do When the DLS Fails

If the DLS fails during the day, allow the Contractor to complete the day's work and document the application quantities. Make the calculations for gallons of material per mile and pounds of beads per 100 square feet from the quantities used, provided by the Contractor, with your confirmation of accuracy. The Contractors are expected to repair the DLS before resuming work. See C&MS Section 641.04, paragraph three.

If you have any significant issues regarding DLS use, please call Dan Groh at Central Office Construction, (614) 387-1162 or Maria Kerestly at the Office of Material Management, (614) 275-1349 for further assistance.

DLS Reports

The DLS Report is an Excel spreadsheet which contains data on environmental conditions and material application parameters recorded during striping operations.

ODOT has developed standard DLS Reports for four different types of striping trucks:

- Weight-Based DLS – for pressure tank trucks (CA-T-1, CA-T-2)
- Stroke-Based DLS – for pumper trucks (CA-T-3, CA-T-4)
- Flow-Based DLS – for either type, but using material flow meter (CA-T-5, CA-T-6)
- Thermoplastic DLS – for thermoplastic trucks. Note: the thermoplastic DLS is an abbreviated report, as we cannot yet measure material used, although beads used and environmental conditions are recorded (CA-T-7, CA-T-8).

Two versions of the DLS Report are contained in each Excel file: DLS Short Report and DLS Full Report. The DLS Short Report is an abbreviated format containing only critical application information which can be easily printed on an 8.5 inch by 11 inch paper using in-truck printers. DLS Full Reports contain all project, application, and environmental data.

Delivery of DLS Reports

Each district should establish a District DLS Contact person who will receive email copies of the DLS Reports and provide that person's name and email address at the preconstruction meeting.

The paper copy of the DLS Short Report covering all route sections completed each day must be provided to ODOT personnel the next working day. A paper copy of the DLS Short Report may be requested from the Contractor by ODOT personnel at any time during striping operations for those route sections completed so far that day. The paper copy of the DLS Short Report should be retained by the project and compared to the DLS Full Report for the same route sections, which will be provided to ODOT personnel by the Contractor at a later time, as described below.

DLS Full Reports contain all project, application, and environmental data and can be provided to ODOT by any one of the following methods, which should be agreed upon at the preconstruction meeting:

- Hand delivery of paper report.
- Fax delivery of paper report.
- E-mail an electronic version of the Excel spreadsheet file.

Within two weeks of the application date of the markings which require documentation with the DLS, the Contractor is required to furnish the District DLS Contact with an electronic version of the Excel spreadsheet file of the DLS Report in ODOT standard DLS Report format by e-mail at the e-mail address provided at the preconstruction meeting. Note: This file will contain both the DLS Full Report and the DLS Short Report on separate sheet tabs.

At the end of the project, the Contractor is required to furnish the District DLS Contact with all DLS Excel spreadsheet files in ODOT standard DLS Report format. Note: This file will contain both the DLS Full Report and the DLS Short Report on separate sheet tabs. The Engineer shall forward the final electronic copy containing the DLS Long report and the DLS short report to the following address:

DLS.Report@dot.state.oh.us

DLS Report Security

ODOT has established a method to monitor accuracy of DLS Reports. This method is based on comparison of the paper copy DLS Short Reports for daily production to the DLS Full Report for the same day. Note: The DLS Short Report does not contain all project or environmental information, but does contain all information necessary to monitor correct application rates and speed.

The Contractor is required to provide ODOT personnel with a paper copy of the DLS Short Report for each day's production the next working day. ODOT personnel may also occasionally request a copy of the DLS Short Report during the day for those route sections completed thus far that day. On projects with only partial days of striping work, ODOT personnel should request the DLS Short Report immediately after the Contractor finishes the striping operation. Printing of the DLS Short Report soon after completion of the striping operation will minimize the opportunity for tampering.

ODOT will keep these paper reports and compare them to the DLS Full Report that is received later. Any differences in sections, lengths, quantities, or application rates between the Short Report and Full Report should be considered suspect and will be investigated more closely. There should be no valid reason for any differences between these reports beyond the complete listing of route sections between partial day and full day reports.

Pay Items

Pay items are plan quantity. If there is a significant variance between the actual and plan quantities, meet with the ODOT project personnel to address the issue. Please note that per C&MS Section 641.12, Method of Measurement, pavement markings are designed, measured, and paid "end-to-end," including gaps, intersections, and other sections of pavement not normally marked. This provision applies to all types of roadways and lines.

The DLS is used for two purposes, neither of which is to measure pay item quantities:

1. To monitor environmental conditions and material application parameters, such as temperatures.
2. To monitor actual application rates of marking materials and glass beads for purposes of determining deficiencies in accordance with Section 641.11.

How Data Is Entered into DLS Reports

Each report has three different types of cells which are color-coded:

1. One type contains data which may be manually entered during striping operations (yellow). Note that this information may also be entered into the job screens of the DLS console and come into the Report without additional manual entry.
2. One type contains data which must come directly from the DLS (green).
3. One type contains values that are calculated by the spreadsheet (rose) from data provided by the DLS.

The DLS Short Report and the DLS Full Report will have one row for each section painted, by route and by direction, even if the section length is less than 10 miles. (A route section is a continuous section of highway without breaks, with the same route number designation in one direction of travel.) A new route section is not started at 10

miles if the route and direction stay the same even when the section length exceeds 10 miles. Whenever material or beads are loaded, the route section is ended. Start a new route section, for that route, to complete the route or, if needed, until reloading.

Depending on how the Contractor sequences work, the route sections will generally match the plan sub-summary.

How to Read a DLS Report

The Contractor is required to provide a DLS Short Report for each day's work. It should be furnished to the project the next working day after striping occurs. A paper copy of the DLS Short Report is printed from an in-truck printer each day or upon demand of ODOT personnel. This copy should be compared to the DLS Full Report, which is provided to the District DLS Contact person within two weeks of application.

Check General Project Information

Check the date box in upper left corner for correct information. Note that the yellow color indicates manual entry.

Project Name	256-04
Date	7/16/2004
Start Time	7:00 AM
Finish Time	6:00 PM
Total Hours	11

Check crew names and day's production boxes in center and right upper parts of report.

Employee Name	

The mileage values may be entered by crew from their daily work logs.

	Miles
Days Total CL	
Days Total LL	
Days Total WEL	
Days Total YEL	
Days Total CHAN	

Next, check to make sure each cell in the body of the report contains data. There should be a row for each route section, by direction, striped. Start with the yellow columns on the left side. Note: The rose color indicates a value calculated by the spreadsheet. Manual entry of values in rose colored cells is not permitted.

County	Route Number / Name	Direction	Start Time	Marking Type	Start Hwy SLM	End Hwy SLM	Road Length	Tank 1 Color	Tank 2 Color	Line Width
ROS	50	WB	8:45:41	CL	0.00	10.36	10.36	Y	Y	4.00
ROS	50	WB	9:59:05	CL	10.36	20.82	10.46	Y	Y	4.00
ROS	50	WB	10:35:58	CL	20.82	21.78	0.96	Y	Y	4.00
CLI	134	NB	13:42:10	WEL	0.00	13.09	13.09	Y	W	4.00
CLI	134	SB	14:33:35	WEL	13.09	0.00	13.09	Y	W	4.00

Then, check the yellow columns on the right to confirm that the correct material and bead batch numbers have been entered. These should be supported by TE-24s.

Paint1 Batch No	Paint2 Batch No	Bead1 Batch No	Bead2 Batch No
MP20341	MP20341	64.00	mnbvcxzas
MP20341	MP20341	64.00	mnbvcxzas
MP20341	MP20341	64.00	mnbvcxzas
MP20341	MP20341	65.00	mnbvcxzas
MP20341	MP20341	66.00	mnbvcxzas

All of the above information is manually entered into either the report or the DLS console and is the same for Section 614, Class III markings using 740.02 paint, 642, 643, 644, and 646 materials, for all types of trucks and for all types of DLS.

Check for proper material application rates – varies by type of material:

For Section 614, Class III markings using 740.02 paint, 642, 643, and 646 materials only:

Review the application thickness (which is the average mil thickness over the section), distance painted (linear feet from gun counters and equivalent miles painted calculated

by spreadsheet [linear feet/5280]), gallons used, and gallons per mile applied (gallons used/equiv miles painted). Compare the actual gallons per mile applied to the requirements in Section *614.11*, *642.04*, *643.04* or *646.05*. Determine any deficiencies per Section *641.11*. Note: The green color indicates values which come directly from the DLS and rose color indicates values calculated by the spreadsheet. Manual entry of values in these cells is not permitted.

Tank 1 Avg Mils	Tank 2 Avg Mils	Linear Feet Painted	Equiv Miles Painted	Tank 1 Gallons Used	Tank 2 Gallons Used	Gals Paint per Mile Applied
0.00	18.70	85089.00	16.12	0.00	274.58	17.04
0.00	20.17					22.19
0.00	20.30					22.82
0.00	20.08					22.10
0.00	20.07					22.04

If using 642 Type 1, this section is deficient: 22 gal/mi is required; mil thickness is also deficient: 20 mil is required.

For Section 644 materials only:

Present technology does not permit measuring the material usage of hot thermoplastic. Determine pounds per mile from field measured amount of material used and the equivalent miles painted from the DLS report. Determine any deficiencies per Section 641.11.

Linear Feet Painted	Equiv Miles Painted
54700.80	10.36
55228.80	10.46
5068.80	0.96
69115.20	13.09
69118.80	13.09

Check for proper glass bead application rates – the same for all materials:

Check the weights of beads used and the actual pounds per 100 square feet (weight of beads used/100 square feet of markings applied). The spreadsheet divides the sum of pounds of beads used, by the linear feet painted, multiplied by line width in inches, divided by 12 inches, divided by 100.

$$Lbs\ \ per\ \ 100\ \ sq\ \ ft\ \ \equiv \frac{\sum \ \text{Lbs Beads Used}}{\text{Linear Ft Painted} \times \left(\dfrac{4''}{12''}\right) \div 100}$$

Compare the actual pounds per 100 square feet applied to the requirements for Section 614.11, Class III, 642.04, 643.04, 644.04, or 646.05. Determine any deficiencies per Section 641.11.

Bead 1 Lbs Beads Used	Bead 2 Lbs Beads Used	Lbs Beads per 100 Sq Ft
3322.00	0.00	11.71
2554.07	0.00	15.39
263.14	0.00	16.17
0.00	2632.00	

For 642.04 Type 1, the requirement is 15# / 100 sq ft. First route section is deficient.

Check the average speed of application:

Avg MPH
14.8
15.0
14.7
14.9
15.0

This striper has been equipped with high capacity guns and tips which permit travel up to 15 mph.

Check to confirm the material temperatures and environmental conditions have been recorded:

The average material temperatures and environmental conditions over the section painted are recorded in the remaining green columns. These values are the average of all readings recorded over the section painted. There are slight differences between DLS types.

Pump 1 Temp	Pump 2 Temp	Humidity	Dew Point	Air Temp	Road Surface Temp
102.00	73.00	55.00	48.00	73.00	76.00
110.00	79.00	59.00	44.00	78.00	83.00
109.00	80.00	86.00	64.00		
90.00	114.00	62.00	52.00		

For weight, stroke and flow based systems, this data is recorded.

Most sprayed materials (paints, polyester, and epoxy) can be heated slightly to improve flow and spraying characteristics. ODOT does not specify minimum or maximum temperatures, but defaults to those recommended by the material manufacturer.

Thermoplastic materials have temperature requirements for both pavement and air temperatures and material temperatures. See Section 644.04 for specific requirements. These values are the average of all readings recorded over the section painted.

Kettle 1 Temp	Kettle 2 Temp	Matl 1 Temp @ Applic'n Point	Matl 2 Temp @ Applic'n Point	Humidity	Dew Point	Air Temp	Road Surface Temp
438.00		405.00		55.00	48.00	73.00	76.00
420.00		403.00		59.00	44.00	78.00	83.00
439.00		410.00		86.00	64.00	78.00	90.00
	440.00		415				
	430.00		412				

For thermoplastic based systems, this data is recorded. More temperatures are recorded as they are critical to long-term performance.

Kettle temperature cannot exceed 450 °F and material at point of application must be between 400 °F and 440 °F. If thermoplastic material is overheated in the kettle or applied below 400 °F, it will not perform as intended and should be considered unsatisfactory and must be replaced per Section 641.11 and 644.05.B. Thermoplastic applied when pavement and air temperatures are below those specified in Section 644.04 will not bond adequately to the pavement and applications should not be made under those conditions.

Check to confirm the weight per gallon (for liquid materials – all DLS types) and stroke information (for stroke-based DLS) has been recorded:

Weight per Gallon	Volume per Stroke Calibration Value	Number of Strokes
13.26	0.81	339
13.80	0.81	258
13.19	0.81	26
13.85	0.81	269
13.11	0.81	156

Weight per gallon, per batch, is entered into the DLS console during job setup for liquid materials for all DLS types and reported here as recorded data. Note the weight per gallon may vary per batch.

For stroke-based DLS only, stroke calibration is entered into the DLS console during setup and reported here as recorded data. The number of strokes is recorded during striping. This information is used by the DLS to calculate gallons used.

If You Need Further Assistance

Should it be necessary, please contact Central Office, Construction Administration, (614) 387-1162 or Office of Material Management, (614) 275-1349 for further assistance.

Construction Inspection during Pavement Marking Installation

Before the application of marking material, pavement surface should be clean and dry by using:

1. Power broom.
2. Air jets (guns).

Approve the pre-marking for long lines and auxiliary markings to ensure proper layout placement.

Center lines shall be “T” marked to establish no-passing lines.

Figure 640.R – Example of premarking

District shall provide center line paint logs.

As per Item 641.06, the Contractor shall establish reference points to ensure proper placement of restored markings on projects where resurfacing or other operations will result in obliteration of the existing pavement markings.

Figure 640.S – Example of measurement of markings

Marking lines shall be applied to the width specified, ±1/4 inch.

Pavement markings shall be free of uneven edges, overspray, and other visible defects.

Figure 640.T – Example of uneven edge line placement

Pavement marking lines shall be placed as per SCD TC-73.10 as follows:

1. Edge lines shall be applied 6 inches from the pavement edge.
2. Lane lines shall be applied 2 inches to left of joint.
3. Center lines shall be applied 2 inches from joint.

Pavement marking lines shall be straight or smoothly curved true to the alignment of the pavement.

1. If deviation is greater than 3 inches in 100 feet, it shall be corrected.

Gaps shall be filled that were not marked as a result of template use for spray-applied auxiliary markings with marking material after the template is removed.

1. For extruded thermoplastics, gaps may be left.

Figure 640.U – Example of retroreflectivity check

Pavement marking lines shall be sharp, well defined and uniformly retroreflective.

1. To check for retroreflectivity, put sun over shoulder.
2. If it is not sunny:
    a. A well beaded line in the daylight will appear dull.
    b. An unbeaded line will be shiny.
3. If possible, review lines at night for retroreflectivity.

642 Traffic Paint

Quick guide for Traffic Paint:

1. Material Type, 740.02.
    a. Traffic Paint Type 1, fast dry, water-based paint.
    b. Traffic Paint Type 1A, fast dry, water-based paint for cold weather conditions.
2. Glass beads, 740.09 Type A.
3. Application of Traffic Paint, Item 642, Type 1 and 1A.
    a. Traffic Paint Type 1 shall be applied when the pavement and air temperature are 50 °F and above.
    b. Traffic Paint Type 1A shall be applied when the pavement and air temperature are between 35 °F and 50 °F.

c. Glass beads, 740.09 Type A shall be applied at the rate of 15 pounds per 100 square feet of Type 1 traffic paint applied.
d. Glass beads, 740.09 Type A shall be applied at the rate of 8 pounds per 100 square feet of Type 1A traffic paint applied.
e. Type 1 Traffic Paint shall be applied at the rate of 22 gallons per mile of 4-inch solid line, 33 gallons per mile of 6-inch solid line, and/or 1.25 gallons per 100 square feet.
f. Type 1A Traffic Paint shall be applied at the rate of 16 gallons per mile of 4-inch solid line, 24 gallons per mile of 6-inch solid line, and/or 0.94 gallon per 100 square feet.
g. Striper equipment speed shall be according to the paint manufacturer's recommendations.
h. Coning of line required because pavement marking is not track free in 2 minutes or less.

643 Polyester Pavement Marking

Quick guide for Polyester Markings:

1. Material Type, 740.03.
2. Glass beads, 740.09 Type B.
3. Application of Polyester, Item 643.
    a. Polyester shall be applied when the pavement and air temperature are 50 °F and above.
    b. Polyester shall be applied in two components (catalyst and resin) in proportions recommended by the manufacturer.
    c. Glass beads, 740.09 Type B shall be applied at the rate of 16.5 pounds per 100 square feet of polyester used.
    d. Polyester shall be applied at the rate of 16 gallons per mile of 4-inch line, 24 gallons per mile of 6-inch line, and/or 0.94 gallon per 100 square feet.
    e. Striping equipment speed shall be not less than 7 miles per hour (11 km/hr).
    f. Dry time is 45 minutes and less.
        i. Coning is required to protect the line until track free.
        ii. If tracking continues after 45 minutes, cease marking operation until tracking problem is corrected.

644 Thermoplastic Pavement Marking

Quick guide for Thermoplastic Markings:

1. Material Type, 740.04.
2. Glass beads, 740.09 Type C.
3. Application of Thermoplastic, Item 644.
    a. Thermoplastic shall be applied to pavements less than a year old when the pavement surface and the air temperature are 50 °F or more.

i. At the end of the construction season, if the surface temperature is 50 °F or less, apply Traffic Paint Type 1A.

b. Thermoplastic shall be applied to pavements one year or older when the pavement surface and the air temperature are 70 °F or more.

c. At the point of application, the temperature of thermoplastic shall be at least 400 °F, but no more than 440 °F.

d. Glass beads, 740.09 Type C, shall be applied at the rate of 12 pounds per 100 square feet.

    i. Thermoplastic material shall be applied at a thickness of 125 mils.

    ii. Use an applicator that has a shoe which rides on the pavement and extrudes the thermoplastic.

e. Thermoplastic shall be applied at the rate of 2,340 pounds per mile of 4-inch line, 4,680 pounds per mile of 6-inch line, and/or 133 pounds per 100 square feet.

645 Preformed Pavement Marking

Quick guide for Preformed Markings:

1. Material Types, 740.05 and 740.06.
2. Type A, Item 740.05, shall be used for permanent markings.
    a. Type A1 material, 0.090 inches thick, shall be applied with a pre-coated adhesive layer.
    b. Type A2 material, 0.060 inches thick, shall be applied with a pre-coated adhesive layer.
    c. Type A3 material, 0.020 inches thick, shall be applied with a pre-coated adhesive layer.
3. Type B, Item 740.06, 0.015 inches thick, shall be used for Work Zone Pavement Markings.
    a. Type B, Type II material (non-removable).
4. Type C, Item 740.06, 0.030 inches thick, shall be used for Work Zone Pavement Markings.
    a. Type C, Type I material (removable).
5. Glass beads, none.
6. Application of Preformed Pavement Marking, Item 645.
    a. Preformed Pavement Marking shall be applied according to the manufacturer’s recommendations packed with the material.

646 Epoxy Pavement Marking

Quick guide for Epoxy Markings:

1. Material Type, 740.07.
2. Glass beads, 740.09 Type D.
3. Application of Epoxy Pavement Marking, Item 646.
    a. Epoxy shall be applied at a surface temperature of 50 °F and above.

   b. Epoxy shall be applied in components, Part A and Part B, in proportions recommended by the manufacturer.
   c. Cleaning and surface preparation shall be done according to Item 646.04 for different pavement types and done according to manufacturer's recommendations.
   d. Glass beads, 740.09 Type D, shall be applied at the rate of 31 pounds per 100 square feet.
      i. Glass beads shall be applied in a double-drop system with Size I, large gradation first and Size II, regular graduation second in equal amounts by weight in the same pass.
   e. Epoxy shall be applied at the rate of 22 gallons per mile of 4-inch (100 mm) line, 33 gallons per mile of 6-inch line and/or 1.25 gallons per 100 square feet.

647 Heat-Fused Preformed Thermoplastic Pavement Marking

Quick guide for Heat-fused Markings:

1. Material Type, Item 740.08.
   a. Type A90 is 90 mil thick.
   b. Type A125 is 125 mil thick.
   c. Type B90 is 90 mil thick.
   d. Type B125 is 125 mil thick.
2. Glass beads, 740.09.
   a. Type A and B shall contain intermix beads throughout. Drop-on glass beads are not required unless using non-surface beaded markings.
3. Application of Heat-Fused Preformed Thermoplastic Pavement Marking, Item 647.
   a. According to the manufacturer's recommendations, Heat-Fused Preformed Thermoplastic Pavement Marking shall be applied only as auxiliary markings.
   b. If recommended by the manufacturer, apply primer sealer on Portland cement concrete pavement.

648 Spray Thermoplastic Pavement Marking

Quick guide for Spray thermoplastic Markings:

1. Material Type, 740.10.
2. Glass beads, 740.09 Type C.
3. Application of Spray Thermoplastic, Item 648.
   a. Spray Thermoplastic shall be applied to pavements less than a year old when the pavement surface and air temperature are 50 °F or higher.
      i. At the end of the construction season, if the surface temperature is 50 °F or less, apply Traffic Paint Type 1A.

b. Spray Thermoplastic shall be applied to pavements one year or older when the pavement surface and air temperature are 70° F and rising.
c. The Temperature of the Spray Thermoplastic, at the point of application, shall be at least 375 °F, but no more than 425 °F.
d. Glass beads, 740.09 Type C, shall be applied at the rate of 10 pounds per 100 square feet.
e. Spray Thermoplastic material shall be applied at a thickness of 45 mils.
f. Spray Thermoplastic shall be applied at the rate of 762 to 886 pounds per mile of 4-inch line and 1,143 to 1,329 pounds per mile of 6-inch line.

650 Roadsides

651 Topsoil Stockpiled

Because of the straightforward nature of this item of work, no detailed explanation of the item is required in this manual.

652 Placing Stockpiled Topsoil and 653 Topsoil Furnished and Placed

Because of the straightforward nature of this item of work, no detailed explanation of the item is required in this manual.

654 Renovating Existing Soil

Because of the straightforward nature of this item of work, no detailed explanation of the item is required in this manual.

656 Roadside Cleanup

Intensity of Cleanup (656.02)

Control the intensity of cleanup to effect a natural transition in cleanup treatment from the edge of the pavement outward to the limits of the Right-of-Way to avoid sharp demarcation between the artificial and the natural.

Cleaning (656.03)

The contractor shall remove large objects, then clean the designated areas with grubbing rakes or wide-spaced tooth rakes. Ensure that desirable grass, vines, or wild flowers are not disturbed or injured.

Pruning (656.04)

To determine the diameter of the tree measure the tree 54 inches above the ground. 6 inches or less in diameter and native shrubs and similar vegetation shall be pruned according to Item 666.

Disposal of Refuse (656.05)

Removed materials may be reused in the Work when the material conforms to the specifications; if not, then recycle or dispose of the material according to 105.16 and 105.17.

657 Riprap for Tree Protection

Tree Wells in Fill (657.03)

A dry hand-laid stone riprap tree well should be constructed where a fill around a tree or shrub not marked for removal will be 12 inches (0.3 m) or more in depth over the feeding root area or ground surface lying within the periphery of the tree,. A wall, of the same height as the fill should be constructed, circling the tree or shrub and 3 1/2 feet (1 m) from the tree trunk or as specified. The top of the wall shall follow the contour on the finished grade in a neat line.

Tree wells should be constructed before placing the fill over the root area. However, the Contractor may bring up the fill with the wall after required aggregate for root aeration is in place according to Item 658.

Walls in Cut (657.04)

Where the top of the slope in cut is within 6 feet (2 m) of the trunk of a tree not marked for removal, a dry hand-laid stone riprap wall should be constructed. The bottom of the wall shall be toed into the ground 2 inches (50 mm) unless otherwise shown on the plans, and the top of the wall even with the original ground line at the base of the tree.

Hand-Laid Stone Riprap (657.05)

The earth bed should be constructed on riprap is to be placed to a slope of 1 foot (300 mm) vertical to 2 inches (50 mm) horizontal. The earth bed should be dressed to a true plane.

Each course of stone shall be placed with the long dimensions of each stone perpendicular to the slope or batter.

Use individual stones that are roughly rectangular in cross-section and are a minimum of 3 inches (75 mm) in the vertical depth with a horizontal dimension of not less than 15 inches (0.4 m). Place the individual stones by hand, one upon the other so that they break joints with the stone in the course below. Where it is necessary to use more than one stone to provide the specified thickness or depth of the wall, thereby resulting in joints parallel to the face of the wall, place such stones to break joints with the adjacent stones.

Fill the space between the larger stones with spalls rammed into place. Ensure that the surface of the finished riprap does not vary more than 3 inches (75 mm) from that shown on the plans, and that it presents an even, tight surface, pleasing in appearance.

Earthwork (657.06)

Excavation and embankment shall be placed as necessary, according to Item 203.

Pipe Drains (657.07)

Drain tree wells with pipe starting on the original ground surface and lay to drain beyond the toe of the fill. Pipe for drains shall be installed according to Item 611.

658 Tree Root Aeration

Preparation (658.03)

The feeding root area to be protected and aerated is the ground surface area lying within the periphery of the tree or shrub not marked for removal. These areas shall be prepared by excavating all vegetation, wood, brush, and debris.

Aeration for Trees Not Welled (658.04)

Where the earth fill is less than 12 inches (300 mm) and more than 4 inches (100 mm) over the feeding root area, an aggregate aeration course of one-half the height of fill, but not less than 3 inches (75 mm),shall be loosely spread over this area. At the tree trunk, the thickness to the height of the fill shall be increased and extended outward from the tree trunk in collar form for a distance of 15 inches (0.4 m). A 2-inch (50 mm) layer of straw or hay shall be placed over the aggregate.

Aeration with Tree Wells (658.05)

An aeration course of aggregate needs to be placed while constructing the tree wells and before any other filling. No aggregate shall be placed inside the tree well (between the wall and the tree trunk). The aggregate should be placed over the entire feeding root area outside of the tree wells to a total depth of 6 inches (150 mm) for each 12 inches (300 mm) of earth fill, or proportion thereof, but place a minimum depth of 6 inches (150 mm) regardless of depth of overlying fill. A 2-inch (50 mm) layer of straw or hay shall be placed over the aeration layer.

Earth Embankment (658.06)

Excavation and embankment shall be placed as necessary, according to Item 203.

659 Seeding and Mulching

Because of the straightforward nature of this item of work, no detailed explanation of the item is required in this manual.

660 Sodding

Because of the straightforward nature of this item of work, no detailed explanation of the item is required in this manual.

661 Planting Trees, Shrubs, and Vines

Description (661.01)

This item of work involves furnishing plantings (trees, shrubs, vines and other materials) and planting them according to the plan details, these specification requirements and applicable Standard Construction Drawings.

Location and Source of Supply (661.03)

Supply the Engineer with complete and detailed information concerning the source of supply for each item of required plant material within 15 days after receiving the notice of award of the Contract.

Ensure that all plant materials have been grown in the same hardiness zone or 1 zone colder than the project.

Transportation, Storage, and Handling (661.04)

Transport all plants from nursery sources to the project site with the entire load completely covered for protection from drying winds. Thoroughly water all plants that cannot be immediately planted so as to keep the roots in a continually moist and protected condition. The Engineer may reject plants that are not adequately protected during transportation and storage. Immediately remove all rejected plant materials from the project site. Handle all plant materials by the root ball or container.

Labeling (661.05)

All plantings delivered to the project must have legible labels which indicate detailed information of the botanical genus and species name, the common name, the size, or age of each plant variety. The labeling must state the quantity in the individual bundles,

boxes, and bales. These labels must be removed before the completion of the establishment period.

Acceptance (661.06)

General Appearance

The general appearance of a plant is the quickest way to judge its health and vigor. Be sure that the plant:

- Is healthy, typical of their species or variety, and have a normal growth habit.
- Meets the minimum dimensions given in the General Notes.
- Container is not cracked or severely dented.
- Container is weed free.
- Is generally symmetrical with no large gaps in the branching structure.
- Has no broken limbs.
- Is free of excessive bark damage.

The foliage of the plant should be:

- Erect and firm (except for weeping type plants).
- A uniform green color (except for fall color).
- Vigorous, healthy, and robust.
- Free of wilting, yellowing, and browning.

Note: Inspection of the plants before unloading from truck will save time and effort. Plants do not need to be individually inspected; a random inspection will be ok. The source of supply should be verified from the shipping ticket and compared to the plant material list (C&MS 661.03) as submitted earlier. Plants that do not meet specifications or differ in source of supply is justification for non-acceptance.

Problem Signs

Substantial amounts of brown or yellow foliage indicate the plant may be experiencing stress or shock. (Be aware that some trees, depending on whether they are deciduous or evergreen, may change color during the fall.)

Wilted foliage probably indicates a lack of water during shipping or storage. All plants must be completely covered during shipping (C&MS 661.04). A thorough watering should restore the foliage to a healthy appearance within a couple of days. If not, the plant should be monitored for a few more days to see if it recovers before planting. If the condition does not improve, reject the plant. Broken and dead limbs indicate poor growing or handling conditions.

Testing for Dead Plants or Limbs

It is not always easy to tell if a plant is alive, particularly during the winter if the plant is a deciduous variety and has shed its leaves. Some of the techniques listed below will help to determine if a plant or a part of the plant is alive.

- Using your fingernail, pocket knife, or other sharp object to scratch the bark on the trunk or limbs. A living plant will be light-green and moist just below the soft bark. If the bark is hard and the scar is brown, that part of the plant is dead. A random check of other areas will help to determine if the plant is vigorous and healthy.
- Wrinkled bark that is off-color is an easy visual clue to dead parts of a plant.
- Healthy limbs are flexible. They can be bent without breaking. Dead limbs are dry and brittle.

Container Grown Plants

The roots of a container grown plant should:

- Be growing throughout the growing medium.
- Bind all the soil together.
- Be white in color and moist; dark brown or blue black roots indicate damaged or dead roots.

Test for adequate root system: **Inspecting the root systems of plants is very important**. It is not necessary to test all the plants; random checks will be sufficient if all the plants are from the same grower. If the plants are provided from more than one supplier or grower, be sure to random-check each group. Also, inspect any plants that appear different or out of character with a group of like plants.

- For shrubs, hold the plant at the base of the trunk and gently lift the plant a few inches out of the container. If the entire contents of the container move and hold its shape in a firm mass of roots, the plant is properly "rooted-out" and ready for planting.
- For trees, lay the container on its side. Hold the tree at the base of the trunk as close to the soil level as possible and gently slide the tree from the container a few inches. If soil is left in the container or if the root system is not growing throughout the entire container, the plant is not ready for planting and should be considered for rejection.

This method is not possible for large trees. Instead, dig 2 to 3 inches into the soil at the very edge of the container and look for a firm mass of small roots.

Root-Bound Container Plants

If plants have been growing in their container for a long time, the roots will wrap around the inside of the container. These roots need to be cut or sliced prior to planting. These cuts should be made along the sides and bottom. Cutting these circling roots will enable the plant to produce new root offshoots and grow without problems.

Checking Container Sizes

The size of large plastic containers may be indicated on the handle. Since these are nominal volume sizes only, there may be some variation in actual size, even though the containers from two different growers are labeled as being the same volume. Refer to Appendix for the minimum acceptable size ranges for containers without sizes printed on them or for wooden or metal containers.

Soil Condition in Containers

Check for the following soil conditions:

- The soil level should be within a couple of inches of the top of the container. It should be a light (by weight) soil mix of mostly bark mulch and perlite or vermiculite (small white or silver particles that help hold water).
- If you see clay, burlap, or wire in what is supposed to be a container grown plant, inspect closer to determine if the plant has been dug from the field and then placed in the container. The root development test described previously should determine this. A containerized plant in lieu of a container grown plant is not acceptable and must be rejected.

B&B Plants (Balled & Burlapped)

Inspect the rootball of B&B material for:

- A firm, tight ball with no roots protruding outside the wrapping.
- Wrapping that is snug and free of rips and holes.
- Cracked balls or balls that are soft and look like a bean bag (these should be rejected).
- Damage to the base of the trunk caused by wire or string used to secure the wrapping moist soil.

Soil Condition of the Rootball

The soil in a B&B rootball will almost always be clay or tight, sandy clay. This is necessary so that the soil will hold its shape during digging, as well as hold water during shipping and storage. Rootballs that are mostly sand may crack and break easily, possibly exposing roots to heat and dry air. Plants with a sand rootball should not be accepted. The rootball must be moist and shaded for protection at all times when shipping or storing.

Measuring Caliper

This is measured 6 inches above the ground (or top of rootball) up to and including 4-inch caliper size and 12 inches above the ground for larger sizes. Measurement should be taken with pincher type caliper or diameter tape.

Proper Habit of Growth

If a particular habit (e.g., single stem, multiple stem, etc.) has been specified, be sure to obtain plants that conform to this requirement. Height of branching should bear a relationship to the size and kind of tree, plus, the crown of the tree will be in good balance with the trunk as the tree grows. For example, 2-inch caliper = 12 to 14 feet average height; 16 feet maximum height.

Shade and flowering trees should have top growth symmetrically balanced. Shade trees should have a single leader. The branching should be well developed and characteristic of the species. For example, 3/4-inch caliper = 7 or more branches.

Multi-stem trees can be defined as clump or shrub form. Clump form is a tree which has two or more main stems arising from the root crown. Shrub form has multiple stems

arising from the root crown in the manner of a shrub. Multi-stem trees are measured by height, taken from the ground level (or top of root ball) to the average uppermost point of growth of the plant.

Evergreen trees and shrubs should be full foliaged plants with uniform density. Sheared plants, such as pines sheared for Christmas trees, must be avoided unless specified. Most evergreen shrubs, such as juniper and yew, are measured by spread and should be the plant average. Evergreen trees like pines and spruces are measured by their height.

Deciduous shrubs should be well branched and full with no large holes from missing branches. Most are broad, upright type plants and are measured by their height. Well grown material should have a height equal to, if not greater than, the spread. However, the spread should not be less than two-thirds of the height.

Rejected Plants

Plants rejected for the project should be removed as soon as possible. They should be marked to preclude the possibility of their installation on the job. Since discarded plants are the property of the Contractor, they should not be marked or mistreated in such a way as to make them unfit for other uses.

Insects

Do not allow the Contractors to deliver any plants to the site that are infested with harmful insects. Harmful insects are those that eat or bore into the plant including:

- Caterpillars
- Borers
- Aphids
- Scale
- Mealy bugs
- Bagworms

When inspecting for insects, look for:

- The insects themselves. Most insects that suck plant juices usually do so from the undersides of leaves, particularly tender new leaves. Be sure to check these areas for aphids and mealy bugs.
- Leaves that have holes or portions chewed out of their margin. Typically caused by caterpillars.
- Small bag-like structures hanging from limbs. Typically an indication of bagworms.
- Holes in the bark that looks like shotgun holes. Typically a result of borers.
- Discolored bumps along a stem that look like shells. Typically an indication of scales.

Beneficial insects include lady bugs and butterflies. If insects are found, and it is unknown whether they are harmful or beneficial, the Inspector can call the local County Extension Office.

Table 661.A – Plant Damage - Trees and Shrubs

Things To Look For	What It Means	Action To Take
Minor amounts of breakage of small, twiggy growth.	Normal shipping damage. Should not be excessive.	Damaged twigs should be not be pruned.
Many small limbs broken.	Poor handling. Should not be excessive.	Broken limbs should be pruned. Reject if breakage is excessive.
Minor amounts of nicks and scratches.	Normal shipping damage. Should not be excessive.	None.
Gashes in trunk that are 1/8 (0.3 mm) deep or less and less than 1 inch (2.5cm) long.	Poor handling. Should not be excessive.	Treat with pruning paint. Reject if damage is excessive.
Gashes longer and deeper than the above.	Excessive damage. May stress plant and lead to loss of plant	Reject the plant.
Broken limbs 3/8 inch (l cm) in diameter or larger.	Poor handling. Damage done to larger limbs is more critical.	Broken limbs should be pruned. Reject if major limb or more than one.
Central leader (main trunk) is broken or cut.	Poor care or may have been pruned to meet specifications.	Reject the plant.
Limb partially broken or cut and has to be wrapped or repaired.	Someone tried to repair evidence of poor handling.	Reject the plant.

Inspection during Planting

The purpose of this part is to serve as a guide for an inspector who may not have the experience to determine that planting operations at the construction site are being properly completed in conformance with contract plans and specifications and good horticultural practices.

Planting stock should be inspected upon delivery. This will ensure that the plants delivered meet the requirements of the contract planting plans and specifications.

If plants are delivered before the site is ready for planting, a location should be chosen to store the plants until time to plant. This site should be away from construction traffic and protected from direct sun and wind. Asphalt or concrete areas are not acceptable as storage locations. Plant rootballs should be covered entirely with mulch, approximately 3 inches deep. Plants should be watered as necessary (see watering table) while in this temporary location.

Planting (661.10)

Unless in conflict with the contract specifications, the following check list of horticultural practices may be used by the Inspector. This information pertains to new or replacement nursery stock and not to large, mature plants.

1. Plantings should be performed only during the specified planting season (see C&MS 661.07). Planting must be done between September 15 and June 1.
2. The Inspector should check for proper positioning of the plants. After plants are set, burlap and any twine should be loosened, laid back, and cut away if

bulky, without damaging the ball. Non-biodegradable materials should not be used in lieu of burlap.

3. Check for correct depth of the plant crown. Depth of crown will vary for different soil conditions. See SCD LA-1.2 for details.
4. Place approved backfill material around plant roots or plant balls. Be careful not to damage the ball or the fine root system. Backfill which is frozen or too wet is not acceptable.
5. Eliminate air pockets in the backfill by filling, tamping, and watering as required by the specifications. It is best to water plants thoroughly before backfilling. Container plants should be moist at the time of planting.
6. When the above operations have been completed, unless otherwise specified, place a berm of soil around the perimeter of the pit to form a basin or saucer to facilitate watering and retention of moisture.
7. Mulch all plants to the specified depth with approved material (C&MS 661.11). The use of mulches prevents rapid temperature fluctuation, reduces moisture loss, and aids in weed control.

Note: Installation can directly affect a plants survival rate. Concentration on the installation process is critical to a project's success or failure. Because the nature of this work is based upon the end result (i.e., plants live or die), Inspectors need to watch the installation closely. If the Inspectors have any questions during the installation work, they should contact the Project Designer or other knowledgeable personnel as soon as possible.

Preliminary Preparation

1. The Inspector and Contractor should jointly review and become familiar with all plan sheets, quantities, details, specifications, and other provisions of the Contract. At this time, questions or interpretations can be answered or problems resolved through discussion with the landscape architect, horticulturist, or other authorized persons.
2. Sources of materials, other than plants required for planting operations, should be submitted for approval prior to use in the planting operation. Some of the materials that may require approval prior to use are topsoil, peat materials, (peats, mosses, humus, and related projected), compost, fertilizer, lime, mulch, stakes, wire and hose, and wrapping material.
3. The Inspector or other approved personal should check and approve the stakeout of all planting areas and planting pit locations prior to excavation. Minor relocation of planting areas and pits can be done at this time to avoid utility lines, rocky outcrops, drainage ditches, existing plants, or impervious or wet soil conditions. If minor relocations of plantings are not possible, the Inspector should contact the Landscape Architect to adjust the design requirements.

Site Preparation

Prior to installing plant stock at the construction site, the following preparation must be completed according to the requirement of the contract plans and specifications.

1. Excavation of planting pits, pockets, or beds to the required size and depth and spaced as shown on the plans.

2. On-site preparation of backfill mixture, as called for by contract specifications. The backfill mix must consist of the following (C&MS 661.09):
    a. One part excavated soil.
    b. One part sphagnum peat moss, shredded pine bark, or EPA rated Class IV compost.
    c. One part sand.
    d. A slow release commercial fertilizer (0-20-20 or equal) added at a rate of 5 pounds per cubic yard (3kg/m) to the backfill mix.

Wrapping, and Bracing (661.12 and 661.13)

All plants should be pruned, wrapped, and braced as specified.

1. Drive stakes solidly into the ground and guying installed to prevent movement of the plant until the root system is firmly established in the new planting location. See SCD LA-1.2 for details.
2. Wrap trunks or stems of plants from the root crown to the lower limbs with approved material to protect against drying or other physical damage. Wrapping should not be done prior to planting deciduous trees.
3. Plants should be pruned at planting time to restore a balance between the root and top growth. Tops should be pruned to compensate for the partial loss of roots when the plant was removed from the nursery. Tops should be pruned in a manner that will retain the characteristic shape of the plant.
4. Broken or damaged branches must be removed. The central leader of a deciduous tree should never be trimmed or removed. Deciduous trees with competing leaders should not be accepted for the project.
5. Prune all broken, torn, or damaged roots, leaving a clean cut surface to help prevent rot and disease.
6. Prune deciduous shrubs if only branches are broken during installation. Coniferous evergreens normally should not be pruned, except for broken branches, unless otherwise specified or directed.
7. Trees may be pruned before planting to save time and trouble. At this time, hand clippers can be used to cut closer than can be done with pole pruners (usually used for trees in an upright position). Pruning may be done under the Inspector's supervision prior to planting.
8. The planting operation is complete by watering all plants as specified.
9. See pruning diagram below.

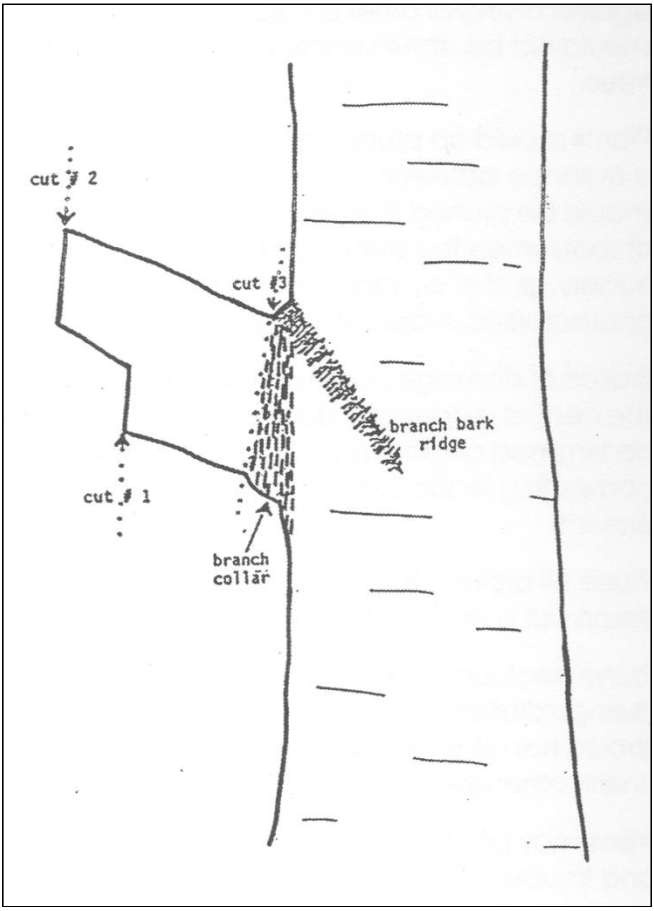


Figure 661.A – Pruning diagram

LANDSCAPE INSTALLATION INSPECTION CHECKLIST

Project No.:______________________ Date: ___________

County: _________ Route: _______ Section: _____________

Contractor: _____________________________________

Certified Landscape Technician: _____________________________________

Inspector: _____________________________________

Y	N	Item	Remarks
		Plant Installation: General Condition	
		Plant identification (proper species, tag, certification)	
		Overall foliage, condition (shape, leaf color, wilt, scorch, etc.)	
		Leaf discoloration (spots, splotches)	
		Evidence of pruning (needed or properly performed)	
		Insects (chewing damage, presence of insects)	
		Condition of trunks and limbs (gashes, breakage)	
		Soil conditions in container or rootball (moist, dry)	
		Root system (rooted throughout, healthy white color)	
Y	N	Size Specifications	
		Container size	
		Rootball size	
		Height	
		Spread	
		Caliper	
		Plant Delivery. Storage and Handling	
		All plants delivered on trucks are completely covered during transit	
		Rootballs and containers protected from direct sun	
		Handling and unloading from truck is done by the rootball or container and not by truck.	
		Are plants adequately watered	
		Plants are healed in until planted	
Y	N	Plant Installation	
		Plant location staked in field	
		Plant spacings conform to plan notes	
		Plant pit or bed preparation conforms to details	
		Plant is properly placed in pit	
		Rootball relation to finished grade meets spec	
		Rootball supporting devices removed (twine, wire, etc.)	
		Backfill mix meets specifications	
		Backfill placed in lifts and properly watered	
		Fertilizers added if specified	
		Plant is properly watered during installation	
		Watering basin conforms to details	
		Tree supports installed according to details(stakes, guy wire)	
		Vegetation barriers installed according to details	
		Mulch installed according to details	
		Tree trunk is wrapped to first branch	

Period of Establishment (661.14)

Warranty Periods

Landscape projects normally include a period of establishment. During this time, all plantings on the projects shall be under the care of the Contractor. This period begins immediately upon completion of the planting operation for any plant or species group and continues until October 1, but no less than one growing season (i.e., June 1 to October 1).

The stress caused by improper handling may not show its effect immediately. Plants, particularly large trees, may be under stress for months before showing obvious signs. By then, it is difficult to relate the damage to the plant installation phase rather than the maintenance it has received. Again, this points out the need for care early in the installation to make sure that the quality of plants is the highest and the care they receive is the best.

During the establishment period, the Contractor must water, re-mulch, re-stake, and cultivate as necessary. The Contractor is required to perform two weeding and mowing programs around trees, guy stakes, shrubs, and bed edges in order to remove all weeds and grasses from the planted and mulched areas. The first program should begin around June 15 and the second approximately 8 weeks later.

Plant Establishment Period – Final Inspection

This inspection should be done on or about October 1 and include a plan-in-hand review of each planting area or bed to determine the arrangement, number, and species of plants called for on the planting plans are present. If all plants have been properly installed, there should be minimal settlement of the backfill. Proper mulch depth should be checked, as this will affect plant survival.

The Contractor must remove all stakes, guy wires, and wrapping material from plantings just prior to final inspection, except for any replacement plantings that have not been through their establishment period (C&MS 661.14).

Since this inspection is of major importance to the ultimate success if the project, the Contractor, Inspector, and Designer should be members of the inspection team.

All plants rejected during the inspection should be removed and replaced by new plants which meet all of the requirements of the project and specifications. The final acceptance of the project should not have been completed until all plant replacements have been satisfactorily made.

ESTABLISHMENT CHECKLIST - FINAL INSPECTION

Y	N	Item	Remarks
		Foliage	
		Leaf wilt or browning	
		Leaves healthy and green	
		Yellowing	
		Spots of discoloration	
		Evidence of insect damage	
		Web or cocoons (caterpillars present)	
		Disease present	
		Remarks:	
		Tree trunk and limbs	
		Damage at the base of trunk	
		Broken limbs that need to be pruned	
		Dead limbs (no leaves present)	
		Damage from insects, birds, rodents, or animals	
		Sucker growth (prune out)	
		Straighten plant if needed	
		Misc.	
		Planting pit and rootball	
		Exposed roots (mulch is needed)	
		Settled backfill (replace as needed)	
		Animal damage	
		Moisture level of soil (water if needed)	
		All stakes, guy wires and wrapping removed	
		Weeds in mulch	
		Leaning trees (straighten if needed)	
		Plant replacement	
		Dead and missing plants replaced	
		Vandalism or vehicular damage	
		Ground cover and shrub bed area	
		Weeded	
		Dead shrubs (replace if needed)	
		Straighten if needed	
		Misc.	
		Remarks:	

Plant Substitution List

Occasionally, landscape contractors may need to make recommended substitutions to the plant material list. This can occur if the plants are not available locally, there's not enough to meet the project requirements, or the specified size is no longer available. These substitutions should be pre-approved by the Designer before the Contractor purchases the plants.

Listed below is an example chart to keep records on these substitutions.

Specified Plant	Substitution

Method of Measurement and Basis of Payment (661.17 and 661.18)

Measurement is done by counting the number of each species and size that was completed and accepted.

The Contractor is paid 40 percent of the bid price of each item when it is delivered to the project and is paid 40 percent after each item is planted.

At the end of the establishment period, after the final inspection, the Department will determine the actual number of living plants. The Department will pay the remaining 20 percent of the bid price for all living plants at the end of the establishment period.

If for each pay item, less than or equal to 5 percent of the installed plants require replacement at the time of Project Completion, the Engineer may waive the establishment period for the replacement plantings, provided that the replacement plantings are installed in accordance with this specification and in the presence of the Engineer or Inspector.

If for each pay item, more than 5 percent of the installed plants require replacement at the time of Project Completion, the Contractor is required to install the replacement plantings in accordance with this specification. The Department will pay the remaining percentage of the bid price at the time of Project Completion. The replacement plantings are subject to the one year establishment period regardless of the Project Completion date. After the replacement plantings complete the one year establishment period, the Department will inspect the replacement plantings and notify the Contractor of the Departments' findings. As final remedy under the contract, the Contractor is required to

install replacement plants for all plantings that did not survive the establishment period at no additional cost to the State.

661 Appendix I – Shade Trees

Height relationship to caliper:

Caliper (inches)	Avg. Height Range (feet)	Maximum Height (feet)	Minimum Diameter Ball (inches)
3/4	6 to 8	10	14
1	8 to 10	11	16
1-1/4	8 to 10	12	18
1-1/2	10 to 12	14	22
1-3/4	10 to 12	16	24
2	12 to 14	16	24
2-1/2	12 to 14	16	28
3	14 to 16	18	32
3-1/2	14 to 16	18	38
4	16 to 18	22	42
5	18 and up	26	54

Tree caliper is measured 6 inches above ground level, up to and including 4 inch caliper size, and 12 inches above the ground for larger sizes.

Container Specifications – Shade Trees

Tree sizes and acceptable container sizes:

Height	Container Size
12 in. through 3 ft.	#1
2 ft. 3 ft. 4 ft.	#2
4 ft. 5 ft. 6 ft.	#3

All container grown plants shall be healthy, vigorous, well rooted, and established in the container in which they are sold.

An established, container-grown tree is a tree which is transplanted into a container and grown sufficiently long for new fibrous roots to have developed, so the root mass will retain its shape and hold together when removed from the container.

661 Appendix II - Deciduous Shrubs

Height	Minimum Diameter Ball (inches)
12 in.	8 in.
18 in.	9 in.
2 ft.	10 in.
3 ft.	12 in.
4 ft.	14 in.
5 ft.	16 in.
6 ft.	18 in.
7 ft.	20 in.
8 ft.	22 in.
9 ft.	24 in.
10 ft.	26 in.

Plants dug to the specifications in the above table should have the center of the stem or cluster of stems of the plant in the center of the ball.

661 Appendix III - Coniferous Evergreens

Broad spreading and Globe Types (eg., Taxus media)

Height	Minimum Spread	Minimum Diameter Ball
6 in.	6 in.	
9 in.	9 in.	8 in.
12 in.	l0 in.	8 in.
15 in.	12 in.	10 in.
18 in.	15 in.	10 in.
2 ft.	18 in.	12 in.
2-1/2 ft.	21 in.	14 in.
3 ft.	24 in.	16 in.
3-1/2ft.		18 in.
4 ft.		21 in.
5 ft.		24 in.

Container Grown Specifications

Height	Container Size
6in. 9in. 12 in.	#1
12in. 15in.	#2
18in. 2 ft. 2-1/2 ft.	#3

Conicals, Broad Upright, and Columnar (e.g., Pinus, Picea, and Thuja)

Height	Spread	Minimum Diameter Ball
12 in.	8 to 12 in.	10 in.
15 in.	9 to 15 in.	10 in.
18 in.	12 to 18 in.	10 in.
2 ft.	15 to21 in.	12 in.
2-1/2 ft.	18 to 24 in.	12 in.
3 ft.	21 to 30 in.	14 in.
4 ft.	2-1/2 to 3 ft.	16 in.
5 ft.	3 to 4 ft.	20 in.
6 ft.		22 in.
7 ft.		24 in.
8 ft.		27 in.
10ft.		34 in.
12 ft.		34 in.

Ball sizes should always be of a diameter and depth to encompass enough of the fibrous and feeding root system as necessary for the full recovery of the plant.

Plants dug to the specifications in the above table should have the center of the stem or cluster of stems of the plant in the center of the ball.

Container Grown Specifications

Height	Container Size
6 in. through 18 in.	#1
12 in. through 2 ft.	#2
18 in. through 3-1/2 ft.	#3

661 Appendix IV - Broadleaf Evergreens

Spreading and Dwarf Types (e.g., Buxus and Cotoneaster)

Spread	Minimum Diameter Ball (inches)
18 in.	10 in.
2 ft.	12 in.
2-1/2 ft.	14 in.
3 ft.	16 in.
3-1/2 ft.	18 in.
4 ft.	21 in.

Container Grown Specifications

Height	Container Size
6 in. through 12 in.	#1
12 in. 15 in.	#2
18 in. 2 ft. 2-1/2 ft.	#3

All container grown plants shall be healthy, vigorous, well rooted, and established in the container in which they are sold. They shall have quality tops and be in a healthy growing condition.

Cone and Broad Upright Types (e.g., Rhodoendron)

Height	Minimum Diameter Ball (inches)
18 in.	10 in.
2 ft.	12 in.
3 ft.	14 in.
4 ft.	16 in.
5 ft.	20 in.
6 ft.	22 in.

Container Grown Specifications

Height	Container Size
6 in. through 18 in.	#1
12 in. through 2 ft.	#2
18 in through 3-1/2 ft.	#3

662 Landscape Watering

General

When watering by hand, attention should be given to the type of device used to apply the water. If the water is applied at too high a rate, the force of the water will displace mulches, soil, and expose roots. All equipment used to direct water into the watering basin should have a flow-control device that will break the impact of the water, so it will flow gently into the basin.

Water should not be applied where runoff will occur. If the plant is newly planted, too much water can erode the watering basin and allow water to escape before it can soak down into the soil. If this occurs, the basin should be repaired before the next watering.

WATERING TABLE (662.03-1)

Shrubs	12 to 36 inches (300 to 900 mm), height	4 gallons (15 L)
Shrubs	36 inches to 5 feet (900 mm to 1-1/2 m), height	7 gallons (25 L)
Trees	5 to 8 feet (1-1/2 to 2.5 m), height	15 gallons (55 L)
Trees	2 to 3 inches (50 to 75 mm), caliper	25 gallons (95 L))
Trees	3 to 4 inches (75 to 100 mm), caliper	30 gallons (115L)
Trees	Greater than 4 inches (100 mm), caliper	35 gallons (115 L)

WATER-RELATED STRESS SYMPTOMS

Symptoms	Soil Condition	Problem	Action to be Taken
Leaves are slightly dropping. Soft, hazy-green color.	Dry	Lack of water	Apply water as soon as possible.
Leaves are dropped and wrinkled.	Dry	Severe lack of water	Apply water immediately
Leaves are dropping, brown and falling from the plant.	Very dry, look for cracking.	Severe lack of water	Water immediately. Plant is near to shedding its leaves to compensate for lack of water.
Leaves are brown along margins but not drooping. Some leaves are falling from the tree.	Wet	Over-watering	Stop watering. Allow soil to dry

666 Pruning Existing Trees

Wound Dressing (666.02)

Ensure the contractor is using approved material specifically manufactured for tree wound dressing.

Pruning (666.03)

Trees should be pruned to make them shapely, typical of the species, using standard drawings on the plans as a guide. Ensure the contractor is using approved pruning tools and methods.

All dead wood and dead branches 1 inch (25 mm) or more in diameter should be removed. All branches interfering with or hindering the healthy growth of the tree should be removed with a good clean cut made flush with the parent trunk.

Low hanging, unsound, or unsightly branches on trees or shrubs designated to remain should be cut. Branches of trees extending over the roadbed to should provide a clear height of 20 feet (6 m) above the roadbed surface.

All stubs or improper cuts resulting from former pruning or limbs that have been broken flush with the trunk or limb of the tree in order to ensure proper healing should be cut.

Painting (666.04)

Ensure the contractor paints all cuts or wounds measuring 1 inch (25 mm) or more in diameter and all exposed wood and scars resulting from previous work or damage with approved tree wound dressing.

Removal or Foreign Materials from Trees (666.05)

All nails, spikes, bolts, wire, or other foreign materials driven into or fastened to the trunk or branches of the tree, shall be removed or, if directed by the Engineer, cut them flush with the bark of cambium layer to ensure complete healing over

.

670 Erosion Protection

Because of the straightforward nature of this item of work, no detailed explanation of the item is required in this manual.

671 Erosion Control Mats

Because of the straightforward nature of this item of work, no detailed explanation of the item is required in this manual.

SS 832 Temporary Sediment and Erosion Controls

Description (832.01)

This Sediment and Erosion Control contract item will remain as a supplemental specification to allow for the timely contract revision of the NPDES construction general permit, commonly referred to as the storm water permit. Projects which involve 1 acre or more of earth disturbing activity are required to have an NPDES Permit. This permit pertains to both the work within the project work limits and related support activities. Supplemental Section 832 is required to be installed in all contract documents regardless of the amount of Earth Disturbed Area (EDA).

1. The Contractor is required to furnish a fully executed Co-Permittee form.
2. The Contractor is required to furnish a site specific Storm Water Pollution Prevention Plan (SWPPP) that is compliant with the NPDES Permit (see SS832 Appendix E).
3. The Contractor is required to locate, furnish, and maintain all BMP as identified in the Contractor's SWPPP.
4. Project personnel are required to read the permit, SS832 Appendix E, and should inform the Contractor of any non-compliant permit conditions known on the construction site.
5. If stream or river crossing (causeway) provisions are not specifically included in the contract documents, the Contractor must obtain the proper permit to construct a stream or river crossing. **Fording streams, rivers, or waterways is not permitted.**

Definitions (832.02)

Co-Permittee: The Contractor is required to file the Co-Permittee form to OEPA. This form notifies OEPA that the Contractor is an "Operator." If the Contractor hires a sub-contractor to perform the major earthwork operations and they are responsible for parts of the erosion and sediment controls, they also should submit a Co-Permittee application.

- Both ODOT and the Contractor are identified as "Operators" in the NPDES Permit. As a result, both ODOT and the Contractor are required to keep the construction activity in compliance with the NPDES Permit.
- ODOT contractually holds the Contractor responsible for compliance and provides compensation for the Contractor's efforts. ODOT cannot knowingly allow a permit violation to exist without taking corrective measures. If a permit violation or deficiency is identified, the Contractor should be notified and reminded of his contractual responsibility to maintain permit compliance.

Standard Construction Drawing References (832.03)

The Standard Construction Drawings (SCD) provide detailed information which describe the materials, construction, and installation requirements for most of the BMP. The SCD

contain details that are often overlooked by the Contractor. The SCDs have been revised to address the latest version of the storm water permit. Earlier SCD versions may reference sediment and erosion controls that are no longer recognized by OEPA as viable BMPs.

Materials

Furnish the materials as outlined below:

1. Furnish commercial fertilizer, seed, and mulch material that meet *659*.
2. Furnish filter fabric material for ditch checks that meets standard drawing DM-4.4. It is important to note that this BMP includes the installation of an aggregate component to prevent high flows and sediment accumulation from collapsing the fabric fence.
3. Furnish rock material for ditch checks that meets standard drawing DM-4.4.
4. Furnish filter fabric material for inlet protection that meets standard drawing DM-4.4.
5. Furnish filter fabric material for perimeter controls that meets standard drawing DM-4.4.
6. Furnish excavation and embankment material for sediment basins and dams that meets the capacity and 48-hour draw down requirements described in the NPDES permit.
7. Furnish pipe material for slope drains that meets standard drawing DM-4.3.
8. Furnish rock channel protection material that meets standard drawing DM-4.3.

Requirements and Provisions (832.04)

Post construction NPDES Storm Water Management Requirements are not included in this specification. Post construction controls are not considered temporary, and therefore, are addressed in the project plans. Project staff should be familiar with the Post Construction BMPs, where they are located in the plans and on-site. OEPA may specifically inspect these BMP during a field visit.

Provisions

The “Provisions” portion of the specification identifies how the ODOT contract handles storm-water enforcement actions resulting from non-compliance. The NPDES Permit holds the Operator responsible for compliance. Since ODOT is the original permit holder, the OEPA prefers that ODOT enforce compliance issues versus waiting for OEPA to issue violations or fines. The provisions in 832.05 indicate the contractor’s responsibility in the event of an OEPA or regulatory action.

In order to show that ODOT is enforcing permit compliance on ODOT projects, project personnel must document steps taken when a Contractor fails to meet the contract requirements. The following is recommended list of steps and notifications to be taken by the project personnel in the event of a non-compliance scenario:

1. If project personnel identify non-compliance items, the Engineer will first send written notice to the contractor to correct deficient items and get the project back into compliance. (Specifically identify the deficient items within the notice. Pictures are beneficial to document the deficiencies.) The contractor has 48 hours to correct the deficiencies to the satisfaction of the Engineer. At

this time, depending on the severities of the deficiencies, the Engineer will provide notice to the Contractor that all payments associated with the SS832 items of work are being withheld. Continue withholding payments on SS832 items of work until all deficiencies have been corrected.

2. If a contractor fails to follow the direction of the Engineer by correcting the deficiencies within the 48 hour period, the Engineer will provide a second notice indicating that the all payments for SS832 items will not be paid if not done so already. The Engineer will also provide notice that failure to correct the deficiencies will result in the removal of the contractor superintendent or personnel responsible for improperly performing the work. This process is described in SS832.04 Provision 5 and C&MS 108.05.
3. If a contractor fails to correct the deficiencies to the satisfaction of the Engineer, the Engineer will provide written notice to the Contractor that the superintendent or personnel responsible for the improper work is removed from the project until further notice. The written notice shall also indicate that if the Contractor fails to remove the personnel and to correct the deficiencies, the Engineer will suspend work on the project. Reference SS832.04 Provision 5, C&MS 108.05, C&MS 105.01. At this time, the Engineer should send a copy to the Contractor's surety company as a preliminary notice.
4. Finally, if necessary further escalate the enforcement as described in C&MS 108.08.

When escalating the enforcement of the contract, ensure that the District Construction Administrator and is copied on all written notices.

EDA Requirements

ODOT Routine Maintenance projects involving less than 5 acres of maintenance work activity are exempt from the NPDES Permitting requirements. For a project to be eligible for this exemption, it is required that all work activity included in the project fall under the OEPA approved list of "Routine Maintenance Activities." The approved list can be found at:

www.epa.ohio.gov/dsw/storm/routine_maint.aspx

If the Contractor elects to work outside of the project limits (typically areas for borrow, waste, staging, or storage) and the EDA is greater than 1 acre, the Contractor is required to either include the areas outside the project limits on the SWPPP or obtain a separate, Contractor-held NPDES Construction General Permit coverage. Borrow, waste, staging or storage areas may only be included on the project SWPPP when the locations solely serves the ODOT project. If a Contractor elects to utilize a location which has other "Operators", a separate NPDES Construction General Permit and SWPPP will be required. ODOT will not provide compensation for BMP associated with a location where the Department does not maintain full administrative control.

Work Outside the Project Work Limits

If the project has identified any EDA within the project limits, even less than a 1 acre Project EDA, ODOT will compensate the Contractor for the installation of appropriate BMP within the project limits. For projects with more than 1 acre of EDA, the Contractor is required to specifically identify all work areas located outside of the project work limits

on his SWPPP. The cost for expanding the SWPPP coverage outside of the project work limits is included in the lump sum price bid for SWPPP. See 107.19 for general environmental protection requirements. It is important to note that the Contractor EDA may be on ODOT R/W but outside of the project work limits.

Jurisdictional Waters may include Waters of the State or Waters of the U.S. In either case, a permit may be required (107.19). Placement of fill in these regulated waters (streams, ponds, lakes, waterways, etc.) without a permit is illegal. The Contractor is required to furnish the proper permit for any area affected by his operation that is outside of the project work limits. This may include temporary work pads, stream crossings, causeways, or placement of any fill in Jurisdictional Waters that are not otherwise identified in the plans.

The Contractor is required to furnish spill response equipment for all operations working next to a body of water. See 107.19 and Special Provisions.

The Contractor is required to furnish water handling controls that are capable of preventing sediment-laden water from being discharged from the site. This is an important consideration when working in and around water areas on drilled shafts, cofferdams, dewatering operations, etc. (107.19).

The Contractor is required to provide a location to properly wash out cement or concrete trucks. Concrete washdown water is toxic and can cause a fish kill or other serious environmental impact. Concrete truck washdown BMP must be located away from all bodies of water. The Contractor is required to locate the concrete washout BMP(s) on the SWPPP.

Locate and Furnish BMP (832.05)

The NPDES permit requires that the SWPPP identify the type, location, and size of all sediment and erosion controls installed or proposed on the project site. The Contractor is required to keep the SWPPP current with the controls installed and maintained on site SS832 Appendix E Part III.C.2.D.

Figure 832.A – Sediment dam with construction fence and stream perimeter filter fabric fence

Figure 832.A2 – Perimeter filter fabric fence

Perimeter Controls (SS 832.05.A)

Apply perimeter control practices to prevent the migration of sediment from being discharged off-site by stormwater runoff. Perimeter controls are typically sediment controls that encourage sedimentation on-site and protect Ohio's surface waters.

1. Perimeter controls must be placed and identified in the SWPPP before or concurrent with any clearing and grubbing operation.
2. The perimeter controls should be dated on the SWPPP along with the dates of the clearing and grubbing.
3. Perimeter controls BMP are detailed in standard drawing DM-4.4.
4. Dikes can effectively divert water away from the project, and when designed properly, can separate watersheds into smaller drainage areas reducing the need for large sediment settling ponds.
5. Perimeter controls should be used to protect all water bodies (ponds, streams, wetlands, etc.) and any areas shown on the plan which may be adversely affected by construction surface drainage.

Figure 832.A3 – Perimeter control, water body protection

Filter Fabric Fence

Filter Fabric Fence is used to control sheet flow, not concentrated flow. The application of Filter Fabric Fence is limited by the steepness of the slope and the size of the surface area draining toward the fence. The regulatory limitations for Filter Fabric Fence are outlined in the NPDES Permit. See SS832 Appendix E, Part III.G.2.d.iii.

It is critical that Filter Fabric Fence be installed in accordance with standard construction drawing DM 4.4. The fabric must be installed in a 6-inch by 6-inch trench and backfilled with compacted earth. Placement of the fence along the ground surface and shoveling fill on top of the lower edge of the fabric is not acceptable.

Filter Fabric Fence is not a filter. It is intended to slow water down to encourage sedimentation behind the fence. It should be installed down gradient of EDA to remove sediment from sheet flow. Do not install silt fence above EDA areas.

When Filter Fabric Fence fails in the field, it is typically caused by one or more of the following:

1. Improper burial depth.
2. Drainage area exceeds the capacity of the fence.
3. Concentrated flows.
4. Poor maintenance.

Dikes

Dikes can be used as a perimeter control. Dikes function best by collecting and concentrating sheet flow then directing it to an appropriate controlled outlet or other BMP which does not allow the discharge of sediment.

Inlet Protection (SS 832.05.B)

Place Inlet Protection as outlined below. The location and date of placement, maintenance, or removal should be identified on the SWPPP. It is recommended that all Inlet Protection be numbered and dated both in the field and on the SWPPP.

Figure 832.B – Inlet protection

1. If Inlet Protection is being used as a BMP, it is required that they be located on the SWPPP.
2. Inlet Protection should be dated on the SWPPP.
3. Inlet Protection should be used around Catch Basin inlets and/or any structure that conveys storm water.
4. Inlet Protection requirements are detailed on standard drawing DM-4.4.
5. When Inlet Protection fails in the field, it is typically caused by one or more of the following:
    a. Improper burial depth.
    b. Inadequate height of fence above inlet invert.
    c. Improper lap of fabric.
    d. Poor maintenance.

Construction Seeding and Mulching (SS 832.05.C)

Seed and mulch all disturbed areas that have been idled, particularly before winter shut down.

Figure 832.C – Construction seeding and mulching

Figure 832.C2 – Winter seed and mulch, with mulch crimped in place

1. The rate furnished for straw mulch is 3 tons per acre (0.5 metric ton/1000 m^2).
2. The rate furnished for fertilizer is half the rate found in Item *659*.
3. Do not place Construction Seed on frozen ground.
4. Install Construction Seed and Mulch on disturbed areas that work will be suspended during the winter. Standard Construction Seed and Mulch should not be installed between October 15 and March 15.

5. Winter Seed and Mulch is the standard erosion control practice for EDA occurring between October 15 and March 15. This BMP includes mulch crimped in place or a Bonded Fiber Matrix capable of providing sufficient protective cover to comply with the NPDES permit. The cost for installing BFM mulch is typically greater than crimped mulch. The BFM mulch is better suited for limited area applications on steep slopes or areas where crimping implement access is limited. The use of other seed and/or mulch materials in this time period requires Department approval.
6. Temporary cover such as Construction Seed and Mulch, Construction Mulch or Winter Seed and Mulch should be installed as the construction progresses and not when a big enough area is exposed to the elements. Temporary cover requirements address the allowable time that disturbed earth may remain exposed. It is important that temporary cover installation keeps up with construction progress.
7. The date of construction seed placement should be recorded on the SWPPP and corresponding NPDES inspection reports.

Slope Protection (SS 832.05.E)

Fill slopes that are greater than 8 feet (2.5M) and have had no filling activity for 3 weeks.

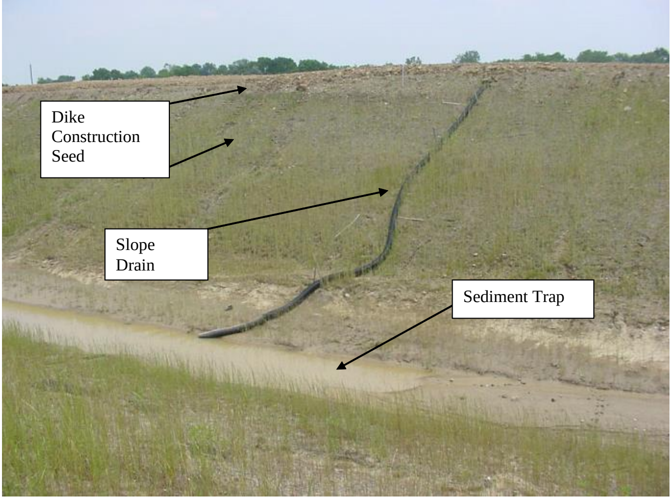


Figure 832.E – Erosion control items required for slope protection

1. If dikes are being used as a BMP, it is required that they be located on the SWPPP.
2. Dikes should be dated on the SWPPP along with the date of the slope construction.
3. Dike and slope drain construction requirements are outlined on standard drawing DM-4.3.

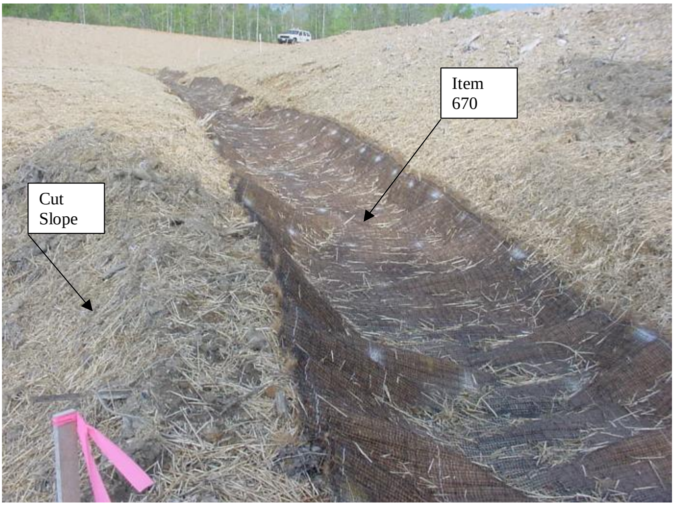


Figure 832.E2 – Item 670 recommended for cut slope construction

When constructing cut slopes, a surface water control ditch should be installed before the slope excavation begins.

1. The ditch should be constructed at the top of the cut slope.
2. If the ditch is being used as a BMP, it is required that it be located on the SWPPP.
3. It is important that the ditch is constructed with sufficient grade to prevent water from saturating the underlying soils and causing slope instability problems.

Ditch Checks and Ditch Protection (SS 832.05.F)

Figure 832.F1 – Filter fabric ditch check

1. Construct Filter Fabric Ditch Checks as soon as ditch is cut.

2. Ditch Checks shall be placed per the SWPPP or as required.
3. Ditch Checks are BMP and are required to be recorded on the SWPPP along with the ditch construction.
4. Filter Fabric Ditch Checks construction requirements are detailed on the standard drawing DM-4.4.
5. Filter Fabric Ditch Checks are limited to drainage areas of 2 acres (0.8 ha) or less.
6. Filter Fabric Ditch Checks include No. 1 thru No. 4 aggregate components. The Engineer may waive the aggregate requirement when ditch checks are needed in the clear zone. The aggregate should be replaced with straw bales staked in place against the filter fabric as detailed on standard construction drawing DM-4.4 (see Figure 832 F2).
7. It is important that Ditch Checks be in place by the end of the day if working on the ditch.

Figure 832.F2 – Filter fabric ditch check with straw bale backing

Figure 832.F3 – Rock ditch check

1. Rock Ditch Checks shall be placed per the SWPPP or as required.
2. If Rock Ditch Checks are used as BMP, they should be recorded on the SWPPP.
3. Rock Ditch Checks should be installed as soon as the ditch is cut.
4. Rock Ditch Checks construction requirements are detailed on the standard drawing DM-4.4.
5. Rock Ditch Checks are limited to drainage areas between 2 and 5 acres (0.8 and 2.0 ha).
6. It is important that Ditch Checks be replaced by the end of the day if working on the ditch.

Bale Filter Dike (SS 832.05.G)

OEPA no longer recognizes Bale Filter Dikes or Bale Ditch Checks as acceptable BMPs.

Filter Fabric Ditch Checks that are installed in the clear zone may use straw bales in lieu of the aggregate backing (see DM 4.4). Installation of straw bales is permitted only when allowed by the Engineer.

Sediment Basins and Dams (SS 832.05.H)

Place Sediment Basins and Dams as outlined below and as required by the NPDES Permit.

Figure 832.H – Sediment basin w/ surface dewatering device

1. Sediment basins and dams are required to be placed within 7 days after completion of grubbing and constructed before grading begins.
2. Sediment basins and dams should be installed as per the SWPPP and as required by the NPDES Permit.
3. Sediment basins are a BMP and are required to be recorded on the SWPPP and routinely inspected.
4. Concentrated flow discharging from areas containing EDA is required to pass through a Sediment Basin or Dam.
5. Typical field locations include the bottom of a ravine, culvert inlets and outlets, at the end of a ditch, and any concentrated water exit point.
6. Sediment, Basins or Dams should never be constructed in a body of water.
7. Both Sediment Basins and Dams should have a dewatering zone sized to retain 67 cubic yards (125 cubic meters) of water for every acre of drainage area. They should also include a sediment storage zone sized at 34 cubic yards per acre of drainage area. The total volume is therefore, a minimum of 101 cubic yards per acre of drainage area. The SWPPP designer is required to attach the computations for sediment settling pond design to the Acceptance submittal (832.10).
8. Sediment Basins are required to have a surface dewatering device with a designed outfall that draws down the dewatering zone over a 48-hour period.
9. Sediment Dams have a rock dewatering device. The dewatering zone is required to pass through the rock, not over it.
10. Construction requirements for Sediment Basins and Dams are detailed on the standard drawing DM-4.3.
11. Install construction fence as needed for safety considerations.

River, Stream, and Water Body Protection (SS 832.05.I)

All rivers, streams, and water bodies must be protected from all sediment-laden or turbid water.

Figure 832.I – Stream protection

Stream Relocation (SS 832.05.J)

Fully stabilize any temporary-relocated waterway before the water is diverted, as outlined below. Examples are temporary run-arounds to constructed culverts, temporary ditches, or any temporary waterway constructed by the Contractor to build the project. General and/or specific permits may be attached to part of the special provisions shown in the plan. Some individual or specific permits may include requirements in addition to what is required under the general NPDES Permit.

Figure 832.J – Temporary channel

Temporary Channel

1. Temporary channels require stabilization with rock channel protection (Item 670 Erosion Protection) or a stand of grass at least 70 percent established.
2. Temporary channels are required to be stabilized before any flow is diverted into the channel.
3. If the Temporary channel is a 404/401 permit requirement, costs associated with constructing, maintaining, and removing the temporary channel are incidental to the work taking place within the footprint of the 404/401 permit area.

Causeways and Access Fills (Stream and River Crossings and Fills) (SS 832.06)

Equipment can cross a waterway only by means of a permitted crossing or causeway. Regulatory permits are required prior to any disturbance to the waterway. Place Stream or River Crossings (Causeways) as outlined below and date the placement on the SWPPP.

Figure 832.K – Stream crossing

1. Ensure the causeway is a height of 1 foot (.3m) above the Ordinary High Water Mark (not necessarily the "normal water elevation").
2. The causeway should be as narrow as practical to provide for passage of the equipment while preventing the movement of any fill into the water.
3. Furnish culvert pipes if filling more than one-third of the waterway. Pipes may be specifically required per the terms of the 404/401 permit.
4. Only clean, dump rock (non-erodible fill) is permitted for use in the waterway. Broken concrete can be used as a temporary fill if all exposed rebar has been removed.
5. Furnish 50 feet (15m) approach drive of dump rock (non-erodible fill) on both sides of the causeway.
6. When a high water event impairs the Contractor's ability to work and causes a delay, the Department will allow an excusable, non-compensable delay. The Department will compensate the Contractor for required repairs to the causeway and access fills that were damaged as a result of the high water event.

Causeways and Access Fills Construction and Payment (SS 832.07)

Typically, Causeways and Access Fill environmental protection costs are incidental to the work contained within the 404/401 permit boundary. In some cases, Causeways and Access Fills are paid as a separate item. It is important to note that all environmental controls within the 404/401 permit boundary are incidental to the work conducted within that boundary. The Sediment and Erosion Control Prices (SS 832 Appendix F) should not be used as compensation when BMP are installed within the 404/401 permit boundary.

Figure 832.L – Required maintenance

Maintenance (SS 832.08)

1. The Contractor is required to maintain all BMP throughout its functional life on the project.
2. The cost for maintaining BMP is included in the price paid per unit of BMP. Compensation is provided for BMP replacement and/or repair required as a result of a rainfall event greater than 1/2 inch. The Contractor is required to inspect, record, and report all impacts to the BMP that require maintenance and/or replacement. BMP must be inspected weekly and within 24 hours of a 1/2-inch or greater rainfall event.
3. Sediment that accumulates at the BMP requires removal and proper disposal as part of the Contractor's responsibility for maintenance. Safeguards must be in place to prevent the release of sediment into waters of the state during the BMP maintenance effort. Disposal of accumulated sediment must be compliant with C&MS 107.19.
4. Routine maintenance and repair of BMP is required to be conducted within 3 days of the inspection which identified the need. Sediment settling ponds must be repaired and/or maintained within 10 days of the inspection. If deficiencies or violations have been identified on-site, the Contractor is required to correct and mitigate the conditions within 48 hours of notification by the Department or regulatory agency SS832.04. Provision 5.

5. BMP should not be removed until the Earth Disturbing Activity has been completed and, "A uniform perennial vegetative cover with a density of at least 70 percent has been established," on all unpaved areas. If a silt fence is removed to accommodate the final grading and seeding operation, it should be replaced after the seeding work is completed or other perimeter control BMP should be installed to provide appropriate protection. OEPA recommends the installation of sediment basins down gradient as an appropriate control measure when perimeter controls are removed for final grading and seeding.

BMP Maintenance Requirements

Routine maintenance on BMP is required when repairs are needed and when:

1. Rock Ditch Checks have sediment covering half the height of the rock.
2. Perimeter Filter Fabric Fence, Filter Fabric Ditch Checks, and/or Inlet Protection have sediment covering half the height of the fabric.
3. Sediment Basins and Dams require sediment remove maintenance when the required sediment storage zone full.
4. Erosion Control Mats require replacement when they are torn and/or displaced.
5. Construction Seeding and Mulching has been displaced and re-application is needed.

Permanent stabilization must be achieved before the project is accepted. Once the project is permanently stabilized, (see SS832 Appendix G, Part VII.H) all temporary BMP must be removed and resulting debris disposed of appropriately.

Storm Water Pollution Prevention Plan (SS 832.09)

1. The Department requires that the SWPPP be designed by a Registered Engineer (P.E.) that is also a Certified Professional in Erosion and Sediment Control (CPESC). Registration of certified professionals can be found at the following websites:

   https://license.ohio.gov/lookup/default.asp

   http://www.cpesc.org/cc-info/us-directory.asp

2. The SWPPP must show the location of the BMP for all areas with EDA related to the project. This includes borrow, waste, staging, and storage areas that experience EDA.
3. It is important that the SWPPP identify the watersheds and the area disturbed by the construction in each watershed (SS 832.12 G). This provides the project and Contractor with the location of all drainage outlets from the project. This information is helpful in conducting appropriate inspections (see SS 832.14 below).
4. If the Contractor is proposing BMP other than those identified on the standard BMP pricing schedule, the SWPPP needs to describe the proposed BMP for the Engineer's approval, particularly if compensation is a consideration.

SWPPP Acceptance (SS 832.10)

The intent of acceptance is to determine if the SWPPP developed by the Contractor is a reasonable reflection of the site conditions and identifies reasonable controls that will uphold compliance with the NPDES Permit. Acceptance is not regulatory approval. If the SWPPP is accepted, the Department is recognizing that the Contractor has developed what appears to be an appropriate plan to comply with NPDES. Sections A through G of Part III in the NPDES Permit is a checklist that identifies the minimum SWPPP elements that the Contractor must have on his plan. If the SWPPP is not accepted by the project, and the Contractor requests assistance from the project to develop an acceptable SWPPP, guidelines are available in the form of a checklist from OEPA. The checklist is titled, "SWPPP Checklist for Construction Activities," and can be found at:

www.epa.ohio.gov/dsw/storm/const_SWP3_check.aspx

Project staff can, and should, make recommendations to the Contractor to facilitate permit compliance. It is important to note that the Contractor's responsibility and liability related to NPDES compliance is reduced when he is directed to perform compliance work by the Department. The Contractor is required to tailor his operation in order to comply with the NPDES Permit. The purpose of this submittal is to demonstrate compliance with the contract documents. If the Contractor intends on using the submittal as a mechanism to alter the contract requirements, he is required to "prominently call attention to the proposed deviation from the contract in the submittal."

Inspections and Updates (SS 832.11)

Inspections are a requirement of the SWPPP. The NPDES Permit requires that all controls (BMPs) and all surface water outfalls on the site are inspected at least once every 7 calendar days and within 24 hours of any storm event greater than 1/2 inch as per SS832 Appendix E part III.G.2.i. The Storm Water Inspection Report is a document of record that carries legal liability. The Contractor has the contractual responsibility to conduct the inspections by or directly under the supervision of the SWPPP designer who sealed the SWPPP. At least once a month, the SWPPP designer is required to sign off on the inspection report with the following standard certification language:

> *"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."*

SS832 Appendix E part III.G.2.i describes the minimum components of an inspection report.

It is important that the inspection specifically includes all discharge locations. If erosion is occurring or sediment is accumulating at a discharge location along the boundary of the project, immediate action needs to be taken to document and correct the problem. For situations where off-site sediment is mixing with surface water from the project, care should be taken to separate the flows and divert the off-site water away from the site (when possible). In many instances, the separation and diversion of off-site surface water

is not possible. In these cases, the Contractor should monitor the in-coming surface water and document the conditions as part of the routine inspection effort. In the event that OEPA or others identify an NPDES Permit violation, the remedy and/or corrective action can be identified and implemented quickly and additional enforcement actions can often time be avoided.

OEPA refers to the SWPPP as a "living, breathing document." The intent of the SWPPP requirement of the permit is to plan the work in advance and incorporate the BMP in such a way that prevents the discharge of pollutants to waters of the state. The permit requires that the SWPPP be kept current with the site conditions and document the addition, removal, and maintenance of the BMP on the SWPPP (see SS832 Appendix E, part III.D). The Department requires that the Contractor perform the required inspections. The Inspector must be CPESC trained. When modifications to the SWPPP are needed, the Inspector is required to get approval from the SWPPP Design Engineer. The SWPPP Design Engineer's approval is documented as part of the routine inspection report, which is provided to the project at least once a month. The Contractor's Erosion Control Inspector is required to provide the project with a weekly certification that the site is compliant with the permit. If the project does not receive the weekly certifications, SS 832.04 should be enforced, and the Contractor should be notified in writing. The certification requirement provides the project with the ability to track compliance issues and to stay current with the required documentation.

Project File Requirements – SS 832 Temporary Sediment and Erosion Controls

Documentation requirements include the entries in the Inspector's Daily Reports, which reflect the Inspector's observations relative to the sediment and erosion control compliance of the site. A BMP Inventory form is furnished in SS 832 Appendix A to assist in documenting and recording the BMP quantities for payment. **<u>The BMP inventory form in Appendix A is not a substitute for the inspection report described above.</u>**

The Contractor is required to provide the Engineer with an inspection report every 7 days and within 24 hours of a 1/2-inch (13 mm) or greater rainfall event throughout the life of the Contract. Inspection requirements can be reduced to once a month if the SWPPP Engineer certifies that the entire project has been temporarily stabilized and the construction activity will be suspended over the winter.

Include the following in the inspection report:

- The OEPA NPDES Permit inspection checklist information (see appendix E, Part III.G.2.i).
- A map identifying all BMP needed, installed, maintained, or removed since the last inspection report.
- Certification that all construction activities are compliant with the SWPPP and the signature of the CECI responsible for the inspection.
- The signature of the Professional Engineer who sealed the SWPPP is required as part of the inspection report on a monthly basis or when modifications to the SWPPP design are made.

Include the certification requirements according to OEPA NPDES Permit Part V.H with all reporting sign offs.

SS 840 Mechanically Stabilized Earth (MSE) Walls

Introduction (840.01)

MSE retaining walls have been constructed in the State of Ohio for over 30 years. Several wall system suppliers have provided their unique designs and components to construct these walls. Supplemental Specification 840 combines all of the specific MSE systems' requirements, and general requirements, into one document.

SS 840 is periodically updated. Check the plan cover sheet and addenda for the specific version applicable to the project. If a more recent version is available, consider adopting the new version by a change order.

The figures below illustrate typical profile and plan views of MSE walls at a bridge.

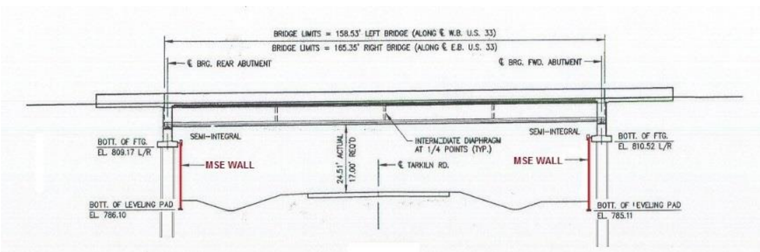


Figure 840.1.A MSE Wall profile view

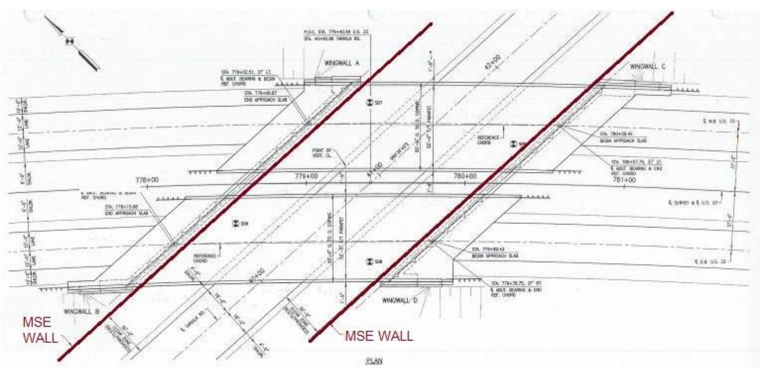


Figure 840.01.B - Plan view of the MSE walls and bridge

MSE wall specifications are different than the typical construction specification in that they address both design and construction criteria. The plans will detail a diagram of the MSE wall structure showing the wall location, the top and bottom elevations of the wall, and the existing and final grades. The internal details and the construction shop drawings are submitted after the project award.

The figures below illustrate typical cross sections found in the plans. The details show the foundation preparation, soil reinforcing, limits of the select granular backfill, and 203 embankment backfill areas.

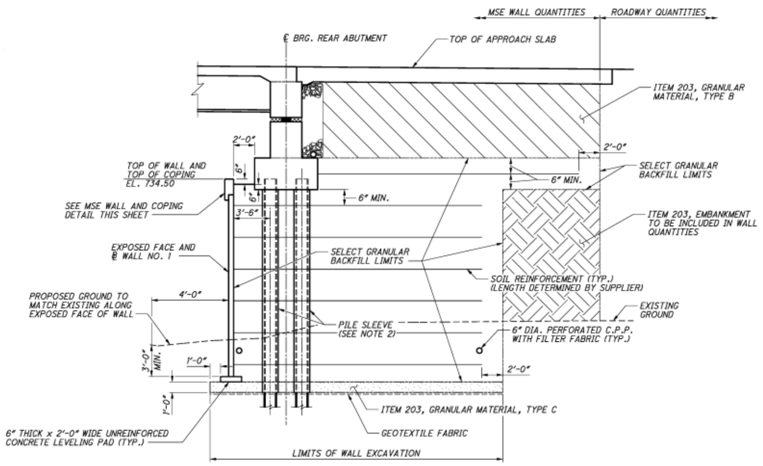


Figure 840.01.C - Typical plan cross section of an MSE wall at abutment

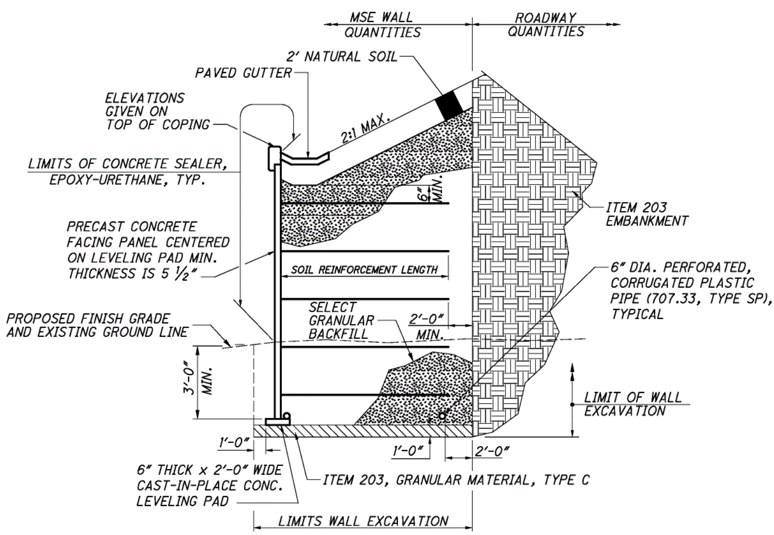


Figure 840.01.D - Typical plan cross section of MSE wall

On some projects back to back walls may be required, as detailed below.

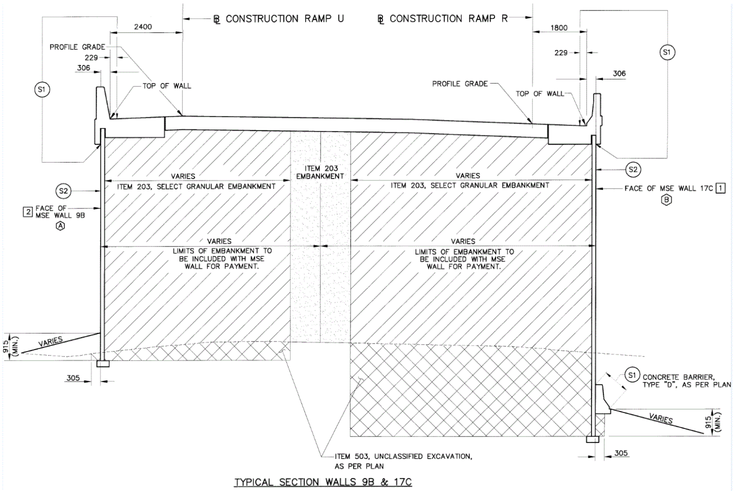


Figure 840.01.E - MSE walls on both sides

General Information (840.02)

The figure below illustrates the general configuration of an MSE wall system, which is a retaining wall system that consists of soil reinforcements embedded in select granular backfill and connected to facing panels.

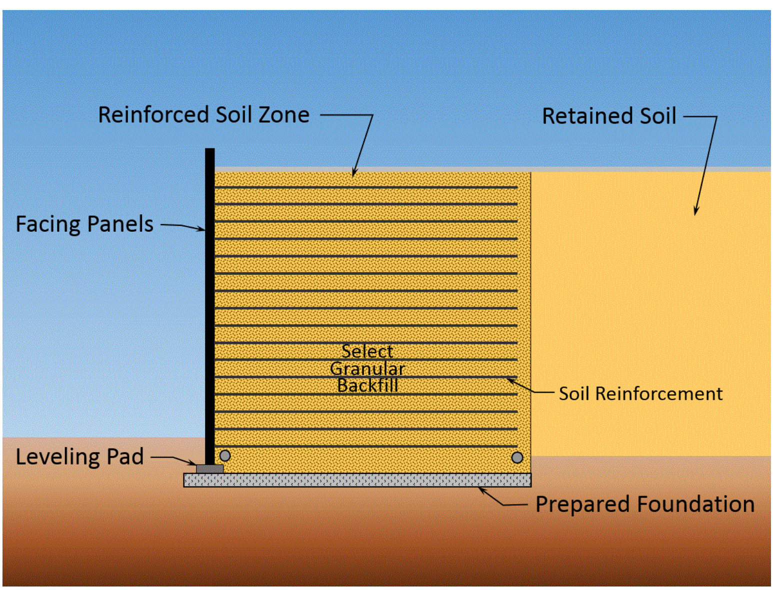


Figure 840.02.A - Typical section of an MSE wall structure

Definitions (840.02.A)

The following are standard terms that will be used in this document and as illustrated in Figure 840.2.B.

Bearing Pads: Wall panel bearing pads are typically ribbed elastomeric or polymeric joint material inserted between panels to provide proper sized joint. Bearing pads prevent the panels from having concrete point contact that causes panel spalling.

Connection Devices: These are the mechanism where the connection is made between the facing panel and the soil reinforcements. The devices are cast into the facing panel.

Coping: The coping is used to tie in the top of the wall panels and to provide a pleasing finish to the wall top. It is cast-in-place.

Existing Groundline: The existing ground surface at the site.

Facing Panel: Facing panels restrain the soil in position at the face of the wall, and are typically precast concrete.

Geotextile: A geotextile (filter fabric) is used to cover the joints between panels. It is placed on the backside of the panels and prevents the soil from piping through the joints and allows for free drainage.

Leveling Pad: The leveling pad is unreinforced cast-in-place concrete. The concrete is 24 inches wide, 6 inches thick, and has a minimum compressive strength of 2,500 psi. Cure the cast-in-place concrete for a minimum of 12 hours prior to placing the first row of facing panels.

Retained Soil: Retained soil is the material behind the reinforced soil zone and follows the material requirements for embankment. It can be the natural in-place soil or constructed embankment.

Select Granular Backfill: Select granular backfill is the backfill within the reinforced soil zone and that meets the gradation, electrochemical, unit weight, and internal friction angle requirements.

Soil Reinforcement: Soil reinforcement holds the wall facing panels in position and reinforces the soil. Soil reinforcement can be strips, grids, or mesh, and can be made of steel (inextensible) materials, or geosynthetic (extensible) materials.

Wood Clamps: Wood clamps are used to temporarily hold the panel in place during construction.

Wooden Spacers: Wooden spacers are temporarily placed in the vertical joints to maintain the 3/4 inch spacing between panels.

Wooden Wedges: Wooden wedges are used in the front face of the panels to temporarily hold the panels at the correct batter during the fill placement.

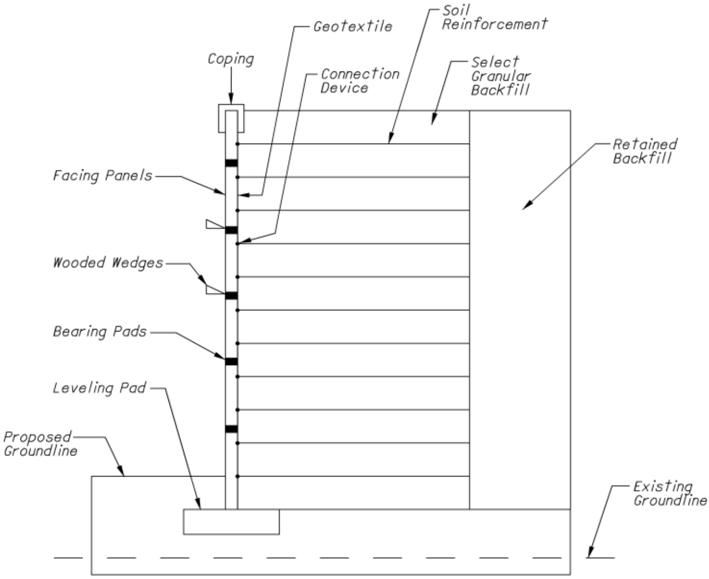


Figure 840.02.B - Typical MSE wall components

Facing Panels Types (840.02.B)

Facing panels come in many shapes, sizes and finishes. The most common shapes are rectangular, square, and cruciform, although custom panels made to address geometric needs are common. The panel's front face can have any type of finish, shape, texture, or other surface treatments that can be formed with concrete.

Figure 840.02.C - Rectangular panels

Figure 840.02.D - Square panels

Figure 840.02.E - Cruciform panels

Figure 840.2.F - Textured finish panels

Corner Panels (840.02.B.1)

Corner panels provide a good connection between the two walls and act like a slip joint by allowing differential movement between the two walls.

Figure 840.2.G Corner panels

Slip Joints (840.02.B.2)

Slip joints are used to address large differential vertical movement along the wall. Slip joints are also used at the interface line for phased construction.

Figure 840.2.G Slip joint behind abutment

Facing Panel Inspection (840.05)

Panel Dimensions and Tolerances (840.05.G)

Panel documentation should be checked when the panels first arrive on the project. The panels come with a TE-24, which is a record of final inspection of all precast panels and the measurements of the tolerances, strength, and dimensions. As a final check, the dimensions should be randomly checked at delivery. The shipment paperwork, shop drawings, and the actual panel dimensions should be compared to ensure that any issues are identified in a timely manner. The earlier in the process that these problems are found, the easier it will be to correct the issues. Panel items to pay particular attention to are:

1. Length, width, and thickness.
2. Squareness.
3. Finish.

Physical measurements of the panels are required. The project should use a tape and carpenters square to check the above. All panel dimensions have an effect on the Contractor's ability to construct the wall within the specification tolerances.

Figure 840.05.A - Checking the squareness of the panel

Handling, Storing and Shipping Panels (840.05.H)

Panels should be stored flat and on blocking or dunnage. Blocking is provided by the supplier on pallets of panels. Blocking protects the embedded connections devices from being bent or damaged by other panels. Panel faces should be kept away from areas that are muddy to prevent staining of the face of the panel. The project staff should ensure that panels don't have spalling or cracking upon delivery to the site.

Correct storage is shown in Figure 840.05.B. Note that the blocking height is more than the height of the soil reinforcement connections to avoid damage.

Figure 840.5.B - Proper panel storage with dunnage

Figure 840.05.C is an example of improperly stored panels. The panels in this case can get chipped or cracked. The soil reinforcement connection devices also can get bent.

Figure 840.05.C - Improper panel storage

Figure 840.05.D - Bent connection tabs causes damage to galvanization

Precast Panel Rejection (840.05.J)

Damage to the Galvanized Soil Reinforcement Connections

If the soil reinforcement connections are damaged to the point that it inhibits the soil reinforcement from being attached, then the panel should be rejected. Sometimes the connection is filled with residual cement or concrete that does not allow the soil reinforcement to be connected. If this is the case, the Contractor should clean out the connections. Do not cut the soil reinforcements because this will damage the galvanization.

If the steel connections are bent more than 15 degrees from perpendicular, the panel should be rejected. When bent beyond 15 degrees, the galvanizing is compromised and cannot be repaired.

Damage to the Panels

The panels should be inspected for damage. Panels can be damaged almost anywhere during the manufacturing, transportation, and construction processes. Chips, cracks, and spalls are often caused by poor handling and can be prevented by using nylon straps in the handling process. Damage can be avoided by taking care in the handling process. SS 840.05.H contains a list of defects and damages that are sufficient for rejecting a panel. Depending on the severity of the damage, the Contractor may propose a repair.

Figure 840.05.E - Rejected cracked panel

Figure 840.05.F - Rejected lifting spall

Figure 840.05.G - Repairable lifting strap spalling

Figure 840.05.H - Repairable handling spalls

Construction (840.06)

Components which affect the behavior of an MSE wall system include the concrete leveling pad, facing panels, soil reinforcement, select granular backfill, and the retained and foundation soils. All of these components influence the design, construction, and the performance of the MSE wall and changes to them during construction could have a detrimental effect on the wall.

The construction sequence of a typical MSE wall is as follows:

Wall Excavation (840.06.C)

MSE walls are sometimes constructed in a cut section. In this case, the excavation behind the wall is temporarily supported to construct the wall. A pay item for this excavation support (Cofferdams and Excavation Bracing) should be included in all MSE wall plans. However, if it is not included, the MSE specification states that the cost for the excavation support is to be included with the MSE Wall pay item. All work necessary to support the excavation or to fill the void behind the wall is the responsibility of the Contractor.

Figure 840.06.A.1 illustrates the wall excavation and retained backfill areas. All of the areas below the long dashed line to the lower solid line is paid for as Wall Excavation.

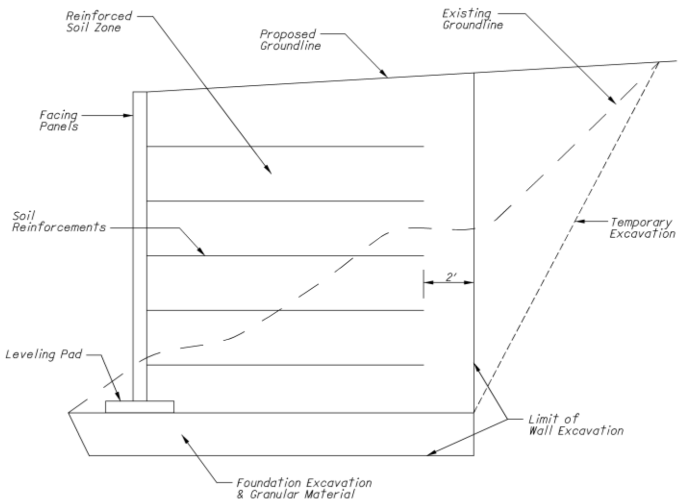


Figure 840.06.A.1 - Excavation and select granular backfill areas

Figure 840.06.A.2 is a field view of this situation. The sheet piling along the bridge is the excavation support at this site.

Figure 840.06.A.2 Area behind the wall

Figure 840.06.A.3 below shows a track hoe excavating for the MSE wall foundation. All organic matter, vegetation, debris, and other unsuitable materials, detailed in 703.16, need to be removed. The minimum excavation depth is one foot below the bottom of the leveling pad, but a deeper depth may be shown in the plans. The foundation excavation bottom extends laterally from one foot outside of the leveling pad to two feet beyond the end of the soil reinforcement, or as detailed in the plans. During excavation, the soils

removed should be compared to those described in the soil borings to see if they are different (see Section 840.06.B.2. in this manual).

Figure 840.06.A.3 - Foundation excavation

Foundation Preparation (840.06.D)

Foundation Preparation

The MSE wall foundation area needs to be prepared for the construction of the leveling pad and placement of the soil reinforcements and the select granular backfill.

After the wall foundation area has been excavated, the entire area should be graded level to allow for inspection of the foundation soil conditions.

Foundation Evaluation

The Department will evaluate the actual soil conditions for the wall foundation. Contact the District Geotechnical Engineer or the plan design geotechnical consultant to evaluate the foundation. This requirement can be paid for through continuing services arranged by the project design manager. In the design phase, a bearing resistance and stability analysis was performed for the MSE wall based on the plan borings. These analyses should be reevaluated based on the subsurface conditions observed during construction. The DGE or geotechnical consultant will make a site visit to determine if the foundation soils meet the soil conditions determined during design. The results will then be reported to the Engineer.

The evaluation results, along with the Structure Foundation Exploration sheets and geotechnical consultant's design report if necessary, should be reviewed by the Engineer to confirm that the excavated soils match the soil conditions determined for the wall design. If the existing conditions do not match the design subsurface conditions or there are any unusual problems identified in the evaluation, contact the State Construction Geotechnical Engineer.

Undercut

The foundation conditions are important parameters to the design of the MSE wall system. Sometimes, the subsurface conditions immediately beneath the MSE wall are insufficient to support the wall. A deeper excavation below the leveling pad is required to obtain the necessary support. In design, the plans will detail a foundation excavation depth greater than the minimum one-foot. If an undercut is required, the foundation evaluation detailed above should be performed on the bottom of the undercut. During construction, the need for an undercut, not shown on the plans, may be determined based on what is encountered while excavating and the foundation evaluation.

The following figure shows a typical foundation undercut detail. Unlike pavement subgrade undercuts, additional drainage and geotextile layers are not provided. The necessary drainage for the MSE wall is already included in the select granular backfill.

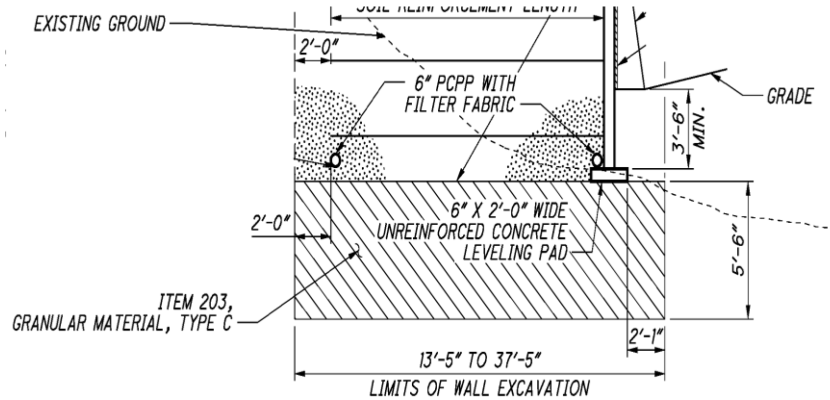


Figure 840.06.B.1 - Typical foundation undercut detail

Figure 840.06.B.2 below shows a 5-foot undercut operation. The backfill material in this example was a well graded blast rock. The material of choice for foundation undercut should be Item 203, Granular Material Type C. If a porous well graded material is used, the upper portion should be choked with about a foot of Item 203, Granular Material Type B.

Figure 840.06.B.2 - Backfilling foundation undercut

Leveling Pad Construction (840.06.E)

Once the foundation area is compacted and graded level, the leveling pad is constructed. This pad serves as a guide for the wall facing panel erection. The leveling pad is not intended to provide structural foundation support in the final configuration of the wall, but there is significant construction panel loading on the leveling pad. Therefore, it must be properly constructed and on a firm foundation in order to minimize potential wall movements during construction.

Figure 840.06.C.1 - Leveling pad construction

The leveling pad is important to the construction of the wall, because the leveling pad sets the horizontal and vertical alignment of the wall. It must be in the correct horizontal position, level, and at the correct grade.

Figure 840.06.C.2 - Leveling pad surveying

If the wall is not started correctly, that is level, then the panels will bind against each other causing spalling of the edges and corners.

Before wall panels can be placed on the leveling pad, it must be cured to obtain a minimum required strength (modulus of rupture). Generally, this occurs in about 12 hours.

Figure 840.06.C.3 - Completed concrete leveling pad

No more than 2 shims (each 3/16 inch thick) should be required to level the panels on the leveling pad. If the panels cannot be leveled with two shims, then the leveling pad

may need to be reconstructed in the effected portion. The panels may need to be rechecked for straightness and squareness. The panels shown in Figures 840.06.D.6, 840.06.D.8, and 840.06.D.9 are properly shimmed.

Figure 840.06.C.4 - Improper shimming

Under no circumstances should bearing pads be used to level panels on the leveling pad.

Figure 840.06.C.5 - Bearing pads are not to be used to level panels

Care must be taken to ensure the leveling pad is correctly aligned. The leveling pad is 24 inches wide to allow for some alignment errors and to accommodate panels going around corners and curves.

Do not allow any panel overhang off the leveling pad. If this occurs, stop the construction and investigate the problem. If needed, reconstruct the leveling pad.

Figure 840.06.C.6 - Improper panel overhang

Leveling pads which require changes in elevation present special challenges in design and construction. Figure 840.06.C.6 below illustrates this challenge.

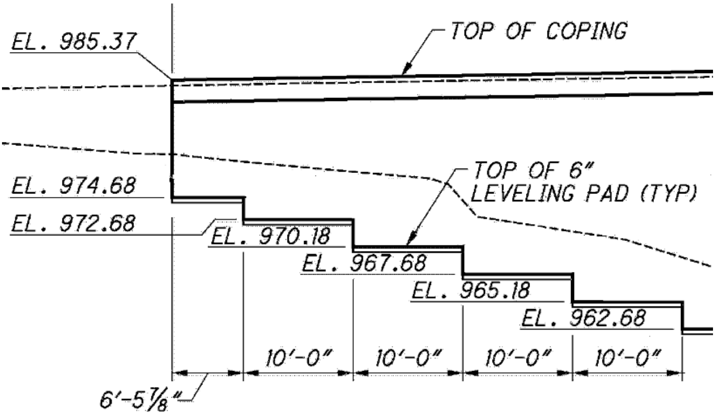


Figure 840.06.C.7 - Change in leveling pad elevation

Arrange the leveling pad and panels so that when elevation changes occur, the panels are almost fully supported by the leveling pads. Multiple elevation changes along the wall alignment are even more difficult to construct. The maximum panel overhang along the wall is 6 inches beyond the end of the leveling pad.

Figure 840.06.C.8 - Unacceptable panel overhang

Wall Erection (840.06.G)

Panel Identification

An important step prior to constructing the wall is to check the wall erection and fabrication shop drawings to ensure that the correct panels are being used in the correct location along the wall. Depending on the wall height, the panel shape, or design, the number and location of soil reinforcement connections will vary. The panels must be used in their proper position. Below is a portion of a typical shop drawing showing the panel organization.

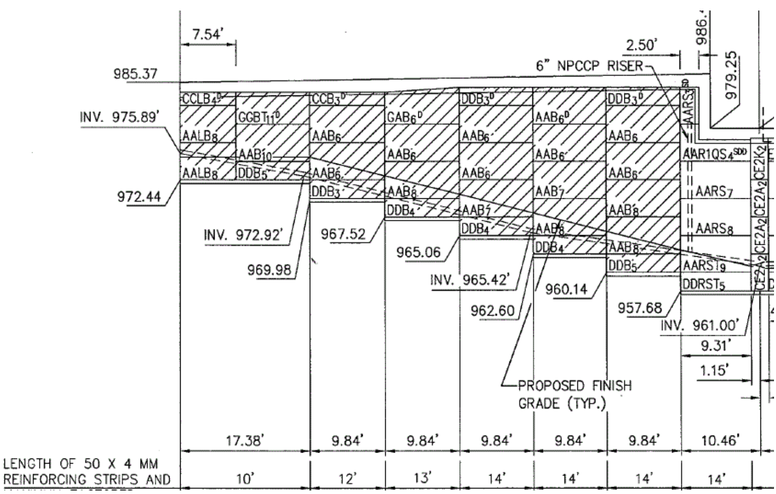


Figure 840.06.D.1 - Typical panel erection shop drawing

The erection drawings show an identification code for each panel that depicts its position in the wall. The code indicates: panel shape (rectangular or trapezoidal); general panel dimensions (full-height or part-height; standard-width or part-width); and if panel edges are squared-off (left, right, bottom, or top). The code indicates the required number of soil reinforcements connected to that panel. The code may also indicate if that panel is to have coping dowels, or a specific aesthetic pattern. Below is the code that details the panel letter and numerical system for the wall in Figure 840.06.D.1.

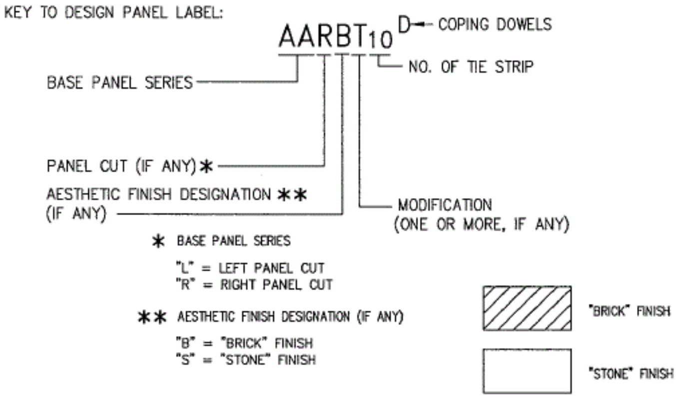


Figure 840.06.D.2 - Example code for panel identification

This code is for a specific wall system supplier. The code for other wall systems will be different, and the code for a particular wall system may change at any time. The codes are marked on the back of the panels for easy reference during construction.

Figure 840.06.D.3 - Actual panel markings

Above is a photo of the markings on the back of a panel that uses a different coding system than the one in Figure 840.06.D.2. The above markings (A-4-R6) show that it is a standard panel shape A and has 4 reinforcement connectors. The R6 refers to the steel rebar arrangement in the panel. Other required markings include date of manufacture, production lot number, and the precaster’s inspection and acceptance marks.

Placing the Panels

Picking up the panels is an important aspect of the construction procedure. If the panels are not properly picked up, spalling or cracking can occur. The figure below shows the correct method of picking up the panels. The crane lifts the panel so that no concrete to concrete contact occurs.

Figure 840.06.D.4 - Picking up the panels

The correct placement of the first row or two of panels is very important. When the panel construction is not started correctly, the finished product is rarely satisfactory.

In the figure below, a chalk line is placed on the leveling pad to properly align the panels along the leveling pad. Sometimes a 2×4 is used to align the panels. Adjust the alignment using a crowbar as shown below. At this point, the panel is still supported by the crane.

Figure 840.06.D.5 - Proper placement

The horizontal alignment and the panel to panel horizontal offset should be checked. Use a straightedge across the panel horizontal joints to ensure that the panel to panel horizontal offset does not exceed 1/2 inch.

The first row may be composed of both half- and full-height panels. A photo of full- and half-height panels is shown below.

Figure 840.06.D.6 - Half height panels

Horizontal Leveling

Once the panel is placed on the leveling pad, the panel should be leveled horizontally. A 6-foot level is placed on the top surface of the panel to determine if it is level.

Figure 840.06.D.7 - Proper horizontal leveling

If the panel is not level, shims are placed under the panel. Galvanized metal washers or rubber shims are allowed. A maximum 3/8 inch in total shim height, at any location, is allowed. If more shims are required, then the leveling pad is not level or the panel bottoms are not flat. In either case, the issue is the Contractor's responsibility to resolve.

Figure 840.4.D.8 Metal shims to level the panels

Horizontal Joint Spacing

Without the correct joint spacing, panel corners will crack and spall with wall settlement. As the panels are placed together, the 3/4-inch spacer blocks are placed in the joints. The panels are adjusted so that there is contact between both panels and the spacer. The required joint spacing is ½ to 1 inch. The spacer is shown in the figure below.

Figure 840.06.D.9 - Wooden joint spacers

If this spacing cannot be achieved, the Contractor is required to submit an action plan to correct the problem.   If the panel is moved during the joint spacing adjustment, then the horizontal leveling should be checked again.

Leave the horizontal spacers in place until half of the panel height has been backfilled.

Vertical Alignment

Panels should be set with a batter toward the inside of the wall. The typical batter is about 1/8 inch per foot of panel height or about 1/2 to 1 inch per panel. Placement and compaction of the backfill behind the wall rotates the top of the panel outward, so the panel will be vertical once fill placement is complete.

The amount of batter should be adjusted for backfill properties and soil reinforcement type. A fine-graded, sandy material may require a 1-inch batter, while a well-graded, crushed limestone may require a 1/2-inch batter. A geosynthetic reinforcement will require more batter than a steel reinforcement. Generally, the wall system supplier should know when the batter would need to be adjusted.

Figure 840.06.D.10 - Batter check

A level with a batter spacer is placed on the outside or inside of the wall. Use the outside of the wall unless textured. The batter spacer can be used on the top or bottom of the level. If the level is used on the outside of the wall, the batter spacer is used on the top of the level. If the level is used on the inside of the wall, the spacer is used on the bottom of the level. In the figure below, the level and batter spacer is being used on the inside of the wall.

Figure 840.06.D.11 - Vertical leveling spacer on the inside of the wall

The level can also be used on the outside of the wall as shown below.

Figure 840.06.D.12 - Vertical batter on the outside of the wall

Vertical and horizontal alignments and joint spacing should be checked prior to temporarily locking the panel in place. During the entire time the horizontal leveling, joint spacing and vertical alignment are being adjusted, the panel is still suspended from the crane so that the panel is not damaged.

Wooden Wedges and Clamps

Wooden triangular wedges are used to lock the panel into vertical alignment once the wall is battered with the level. The wedges are shown below on the leveling pad.

Figure 840.06.D.13 - Wooden wedges for vertical alignment

No more than three vertical levels of the wooden wedges should be placed in the wall without removing the lower row. If more than three levels of wedges are used they may become bound in the joint and can cause the panel to spall.

Wooden clamps are used to temporarily hold the panels together. Wooden clamps are two pieces of wood held together with a long bolt. The bolt is tightened to hold the panels together.

Figure 840.06.D.14 - Wooden clamps

Triangular wedges are also used in combination with the clamps to secure the upper panel in its battered position as shown in the figure below.

Figure 840.06.D.15 - Triangular wedge with wooden clamp

External bracing is required for the first row of panels to maintain stability and alignment. Typical bracing is shown below.

Figure 840.06.D.16 - Proper bracing

At this point, the geotextile, select granular backfill, and first row of soil reinforcement are placed to the height of the wooden clamps. These steps will be described in detail later.

When panels are placed on one another, a horizontal bearing pad is used to separate the panels. A minimum of two bearing pads is used. The horizontal joint should be 3/4 inch at this point. Some Accredited Wall Systems may supply thicker bearing pads and have different joint sizes. This is in anticipation of the bearing pads compressing more under the load of the panels. Check the accepted wall shop drawings to ensure that the thicker pads are allowed.

Figure 840.06.D.17 - Bearing pads on lower panel

Subsequent panel rows are placed between panels that were previously placed. The ability to properly space and align these rows relies on the proper placement of the lower rows. The errors produced in the lower rows are propagated upward and are difficult to correct. The same leveling, joint spacing, and vertical and horizontal alignment tolerances apply to all the rows.

Figure 840.06.D.18 - Panel placement

Panel-to-panel face offset should be checked as soon as the next row of panels is placed. Use a straightedge across the horizontal joints to ensure that the offset between the lower and upper panels is less than 1/2 inch. The process is repeated as crow bars are used to align the next row of panels.

Figure 840.06.D.19 - Next row of panels placed and adjusted

Figure 840.06.D.20 - Face offset problem at horizontal joint

Alignments should be checked periodically to ensure proper alignment. This will ensure that issues are spotted early and corrections can be made before the panels become further out of alignment.

Figure 840.06.D.21 - Wall alignment

The panels are back battered so that the fill placement and compaction can rotate them outward into a vertical position. After the fill is placed, check the vertical position of the wall. After the third row of panels is placed, use a plumb bob to check the vertical alignment. Hold the plumb bob at the top of the panel and measure the plumbness deviation, as shown below.

Figure 840.06.D.22 - Checking vertical alignment with a plumb bob

The vertical alignment tolerance is 1/2 inch in 10 feet. By using a 10-foot straightedge and a level or a plumb bob, this tolerance can be measured. At no point along the straightedge can any portion of the panel be more than 1 inch away from the string or straightedge.

Figure 840.06.D.23 - Measure from the wall to the string (out of plumb here)

A summary of the wall erection tolerances are listed below:

1. Vertical Tolerance: 1/2 inch overall and 1 inch at any point.
   Use a 10-foot straightedge or plumb bob.
2. Horizontal Tolerance: 1/2 inch overall and 1/2 inch at any point.
   Use a 10-foot straightedge.
3. Panel to Panel Tolerance: 1/2 inch horizontal and vertical.
   Use a 6-foot straightedge.

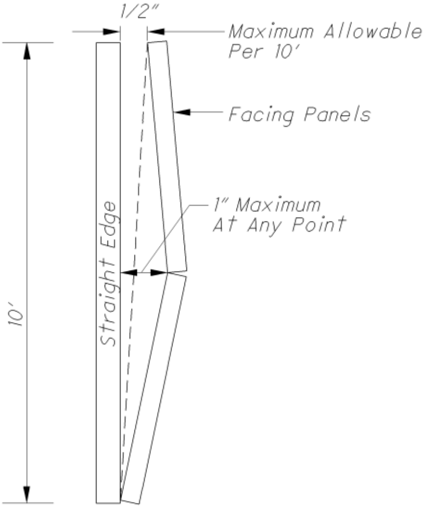


Figure 840.06.D.24 - Vertical panel tolerances

Geotextile Fabric Placement and Inspection (840.06.G)

Geotextile fabric is placed across the joints so that the granular backfill does not leak through the joints to the outside of the wall. The minimum lap on each side of the joint

is 6 inches on each side of the joint and 1 foot along any cut piece of geotextile along the joint. These requirements apply to horizontal and vertical joints.

The geotextile should be cut in lengths to cover the horizontal and vertical joints, and any necessary overlaps. An adhesive is used to hold the geotextile in place until the select granular backfill is placed over the joints. A thick bead of the adhesive, approximately 1/2 inch in diameter, is applied around the entire perimeter of the fabric, about 2 inches from the edges of the fabric. The adhesive may be applied to either the geotextile (see the figure below) or to the facing panel.

Figure 840.06.E.1 - Correct application of adhesive on geotextile

Once adhesive is applied, the geotextile should be immediately placed on the wall, before the adhesive dries. The geotextile should be flat and not wrinkled or folded. It should fully engage the wall along its perimeter to keep the backfill from leaking through the joints.

Figure 840.06.E.2 - Geotextile completely covering the joints

If the adhesive is applied to the panel, the adhesive bead must be located to continuously seal the entire perimeter of the geotextile piece.

Figure 840.06.E.3 - Poor application of the adhesive on the wall

As shown above, randomly placing adhesive on the wall does not ensure that the joint is properly sealed. More adhesive is not necessarily good. Correctly applied adhesive and the appropriate placement of the geotextile is the solution.

Figure 840.06.E.4 - Unacceptable partial gluing (do not allow this)

The geotextile must be fully glued to the panel. Premature drying of the adhesive or rough backfill placement can cause the geotextile to not adhere to the panel.

Partially glued edges, small tears or wrinkles in the geotextile can allow leaking of backfill. Any leaking of material through the joints is not tolerable. Once the geotextile and the backfill are placed, the project staff should inspect, from the front of the wall, the joint spaces and the geotextile's ability to retain the backfill. Look at the joints to see if the geotextile is in place and look for deposits of sand in the joints, as shown below.

Figure 840.06.E.5 - Sand in the joints on the outside of the panels

Sand deposits may be caused by material falling over the wall during construction or the material leaking through the joints. By carefully inspecting the joints, the source of the deposit will be found. In the figure below, the sand is leaking out of the joints and being deposited on the ground.

Figure 840.06.E.6 - Sand deposited from several joints

This project was about three-years-old when this material leakage was investigated. It was found that the geotextile was not placed in the upper portion of the wall. An inspection during the construction of the wall would have prevented this problem.

Figure 840.06.E.7 - No geotextile placed behind the wall

The photo below was taken shortly after construction. There are large sand deposits at the bottom of the slip joint. In this case, the geotextile was either not placed or improperly placed.

Figure 840.06.E.8 - Sand deposits around slip joint

In the figure below, at a typical slip joint during construction, it can be seen that the geotextile has to go around a bend. Careful construction in this location is required. When placing geotextile around corners or obstructions, leave the geotextile loose so that it does not tear during the placement of the backfill in the corner.

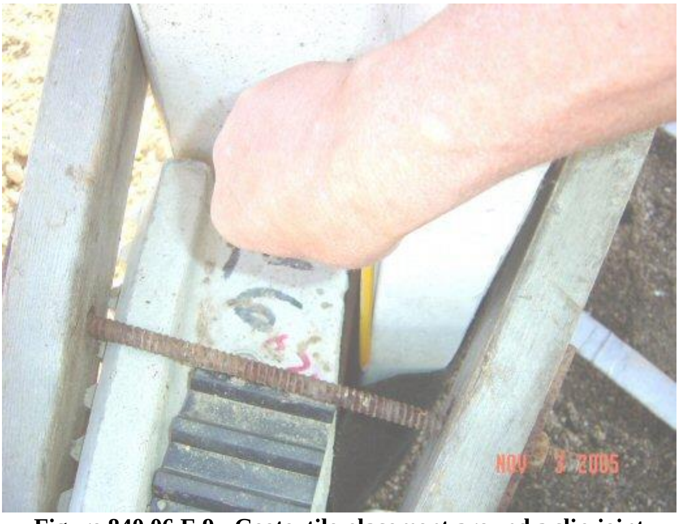


Figure 840.06.E.9 - Geotextile placement around a slip joint

There are other work details that may obstruct the proper placement of the geotextile. In the figure below, there are the soil reinforcements, wooden clamps, and a plastic pipe that obstruct the geotextile placement.

Figure 840.06.E.10 - Obstructions near a slip joint

There may be cases where the joint spacing has become wider than the allowable maximum of 1 inch, while the wall is being constructed. It is therefore important to periodically check the joint spacing during wall construction.

Figure 840.06.E.11 - Wide joint with exposed geotextile

The joint gap in the above figure is almost 2 inches. The gap is wider than the panel's shiplap, therefore, exposing the geotextile. The width of the shiplap is about 1 ½ inches. In the above case, place expansive foam and caulk to the joint to prevent the geotextile from being exposed to sunlight.

Sunlight can cause the geotextile to deteriorate with time, whether direct or indirect sunlight. A flashlight is used to check sunlight exposure onto the geotextile. As shown in the following figure, a flashlight is held perpendicular to the joint, about 6 inches away

from the joint. If the light from the flashlight can be seen on the geotextile, then the Contractor needs to be instructed to seal the joint.

Figure 840.06.E.12 - Flashlight test

There have been instances where, after the wall has been constructed, the geotextile is damaged during pressure washing operations. Pressure washing is used to clean the panels prior to concrete sealing; therefore, reexamine the joints after the sealing operation.

As a final note on the wall construction, continue to monitor the wall throughout the duration of the project. The wall is designed and constructed to tolerate movement, however, too much movement may be detrimental to the wall and the structural items around the wall.

Soil Reinforcement Installation (840.06.H)

Soil Reinforcement Storage

The soil reinforcement should be stored on dunnage and carefully handled to prevent damage. Damage may include bending of the metallic reinforcement and damaging the galvanization. The geogrid soil reinforcement should not be torn, cut, left in the sun, or otherwise damaged.

No equipment should be allowed to run directly on the reinforcement.

Figure 840.06.F.1 - Reinforcement storage on dunnage

The project staff should check for required length and gauge of steel reinforcement. Check the condition of steel reinforcement upon delivery to the site. Geosynthetic soil reinforcement is delivered in rolls that may have different strengths (product numbers) and are very similar in appearance. These different products should be clearly marked and separated in the storage area.

Below is a typical plan view of the soil reinforcement on a project. The length of the reinforcement from the wall is directly proportionate to the height of the wall. The wall height below is the highest in the center and the length of the reinforcing is the longest. The length of the reinforcing cannot change from the bottom to the top of the wall. It can only change along the wall due to changes in the height or design changes.

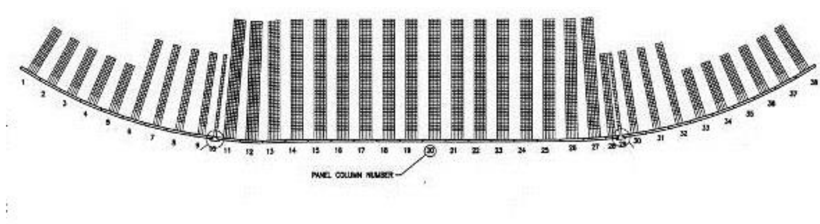


Figure 840.06.F.2 - Typical reinforcement layout

Below is a cross sectional view of the geogrid soil reinforcement MSE wall. Notice the soil reinforcement connection to the facing panels and regular vertical intervals. Although the spacing may need to be smaller at the top or bottom of the wall. The length of the reinforcement is the same from the bottom of the wall to the top of the wall. Many MSE walls are used in abutment applications as detailed below.

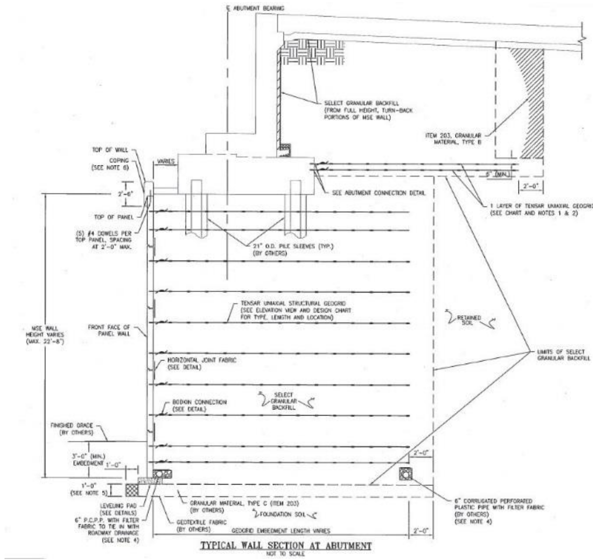


Figure 840.06.F.3 - Cross section of the soil reinforcement layout

For walls with mesh soil reinforcements, the reinforcing mesh bar sizes and spacings will change frequently within the wall. Below are the reinforcing mesh detail codes for a Retained Earth wall. The project staff should become familiar with their codes on the shop drawings and ensure that the correct mesh types are placed in the proper locations.

Careful review of these keys is required by the project staff.

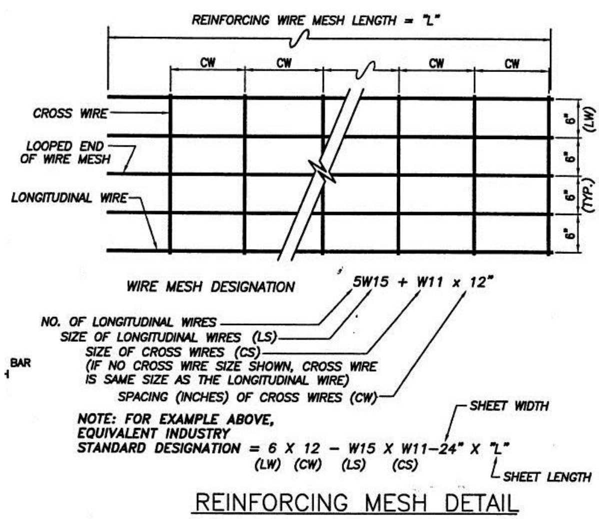


Figure 840.06.F.4 - Reinforcing mesh details

The figure below is an example of how the reinforcing mesh is laid out as it relates to the facing panels. The panels are numbered in the example and the type of reinforcing mesh is detailed beside the panel type.

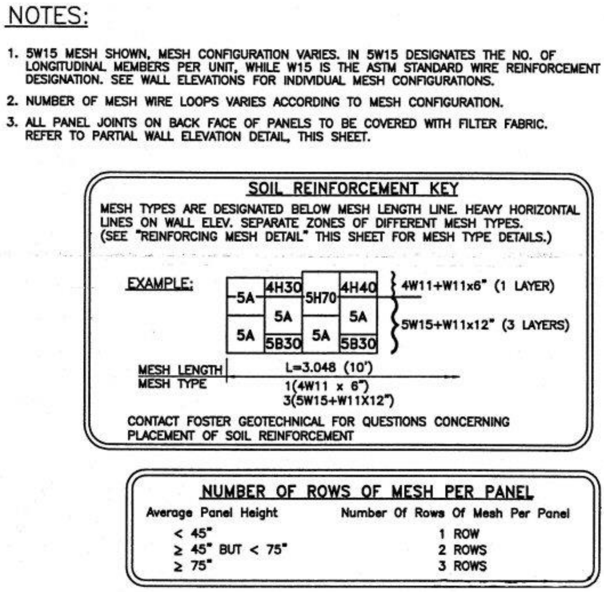


Figure 840.06.F.5 - Reinforcing panel and reinforcing key

Typically, the reinforcement is placed perpendicular to the wall face. Any slack in the reinforcement should be removed by pulling.

Geogrid soil reinforcement is required to have some tension placed in the reinforcement and remove slack from the connection at the facing panel. By using the placement and compaction procedure detailed in the following section, the tension in the reinforcements will be maintained.

The soil reinforcement is laid out once select granular backfill placement approaches the elevation of the soil reinforcement. The reinforcements are then attached to the facing panels and placed perpendicular to the face of the wall on top of the compacted material.

Connections

Connecting the soil reinforcing to the wall is a relatively simple operation. Three connections are detailed below.

a. Bolted Connection

Wall systems with bolted connections use galvanized steel strip soil reinforcements, connection devices of twin steel tabs cast into the facing panel, and washers, nuts and bolts to connect them. The tabs with predrilled holes stick out of the panel about 3 inches. The top and bottom tabs envelope the reinforcement strip when they are connected.

Figure 840.06.F.6 - Bolted connection with strip

At times, there is concrete inside the tabs that make it difficult to place the strips inside the tabs. The concrete should be cleaned out to line up the holes. Many times the Contractor will cut the strips instead of cleaning out the concrete. Do not allow the strips to be cut in the field. This practice will reduce the connection strength by damaging the galvanization.

Figure 840.06.F.7 - Tabs for bolted connection

Once the holes are lined up, the bolt is inserted from the bottom up, a washer is placed over the bolt, and the nut is tightened. By placing the bolt from the bottom, it is easy to see if the nut has been placed on the connection. The washer protects the galvanization on the tab from being scratched when the nut is tightened.

Figure 840.06.F.8 - Bolted connections

Below are multiple strips connected to the facing panel. Leaving the select granular backfill lower at the tabs is acceptable, however the select granular backfill should be as close to the strips as possible for all wall types.

Figure 840.06.F.9 - Steel strip soil reinforcement MSE wall

b. Wire Mesh Connection

The connection for steel wire mesh soil reinforcement consists of hooked eyelets in the panels and reinforcing mesh with two transverse bars at the end. The end of the wire mesh is laid with the two transverse bars resting on top of the hooked eyelets. A rod is inserted through the eyelets, locking the mesh into place, as shown below. Wooden

wedges are placed between the panel and the mesh to put the eyelets in full contact with the mesh and the soil reinforcement in tension.

Figure 840.06.F.10 - Completed wire mesh connection

Below is a typical layout of the soil reinforcement of a wire mesh wall. The select granular backfill should be at the bottom of the mesh at the panel.

Figure 840.06.F.11 - Wire mesh soil reinforcement MSE wall

c. Geogrid Connection

The connection for geogrid soil reinforcement consists of short sections of geogrid cast into the panels and a plastic bodkin bar. The ribs of the geogrid soil reinforcement are meshed with the short sections of geogrid that are cast into the panels. The plastic bodkin

is then weaved between the two sets of ribs and the soil reinforcement is pulled tight. The completed connection is shown below.

Figure 840.06.F.12 - Geogrid soil reinforcement connection

Figure 840.06.F.13 - Geogrid soil reinforcement MSE wall

Obstructions

There are times when the soil reinforcements have to go around obstructions. It is not acceptable to simply leave out the reinforcement at that location. At horizontal obstructions, such as pipes, the reinforcement should not be angled more than 15 degrees up or down. All situations that exceed 15 degrees must be detailed on the accepted shop drawings or acceptable to the Office of Geotechnical Engineering. The soil reinforcement must have a 4 inch clearance above or below the obstruction. When clearing horizontal obstructions, the reinforcement should be smoothly curved around the obstruction. The reinforcement should not be kinked at any time.

The detail below shows a horizontal obstruction lower than the soil reinforcing and connection.

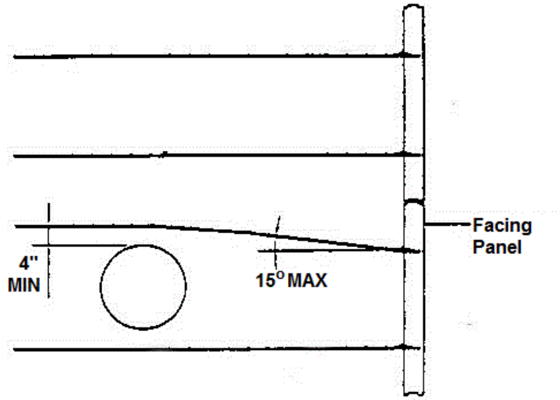


Figure 840.06.F.14 - Soil reinforcement over a horizontal obstruction

The detail below shows a horizontal obstruction higher than the soil reinforcing and connection.

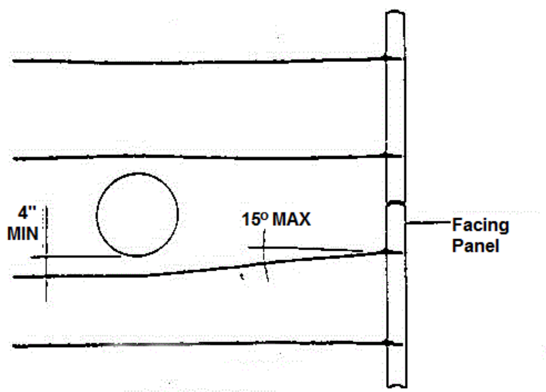


Figure 840.06.F.15 - Soil reinforcement under a horizontal obstruction

The photo below shows the soil reinforcement going under a storm sewer line.

Figure 840.06.F.16 - Soil reinforcement going under a storm sewer line

At vertical obstructions, such as piles or catch basins, if the reinforcement must be splayed more than 15 degrees for steel strips and geogrids or 5 degrees for geosynthetic strips from perpendicular to the facing panels, the accepted shop drawings should detail a modification. All situations that exceed the 15 or 5 degree limits must be detailed on the shop drawings or acceptable to the Office of Geotechnical Engineering. Additional reinforcement length may be required to meet design loads.

Figure 840.06.F.17 - Soil reinforcement splayed around piles

In the detail below, the soil reinforcement was designed around the inlet by using a galvanized angle in front of the inlet and keeping the reinforcing steel perpendicular to the wall. Again, this would have to be detailed on the shop drawings.

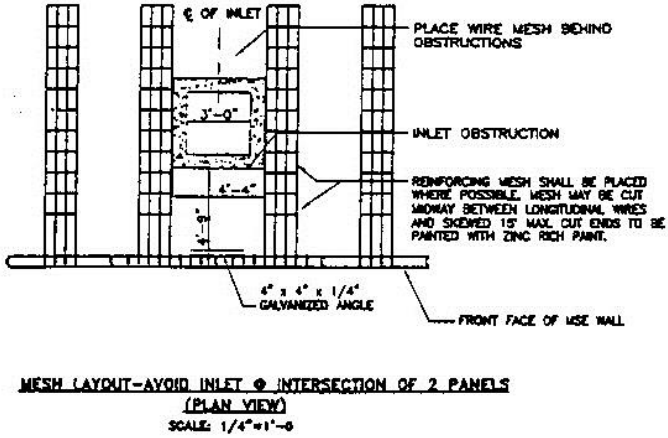


Figure 840.06.F.18 - Typical details for vertical obstruction

Below is a photo of the galvanized angle in front of the catch basin to allow the soil reinforcement to be offset to pass around the catch basin.

Figure 840.06.F.19 - Soil reinforcement offset at an obstruction

In the detail below, the reinforcing mesh is cut and splayed around the inlet. No angle is required in front of the inlet.

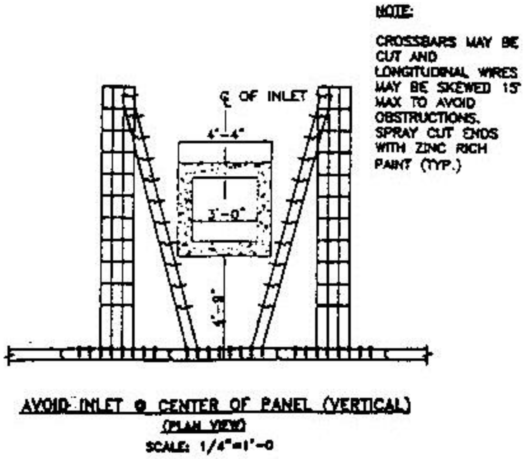


Figure 840.06.F.20 - Cutting the mesh to go around the obstruction

Select Granular Backfill Placement (40.06.I)

Material

The Select Granular Backfill material has special requirements that are not normally associated with granular material in other items of work. There are material requirements such as pH, resistivity, chloride, and sulfate levels. These requirements minimize the corrosion of the metal soil reinforcement. Wall systems using geosynthetic soil reinforcements have different material requirements. The project and district test laboratory need to review and evaluate the test data for these requirements. Ensure that the test results meet the specification requirements and that the correct tests were performed. If the backfill material does not meet these requirements, then there is a high probability that the soil reinforcements will prematurely deteriorate and the life of the MSE wall will be shortened.

Another requirement is the internal angle of friction. The internal angle of friction is critical to the design of the wall. The wall design and the limit states are sensitive to numerical value of the friction angle. The design adequacy can change dramatically with only a few degrees of friction angle change. The design friction angle is 34 degrees.

The specification allows the use of Granular Material Type 2 which can be a fine sand or a coarse Item 304 type material. Since economics drives the material choice, the vast majority of the time sand is used. The specification also allows the use of Item 304 material, which is a well graded and very stable material.

Select Granular Backfill Placement and Compaction

The following placement and compaction procedures were developed to produce uniform compaction of the Select Granular Backfill (SGB). Uniform placement and compaction of this material is essential to maintain uniform pressure against the wall as it is constructed. Unnecessary compaction or non-uniform compaction of this material can create bulges in the wall or loose areas in the backfill behind the wall. This procedure is to be followed for the entire wall height.

For the initial row of panels (and only the initial row of panels), the backfill is not placed against the panel until the first layer of soil reinforcement has been connected and the initial layer of backfill is placed and compacted on top of the soil reinforcement. This prevents the bottom of the panels from “kicking out.” If the SGB cannot be placed and compacted effectively below the first row of soil reinforcement (for example, geogrid soil reinforcements), then the wall supplier will need to design or provide a temporary brace to prevent the wall from displacing at the bottom.

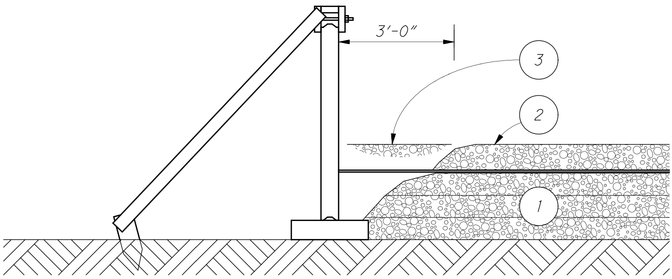


Figure 840.06.G.1 - Backfilling for the first panel only

Once the backfill is placed and compacted to the elevation of the first layer of soil reinforcement as shown in Figure 840.06.G.1, the soil reinforcement is connected. The next loose lift is then placed on top of the soil reinforcement 3 feet away from the wall facing panels. The material is then leveled by moving it parallel to the wall and windrowing the material toward the soil reinforcement free ends and away from the wall. See Figure 840.06.G.2 for the spreading operation details. This SGB material which is 3 feet away from the wall is then compacted in the same way as it was placed.

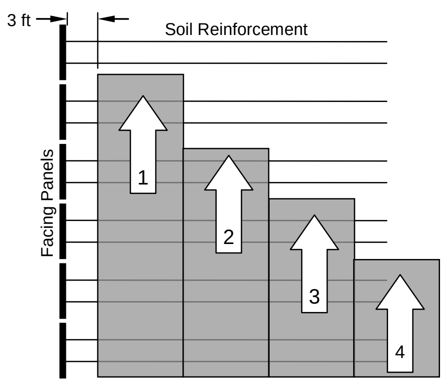


Figure 840.06.G.2 - Procedure for SGB placement and compaction (plan view)

The void is then filled and compacted next to the panels to the elevation of the soil reinforcement. The material void left above the soil reinforcement is then placed and compacted. Place and compact this 3-foot zone as shown in Figure 840.06.G.3. Within 3 feet of the wall, the SGB should be compacted with six passes of a mechanical tamper or vibratory plate compactor. The compaction equipment should have a centrifugal force between 1/2 to 2 tons.

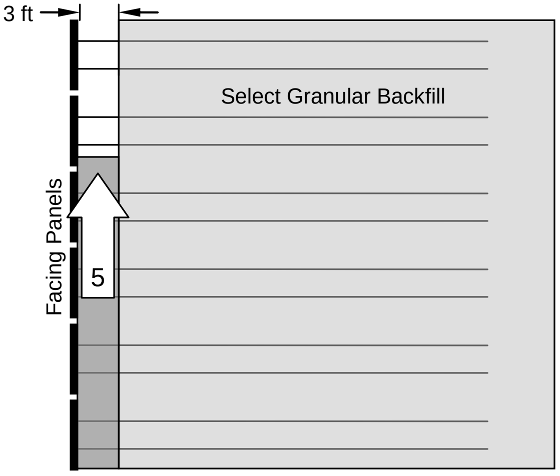


Figure 840.06.G.3 - Place and compact the SGB next to the facing panels

Figure 840.06.G.4 - Final compaction operation next to the wall

Use the procedure detailed in Figures 840.06.G.2 and 840.06.G.3 for the SGB placement and compaction procedure for the remaining sections of wall.

The SGB is placed in maximum 8-inch loose lifts. It may be helpful to mark the lift thicknesses on the back side of the wall panels. The action of moving the SGB parallel to the panel and windrowing or compacting the material toward the reinforcement ends and away from the wall removes the slack in the reinforcement and locks the reinforcement and the panels in position.

Figure 840.06.G.5 - Incorrect spreading technique
(From back to front is incorrect)

Any slack in the reinforcement should be removed to avoid excessive panel movement. With geosynthetic soil reinforcement, tension needs to be applied at the free end of the soil reinforcement during backfill placement. Consistent placement and compaction of SGB are one of the keys to a good performing MSE wall.

Figure 840.06.G.6 - Geogrid tensioning during backfill placement

When SGB placement reaches the next layer of soil reinforcement, the SGB should be placed 2 inches above the connection device and sloped downward to the bottom of the connection, as detailed in Figure 840.06.G.7.

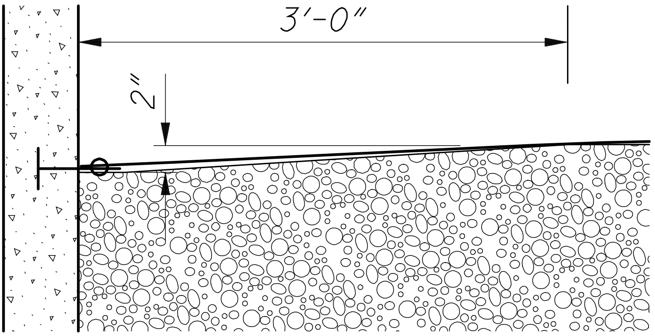


Figure 840.4.G.7 SGB Placement at soil reinforcement level

SGB Inspection and Compaction Testing (840.06.N)

No compaction testing should be performed on the SGB within 3 feet of the facing panels. For the SGB, more than 3 feet from the facing panels, compaction testing is performed according to Supplement 1015 and Supplemental Specification878.

SS 878 details the general inspection and compaction testing requirements when these services are hired through the Contractor. All of the inspection and compaction procedures that are required for ODOT inspection personnel are required for the Contractor's personnel under SS 878. A trained compaction and inspection person is required under this specification. The Department inspection and compaction forms are to be used.

Supplement 1015 details the inspection and compaction procedures to be employed during the work. A test section is constructed to determine the density and roller pass requirements for the SGB. Typically, a Method A test section is used and the moisture content for compaction is determined from the laboratory moisture-density curve. Occasionally, the Method B test section is necessary to determine both the density requirements and the proper compaction moisture content.

The select granular material should be compacted within 2 percent of optimum moisture content to achieve the require density. A minimum of 98 percent of the maximum dry density from the test section is required.

Figure 840.06.H.1 - Taking a compaction test

Occasionally, a new test section should be constructed if the compaction tests are not close to the initial maximum value. New test sections should be constructed if the material, the source, or foundation conditions change.

In the figure below, the compaction starts 3 feet away from the wall and proceeds to the free end of the soil reinforcement. In the background, the area within 3 feet from the wall is compacted after the roller compaction is complete. This procedure is detailed in Section 4.G of the manual.

Figure 840.06.H.2 - Smooth-drum vibratory compaction equipment

Wall Drainage (840.06.F)

Internal Drainage

Internal drainage pipes are installed near the bottom of the SGB to prevent saturation of the backfill. As shown in the typical section in Figure 840.01.C, one drain is located along the facing panels and a second is located at the back of the reinforced soil zone. The drains consist of 6-inch diameter, perforated, corrugated plastic pipe wrapped in geotextile fabric and surrounded by the SGB. The pipes should have positive slope to remove water from of the wall. Outside the SGB limits, outlet pipes are non-perforated and should discharge into a ditch, catch basin, or manhole.

External Drainage

At the end of each day's operation, the Contractor is to shape the last layer of backfill to direct surface runoff away from the wall face. The SGB of the wall can be drained laterally to dissipate excess water toward the ends of the wall. Failure to control surface and subsurface drainage during construction results in problems similar to the figure below.

Figure 840.06.I.1 - Washout around soil reinforcement

Water ponding in front of the wall during construction can also be a significant problem. The figure below shows ponding of water in front of the wall. The water should be pumped out of this area immediately after the water is ponded. In addition, once the wall is erected up to the ground elevation, this wall excavation should be filled with embankment material.

Figure 840.06.I.2 - Water ponding in front of the wall

If water is ponding behind the wall during construction as shown below, the water should be diverted away from the reinforced backfill by ditches draining to the ends of the wall, or by pumping from a sump.

Figure 840.4.I.3 - Water ponding behind the wall

Side slope erosion can also be a problem. One solution has been to construct 2 feet of embankment on the side slopes which bury the highly erosive select granular material and, hence, erosion can be minimized.

Figure 840.06.I.4 - Protection of the erosive side slopes with embankment

Coping (840.06.K)

The coping is placed on the top of the wall to smooth out the appearance of the top of the wall and to connect adjacent panels at the top of the wall. The coping has to be cast in place on the top of the wall facing panels. Below is the typical form and reinforcing steel for the coping.

Figure 840.06.J.1 - Forming the coping

The joints in the coping have to be vertical and aligned with the joints in the facing panels to allow for differential movement of the panels. Aligning the joints is necessary to avoid damage to the coping and facing panels.

Figure 840.06.J.2 - Correctly aligned coping joints

Figure 840.06.J.3 - Incorrect coping joints

Moment Slab & Barrier

The moment slab and barrier is placed at the top of the wall to prevent vehicles from leaving the roadway, and hence, must have a large support system to resist these loads. The reinforcing steel is shown below.

Figure 840.06.J.4 - Moment slab and barrier reinforcing steel

The finished moment slab is shown below.

Figure 840.06.J.5 - Completed moment slab

Some projects have a concrete pavement on top of the moment slab, there may be a problem with crack propagation of the barrier joints on to the pavement. For these cases, review these details carefully and have adjustments made as required to align the joints to avoid this problem.

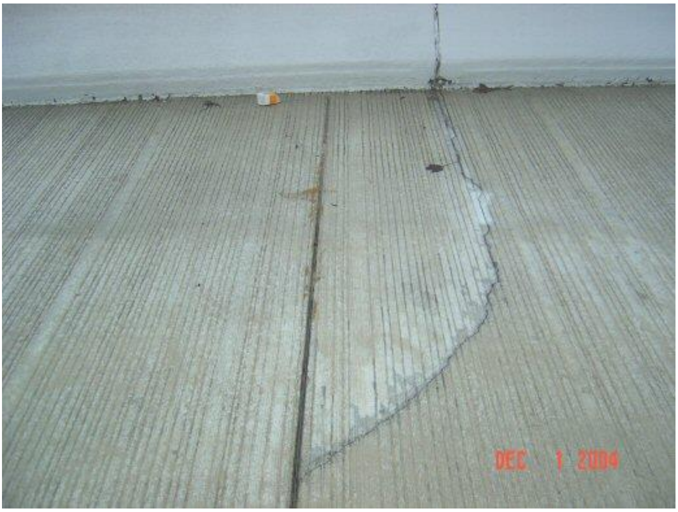


Figure 840.06.J.6 - Align the joints of the barrier and the concrete pavement

Reviews and Checks

Design Conflicts, Design and Construction Loads

Before the actual start of wall construction, the various parts of the plans (MSE wall shop drawings, drainage, lighting, etc.) should be compared to the contract wall plans for conflicts. A conflict may not have been noticed in the design stage. If the plans show loadings on the wall or obstructions in the reinforced soil and the shop drawings do not, the Office of Geotechnical Engineering should be contacted. The Designer may have missed some loadings conditions.

Final Checks

There are various items that should be evaluated at the end of the project, such as fine backfill leaking from the joints, open joints, exposed geotextile, and settlement.

MSE Wall Checklist

The following is a general checklist to follow when constructing a Mechanically Stabilized Earth wall. The answer to each of these should be yes unless the plans, specifications, or specific approval has been otherwise provided.

YES NO

☐ ☐ 1. Has the Contractor submitted wall shop drawings?

☐ ☐ 2. Has the Contractor submitted select granular backfill certified test data?

☐ ☐ 3. Has the Contractor supplied a wall supplier’s construction manual?

☐ ☐ 4. Have the shop drawings been accepted?

☐ ☐ 5. Has the preconstruction meeting been held with all involved parties present?

☐ ☐ 6. Have the correct panels (shape, size, and soil reinforcement connection layout) per the accepted shop drawings been delivered?

☐ ☐ 7. Have the correct reinforcements (proper length and size) been delivered?

☐ ☐ 8. Have the panels and the reinforcement been inspected for damage as outlined in the specifications?

☐ ☐ 9. If any panels or soil reinforcement were found damaged, have they been rejected or repaired in accordance with the specifications?

☐ ☐ 10. Are the panels and the soil reinforcement properly stored to prevent damage?

☐ ☐ 11. Has the MSE wall area been excavated to the proper elevation?

☐ ☐ 12. Has the foundation been properly evaluated?

☐ ☐ 13. Has the drainage for the wall been installed?

☐ ☐ 14. Has the leveling pad area been properly excavated?

☐ ☐ 15. Has the leveling pad been set to the proper vertical and horizontal alignment?

☐ ☐ 16. Has the leveling pad obtained the minimum strength required before setting any panels?

☐ ☐ 17. Is the first row of panels properly placed? Do they have proper spacing, bracing, and batter?

☐ ☐ 18. Has the proper geotextile and adhesive been supplied?

☐ ☐ 19. Is the geotextile being properly placed over the joints?

☐ ☐ 20. Is the geotextile (and geogrid reinforcement if used) being stored properly (stored out of the sunlight and protected from UV radiation)?

☐ ☐ 21. Is the Contractor using the correct panels (correct size, shape, and with the proper number of connections) for that panel’s wall location and elevation?

☐ ☐ 22. Is the fill being placed and compacted in 8-inch loose lifts?

☐ ☐ 23. Is the equipment being kept off of the soil reinforcement until a minimum of 8 inches of select granular backfill is placed?

☐ ☐ 24. Are the lifts being placed by the proper method and sequence?

☐ ☐ 25. Is the fill being compacted by the correct equipment and in the correct pattern?

☐ ☐ 26. Is the proper compaction being met?

☐ ☐ 27. Is the soil reinforcement being properly connected (connections tight and all of the slack in the soil reinforcement removed)?

☐ ☐ 28. Is the soil reinforcement in the proper alignment?

☐ ☐ 29. Is the vertical and horizontal alignment being checked periodically and adjusted as needed?

☐ ☐ 30. Is the Contractor removing the wooden wedges as per the specifications? (The wooden wedges shall be removed as soon as the panel above the wedged panel is completely erected and backfilled.)

☐ ☐ 31. At the end of each day's operation, is the Contractor shaping the last layer of backfill to direct surface runoff away from the wall face or providing a positive means of controlling runoff away from the wall, such as temporary pipe, etc.?

☐ ☐ 32. Has the Contractor backfilled the front of the wall?

☐ ☐ 33. Is the coping being installed correctly?

MSE Wall Construction Do's and Don'ts

1. Review approved shop drawings.
2. Review the Section 840 in the MOP for Mechanically Stabilized Earth (MSE) walls.
3. Verify leveling pad elevations.
4. Confirm select granular backfill material has been tested and approved before it is brought to the site.
5. Inspect panels.
6. Inspect soil reinforcement for damage.
7. Reject all panels that are not in compliance with the plans and specifications.
8. Ensure panels, soil reinforcements, and geotextiles are properly stored to prevent damage.
9. Ensure the reinforcing can go around all obstructions with less than 15 degrees of splay, or 5 degrees of horizontal splay for geosynthetic strips.
10. Install panels in accordance with the plans and specifications.
11. Place and properly compact fill in accordance with plans and specifications.
12. DO NOT use thick fill lifts. Fill lifts thicker than 8-inch loose lifts require more energy to compact and may move the panels out of alignment.
13. Use corner panels at all corners. If corner panels are not indicated on the plans, the designer should be notified.
14. Metallic soil reinforcement strips should not be splayed more than 15 degrees from normal. Geosynthetic soil reinforcement strips should not be splayed more than 5 degrees from normal. If reinforcement needs to be splayed more than the 15 or 5 degree limits, notify the designer.
15. Check the batter of the panels often. Adjust accordingly. The vertical alignment of the panels below the panels being installed may be affected by the compaction of the soil behind the panels being installed.
16. Check overall batter regularly.
17. When attaching geotextile to the back of the panels, it is preferable to apply the adhesive to the geotextile, and then place it on the panels.

Out of Tolerances Conditions and Possible Causes Criteria

MSE structures are to be erected in strict compliance with the structural and aesthetic requirements of the plans, specifications, and contract documents. The desired results can generally be achieved through the use of quality materials, correct construction/erection procedures, and proper inspection. However, there may be occasions when dimensional tolerances and/or aesthetic limits are exceeded. Corrective measures should quickly be taken to bring the work within acceptable limits. Presented below are several out-of-tolerance conditions and their possible causes.

Table 840.A – Out-of-Tolerance Conditions and Possible Causes

Distress	Possible Causes
1. Distress in wall: Differential settlement or low spot in wall. Overall wall leaning beyond vertical alignment tolerance. Panel contact, resulting in spalling/chipping	Foundation (subgrade) material too soft or wet for proper bearing. Fill material of poor quality or not properly compacted.
2. First panel course difficult (impossible) to set and/or maintain level. Panel-to-panel contact resulting in spalling and/or chipping.	Leveling pad not within tolerance.
3. Wall out of vertical alignment tolerance (plumbness), or leaning out.	Panel not battered sufficiently. Oversized backfill placing and/or compaction equipment working within 3 foot zone of back-of-wall facing panels. Backfill material placed wet of optimum moisture content. Backfill contains excessive fine materials (beyond the specifications for percent of materials passing a No. 200 sieve). Backfill material pushed against back of facing panel before being compacted above reinforcing elements. Excessive or vibratory compaction of uniform, medium-fine sand (more than 60 percent passing a No. 40 sieve). Backfill material dumped to close to free end of reinforcing elements, then spread toward back-of-wall, causing displacement of reinforcements and pushing panel out. Shoulder wedges not seated properly. Shoulder clamps not tight. Slack in reinforcement to facing connections. Inconsistent tensioning of the geosynthetic reinforcement. Localized over compaction

Distress	Possible Causes
4. Wall out of vertical alignment tolerance (plumbness) or leaning in.	Excessive batter set in panels for select granular backfill material being used. Inadequate compaction of the backfill. Possible bearing capacity failure.
5. Wall out of horizontal alignment tolerance, or bulging.	Backfill material placed wet of optimum moisture content. Backfill contains excessive fine materials (beyond the specifications for percent of materials passing a No. 200 sieve). Backfill material pushed against back of facing panel before being compacted above reinforcing elements. Excessive or vibratory compaction of uniform, medium-fine sand (more than 60 percent passing a No. 40 sieve). Inconsistent tensioning of the geosynthetic reinforcement. Localized over compaction. Backfill saturated by heavy rain or improper grading of backfill after each day's operations.
6. Panels do not fit properly in their intended locations.	Panels are not level. Differential settlement (see Cause 1). Panel cast beyond tolerances. Failure to use spacer bar.
7. Large variations in movement of adjacent panels.	Backfill material not uniform. Backfill compaction not uniform. Inconsistent setting of facing panels.

SS 842 Correcting Elevation of Concrete Approach Slabs with High Density Polyurethane

Description (842.01)

This work consists of correcting the elevation of concrete approach slabs using high density polyurethane (HDP).

Materials (842.02)

At least 24 hours prior to performing work, the Contractor is required to submit certified test data from an independent laboratory proving the high density polyurethane meets the properties specified in 842.02 to the Engineer.

Manufacturer's Shipping Record (842.03)

The Contractor is required to **p**rovide manufacturer batch numbers and shipping invoices for the high density polyurethane.

Equipment (842.04)

The Contractor is required to use the following equipment, as a minimum:

1. Electric or Pneumatic drill capable of drilling 5/8-inch diameter holes to the depth of the slab.
2. Truck or trailer mounted pumping unit, with pre-heaters and volumetric controls capable of injecting the HDP between the approach slab and sub-base. The unit shall be equipped with certified flow meters to measure flow of both component materials separately to measure the amount of high-density polyurethane injected at each location. The certified flow meter shall have a digital output to show both pounds and gallons of each component material and help insure a one to one mix ratio.
3. Laser-leveling unit to ensure that the approach slab is raised on an even plane and to the required elevations.

Construction Plan (842.05)

Prior to performing work, the Contractor is required to submit a plan to the Engineer that includes the following minimum information:

1. Existing elevations of the approach slab and adjacent pavement.
2. Proposed elevations of the approach slab and adjacent pavement
3. Injection hole layout
4. Mapping of Existing Cracks
5. Contractor's written standard installation plan.

Figure 842.05 - Sunken approach slab

Drilling Holes (842.06)

The Contractor is required to locate and drill a series of 5/8-inch holes as necessary to raise the slab, not less than 12 inches nor more than 18 inches from each edge or joint. The spacing of holes shall not exceed 4 feet (1.2 m) center to center in any direction.

Figure 842.06 - Holes drilled in approach slab

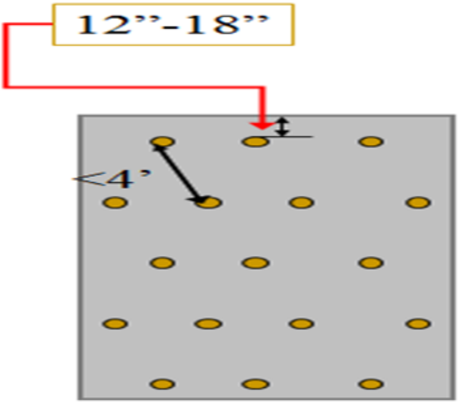


Figure 842.06 - Hole spacing for approach slab

Raising Slabs (842.07)

Work is not permitted when the subgrade temperature is below 32 °F (0 °C) or visibly frozen. The Contractor is required to inject HDP under the slab according to the Contractor’s written standard installation procedures to control the amount of approach slab rise by regulating the rate of injection of the HDP material.

Raise slab to within 3/16 inch (5mm) of the elevations proposed by profile. For section lengths of 50 feet (15 m) or less, use a tight string line or laser level to monitor and verify elevations. For longer sections, use a laser level to monitor and verify elevations. Do not raise slabs more than 1/2 inch (12 mm) while pumping in any one hole at any one time. The Contractor must take precautions to prevent damage to the existing slabs. Stop the operation if cracking occurs during the raising of the slab.

Repair approach slab and pavement areas that do not meet proposed elevations. Repair all areas damaged as a result of the work. Make repairs to the satisfaction of the Engineer.

The Contractor is required to use the flow meters to determine and record the amount of high density polyurethane used and record final elevations of the approach slab and adjacent pavement in the same locations as were recorded for existing elevations prior to beginning work.

Figure 842.07 - Placing polyurethane in holes in approach slab

Filling Holes (842.08)

After the approach slab has been brought to grade, the Contractor is required to clean holes to the depth of the slab, then fill with non-shrink nonmetallic grout conforming to C&MS 705.20.

The Department will measure the weight of HDP material pumped and pay by the pound of the high density polyurethane used.

Figure 842.08 - Checking elevation of approach slab

SS 847 Bridge Deck Repair and Overlay with Concrete using Scarification and Chipping

SS 848 Bridge Deck Repair and Overlay with Concrete using Hydro-demolition

Description (847/848.01)

This work consists of furnishing the necessary labor, materials and equipment to repair and overlay concrete bridge decks, backwalls, and approach slabs in accordance with these specifications and in reasonably close conformity with the grades, thickness, and cross sections shown on the plans or as directed by the Engineer. This work shall include the removal of patches other than sound concrete and all loose and unsound concrete by scarification and or hydro-demolition; hand chipping, preparation of the sound existing concrete surface; removal, forming and concrete for full-depth repairs; blast cleaning or high pressure water cleaning; furnishing, placing, finishing, texturing and curing of a micro silica modified concrete (MSC) overlay, a latex modified concrete (LMC) overlay, or a superplasticized dense concrete (SDC) overlay, as specified; and all other operations necessary to complete this work according to these specifications and to the satisfaction of the Engineer.

Removal of flexible (asphalt) concrete overlays and rigid concrete overlays are included as part of this work if the items Wearing Course Removed, Asphalt, Existing Concrete Overlay Removed ____ Nominal Thickness or Removal Debonded, Deteriorated Existing Variable Thickness Concrete Overlay are part of the project plans.

Bridge Decks with No Existing Rigid Concrete Overlay (847/848.02)

The Contractor is required to remove a uniform depth “D” of the existing deck across its entire surface. In addition to the uniform removal depth, remove unsound concrete where it is encountered. The finished surface of the proposed concrete overlay shall be a dimension “T" above the bottom of the uniform removal depth.

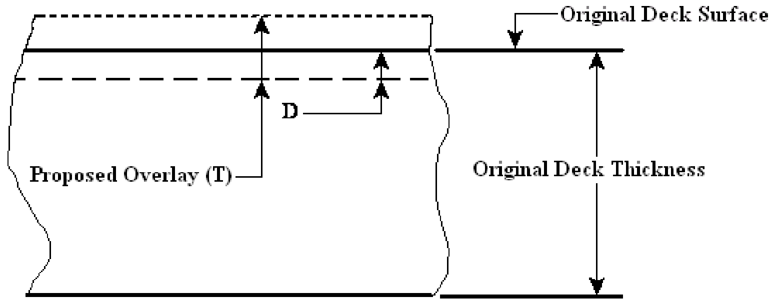


Figure 847/848.02- Illustration of removal and overlay thicknesses for deck with no existing rigid overlay

Bridge Decks with an Existing Rigid Concrete Overlay (847/848.03)

The Contractor is required to remove the plan specified nominal thickness of the existing concrete overlay. Remove a uniform depth “D” of the existing deck’s original concrete across its entire surface. In addition to the uniform removal depth, “D”, remove unsound concrete where it is encountered. The finished surface of the proposed concrete overlay shall be a dimension “T" above the bottom of the uniform removal depth.

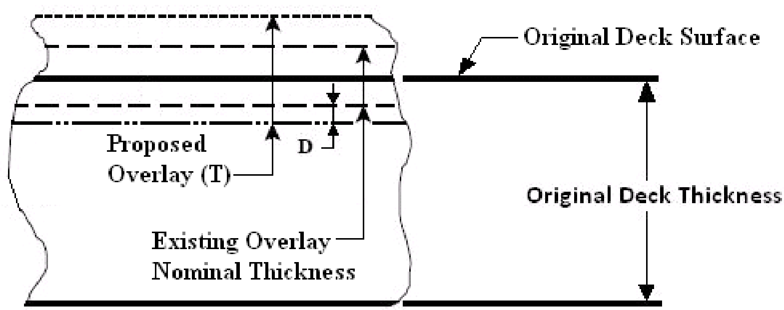


Figure 847/848.03- Illustration of removal and overlay thicknesses for deck with an existing rigid overlay

Materials for Micro-silica Modified Concrete (847/848.04) Latex Modified Concrete (847/848.05) Superplasticized Dense Concrete (847/848.06)

The Contractor is required to furnish aggregates according to Item 703.02, Portland Cement according to 701.01 or 071.04, air-entraining admixture according to 705.10, superplasticizing admixture according to 705.12 (Type F), curing materials per 705.05 or 705.06, Micro-silica admixture according to 701.10, and Latex emulsion according to SS 953. . The Contractor will obtain a written statement from the manufacturers of the chemical admixtures verifying the compatibility of the combination of materials and the sequence in which they are combined. The technical representatives shall act in an

advisory capacity and will report to the Contractor and the Engineer any operations and procedures which are considered by the representative as being detrimental to the integrity of the placement.

Mixers - Micro-silica Modified or Superplasticized Dense Concrete (847/848.07)

1. Concrete shall be mixed in a central mixing plant or by a ready-mixed concrete truck capable of discharging concrete having a maximum water-cementitious ratio of 0.36.
2. Mixing equipment shall meet the requirements of 499.05(B).
3. Admixtures shall be introduced into the concrete in such a manner that will disperse them throughout the entire load.
4. Batch plants shall meet the requirements of 499.05(A) and shall be located such that the maximum time required from start of mixing to completion of discharge of the concrete at the site of work shall not exceed 90 minutes.

Mixers - Continuous Mobile for Latex Modified Concrete (847/848.08)

1. Be capable of producing not less than 6 cubic yards (4.6 m3) of LMC without recharging.
2. Be equipped with a recording meter with a ticket printout device to record an indication of the cement quantity being introduced into the mix. The metering device shall be accurate within a tolerance of -1 to +3 percent. Mixing equipment shall meet the requirements of 499.05(B).
3. Be equipped with a latex metering device to indicate volume dispensed. The metering device shall be accurate within a tolerance of -1 to +2 percent. In addition the latex tank shall have a stand pipe marked in gallons (liters).
4. Be equipped with a water flow indicator, and have a water flow control that is readily adjustable to provide for minor variations in aggregate moisture content. The flow indicator shall be accurate within a tolerance of + 1 percent in the range of expected use.
5. Be equipped with a control to regulate the quantity of each of the LMC components to permit production of a mix having the specified composition. To ensure that the mixer can accurately proportion and blend all components of the LMC on a continuous or intermittent basis, the mixer shall be calibrated prior to the start of the overlay placement.
6. Be capable of discharging mixed LMC through a conventional chute directly in front of the finishing machine.
7. Be kept clean, free of partially dried or hardened materials, and properly operating at all times.

Figure 847/848.08- Latex modified concrete continuous mobile mixer during overlay placement

Finishing Machine (847/848.09)

The Contractor is required to furnish a finishing machine that meets the requirements of C&MS 511.16, which includes being self- propelled, equipped with forward and reverse drive mechanisms that enable precise velocity control of the machine, equipped with one or more rotating rollers, equipped with augers and either a vibrating pan or vibrating rollers. Vibrating frequency for pans and rollers shall be variable from 1500 to 5000 pulses per minute. The Contractor shall furnish the necessary verification of these vibration frequencies. Screeds shall have provisions for raising above the finished concrete surface.

The placing and finishing equipment shall be designed so that the elapsed time between depositing concrete and final finishing shall not exceed 10 minutes.

Figure 847/848.09- Finishing machine with rail during overlay placement

Finishing Machine Rail and Supports (847/848.10)

The Contractor is required to furnish finishing machine rails and supports that meets the requirements of C&MS 511.16, which includes that the weight of the finishing machine causes zero vertical deflection while in motion.

Hydro-demolition Equipment (848.11)

The hydro-demolition machine shall be a self-propelled machine that utilizes a high pressure water jet stream capable of removing concrete to the depth specified herein and/or as shown on the plans and be capable of removing rust and concrete particles from reinforcing steel. Always wear eye protection around this equipment and keep hands and feet away from the high pressure water jets.

Hand held high pressure [10,000 psi (690 bar) minimum] wands or 35 lb (16 kg) maximum jackhammers operated at no more than a 45 degree angle from horizontal shall be used in areas that are inaccessible to the self-propelled machine or in patching areas that require work to remove the remaining unsound concrete.

Figure 848.11- Hydro-demolition machines

Proportioning and Mixing of Micro-silica Modified Concrete (847.11/848.12) / Latex Modified Concrete (847.12/848.13) / Superplasticized Dense Concrete (847.13/848.14)

The required characteristics of the overlay mix, i.e. air entrainment and slump, shall be adjusted off the deck before placement of the overlay begins. The components of the micro silica modified concrete, or latex modified concrete, or superplasticized dense concrete shall be combined into a workable mixture of uniform composition and consistency. Overlays are not QC/QA Contractor designed mixes. The required proportions of the constituents of the micro silica modified concrete mix are listed in SS 847.11 and 848.12. The required proportions of the constituents of the latex modified concrete mix are listed in SS 847.12 and 848.13. The required proportions of the constituents of the superplasticized dense concrete mix are listed in SS 847.13 and 848.14.

The specified cementitious content shall be maintained. For the micro silica modified concrete and or superplasticized dense concrete overlay mixes,

a maximum water-cementitious material ratio of 0.36 shall not be exceeded, after all components have been added, the slump range shall be 6 inches (150 mm) plus or minus 2 inches (50 mm). The air content of plastic concrete at the time of placement shall be 8 plus or minus 2 percent.

Test Slab (847.14/848.15)

At the option of the Engineer, the Contractor shall make one or more trial batches of overlay material of the size to be hauled at least 4 days before the overlay is to be placed. The Contractor shall cast one or more small test slabs demonstrating the ability to finish and texture the concrete in accordance with 847.22.

Protection of the Public (847.15/848.16)

The Contractor is required to provide:

1. Reasonably available engineering controls that limit fugitive dust while being aware that there are state, regional, and local government agencies throughout the State that have requirements regarding control of dust generated by the blasting operation.

2. Protect traffic under and adjacent to the work on the bridge while removing deck concrete.

Figure 847.15/848.16- False decking under bridge to protect traffic during removal of deck concrete

Removal of Existing Asphaltic Concrete Overlays (847.16/848.17)

If an item “847 or 848, Wearing Course Removed, Asphalt” is specified in the plans, the Contractor shall remove the existing asphaltic concrete course to the original concrete deck and any waterproofing material that was part of the deck. Removal shall comply with the requirements of C&MS 202 and be completed before hydro-demolition is

performed. Do not perform additional scarification after the removal of the existing overlay. This item shall be a separate operation from 848.18.

Removal of Existing Concrete Overlays (847.17/848.18)

If an item "847 or 848, Existing Concrete Overlay Removed ____ Nominal Thickness" is specified in the plans, the Contractor shall remove the existing concrete overlay to the nominal specified thickness. Removal shall comply with the requirements of C&MS 202 and as amended below:

Nominal thickness is defined as the specified thickness +/- 1/4 inch (6 mm).

If the Engineer determines during the nominal thickness removal that not enough existing concrete overlay is removed to expose only variable thickness existing concrete overlay islands, the Engineer will require the Contractor to adjust the removal depth, as required, until only variable thickness islands of concrete overlay are visible. Do not perform additional scarification after the removal of the existing overlay.

Removal of Existing Concrete Overlay, Variable Thickness (848.19)

If an item "Item 848, Removal Debonded, Deteriorated Existing Variable Thickness Concrete Overlay" is specified in the plans the Contractor shall perform the following:

1. After removing the existing uniform concrete overlay, the Contractor shall clean the deck to allow sounding.
2. After the Engineer sounds and marks areas of unbounded variable thickness concrete overlay for removal, the Contractor shall remove by chipping all obviously loose, debonded and/or deteriorated concrete overlay (variable thickness), with chipping hammers not be heavier than the nominal 35 pound (16 kg) class and operated at an angle of less than 45 degrees from the deck surface. Any reinforcing steel damaged shall be replaced at the Contractor's expense.

Preparation of Existing Deck (847.18)

For deck preparation for overlays by scarification, the top 1/4 inch (6 mm) of the sound existing concrete surface may be removed by power driven scarifiers, all patches other than sound Portland cement concrete, and all obviously loose and disintegrated concrete shall be removed chipping. Overscarification shall not be allowed and any cost of extra overlay concrete caused by overscarification shall be borne by the Contractor.

1. Chipping hammers shall not be heavier than the nominal 35 pound (16 kg) class and shall be operated at an angle of less than 45 degrees with respect to the surface of the deck.
2. If the use of mechanical scarifying equipment results in exposing or snagging the top mat of reinforcing steel, approval of the use of the scarifying equipment shall be immediately rescinded and the remaining removal will be by hand chipping.
3. Contamination of the deck by construction equipment or from any other source shall be prevented.

4. Where the bond between the concrete and any reinforcing steel has been destroyed, or where more than one half of the periphery of the steel has been exposed, the adjacent concrete shall be removed to a depth that will provide a minimum 3/4 inch (19 mm) clearance around the steel except where other reinforcing steel makes this impractical.
5. Any reinforcing steel damaged shall be replaced at the Contractor's expense.
6. After completion of each removal operation, the Contractor will re-sound and re-outline unsound areas of the deck subject to the approval of the Engineer to ensure that only sound concrete remains.

Figure 847.18- Concrete removal by mechanical scarification and hand chipping

Concrete Removal by Hydro-demolition (848.20)

The intent of this specification is to remove all unsound concrete, both uniform and variable depth, by using hydro-demolition, not scarification or jacking. The entire top surface of the concrete bridge deck shall be completely removed to a minimum depth "D" of 1 inch (25 mm) or as specified in the plans. This measurement shall be taken from the Portland cement concrete surface, immediately prior to the hydro-demolition removal, to the mortar line.

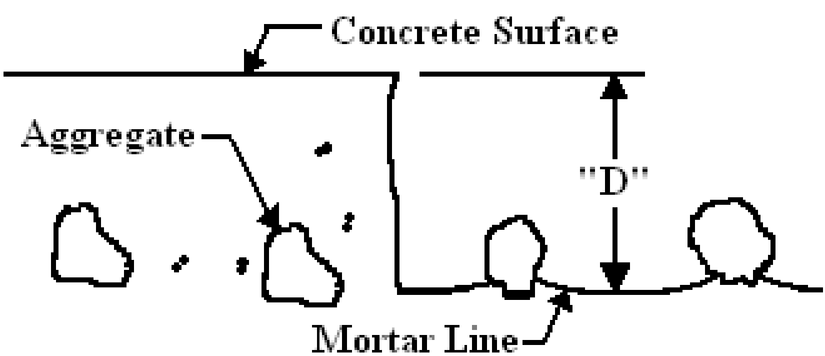


Figure 848.20.A- Concrete removal measurements for Hydro-Demolition

For bridge decks without existing overlays, the Contractor may choose to use conventional scarifying equipment to make an initial pass across the deck to remove ¼ inch (6mm), or depth specified in the plans. The uniform overlay thickness, “T” will need to be increased to account for the scarified removal depth. The final 1 inch, or depth specified in the plans, will be removed using hydro-demolition equipment.

If the use of mechanical scarifying equipment results in exposing or snagging the top mat of reinforcing steel, approval of the use of the scarifying equipment shall be immediately stopped.

Prior to the commencement of the removal operation with hydro-demolition, the equipment shall be calibrated by the Contractor on an area of sound original deck concrete and compared to areas of known unsound concrete. Record machine settings such as:

1. Water pressure gauge
2. Machine staging control (step)
3. Nozzle size
4. Nozzle speed (travel)

Calibration shall be required on each structure, each time hydro-demolition is performed and as required to achieve the results specified by the plan. The depth of removal shall be verified as necessary, and at least every 30 feet (10 m) along the cutting path. The readings shall be documented and, if necessary, the equipment re-calibrated to insure the specified depth of removal.

1. The Contractor shall provide shielding, as necessary, to ensure containment of all dislodged concrete within the removal area in order to protect the traveling public from flying debris both on and under work site.
2. The Contractor is required to contain, collect, quantify, characterize and legally dispose of all wastewater and sludge generated during Surface Preparation using Hydro-demolition according C&MS 107.19 and this Supplemental Specification.
3. The Contractor is required to manage all wastewater and sludge in accordance with ORC Chapter 6111 and all other laws, regulations, permits and local ordinances relating to this waste.
4. The Contractor is required to submit a wastewater and sludge management plan to the Engineer signed by an authorized representative of the Contractor certifying compliance with the Ohio Water Pollution Control Act prior to beginning surface preparation using Hydro-demolition.
    a. The plan shall describe how the work will comply with ORC Chapter 6111 and all other applicable laws, regulations, permits and local ordinances relating to this waste.
    b. The contractor is required to include in the plan, a pH control component that will monitor and prevent the formation of wastewater with a pH above 11.5.
        i. Ensure that all pH monitoring is consistently representative of the wastewater being generated. In the event that the wastewater pH exceeds the regulatory hazardous threshold of 12.5, the contractor is required to immediately stop the operation and notify the engineer.
        ii. Measure and record all wastewater pH with a pH meter equipped with a standard pH probe. Ensure that the pH meter can accurately measure the pH from 0.00 to 14.00.

Hydro-demolition wastewater disposal options include:

1. Recycling at a facility that has a use for the wastewater and can provide verification and manifests that document that the waste was legally recycled.
2. NPDES Permitted Facility that is permitted to accept the waste. Provide verification and manifests that document that the waste was legally discharged at the NPDES Permitted facility. The NPDES Facility's controlling authority may impose additional requirements prior to permitting the wastewater discharge into facility's system.
3. Land application on public right-of-way in compliance with the Ohio EPA General Wastewater Disposal System Permit To Install For Hydro-demolition wastewater. This disposal option is only available when the contract identifies the specific disposal location in the plans.

If a land application disposal location is identified in the contract documents, and the contractor chooses to land apply the wastewater, the contractor shall file the OEPA Notice Of Intent (NOI) for "General Wastewater Disposal System Permit To Install For Land Application of Hydro-demolition Wastewater" (Ohio EPA Permit No. 3745-42-HD001), prior to any wastewater land application activities. Adjust the pH to between 5 and 9 prior to discharging the wastewater during the land application operation.

Figure 848.20.B- Collection of Hydro-demoltion waste water

Resounding (848.21)

After the hydro-demolition operation has completed the removal, and the deck is allowed to dry, the Engineer shall resound the deck to assure that all unsound material has been removed.

Additional removal shall be performed with the hand held wand [10,000 psi (690 bar) min] or 35 pounds (16 kg) maximum weight jackhammer operated at an angle of no more than 45 degrees from horizontal.

If jackhammering results in the exposure of ½ of the reinforcing steel, the adjacent concrete shall be removed to a depth that will provide a minimum 3/4 inch (19 mm) clearance around the reinforcing steel except where other reinforcing steel makes this impractical.

Cleaning (848.22)

Cleaning shall be done in a timely manner, before debris and water is allowed to dry on the deck surface and shall be performed with a vacuum system capable of removing wet debris and water all in the same pass.

All exposed reinforcing steel which is left unsupported by the hydro-demolition process shall be adequately supported and protected from bending from all construction traffic. All reinforcing steel damaged or dislodged by these operations shall be replaced with bars of the same size and coating at no additional cost to the State.

Figure 848.22- Cleaning deck prior to overlay placement

Full Depth Repair (847.19/848.23)

Where the deck is sound for less than one half of the original deck thickness, the concrete shall be removed full depth except for limited areas as may be designated by the Engineer. Forms shall be provided to support concrete placed in full-depth repair areas. The forms for areas of up to 4 square feet (0.4 square meter) may be suspended from wires from the reinforcing steel. For areas greater than 4 square feet (0.4 square meter), the forms shall be supported from the primary members of the superstructure or by shoring from below. Areas of full-depth repair shall have the concrete faces and reinforcing steel cleaned.

Figure 847.19/848.23- Areas of Full and Partial Depth Repair

Preparation Prior to Overlay Placement (847.20/848.24)

The Contractor is required to blast clean the proposed overlay surface, including all exposed reinforcing steel not more than 24 hours prior to placing the overlay. Suitable blast methods may include high pressure water blasting [10,000 psi (690 bar) min], water blasting [less than 10,000 psi (690 bar)] with abrasives in the water, abrasive blasting with containment, or vacuum abrasive blasting. Concrete surfaces shall be made free of spalls, laitance, and all contaminants and steel shall be made free of all loose and built-up rust, asphalt residue, and all other contaminants detrimental to achieving an adequate bond.

The Contractor is required to verify that all the waste was collected and legally disposed of in accordance with the applicable regulations.

Finishing Machine Dry Run (847.21/ 848.25)

After the screed rails have been set to proper profile and prior to placing the overlay, the Contractor shall check the finishing machine clearance to assure the Engineer that the specified nominal thickness of overlay will be attained over the entire deck.

Placing, Consolidating and Finishing (847.22/ 848.26)

The Contractor is required to:

1. Clean the deck surface with compressed air.
2. Keep the surface wet for at least one hour before overlay placement.
3. Consolidate and finish the overlay concrete to the plan surface.
4. Use Hand vibrators for full-depth repair, variable depth areas, at all edges and adjacent to joint bulkheads.
5. Concrete for full-depth repairs shall be the overlay concrete placed either simultaneously with the overlay or, if preplaced separately from the overlay operation, the concrete may be either the overlay concrete or Class QC2 Concrete.
6. After the overlay material has been consolidated finished and cured, it shall be sawed longitudinally per 511.17.
7. The Contractor shall stencil the date of construction (month and year) and the letters MS, LM or SD into the overlay before it takes its final set. The date shall be located in the right-hand corner of the deck at the forward abutment.
8. Finish and test concrete deck overlays according to 451.13.


Figure 847.22/ 848.26- Protection of deck during overlay placement of overlay and placement of wet burlap for water cure

Curing (847.23/848.27)

For any of the three overlay materials, the temperature of the overlay surface shall be maintained above 35 °F (2 °C) until the curing period is completed. Any day during which the air temperature at the overlay surface fails below 45 °F (7 °C) shall not be counted as a cure day.

As soon as the finishing operation is completed, the finished overlay surface shall be covered with a single layer of clean wet burlap. The burlap shall be kept wet by a continuous flow of water through soaker hoses and covered with a 4 mil (100 mm) white opaque polyethylene film or a wet burlap - white opaque polyethylene sheet for 48 hours for Latex Modified Concrete Overlays and 72 hours for Micro-Silica Modified or Superplasticized Dense Concrete Overlays. For Latex Modified Concrete Overlays, the covering shall be removed and the surface dry-air cured for an additional 2 days before subjecting the new surface to vehicular traffic.

Limitation on Placing Operations (848.26/848.30)

No overlay concrete shall be placed when it is raining, when the ambient air temperature is below 45 °F (7 °C) or when it is predicted to fall below 45 °F (7 °C) for the duration of the curing period.

Overlays shall be placed only when the overlay surface evaporation rate, as affected by ambient air temperature, concrete temperature, deck temperature, relative humidity and wind velocity, is 0.1 pound per square foot (0.5 kg/m^2) per hour or less.

SS 849 Heat Straightening of Damaged Structural Steel

Description (849.01)

This work consists of repair and heat straightening of damaged portions of existing steel members in accordance with Item 513 and as noted herein. Methods of repair include fully or partially replacing members, heat straightening, attaching span plates, or drilling holes to relieve stress.

Heat straightening is the “art” of applying heat in a particular sequence to a bent piece of steel to relieve the stresses and allow the member to come back into shape. Mechanical assistance is allowed, but should be kept to a minimum.

The Site Evaluation and Work Plan shall be done in accordance with Federal Highway Administration, FHWA Publication, FHWA-HIF-00-008 & FHWA-IF-99-004.

The Surface Preparation of the steel for paint application shall be in accordance with SSPC-SP 15, Commercial Grade Power Tool Cleaning.

Jacking or Bracing Existing Structure shall follow the requirements of C&MS 501.05.B.5.

Heat Straightening of Structural steel shall be in accordance with C&MS 513.11; AASHTO Standard Specifications for Highway Bridges, Division II, Construction, 11.4.12.2; AASHTO LRFD Bridge Construction Specifications, 2nd Edition, 2004, Section 11.4.12.2; and FHWA, Publication, FHWA-IF-99-004; Final Report No. RC-1456 Sponsored by Michigan Department of Transportation, Heat Straightening Repairs of Damaged Steel, Effects Of Multiple Damage-Heat Straightening Repairs On The Structural Properties Of Bridge Steels.

Repairing, welding and non-destructive testing of damaged steel members shall be in accordance with ASTM A6, AWS D1.5 and C&MS 513.21 and 513.25.

Materials (849.02)

The Contractor is required to submit certified test data according to C&MS 501.06 to the Engineer. The Contractor must furnish material according to Item 711.01. The minimum yield strength of the furnished material shall be equal to or exceed that of the existing material.

Superintendent (849.03)

In addition to the requirements of Item 105.06, the Contractor is required to provide documentation of the Superintendent’s experience in conducting heat straightening repairs on highway bridges.

Heat straightening experience must satisfy at least one of the following three experience definitions:

1. The Superintendent must have successfully completed at least three heat straightening projects in the preceding five years;
2. The Superintendent must be an Ohio Registered Engineer and must have successfully completed at least one heat straightening project in the preceding five years; or
3. The Superintendent must be an AWS, CWI Inspector in accordance with the provisions of AWS QC-1, Standard for Qualification and Certification of Welding Inspectors and must have successfully completed at least one heat straightening project in the preceding five years.

Quality Control (849.04)

The Contractor is responsible for Quality Control of the work in each phase established by the Quality Control Points (QCPs).

Quality Control Points (QCP). QCPs are points in time when one phase of the work has been completed and approved by the Superintendent, and is ready for inspection by the Engineer before the next phase of the work can commence. At a QCP, the Superintendent shall provide quality control documents bearing his signature. The Contractor shall provide access to inspect all affected surfaces. If inspection identifies a deficiency, correct the deficiency according to the Contract Documents before starting the next phase of work. Discovery of defective work, material, or the failure of the final product after a Quality Control Point is past, before final acceptance, shall not, in any way, prevent the Department from rejecting the final product or obligate the Department to final acceptance.

Testing Equipment (849.05)

The Contractor is required to provide and keep in good working order:

1. One digital camera with at least: 5.0 mega pixel resolution, auto focus, 3 x zoom lens, 512M memory and a built in flash.
2. Handheld portable, Infrared, non- contact thermometer capable of reading temperatures from -25 to 1600°F (-30 to 900°C) with temperature sensitivity of ± 1.8°F (1°C)
3. Magnetic Particle Inspection Equipment according to Item 513.25.B Yoke Method with testing particles
4. Digital light meter capable of measuring illumination from 10 to 200 foot candles with an accuracy of ±5%.

Pollution Control (849.06)

The Contractor is required to comply with pollution control laws, rules, or regulations of Federal, State, or local agencies and requirements of this specification.

Safety Requirements and Precautions (849.07)

The Contractor is required to comply with the applicable safety requirements of the Ohio Industrial Commission and OSHA.

Inspection Access & Illumination (849.08)

In addition to the requirements of C&MS 105.10, the Contractor is required to furnish, erect, and move scaffolding and other appropriate equipment to allow the inspector and the Engineer the opportunity to closely observe all affected surfaces during all phases of the work. The Contractor is required to illuminate work area with artificial lighting as necessary to supplement natural light and achieve a general work area lighting equal to 20 foot candles throughout the entire work area. Provide additional artificial lighting equal to 100 foot candles measured at work surfaces during times of inspection.

Quality Control Point Photographic Verification and Documentation (849.09)

Take sufficient number of photographs to document the condition of the work at Quality Control Points 2, through 10.

Qualification Verification (QCP # 1) (849.10)

Verify superintendent's qualifications and work history, sample work plans, welder qualifications, welding procedures, non- destructive testing technician and equipment to be used.

Surface Preparation (QCP # 2, 3 and 4) (849.11)

Existing Paint Removal (QCP #2)

The Contractor is required to remove exiting paint to according to SSPC-SP 15 Commercial Grade Power Tool Cleaning or equal, to allow visual observation of the heating color, and to prevent lead exposure or hazardous fumes resulting from burning paint.

Grinding Flange Edges (QCP #3)

The Contractor is required to round corners to 1/16 inch radius by grinding to prevent cracking during straightening and improve paint repair.

Containment/Waste Disposal (QCP #4)

The Contractor is required to contain, collect, & dispose of removed paint, abrasives, stripper or power tool cleaning debris according C&MS 514.D.

Damage Inspection (QCP # 5) (849.12)

The Contractor is required to visually inspect areas of damage, yield lines, and zones of plastic bending on primary members, secondary members and connections and perform non-destructive testing inspection and documentation with field sketches and photographs of all damages to be repaired.

Figure 849.12 - Damaged beams and cross frames prior to repair

Straightening Work Plan (QCP # 6) (849.13)

After inspecting the damage, and prior to performing the straightening work, the Contractor is required to submit a plan, prepared, signed, sealed and dated by an Ohio Registered Engineer, to the Engineer that includes the following minimum information:

1. Framing plan showing areas to be repaired, include results from the Damage Inspection (QCP # 5)
2. Sequence of work
3. Shape, size and temperature of heating patterns
4. Location and limits of jacking, pulling or restraining forces and calculations of member stresses from jacking, pulling or restraining force
5. Location and details of grinding repairs, of drilled or coped holes, of weld repairs, of material replacements, of paint removal and repair
6. Location, design and details of temporary supports for structural support and stability

Repairing Damaged Members (QCP # 7) (849.14)

The Contractor is required to repair all damaged material including: damaged edges; tears; burrs; sharp edges; punched holes; pull out of secondary members; or cracks by grinding, welding or material replacement while preventing cracking or further damage during straightening to the Engineer's satisfaction.

1. The Contractor shall grind out damaged material, when greater than 98% of the calculated cross sectional area based upon existing member dimensions of the individual plate, flange or web remains after grinding.
    a. taper to the original surface using a 1:10 slope
    b. provide a surface finish according to ANSI B46.1 of 250 mil (6.4 µm).

2. The Contractor shall weld damaged material, when less than 98% of the calculated cross sectional area based upon existing member dimensions of the individual plate, flange or web remains after grinding.
    a. Perform complete penetration welds according to C&MS 513 using approved electrodes, procedures and welders;
    b. Grind the completed welds smooth and flush with the adjacent surfaces to provide a surface finish according to ANSI B46.1 of 250 mil (6.4 µm);
    c. 100% Radiographic and 100% Magnetic-particle testing according to C&MS 513.
3. The Contractor may replace localized section of main members, when less than 98% of the calculated cross sectional area based upon existing member dimensions of the individual plate, flange or web remains after grinding.
    a. Before cutting any main member, provide bracing and support of the loads in the damaged member
    b. Remove localized portions of the structure by cutting and replacing these portions with new steel to match the existing shape and thickness
    c. Connect the new steel to the existing structural member using complete penetration welds
    d. Grinding the welds smooth and flush with the adjacent surfaces and provide a surface finish according to ANSI B46.1 of 250 mil (6.4 µm)
    e. Test the welds using 100% Radiographic tests
    f. Finish reentrant corners with 1 inch (25mm) radius.
    g. Provide 2 inch (50mm) diameter (minimum) cope holes in the web, at all weld intersections and at the web to flange intersection.

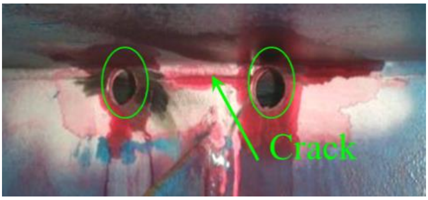



Figure 849.14 - Span plates and drilled holes

The Contractor is required to replace all damaged secondary members: cross frames and other attachments to the Engineer's satisfaction.

1. Before cutting any cross frame or attachment, install bracing and supports necessary for structural stability of the main structural members.
2. Condition the main members by grinding or welding at the existing secondary member connection as described in the table listed above.
3. Connect new secondary members by welding or bolting according to the existing detail.

4. Connect cross frames and attachments in the sequence defined in the straightening work plan.

The Contractor is required to perform all welding using qualified welders, electrodes and procedures in accordance with Item 513.

1. Perform 100% Radiographic testing for all main member repairs according to Item 513, except submit copies of reports to the Engineer for acceptance.
2. Perform 100% Magnetic Particle testing for all secondary member fillet welds to main members and flange to web fillet welds according to Item 513

Straightening Damaged Members (QCP # 8) (849.15)

The Contractor is required to heat straighten all damaged material using controlled temperatures, specified heating patterns, and jacking, pulling or restraining forces to prevent hairline fracture cracks, local buckling and protect material properties. Sharp kinks and bends may be cause for rejection of the work.

The Contractor is not allowed to heat members and then use large jacks or pullers which mechanically hot work the material. Mechanical hot work permanently damages the metal’s material properties.

Prior to straightening a damaged compression member, the Contractor is required to install adequate bracing to support loads and prevent buckling.

A. Restraints or preloads

1. The Contractor is required to apply jacking, pulling or restraining forces to the damaged member, prior to heating, in the direction that tends to straighten the member.
2. The Contractor is required to position and secure jacks, pullers, or restraining forces such that heat straightening shrinkage will relieve the force during the cooling cycle and the jacks and pullers will not dislodge during cooling.
3. The Contractor shall not allow jacks, pullers or restraining forces to subject any part of the structure to unit stresses that exceed 50 percent of the material’s nominal yield (Fy) at ambient temperature.
4. The Contractor is required to provide pressure gages or load cells to control jacks, pullers or restraining forces.
5. The Contractor is required to not apply additional jacking, pulling or restraining forces after beginning the application of heat. Do not apply the next cycle of jacking, pulling or restraining forces until the steel has cooled below 200 ºF (93 ºC).

Figure 849.15.A - Restraining bar between beams

B. Application of Heat

1. The Contractor is required to heat opposite faces of a plate or rolled shape concurrently when the material thickness equals or exceeds 1 1/4 inch (30mm).
2. When heating thick plates, it may be necessary to interrupt heating for periods of less than one minute to allow the heat to soak into the flange and avoid surface over-heating.
3. Perform heating using single and multi-orifice (rosebud) heating torches, air-propane or air-natural gas, and manipulate the torches to avoid overheating

Figure 849.15.B - Applying heat to damaged beam

C. Shape of Heating Patterns

Prior to applying heat, the Contractor is required to mark the steel with chalk or soap stone defining an assigned unique heat number; location; shape and limits of the heating patterns.

1. The Contractor is required to perform Strip, Line and Spot heating patterns of sufficient width, length and position to create the required straightening.
2. For "V" heating patterns, the Contractor is required to place the triangular areas
   a. not less than a flange width apart, (longitudinally)
   b. not exceeding the a 30 degree angle between the adjacent sides of the "V", and
   c. not exceeding a dimension of 10 in. (254mm) for the side opposite the "V" apex
   d. heat starting at the "V" apex; manipulate the torch in a serpentine pattern, progressing toward the side opposite the "V" apex
   e. do not return heating torches to the "V" apex side of the V heating pattern.


Figure 849.15.C - Example of "V" heat pattern and beam with strip and V heats

D. Temperature Control.

The Contractor is required to check the internal temperature of the steel by frequent use of appropriate temperature range indicating crayons or an infrared, non-contact thermometer. After the steel surface temperature is less than 600 ºF (315 ºC) cooling may be accelerated with dry compressed air. After completing a planned set of heat patterns along the member, the Contractor is not to apply additional heat until the entire member has cooled below 200 ºF (93 ºC) and the straightening movement has been verified.

Maximum heating temperatures for various steel:

1. 1200°F (649 ºC) for Mild carbon steel (A7; A373;A36 grade 36; A572 Grade 50; A588 Grade 50W; A709 Grade: 36, 50 and 50W)
2. 1100°F (593 ºC) for Quenched and tempered steel and Thermo mechanical Controlled Process (A514; A709 Gr. 100/100W; A709: HPS50W and HPS70W)
3. 1050°F(566 ºC) for Quenched and tempered steel A709 Gr. 70W and HPS100W

Finish Tolerances (QCP # 9) (849.16)

Measure dimensional tolerances for final acceptance when all heating and welding operations are completed and the member has cooled to160 ºF (70 ºC) or less.

Check tolerances before any cross frames or other lateral restraint devices are attached.

The Contractor shall not force members into position and then weld in the cross frames to hold members within heat straightened tolerances.

1. For beams, truss members or columns, straightness x and y axis (Sweep and Camber) measured offset from a string line stretched along the longitudinal axis, member center line,
   a. Overall alignment:1/8 inch (3 mm) times the overall member length divided by 10 feet(3m) but not more than 1/2 inch (13 mm)
   b. At point of impact: 1/4 inch (3 mm) times the overall heat straightened length divided by 10 feet but not more than 3/4 inch(22 mm)
2. For beams, truss members or columns, straightness x and y axis (Twist and plumb) measured offset from a string line stretched along the longitudinal axis, member center line,
   a. Overall permissible difference in the measured offsets (plumb) from a longitudinal center line, at the top and bottom flanges at any point on centerline of member, when measured from a common longitudinal centerline, shall not exceed 1/4 inch (6 mm)
   b. At point of impact: Permissible difference in the measured offsets (plumb) from a longitudinal center line, at the top and bottom flanges at any point on centerline of member, when measured from a common centerline, shall not exceed 3/8 inch (10 mm),
3. Flatness of web, measured by offset from a straight edge,
   a. D/150 but not greater than 1/4 inch (6mm)
4. Combined warp or tilt of the flange at any cross section
   a. W/100 or 1/4 inch (6 mm) whichever is greater except at bearing points not more than 1/16 inch (1.6 mm)
5. Flange Waviness, the deviation of the top or bottom surface of a flange from a straight line or plan curvature,
   a. shall not exceed 1/4 inch (6 mm) when the number of waves in a 10-foot (3 m) length is four or less, or 1/8 inch (3 mm) when more than four, but sharp kinks or bends shall be cause for rejection.
6. Surface Finish and Cross Sectional Area
   a. Provide existing members with 98% of the calculated cross sectional area based upon existing member dimensions
   b. Taper to the original surface using a 1:10 slope c) provide a surface finish according to ANSI B46.1 of 250 mil (6.4 µm).

c. Provide new materials with 100% of the calculated cross sectional area based upon existing member dimensions

d. Smooth complete penetration welds to a surface finish according to ANSI B46.1 of 250 mil (6.4 μm).

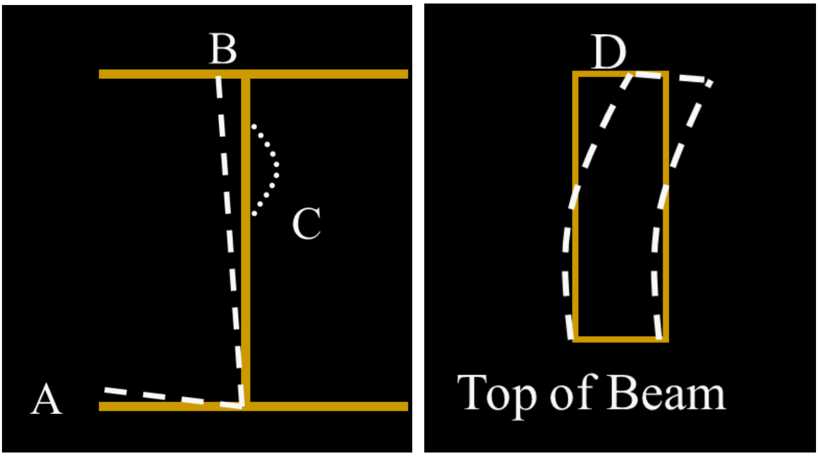


Figure 849.16 - A. Flange Tilt, B. Web Plumbness, C. Local Deflection, and D. Beam Sweep

Final Inspection (QCP # 10) (849.17)

1. Perform a final arms length inspection of all surfaces that were repaired or heated after the work is complete and cooled to160 ºF (70 ºC) or less.
2. Perform non-destructive testing at locations of detected or suspected hairline cracking as part of this inspection.
3. Test these areas using magnetic particle testing.
4. Repair any cracks that are found according to Repairing Damaged Members (QCP # 7).

Figure 849.17 - Magnetic Particle Testing

S 1015 Compaction Testing of Unbound Materials

1. General

Supplement 1015 details the compaction testing requirements for all ODOT projects. ODOT technicians and testing personnel provided by the Contractor must follow the testing procedures and requirements described in S-1015.

When the Contractor provides the compaction testing for ODOT, one of two possible supplemental specifications will be included in the Contract Documents. The two supplemental specifications, SS-878 and SS-879, are similar, but SS-878 pays for the inspection and testing as a lump sum pay item, while SS-879 pays for the work by providing incentive pay to the Contractor.

The Contractor always provides the testing and inspection personnel for Item 611 and permanent and temporary MSE walls, SS-840 and SS-867.

There is only one set of compaction and inspection tables for S-1015, SS-878, and SS-879. They are in S-1015. Table 1015.06-1 includes the material types, nuclear gauge operating mode, and method for determining the maximum dry density, and Table 1015.07-1 provides this information for shale. Table 1015.09-1 includes the materials, maximum lot size, and minimum number of tests. The same number and type of inspections and compaction tests are taken regardless of which specification is used in the Contract.

SS-878 Inspection and Compaction Testing of Unbound Materials

This item is used when construction personnel are limited and the District wants full-time inspection and compaction testing for the work.

SS-878 pays for the inspection and compaction testing as a lump sum pay item and covers Items 203, 204, 205, 206, 304, 411, 503, and MSE wall select granular backfill, SS-840 and SS-867.

The major aspects of the specification are as follows:

1. The Contractor is to supply full-time qualified inspection and compaction testing for all specified items.
2. The compaction tests are performed according to S-1015.
3. The documentation is performed on department forms.
4. The documentation is presented to the Engineer daily and a summary report is required every 2 weeks.
5. There are qualifications requirements for the inspection and compaction personnel.
6. The Department will perform QA compaction tests.
7. There is a lump sum payment for this work.

SS-879 QC/QA for Embankment Construction

The major aspects of the specification are as detailed below:

1. Several of the sections in this specification refer to SS-878, because they are basically the same work with the payment mechanism being different.
2. The Contractor supplies full-time qualified inspection and compaction testing for Items 203 and 204.
3. The compaction tests are performed according to S-1015.
4. The documentation is performed on department forms.
5. There are qualification requirements for the inspection and compaction personnel.
6. The Department will perform QA compaction tests.

This supplemental specification is very similar to SS-878, except there is a pay adjustment ± 4 percent to the amount bid for Items 203 and 204. This specification allows for more Contractor responsibility for the work with an appropriate incentive. It also allows the Department to reduce the amount of full-time inspection of the work.

Rounding

Weight measurements should be measured to the nearest 0.01 pound (1 gram). All calculations are normally recorded to the nearest 0.1 or 4 significant digits. Normally the final compaction results are recorded to the nearest percentage of compaction and acceptance is based on rounding. For example, 97.6 percent compaction is rounded up to 98 percent compaction, while 97.5 is rounded down to 97 percent compaction. The rounding of other calculations and measurements are done in a similar manner.

2. Importance of Proper Inspection and Compaction Testing

The Contractor constructs the embankment. The Department, using Inspectors, Engineers, consultant inspectors, and/or Contractor supplied personnel, observe and test the work to ensure compliance with the specifications. As the Department inspects the work, instructions are given to the Contractor identifying noncomplying earthwork, such as the material is too dry, too wet, not dense enough, or does not have enough stability.

During construction or later on, embankment failures have occurred where the cause of the failure was attributed to one of the following:

1. The instructions to the Contractor were in error.
2. Compaction tests were performed incorrectly.
3. Compaction forms were incomplete.
4. No inspection or part-time inspection occurred during the construction.

These reasons have been arguments in the resulting claims. Valid or not, these are reasons that will be debated when responsibility is discussed. Considerable financial loss to the Department could result during these negotiations or in court because of any one of the above reasons.

Our goal with this section is to minimize the Department liability in the above claim situations.

Compaction testing is an important evaluation tool that measures the quality of the earthwork construction work. Therefore, this entire section is dedicated to obtaining correct and accurate results.

3. Compaction of Soils

Moisture-Density Relationship

In order to understand compaction testing, the project personnel must first understand the moisture-density relationship and some of the variables associated with this relationship.

A relationship exists between the density of a soil and the moisture content of a soil as the moisture content is varied while the compactive effort remains constant. A standard force is used in the test that closely approximates the densities that can be readily obtained in the field with footed drum rollers and other types of common compaction equipment. The greatest dry density obtained in the test is termed, "maximum dry density," and the corresponding moisture content is termed, "optimum moisture content." This moisture-density relationship is shown in Figure 1015.A.

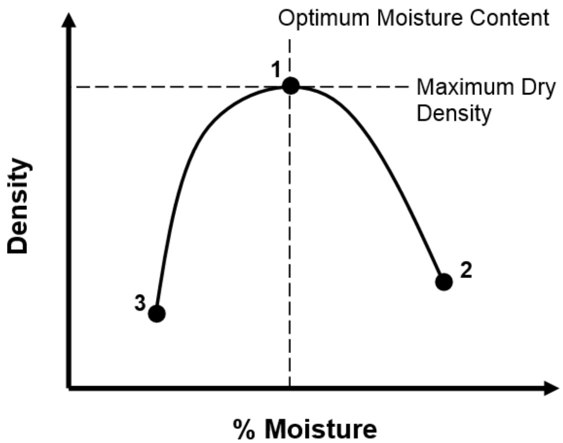


Figure 1015.A - Typical Moisture-Density Curve

The test used by the Department to determine the moisture-density relations of soil is AASHTO T-99, Method C, called the Standard Proctor test. The basic principle involved in the moisture-density relationship is an important tool when evaluating a soil.

For a given compaction effort and given moisture content, a soil will have a corresponding density. Additionally, there is a particular moisture content for each soil at which the soil is densest than at any other moisture content for a given compaction effort. This moisture content is the optimum moisture content.

Structural properties of a soil vary with moisture content and density. For example, a clay soil at a low density will have very high load-supporting strength when dry, but when it is saturated at this same density, it will have a very low load-supporting strength. Hence, when the structural properties of the soil are being determined, its moisture content and density must be defined and controlled to permit accurate evaluation of the soil in that particular condition.

Refer to Figure 1015.A to understand the influence of moisture on the compaction of soils. At point 3, the soil is compacted at a moisture content where the compactive effort

cannot overcome the friction or resistance of the soil to achieve a maximum dry density. As the water content increases, the particles develop larger and larger water films around them, which tend to lubricate the particles and make them easier to move about and reorient into a denser configuration.

As the moisture content is increased, we eventually reach point 1, where the density does not increase any further with water content. At point 1, the soil has just enough moisture to overcome most of the friction and not too much to have excess pore pressure to displace the soil.

As the moisture is increased from point 1 to 2, the density decreases as the water starts to displace and replace soil particles.

3.A. Making a Moisture-Density Curve

This section outlines procedures to determine the optimum moisture content, maximum wet density, and maximum dry density of a soil, shale, or granular material. This procedure is not normally performed in the field. It is generally only needed to determine the optimum moisture content for Test Section Method A.

The procedures outlined in this section follow AASHTO T-99, Method C with some minor modifications.

3.A.1. Equipment

The equipment needed to make a moisture-density curve is as follows:

1. Proctor mold.
    a. Cylindrical brass or cadmium-plated steel mold, approximately 4 inches (102 mm) in diameter, 4-1/2 inches (114 mm) in height, and has a capacity of 1/30 ft^3 ($9.43 \times 10\text{-}4\ m^3$).
    b. The cylinder is mounted on a removable base plate and fitted with a detachable collar approximately 2-1/2 inches (63 mm) in height.
2. Proctor rammer (hammer).
    a. Brass or cadmium-plated steel sleeve rammer which has:
        i. A striking face 2 inches (50 mm) in diameter.
        ii. A weight of 5.5 lbs (2.5 kg).
        iii. A drop height of 12 inches (305 mm).
3. Steel straightedge 10 to 12 inches (254 to 305 mm) long.
4. Scale of 25 lbs (12 kg) capacity sensitive to 0.01 lbs (1 gram).
5. A 3/4-inch (19 mm) sieve.
6. Oil or gas stove or portable oven unless dried by other methods.
7. Baking pans, approximately 12 inches × 8-1/2 inches × 2-1/2 inches (300 mm × 200 mm × 63 mm).
8. Masonry trowel and putty knife.
9. If the test is performed in the field, use a large concrete block or concrete surface such as bridge deck, culvert, or pavement.
    a. Minimum block weight of 30 pounds (14 kg).
    b. Minimum solid concrete block size is 4-inch × 12-inch × 8-inch (100 × 305 × 200 mm).
    c. Minimum cinder block size is 12-inch × 6-inch × 8-inch (305 × 150 × 200 mm).
    d. Do not use wood or asphalt.

3.A.2. Procedure

Use the form CA-EW-4 (shown in Figure 1015.B) to record test data as obtained by the procedure outlined in this section. This form shows an example of recorded test data. Each column is lettered and used throughout this section to facilitate referring to the explanation.

1. Secure a representative sample of soil of about 40 lbs (20 kg).
2. Pass the sample through a 3/4-inch (19 mm) sieve.
3. Wet or dry the sample.
    a. Change the moisture content to 4 to 6 percent below optimum.
    b. See Section 1015.3.E. - Estimating Optimum Moisture Content, in this manual for more information.
4. Make a Proctor.
    a. Make a specimen by compacting the prepared soil in the Proctor mold.
        i. Make three equal layers to give a total compacted depth of about 5 inches (130 mm).
    b. Compact each layer by applying 25 uniformly distributed drops from the 5.5 lbs (2.5 kg) rammer dropping from a height of 12 inches (305 mm) above the elevation of the soil.
    c. See Figure 1015.D for recommended loose and compacted soil lifts.
        i. Loose lifts will change depending on the consistency of the soil.
    d. Ensure that the cylinder is resting on a uniformly rigid foundation during the compaction.
        i. Use a large concrete block or concrete surface.
        ii. Minimum block weight of 30 pounds (14 kg).
        iii. Minimum block sizes as given above.
        iv. Do not use wood or asphalt.
5. Remove the extension collar.
    a. The soil should be less than 1/2 inch (13 mm) above the mold.
    b. If the soil is lower than the top of the mold, repeat the test.
    c. Carefully trim the compacted soil even with the top of the mold using the straightedge.
    d. Add fine material from the tested soil to fill any voids if necessary.
6. Weigh the cylinder and sample. Input this information in Column A
    a. Calculate the density of the specimen by subtracting the weight of the mold from the weight of the specimen and mold, and multiply the difference by 30 for English units and 1,060 for metric units.
        i. Column [1] – Column [2] = Column [3]
           13.34 - 9.81 = 3.53
        ii. Column [3] × 30 = Column [4]
           3.53 × 30 = 105.9
        iii. Column [4] is the wet density of the Proctor soil.
7. Remove the material from the mold and slice vertically through the center.
    a. Take a representative sample of the material from one of the cut faces and determine the moisture content by a method outlined in 1015 Appendix - Alternate Tests for Moisture, in the manual.
    b. If the only available scales are those included in the compaction control kit, a 1 lbs (0.5 kg) sample is required for the moisture

determination. However, if a more sensitive scale is available, use a 0.22 lbs (100 gram) sample. The smaller sample will dry faster.

i. The scales need to be leveled with a carpenter's level. Put the scale on a piece of flat plywood then level the board. You may elect to level the weighting plate.

ii. The older scales must also be balanced once it is leveled. The weighting mechanism should float between the top and bottom bar. If it does not, sand or pebbles can be added to the lever arm to make it balance.

c. Calculate the dry weight and the moisture content as follows:

i. Column [6]…Weight of the dish and the wet soil.
96.2

ii. Column [7]….Weight of the dish and soil after drying.
93.4

iii. Column [8]…Column [6] – [7] = Weight of Water
96.2 - 93.4 = 2.8

iv. Column [10]…Column [7] – [9] = Dry Soil Weight
93.4 – 40.0 = 53.4

v. Column [11]…Column [8] / [10] × 100 = Percent Moisture
Water Content = Weight of Water /Dry Weight
(2.8/53.4) × 100 = 5.2%

vi. Column [12]…Column [4] / (1+ Column [11]) = Dry Density of the Sample
Dry Density = Wet Density / (1 + Wc)
In the Example: Dry Density = 105.9/(1+0.052) = 100.5

8. Thoroughly break up the remainder of the material until inspection shows that it will pass a 3/4-inch (19 mm) sieve. It is not necessary to pass all of the material through the sieve.

9. Add water in sufficient amount to increase the moisture content of the soil sample by 2 or 3 percent, and repeat the procedure outlined in Steps 4 through 8.

10. Repeat Steps 4 through 8, each time adding water until you obtain at least 4 readings for the wet density, dry density, and moisture content.

a. Continue the process until a minimum of two points are plotted on the wet and dry side of the dry density curve and there is a decrease in the wet density.

11. Use Figure 1015.C as an example and plot test data as follows:

a. Plot wet density, Column [4], versus moisture content, Column [11], of the successive tests on linear graph paper.

i. Draw a smooth curve between the successive points.

ii. The peak of this curve is the maximum wet density of the material being tested.

iii. This maximum wet density is not used for compaction acceptance.

b. Plot dry density, Column [12], versus moisture content, Column [11], of the successive tests on linear graph paper. Form CA-EW-4 can plot these points on its second page.

i. Draw a smooth curve between the successive points.

ii. The peak of this curve is the maximum dry density of the soil.

iii. The moisture content at this point is the optimum moisture content.

iv. This curve can be used for compaction acceptance.

Figure 1015.C shows curves plotted from the test data in Figure 1015.B.

CA-EW-4 **Moisture Density Curve Calculation**

Project No. ______ Co-Rt-Sec ______ Date ______

Ref. No. ______ Item No. and Description ______

Wt. of compacted sample & 4-inch mold ($^1/_{30}$ ft³ container) [1] lb	Wt. of 4-inch mold [2] lb	Wt. of sample [3] lb	Wet density of sample [4] lb/ft³	Moisture Content Determination: Dish No. [5]	Wet wt. & dish [6] g	Dry wt. & dish [7] g	Wt. of water [8] g	Wt. of dish [9] g	Wt. of dry sample [10] g	Moisture content [11] %	Dry density of sample [12] lb/ft³
13.34	9.81	3.53	105.9	1	96.2	93.4	2.8	40.0	53.4	5.2	100.6
13.65	9.81	3.84	115.2	2	98.6	93.7	4.9	38.0	55.7	8.8	105.9
13.87	9.81	4.06	121.8	3	97.1	90.9	6.2	39.0	51.9	11.9	108.8
14.13	9.81	4.32	129.6	4	99.6	91.7	7.9	41.0	50.7	15.6	112.1
14.16	9.81	4.35	130.5	5	94.8	86.2	8.6	40.0	46.2	18.6	110.0
14.04	9.81	4.23	126.9	6	95.5	84.5	11.0	38.0	46.5	23.7	102.6

Remarks:

Maximum dry density, lb/ft³ *112.5*

Optimum moisture content, % *15.5*

Curve *Project*

Equations

[3]	Weight of sample	[1] – [2] = [3]
[4]	Wet density of sample	[3] × 30 = [4]
[8]	Weight of water	[6] – [7] = [8]
[10]	Weight of dry sample	[7] – [9] = [10]
[11]	Moisture content	[8] ÷ [10] × 100 = [11]
[12]	Dry density of sample	[4] ÷ (1 + [11] ÷ 100) = [12]

Units

lb — pound

lb/ft³ — pounds per cubic foot

g — grams

Inspector ______ Date ______

ODOT Form date: 3/17/2009

Figure 1015.B – Moisture-Density calculation form

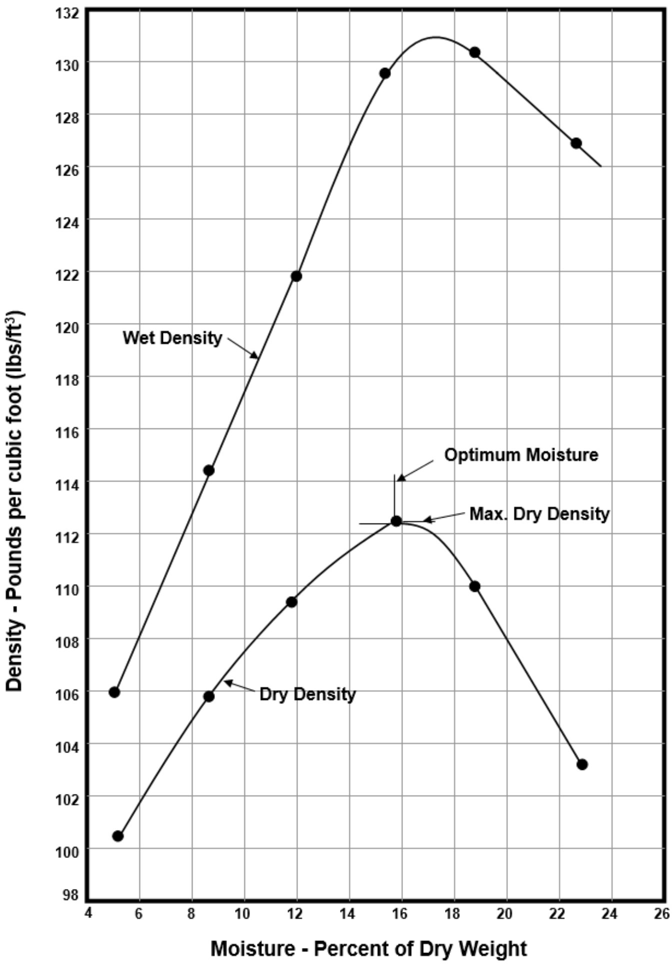


Figure 1015.C – Moisture-Density curve plot

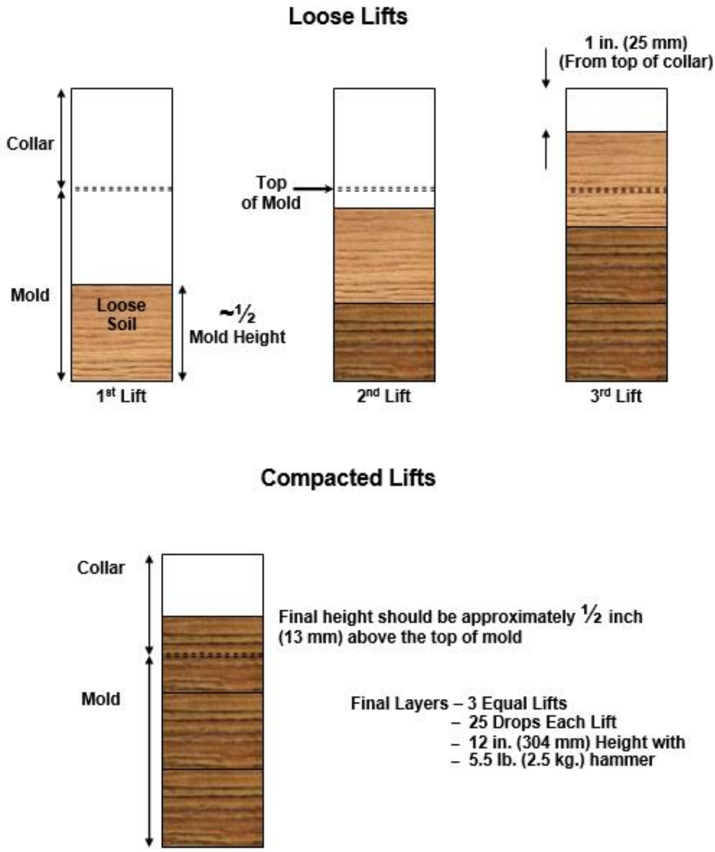


Figure 1015.D - Loose and compacted lifts for the Proctor test

3.B. Ohio Typical Moisture-Density Curves

The Ohio Typical Moisture-Density Curves are a set of soil curves originally developed in the 1930's and 1940's to represent all the soils in Ohio. They were developed in the laboratory using the standard Proctor test. They started with an original set of nine curves that represented over 1,000 samples. Additional curves were added that represent over 10,000 lab samples. These curves are plotted in Figure 1015.E. These curves are still used today to represent all the soils in Ohio. Using these curves minimizes the need to make moisture-density curves for each type of soil encountered in the field.

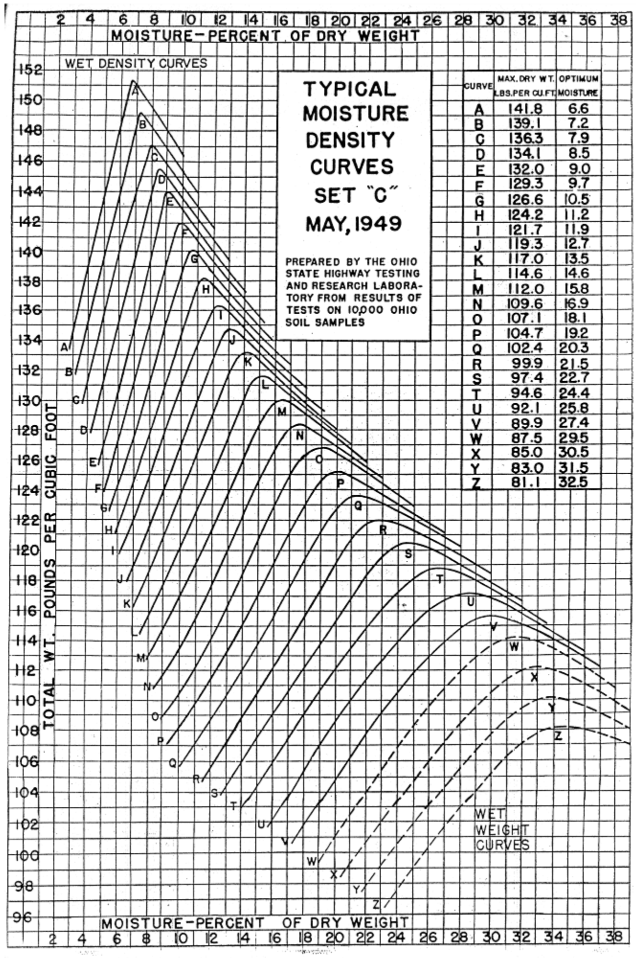


Figure 1015.E - Ohio typical Moisture-Density curves

A one-point Proctor test is used to choose the curve that represents the soil under consideration. The procedure is similar to the AASHTO T 272 test and is detailed in Supplement 1015.06.C.1.

3.C. Usefulness of the Moisture-Density & the Ohio Typical Curves

By examining the moisture-density curve or the Ohio Typical Curves, one can gain general information on the load-carrying capacity and other information about the soil properties.

The optimum moisture content and maximum dry density of the moisture-density relationship are comparative factors. A high maximum dry density ranges from 125 to 140 lbs/ft^3 (2,000 to 2,250 kg/m^3) dry density. A low maximum dry density ranges from 100 to 85 lbs/ft^3 (1,600 to 1,350 kg/m^3) dry density. A low optimum moisture content coincides with a high maximum dry density and will be on the order of 7 to 10 percent.

A high optimum moisture content coincides with a low maximum dry density and may be on the order of 21 to 30 percent.

The maximum dry density of a soil gives approximate information on its gradation and soil type. The approximate range of the maximum dry density for particular soils are as follows:

Soil Type	Typical Maximum Dry Density Pounds per Cubic Feet (Kilograms per Cubic Meter)
A-1 & A-2	120 to 135 (1922 to 2163) Granular Soils
A-2	120 to 130 (1922 to 2082) Granular Soils
A-3	110-to 120 (1762 to 1922) Granular Soils
A-4	105 to 120 (1682 to 1922) Silty Soils
A-6 & A-7	90 to 110 (1442 to 1762) Clayey Soils

The optimum moisture content gives approximate information on the clay and silt content of the soil. The shape of the moisture-density curve varies from a sharply peaked parabolic curve to a flat one or to one sloping irregularly downward as the moisture content increases. This shape gives additional valuable information showing the influence of moisture on the load-supporting value of the soil. For example, a flat moisture-density curve indicates a soil that will have about the same load-supporting strength over a wide range in moisture contents, while a moisture-density curve with a sharp peak indicates a soil that is sensitive to changes in moisture content.

3.D. Variations in the Moisture-Density Relationship

To truly understand the moisture and density relationship as it relates to soil compaction, the project personnel should understand what items affect this relationship. This section briefly addresses these issues.

This moisture-density relationship is affected by, but not limited to, the following conditions:

1. A change in the laboratory compactive effort or a field compactive effort that is different from the laboratory testing compactive effort.
2. A temperature of the compacted soil that is near or below freezing temperature.
3. Coarse aggregate that is added or subtracted from the soil.

3.D.1. Changing the Compactive Effort

The AASHTO T 99 Proctor test, used to make the Department’s moisture-density curve, was originally made to simulate field compaction conditions. It uses a standard compactive effort that allows us to evaluate and compare the compaction and densities of different soils. What happens to this moisture-density relationship as you increase or decrease this compactive effort?

In Figure 1015.F, the compactive effort may be increased or decreased to change the maximum density as much as 10 to 15 lbs/ft^3 (160 to 240 kg/m^3). As the compactive effort increases, the curve shifts to the left and up along the same line of optimum. If the compactive effort is lowered, the compaction curve shifts to the right and down.

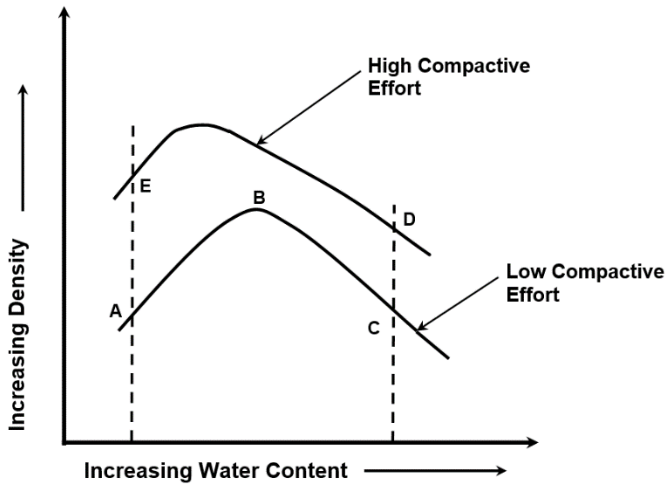
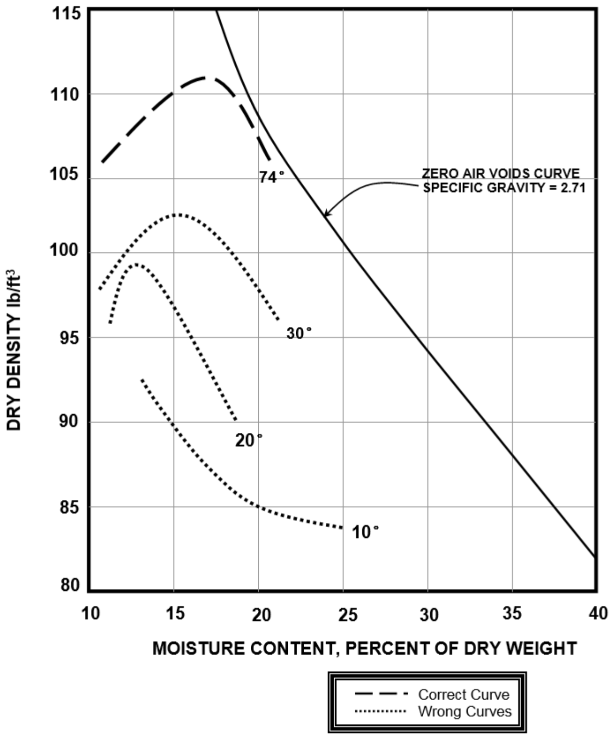


Figure 1015.F - Changing the compactive effort

3.D.2. Temperature Effects on Soil

If a soil is compacted at low temperatures, the maximum density cannot be achieved in the field. The specifications do not allow soil to be compacted that is frozen. Figure 1015.G shows why this is the case. The maximum density can change as much as 10 lbs/ft^3 (160 kg/m^3) for soils compacted at temperature differences of 40 ºF (20 ºC). However, there may not be any difference in maximum density. Temperatures affect some soils but not others. There is not a formula that takes this temperature difference into consideration.



Note: Same Soil (Brown Sand, Some Gravel, Trace of Silt) Compacted at Different Temperatures. (*After W.P. Hoffman*)

Figure 1015.G - Temperature effects on the M-D curve

Compaction procedures must be altered to check for this difference. Use the following procedure when the Contractor is compacting the soil at temperatures lower than 45º F (7º C) or when the site conditions warrant:

1. Take the normal Proctor test during the compaction testing. Choose the curve associated with this compaction test.
2. Take enough soil from the same hole to make another Proctor later. After the soil is warmed to approximately 70 ºF (21 ºC) make an additional Proctor. Pick an additional curve using the wet weight of the second Proctor and moisture content from a drying method.
3. Compare the two results and use the higher curve if there is a difference. Use this procedure at any time the material is suspect in the field.

3.D.3. Coarse Aggregate Problem

The moisture-density relationship is very good for soils passing the 3/4-inch (19 mm) sieve as it relates to the field compaction of soils. There are problems when this relationship is extrapolated to soils larger than the 3/4-inch (19 mm) sieve material or for granular soils. Corrections must be made to account for these materials. In certain circumstances, field densities do not correspond to the laboratory results. These will be pointed out in later sections.

Figure 1015.H details a plot of adding or subtracting coarse aggregate to a soil and the resulting change in the moisture-density curves.

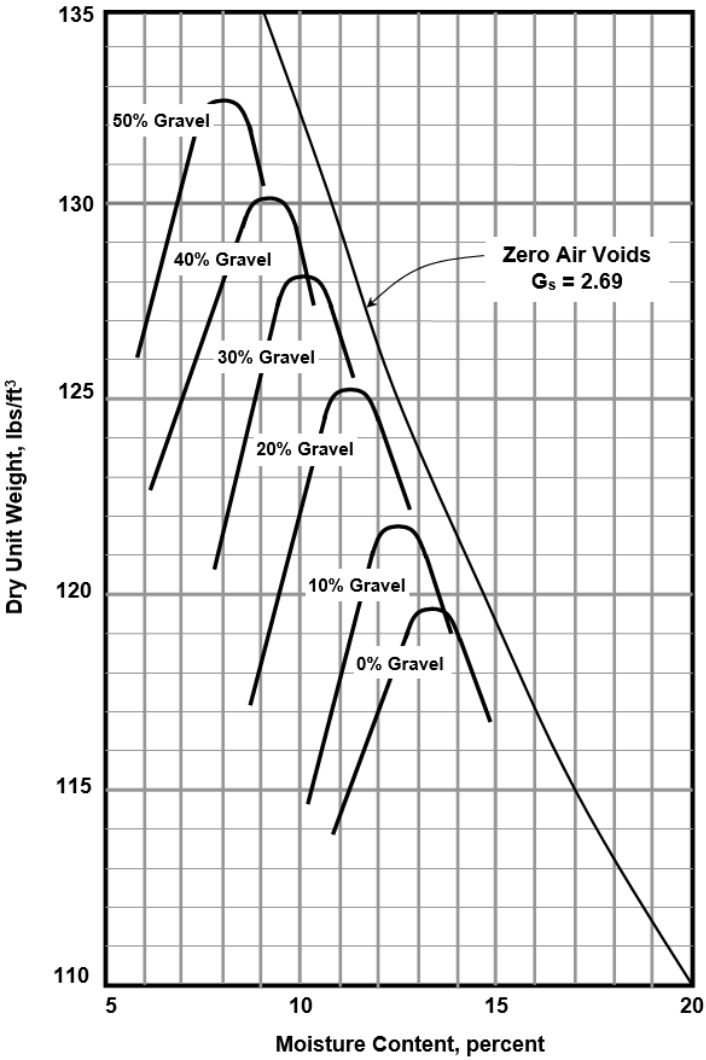


Figure 1015.H - Coarse aggregate effects on soil M-D curve

As you add gravel or 3/4-inch (19 mm) material to the soil, the optimum moisture content shifts to the left and the maximum density increases. The average increase in density is approximately 1 percent per 10 percent of material retained on the 3/4-inch (19 mm) sieve. This effect is addressed on the compaction form CA-EW-6 and is fully explained in Section 1015.5. of this manual.

If you sieve the material through the 3/4-inch (19 mm) sieve, remove 20 percent coarse aggregate, and do not consider this, you could easily be one or two curves lower than intended.

Use the correction on the compaction form CA-EW-6 where more than 10 percent of the material is retained on the 3/4-inch (19 mm) sieve. This correction usually increases the maximum dry density and makes an optimum moisture content correction.

3.D.4. Importance of Temperature and Coarse Aggregate Corrections

The accuracy of all compaction testing is important; however, the importance of making temperature and coarse aggregate corrections in compaction testing are less obvious to the project personnel. Without these corrections, the compaction testing could easily be off by more than 2 lbs/ft^3 (32 kg/m^3) without the project personnel being aware of a problem.

If the compaction testing is off by 2 lbs/ft^3 (32 kg/m^3), or approximately one Ohio Typical Density Curve, this may result in a loss of 15 percent of the soil strength. If the testing is off by two curves, the potential loss could be 30 percent, and so on. The strength may not be apparent in construction, but in the long-term, it may have devastating effects on the performance of the embankment.

3.E. Estimating Optimum Moisture Content

3.E.1. Soil Boring Interpretation Method

All cohesive soils are compacted at water contents less than the plastic limit of the material. For A-7-6 soils, the optimum moisture content is approximately equal to the plastic limit minus 3. For A-4 and A-6 soils, the optimum moisture content is approximately equal to the plastic limit minus 5. The optimum moisture content of granular materials ranges between 5 and 10 percent and for non-plastic silts is around 11 percent.

You can obtain an estimate of the material's consistency by using the above information and looking at the soil's water content from the soil borings before the work begins. Keep in mind, the water content on the soil borings is the water content at the time the borings were drilled. They should be considered an estimate of the present field conditions.

You can approximate the optimum moisture content of a material by the feel of the material in the field using one of the following methods.

3.E.2. Hand Squeeze Method

7. Take a sample of the material in question in your hand.
8. Squeeze the material together and let go.

9. Consult the following table:

If the material…	Then material is…
Falls apart in small pieces	Dry of optimum
Stays together	At or above optimum
Breaks into two or three large pieces	At optimum
Stays together and there is excess water on hands	Above optimum

3.E.3. Ball Method

1. Roll the material into a 1-inch ball.
2. Place it between your thumb and index finger and squeeze the material.
3. Consult the following table:

If the material…	Then material is…
Ball cannot be formed	Below optimum
Becomes oval	Above optimum
Breaks apart into uniform pieces (Some clays will have larger pieces than silts)	At optimum

Use these methods as estimates; they do not replace compaction testing. These estimates are different for each type of soil (clay, silt, granular).

4. Compaction Testing of Soils

4.A. General

Proper compaction at the proper moisture is the most effective and most economical way to improve the stability of soils. Satisfactory performance of pavement and embankment depends on the good compaction of the embankment and subgrade materials. Careful control is necessary to ensure compliance with the specification compaction requirements for embankments and subgrades.

The density test is the principal means by which the Engineer determines whether or not the specified compaction requirements have been met. The number of tests to be made for a given quantity of embankment material placed is set by Supplement 1015.09. The Engineer has the authority to increase or decrease this testing depending on the field conditions. The Engineer may use his or her judgment to make tests at locations where the information is most needed for proper control.

For example, consider an area of embankment under construction, where the soil and moisture conditions are uniform and ideal for good compaction, and where previous compaction tests have shown that the specification requirements are consistently met under the same number of roller passes. As long as inspections show that the uniform conditions of soil, moisture, lift thickness, and roller pass continue for this area, only occasional check tests for compaction are required.

Where relatively few tests are made because materials and conditions are uniform, document this by describing conditions on the Compaction Forms or other appropriate project records. Avoiding a large number of tests in areas of uniform condition, where specified compaction is consistently obtained, allow the project personnel to concentrate their effort on other areas of the project where conditions are less uniform or suspect.

Tests must be made in areas where inspection indicates that the material is questionable, even if specified compaction is obtained. Evidences of questionable compaction, which can be determined by inspection, include the following:

1. Low number of roller passes to obtain compaction.
2. Excessive deflection under heavy construction equipment.
3. The use of lightweight rollers.
4. Very wet or dry soil.
5. Areas compacted without full-time inspection.

6. Inconsistent materials, such as shale and rock mixtures, or recycled concrete mixed with soil.

The observation that a footed drum roller will "walk out" or "ride high" on a layer of hard, dry soil is not evidence of satisfactory compaction. This soil may be stable when dry, but weak when wet.

Areas where compaction or moisture does not meet specification requirements must be corrected before the next lift of embankment is placed.

The Engineer must give specific directions to the Inspectors. These directions must cover the Inspector's responsibility and authority given to them by the Engineer. This ensures that timely decisions are made in the field and that full compliance with the contract requirements is obtained on the project.

Control of compaction includes making moisture and density determinations for establishing whether the compaction meets the requirements prescribed in the specifications.

A sufficient number of tests must be made to ensure that construction complies with the specifications. The Nuclear Gauge Method is the only method used for compaction testing.

A one-point Proctor test is used to identify the curve that represents the soil in question **for each compaction test**, except for materials requiring a test section.

4.B. Equipment (S-1015.04)

1. Equipment listed in Section 1015.03.A of this manual.
2. A 3 to 4-inch (75-100 mm) post-hole auger, shovel, or pick.
3. A container with a 4-1/2-inch (114 mm) hole cut in the bottom.
4. Troxler 3440 Nuclear Gauge, or comparable, and associated tools: reference block, scraper plate, drill rod, extraction tool, hammer.
5. 25 to 50 lbs (12 to 23 kg) of dry, uniform, natural sand passing the No. 10 (2 mm) sieve.
6. Form CA-EW-5, Nuclear Gauge Compaction Form, and Form CA-EW-6, Nuclear Gauge Compaction with Aggregate Correction.

4.C. Preparation of Surface (S-1015.06.B.2)

Select a location for the density test that is representative of a rolled area of the embankment layer being constructed. If loose, uncompacted material, similar to what results from sheepsfoot rolling, exists on the surface, remove the loose material to expose the compacted material underneath. Carefully level the test area by any convenient means, such as a dozer, grader, hand shovel, scraper plate, straightedge, etc.

4.D. Compaction Testing of Soil Using a Nuclear Gauge (S-1015.06.B.3)

The Department uses nuclear equipment manufactured by Troxler Laboratories. Presently, the Department uses the 3440 series gauges. The operator should have a Manual of Operation for the gauge.

There is no radiological danger for the operation of a nuclear gauge so long as the correct operating and safety rules are followed. Each operator is issued a specific set of

instructions governing safety when the gauge is assigned to him or her. For more information about the safety requirements see the following link to OMM's Nuclear Safety website:

> *www.dot.state.oh.us/Divisions/ConstructionMgt/Materials/Pages/Radiation-Safety.aspx*

For addition information, contact the District Radiation Safety Officer, the Radiation Safety Supervisor at (614) 275-1349 or the State Radiation Safety Officer at (614) 387-0714 or cell (614) 588-2101.

For nuclear measurement of density, gamma rays emitted into the soil from a gamma source are scattered by the electrons in the soil and lose energy in the process. The number of scattered rays returned and counted in the gauge depends on the average length of the path of the ray between the detector and source. The electron density increases proportionally with the density of the soil and causes greater scattering and energy loss. Therefore, the chances that scattered gamma rays returning to the detector with sufficient energy to be counted become smaller with increased soil density, and the count rate drops. In common soil types, a low gamma ray count indicates a high density, and a high count indicates a low density.

For nuclear measurements of moisture, the neutron energy absorption technique measures the moisture content of rock or soil materials. The nuclear method for measuring the moisture content of soil and rock materials is based on the principle of measuring the slowing of neutrons emitted into the soil from a fast-neutron source. The energy loss is much greater in neutron collisions with atoms of low atomic weight and is directly proportional to the number of atoms present in the soil. The effect of such a collision changes a fast neutron to a slow neutron. Hydrogen, which is the principal element of low atomic weight found in soils, is contained largely in the molecules of water in an inorganic soil. The number of slow neutrons detected by the gauge, after an emission of fast neutrons from a radioactive source, is counted electronically in the gauge. The count obtained by the gauge is proportional to the amount of water in the soil or rock.

Density and moisture determinations can be made in any of the following two positions relative to the material being tested:

- Backscatter - Source and detector in the gauge are resting on the surface of the material being tested.
- Direct Transmission - Source in the rod is extended below the gauge into the material being tested, and the detector in the gauge is on the surface of the material being tested.

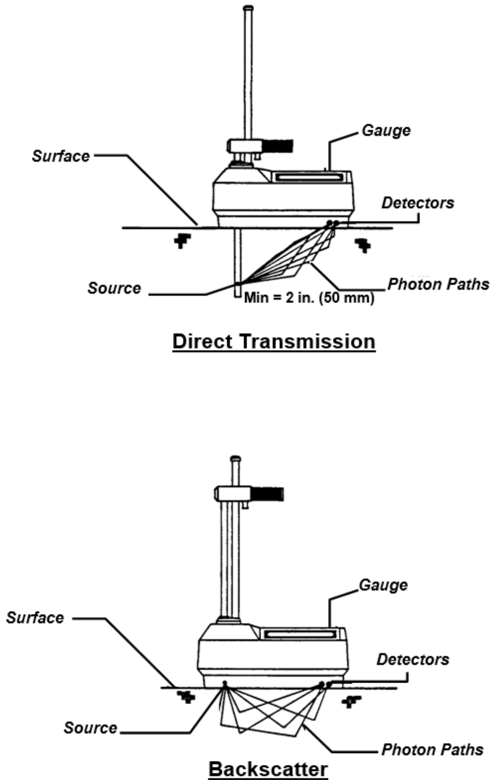


Figure 1015.I - Nuclear Gauge Direct and Backscatter Positions

Moisture-Density Testing

Use Form CA-EW-5 or CA-EW-6 for moisture-density testing when using a nuclear gauge. The following is a summary of the gauge operations when testing soils. Consult the detailed explanation in the owner's manual of operation.

The gauge is self-driven throughout the process. The operator pushes a button and the gauge asks a question or gives an answer.

1. Determine the standard count.
    a. Perform at the beginning of each day the gauge is used or when the test location environment changes.
    b. Put the gauge on the standard block with the handle opposite the metal plate. See Figure 1015.J.

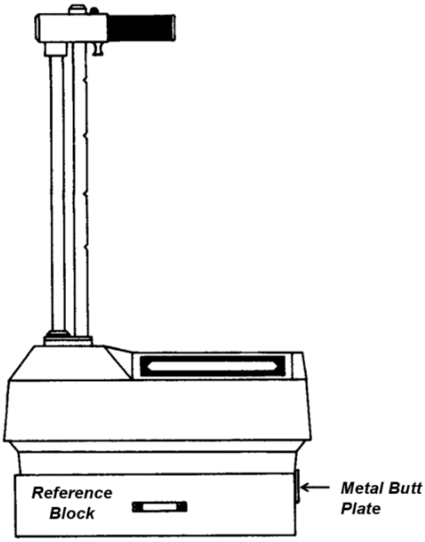


Figure 1015.J - Nuclear Gauge on the Standard Block

c. Make sure the standard block is resting on the ground on a material which has a unit weight more than 100 lbs/ft³ (1600 kg/m3).

d. Press the "ON" button on the gauge panel.
   i. Wait approximately 4 minutes for the gauge to warm-up.
   ii. The gauge may already be on prior to placing it on the block.
   iii. The gauge will beep when ready.
   iv. Readout display will show:
      1. Depth: safe position.
      2. Time: 1 minute (possibly a longer duration).
      3. Battery: volts.

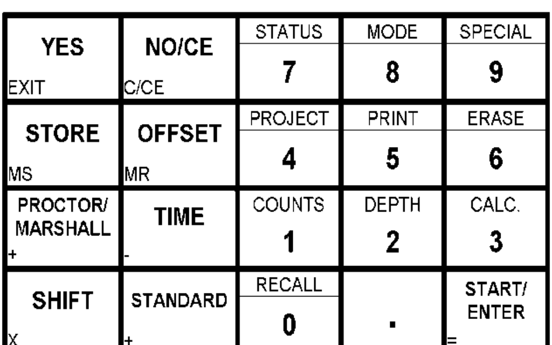


Figure 1015.K - Nuclear Gauge Keypad

- e. Press the "STANDARD" button (see Figure 1015.K).
    - i. Readout display will show the current count values and ask:
        1. Do you want to take a new count?
        2. Press "YES."
        3. Is the gauge on the block & rod in the safe position?
        4. Press "YES."
    - ii. Taking a standard count:
        1. Readout display will count down time.
        2. Takes 240 seconds.
        3. Gauge will beep when complete.
    - iii. Readout display when standard count is complete:
        1. MS= XXXX X.X %P
DS= XXXX X.X %P
        2. P means Pass, F means Fail
        3. If reading is within 1 percent for density or 2 percent for moisture, the standard passed.
- f. Record Standard Counts on Lines 4 and 7 on form CA-EW-5 and/or Lines 1 and 2 on form CA-EW-6.
- g. Display will ask:
    - i. Do you want to accept the new standard?
    - ii. Press "YES" if acceptable.
    - iii. Readout display will show:
        1. Ready.
        2. Depth.
        3. Volts.
        4. Ready to take the readings.

2. Taking Nuclear Gauge Readings.
    - a. Clear away all loose material or dried crust.
        - i. Obtain a level area with sufficient size to accommodate the gauge.
        - ii. Use the scraper plate to help smooth out the surface.
        - iii. See Figure 1015.L.

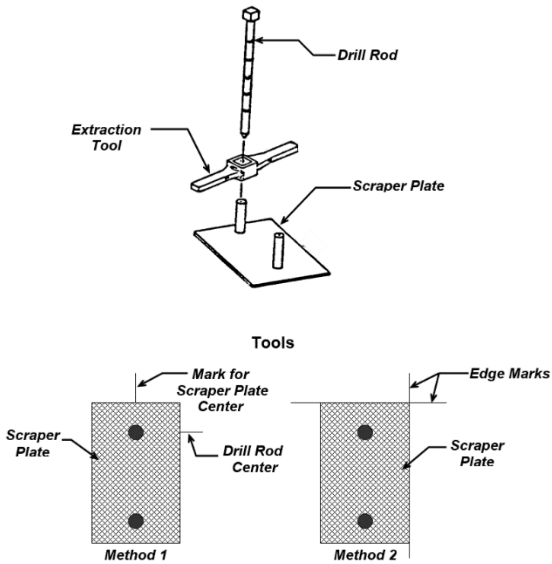


Figure 1015.L - Scraper Plate and Use

b. Use the native fines or fine sand to fill any voids and create a smooth surface.
   i. The maximum void beneath the gauge should not exceed 1/8 inch (3 mm).
c. Make a hole perpendicular to the prepared surface by using the drill rod and scraper plate provided by the manufacturer.
   i. Drive 2 inches (50 mm) further than the depth of the reading.
d. Mark the hole centerlines (Method 1 in Figure 1015.L) or the outside of the scraper plate (Method 2 in Figure 1015.L) to assist in aligning the gauge with the hole.
e. Remove drill rod by pulling straight up and twisting the extraction tool. Do not loosen the rod by hammering from side to side, since this will distort the hole. Remove the scraper plate.
f. Position the nuclear gauge on the prepared location. Use the alignment marks to correctly place the gauge over the hole. Alternatively,
   i. Raise the gauge up on one side and extend the rod out less than 2 inches (50 mm).
   ii. Place the rod into the hole.
g. Extend the rod to the required depth. See Figure 1015.M.

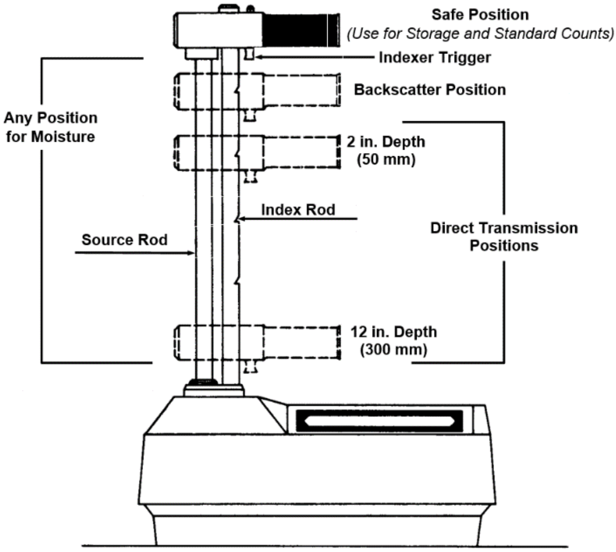


Figure 1015.M - Positions of the Nuclear Gauge

i. Backscatter Position is used for:
   1. Bases.
   2. Granular Materials.
   3. Materials requiring a test section.

ii. 8-inch (200 mm) depth used for embankment.

iii. 12-inch (300 mm) depth used for subgrade.

iv. The gauge display gives the depth.

v. The deepest depth is the most accurate.

h. Pull the gauge toward the detector end or away from handle to seat the gauge into position (see Figure 1015.I).
   i. Eliminates the air gap between the source rod and the hole.

i. Press "START/ENTER."

j. After one minute:, the readout displays:
   i. "DD = XXX.X PCF" , the Dry Density in lbs/ft^3
   ii. "WD = XXX.X PCF" , the Wet Density in lbs/ft^3
   iii. "M = XX.X" , the Moisture Density in lbs/ft^3
   iv. "% M = XX.X" , the Moisture Content in percent.

k. Record WD, DD, and % M on Lines 5, 6, and 8 on form CA-EW-5 and on Lines 3, 4, and 5 on form CA-EW-6.
   NOTE: This is not the same order as on the gauge display.

l. From the example in Figure 1015.N (bold red numbers).
   i. DD = Dry Density = Line 6= 133.0 lbs/ft^3
   ii. WD = Wet Density = Line 5 =144.4 lbs/ft^3
   iii. % M = % Moisture = Line 8 = 8.3%

CA-EW-5 **Nuclear Gauge Compaction Form**

Sample ID: *1113722540 - 416* Personnel ID: *111 - 0000 - 111* Date Sampled: *4/16/2012* Material Code: *20340001*
Type of Inspection: *COMPACTION* Producer Code: *55555 - 2* Contractor: *Peter's Excavating* Test Results: *PASS*

Project No.: ____ Item Code: ____ Ref. No.: ____ Notes: ____

Test of (check which): ☑ Embankment ☐ Subgrade ☐ Base ☐ Other ____ Min. Compaction Req.: *98* %
Test of (check which): ☐ Limestone ☑ Gravel ☐ Slag ☐ Sandstone ☐ Granulated Slag ☐ Other ____
From Sta. *1* + *00* at *5* ft *Rt* (Rt/Lt) of centerline to Sta. *2* + *00* at *20* ft *Rt* (Rt/Lt) of centerline, at Elev. *970* ft
Report No. *2* (check which): ☐ Wet ☑ Dry Maximum Density from Test Section ____ lb/ft³ Optimum Moisture ____ %
98% of Max. Density ____ lb/ft³ Check method used: ☑ Direct Transmission ☐ Backscatter Probe Depth *6* inches

Location		1	2	3	4	5	6
1. Station of test	1.	109+50	109+50				
2. Distance right or left of centerline if different than above ft	2.	10	12				
3. Approximate elevation if different than above ft	3.						
Nuclear gauge readings							
4. Standard Count for Density DS	4.	2208					
5. Wet Density of soil from gauge WD lb/ft³	5.	139.9	144.4				
6. Dry Density of soil from gauge DD lb/ft³	6.	130.1	133.0				
7. Standard Count for Moisture MS	7.	3599					
8. Moisture content of soil from gauge %M %	8.	7.5	8.3				
9. Number of Passes	9.	8	10				
Take sample (about 10 lb) of material from area tested for density. **Procedure when sample contains less than 10% total weight of the stone retained on ¾" sieve.***		Curve D	Curve D		Curve	Curve	Curve
10. Weight of 1/30 ft³ compacted wet soil + weight of container lb	10.	13.95	14.01				
11. Weight of 1/30 ft³ container lb	11.	9.24	9.24				
12. Weight of 1/30 ft³ compacted wet soil #10 – #11 lb	12.	4.71	4.77				
13. Density of compacted wet soil #12 × 30 lb/ft³	13.	141.3	143.1				
14. Optimum moisture from dry density curve Curve No. D %	14.	8.5	8.5				
15. Maximum dry density lb/ft³	15.	134.1	134.1				
16. Amount above or below optimum moisture #8 – #14 %	16.	– 1.0	– 0.2				
17. Percent compaction #6 ÷ #15 × 100 %	17.	97.0	99.2				
18. Max. moisture from the zero air voids curve using line 6 %	18.	10.5	9.5	9.5 > 8.3	OK		
19. Does material tested meet Specification requirements? Yes / No	19.	NO	YES				
20. **"A"** Rolling ordered; **"B"** Aerating ordered; **"C"** Watering ordered	20.	A					
21. Date Tested	21.	5/22/13	5/22/13				

ODOT Form date: 3/17/2009 * Use CA-EW-6 when sample contains more than 10% total weight in stone retained on ¾" sieve.

Calculated by *Steve Compaction* Checked by *Randy Reviews*

Figure 1015.N - Completed compaction form

4.E. Using the Ohio Typical Curves (S-1015.06.C.1)

Optimum moisture content and maximum dry density can be determined from the Proctor test results, nuclear gauge results, and the Ohio Typical Moisture-Density Curves as described in Sections 1015.3.B and 1015.3.C of this manual. Use the plotted Ohio Typical Moisture-Density Curves for compaction testing, which are in S-1015.

Once the wet density and percent moisture is obtained from the Proctor test, it can be used to find the curve that represents the soil being tested. Use the nuclear gauge result or an alternate drying method to determine percent moisture.

4.F. Selecting a Typical Curve Using the Nuclear Gauge Results

1. Secure a representative soil sample of about 10 lbs (5 kg).
    a. Use the soil between the end of the probe and the back of the gauge (see Figure 1015.I).
2. Sieve the material through a 3/4-inch (19 mm) sieve.
    a. Use Form CA-EW-5 if less than 10 percent of the soil is retained.
    b. Use Form CA-EW-6 if more than 10 percent of the soil retained.
    c. Use a Test Section Method if more than 25 percent is retained.
3. Thoroughly mix the material passing the 3/4-inch (19 mm) sieve.
4. Make a Proctor sample using Section 1015.3.A.2-Step 4 of this manual.
    a. Make a Proctor test for every compaction test (a soil cannot be correctly identified without this test).
    b. When weighing the Proctor mold and soil, the scales must be level and balanced.
        i. The scales need to be leveled with a carpenter’s level. Put the scale on a piece of flat plywood and then level the board. You may elect to level the weighting plate.
        ii. The older scales must be balanced once it is leveled. The weighting mechanism should float between the top and bottom bar. If it does not, then sand or pebbles can be added to the lever arm to make it balance.
5. Record and calculate the proctor results on Lines 10 through 13 on the CA-EW-5 and lines 11-14 on the CA-EW-6.
    a. Using Figure 1015.N.
    b. Line 10 (14.01 lbs) – Line 11(9.24 lbs) = Line 12 (4.77 lbs)
    c. Line 12 (4.77 lbs) × 30 = Line 13 (143.1 lbs/ft^3)
6. Pick the Wet Density Curve Using
    a. The Proctor wet density.
    b. Line 13 = 143.1lbs/ft^3
    c. % Moisture from gauge readings or by another drying method.
    d. Line 8= 8.3%
7. Use the Ohio Typical Moisture-Density or Project Curves (see Figure 1015.O).
    a. Draw a horizontal line through the wet density on the Ohio Typical Density Curves from the Proctor weight on Line 13, on the CA-EW-5, or Line 14, on the CA-EW-6 Form.
        i. Line 13 = 143.1 lbs/ft^3
    b. Extend a vertical line from the percent moisture shown on Line 8 on the CA-EW-5 or Line 5 on the CA-EW-6 Form to intersect the horizontal line.
        i. Line 8 = 8.3%

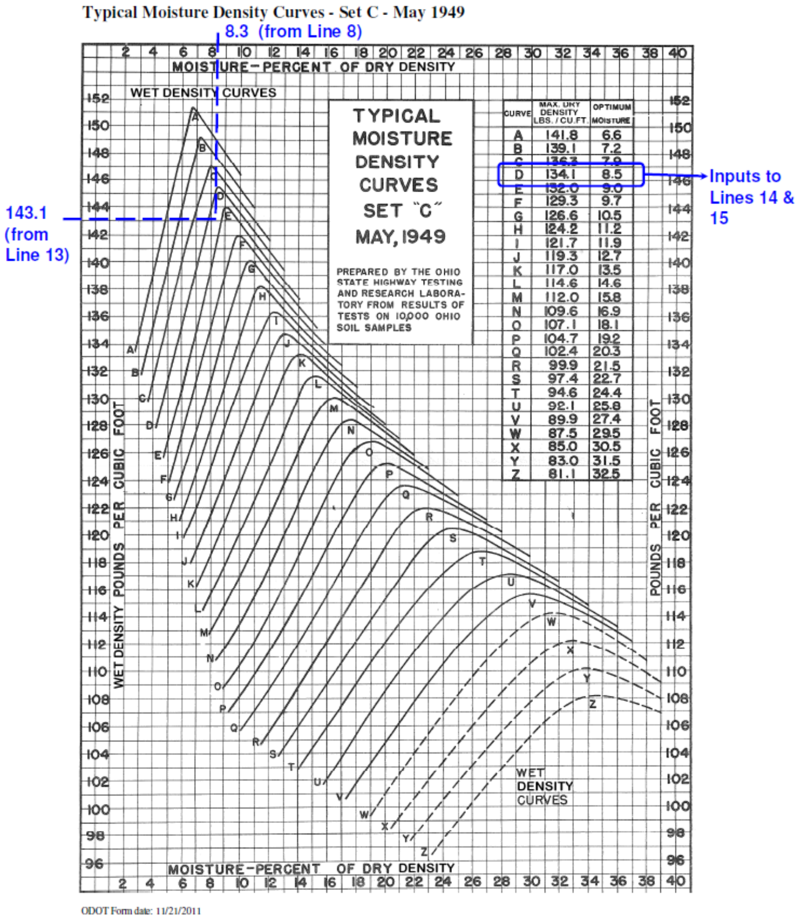


Figure 1015.O - Example of using the Ohio typical Moisture-Density curves

c. If the intersection falls on a curve, choose the curve.

d. If the intersection falls between two curves, choose the next highest curve.

8. Use the maximum dry density and optimum moisture content values from the table in the upper right hand corner of Figure 1015.O from the curve that is chosen.

   a. In this example, curve "D" is the correct curve.

9. After the curve is selected, record optimum moisture content on Line 14 and the maximum dry density on Line 15 of Form CA-EW-5 (Figure 1015.N). For the CA-EW-6, record the optimum moisture content on Line 15 and the maximum dry density on Line 18.

   a. Line 15 = Maximum Dry Density = 134.1 lbs/ft^3

   b. Line 14 = Optimum Moisture Content = 8.5%

4.G. Calculating Compaction and Zero Air Voids

Using Figure 1015.N.

1. Use line 16 to calculate the difference in moisture contents.
    a. Line 14 = 8.5 percent - Line 8 (8.3 percent) = - 0.2 percent (below optimum)
2. Use line 17 to calculate compaction.
    a. (Line 6 / Line 15) × 100 = (133.0 lbs/ft^3 / 134.1 lbs/ft^3) × 100 = 99.2 percent.
3. Compare to the allowable in the specifications shown in C&MS Table 203.07-1.

Table 203.07-1 Embankment Compaction Requirements

Maximum Dry Density (lbs/ft^3)	Minimum Compaction Requirement in Percent of Maximum Dry Density
90 to 104.9	102
105 to 119.9	100
120 and more	98

    a. Since Line 15 = 134.1 lbs/ft^3 > 120 the minimum required compaction is 98 percent.
    b. Line 17 = 99.2 percent > 98 percent
    c. The test passes.
4. If density and stability are achieved, then the moisture requirement passed.
    a. See Manual of Procedures Section 203.07.
5. Check Zero Air Voids.
    a. Use Figure 1015.P.
    b. Use Line 6 = 133.0
        i. Get 9.5 %
    c. 9.5 percent > Line 8 = 8.3 percent
    d. Good (Line 8 may be a maximum of 1 percent above the value from Figure 1015.P).

    Could also calculate the percentage by using the formula in Figure 1015.P:
        i. Where G = 2.67 and D = Line 6
        ii. If you are good with math, then the formula is much easier to use than the graph.

6. The check on the zero air voids curve is not required by S-1015, but it is a good check on the nuclear gauge readings. The moisture obtained from the curve or graph is the maximum moisture that can exist in the soil being tested. If the gauge moisture readings are larger than the ones obtained from the graph, then an error may exist in the test.

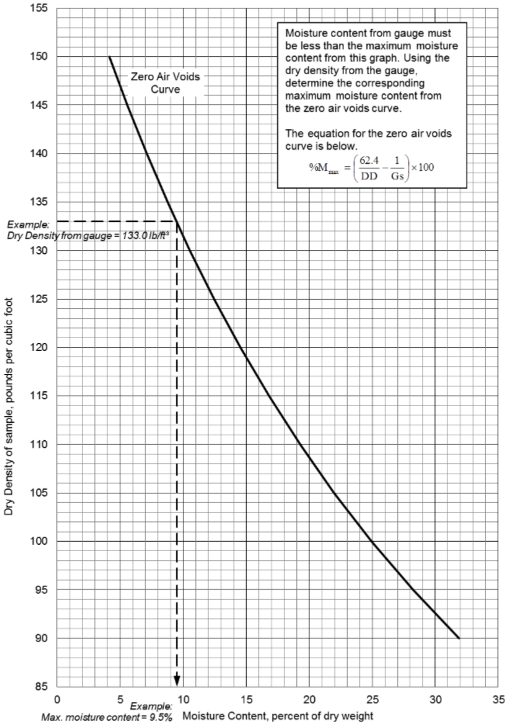


Figure 1015.P - Zero air voids curve

4.H. Moisture Controls

Moisture Control of Soil Embankments during Construction

In this section moisture controls during construction, variables in the moisture controls, and alternate methods used to verify or modify the moisture readings from the nuclear gauge are discussed.

Experience has shown that to obtain the specification density, the moisture content must be at or near optimum. Some soils, particularly silty soils with low plasticity, may meet the moisture (± 3 percent from optimum) and the compaction requirements, but have unsatisfactory stability.

Some soils compact better and meet the density and stability requirements at moisture contents of -3 percent or more below optimum. The reason for limiting the moisture contents for soil embankment this way is to ensure stable embankments.

The Elasticity and Deformation of Soils is discussed in Section 203.02 and Moisture Controls are discussed in Section 203.07.A of this manual.

There is not a numerical moisture requirement in the specifications. The Contractor must compact the material at a moisture content to obtain the density and stability of the

material. Moisture and compaction controls are necessary to secure the quality of embankments and subgrades that are essential for the long life and performance.

Alternate Tests for Moisture

The specifications do not numerically limit the moisture content of embankment or subgrade soils. Moisture determinations must be made in the field to pick the required moisture-density curve and to control the Contractor's compaction operations. The following sections deal with various methods of determining moisture contents of soils.

For engineering purposes, the moisture content of soil is expressed in percent of dry weight.

$$\text{Moisture Content (percent)} = \frac{\text{Weight of water in soil}}{\text{Weight of dry soil}} \times 100$$

Most of the time, the moisture content of a soil should be obtained by using the nuclear gauge readings. However, there are situations where drying methods can and should be used. Moisture content is the most variable reading from the nuclear gauge. There are a variety of chemicals that may be in the soil that can affect the moisture content reading accuracy. This is particularly true for recycled materials, such as fly ash, bottom ash, foundry sand, or asphalt.

Use the moisture estimating principles detailed in Section 203.02 Estimating Optimum Moisture Content.

Alternative field methods for determining the moisture content include: oven drying; microwave oven drying; open-pan drying; and alcohol or gasoline-burning drying. Procedures and the necessary equipment are provided in the 1015 Appendix – Alternate Tests for Moisture in this manual.

For each drying method, the soil to be tested should be a representative sample of at least 1 pound (0.5 kilograms). The soil should be placed in a small, clean can or jar and covered with a tight lid at the construction site to prevent evaporation of moisture while moving to the location of the field test. The test should be conducted as soon as possible after taking the sample. Sample location must be noted.

All the moisture tests should be checked against each other to ensure accuracy of the moisture testing. To record the moisture results, use CA-EW-4, Moisture-Density Calculation Form (Figure 1015.B) and read the appropriate sections.

5. Compaction Testing Requiring an Aggregate Correction (S-1015.06.C.2)

5.A. The Aggregate Correction Problem

As detailed in Section 1015.3.D, Coarse Aggregate Problem, the moisture-density relationship is very good for soils passing the 3/4-inch (19 mm) sieve as it relates to the field compaction of soils. Figure 1015.H showed that when the portion of material larger than the 3/4-inch sieve (gravel) increases, then the maximum dry density increases and the optimum moisture content decreases. The one-point Proctor test is made with the gravel material removed (0% gravel), so the maximum dry density determined from the

Ohio Typical Curves is too low for comparison to the actual field compaction. Corrections must be made to account for these materials.

Use the correction on the CA-EW-6 Compaction Form where more than 10 percent but less than 25 percent of the material is retained on the 3/4-inch (19 mm) sieve. See Figure 1015.Q, Aggregate Correction Method.

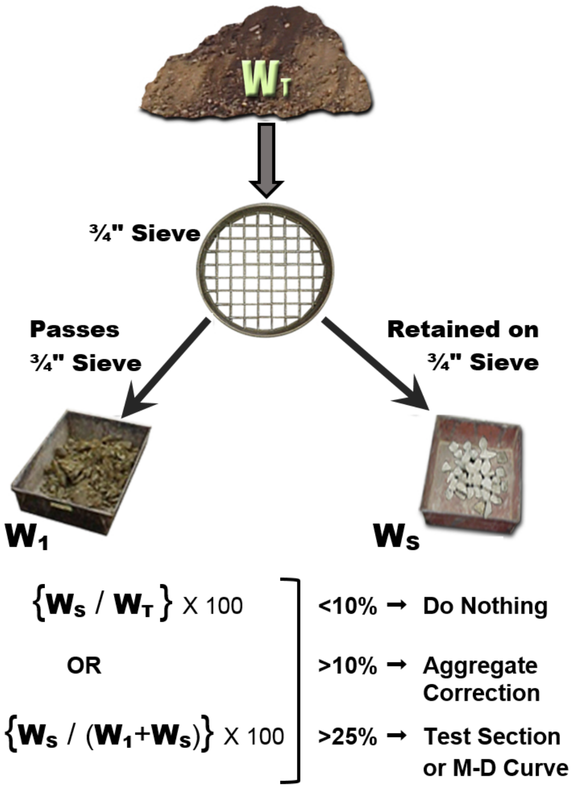


Figure 1015.Q - Aggregate correction method

Caution: This correction method is to be used for Fine Grained Materials with significant granular material retained. Sand is a coarse-grained Granular Material. Regardless of how much material is retained on the 3/4 inch-sieve. Always use a test section method for sand.

5.B. Using Form CA-EW-6 Nuclear Gauge Compaction with an Aggregate Correction

A completed form is shown in Figure 1015.R. The general parts of this form are as follows:

CA-EW-6 Nuclear Gauge Compaction with Aggregate Correction

Sample ID: ______ Date Sampled: ______
Type of Inspection: ______ Producer Code: ______ Contractor: ______
Material Code: ______ Test Results: ______

Contract Alt ID: ______ Item Code: ______ Proposal Line Number: ______

Notes: ______

Test of (check which): ☑ Embankment ☐ Subgrade ☐ Base ☐ Other ______

Min. Compaction Requirement: 100 %

From Sta. ______ + ______ at ______ ft ______ (Rt/Lt) of centerline, at Elev. ______ ft

Item	Formula	Unit	Line	1	2
Nuclear gauge readings					
1. Standard Count for Density	DS		1.	2208	
2. Standard Count for Moisture	MS		2.	3599	
3. Wet Density of soil from gauge	WD	lb/ft³	3.	129.1	
4. Dry Density of soil from gauge	DD	lb/ft³	4.	111.1	
5. Moisture content of soil from gauge	%M	%	5.	16.2	
Take sample from under gauge and pass through a ¾" sieve.					
6. Weight of total sample + weight of container		lb	6.	14.00	
7. Weight of container		lb	7.	2.00	
8. Weight of total sample	#6 – #7	lb	8.	12.00	
9. Weight of stone and container (sieve or pan)		lb	9.	3.40	
9a. Weight of container (sieve or pan)		lb	9a.	1.00	
9b. Weight of stone retained on ¾" sieve	#9 – #9a	lb	9b.	2.40	
10. Percent stone in sample	#9b ÷ #8 × 100	%	10.	20.0	
Proctor Test on the soil passing ¾" sieve					
11. Weight of 1/30 ft³ compacted wet soil + weight of container		lb	11.	13.40	
12. Weight of 1/30 ft³ container		lb	12.	9.24	
13. Weight of 1/30 ft³ compacted wet soil	#11 – #12	lb	13.	4.16	
14. Density of compacted wet soil	#13 × 30	lb/ft³	14.	124.8	
Select curve from Typical Density Curves using lines 14 and 5				Curve N	Curve
15. Optimum moisture from dry density curve		%	15.	16.9	
16. Moisture from line 5		%	16.	16.2	
17. Amount above or below optimum moisture	#16 – #15	%	17.	-0.7	
18. Maximum dry density		lb/ft³	18.	109.6	
Calculation procedure when line 10 is less then 10%					
19. Percent compaction	#4 ÷ #18 × 100	%	19.	≥ 10%	Skip to next Line
Calculation procedure when line 10 is between 10% and 25% *					
Identify average stone type: Limestone, Gravel, Sandstone, Shale, Slag				Limestone	
20. Corrected max. dry density using Agg. Correction Chart		lb/ft³	20.	117.2	
21. Corrected opt. moisture using line 20 and Typical Density Curves		%	21.	12.7	
22. Percent compaction	#4 ÷ #20 × 100	%	22.	94.8	
23. Amount above or below optimum moisture	#16 – #21	%	23.	3.5	
24. Max. moisture from the zero air voids curve using line 4		%	24.	18.7	
25. Does material tested meet Specification requirements? Yes / No			25.	No	
26. "**A**" Rolling ordered; "**B**" Aerating ordered; "**C**" Watering ordered			26.	B	

* If line 10 is greater than 25%, make a granular moisture density curve and use the Test Section Method.

Calculated by ______ Date ______ Checked by ______ Date ______

ODOT Form date: 07/19/2013

Figure 1015.R - Completed compaction form

Part 1. Nuclear Gauge Readings

Lines 1 thru 5 are explained in Section 1015.4.D.

Part 2. Take Sample from Under the Gauge and Pass Through a 3/4-inch Sieve

This part is a straightforward calculation of the stone retained on the 3/4-inch sieve, as shown in Figure 1015.Q. Calculate through Lines 6 through 10.

The percentage on Line 10 is represented by the following equation:

$$\text{Percent of Stone in Sample} = \frac{\text{Weight of stone retained}}{\text{Weight of total soil sample}} \times 100$$

Part 3. Proctor Test Using the Soil Passing the 3/4-inch Sieve

See Section 1015.4.F Steps 4 and 5, and 1015.3.A.2 for an explanation of Lines 11 thru 14.

Part 4. Select the Curve for the Typical Moisture-Density Curves Using No. 14 and No.5

See Section 1015.4.F Steps 6 through 9 for explanation of Lines 15 through 18. This is highlighted in blue in Figure 1015.T.

Part 5. Calculation Procedure When Line 10 is Less Than 10 percent

Line 19 is explained in Section 1015.4.G, but using the values in Lines 4 and 18.

Part 6. Calculation Procedure When Line 10 is Greater Than 10 percent and Less Than 25 percent

This part uses Figure 1015.S - Aggregate Correction Chart, and Figure 1015.T - Moisture Correction for an Aggregate Correction, to find a new maximum dry density and optimum moisture content. The procedures are explained in the following section.

5.C. Calculate a Corrected Maximum Dry Density

This section details the use of Figure 1015.S - the Aggregate Correction Chart, which is included as part of the CA-EW-6 compaction form.

1. The inputs needed are (circled in blue in Figure 1015.S):
    a. The specific gravity of the stone retained on the 3/4-inch sieve. Typical values are listed on the chart. For example, limestone = 2.6.
    b. The maximum dry density found on Line 18: 109.6 lbs/ft3.
    c. The percent retained on the 3/4-inch sieve on Line 10: 20 percent.
2. Draw a line between the specific gravity and the value from Line 18.
3. Input the Line 10 value on the bottom of the graph and draw a line parallel to the gridlines up to the line drawn previously.
4. From the intersection of the two lines, draw a line parallel to the horizontal grid lines and to the right to get the corrected maximum dry density.
5. Input this value on Line 20 on the CA-EW-6.

This is the corrected maximum dry density: 117.2 lbs/ft^3.

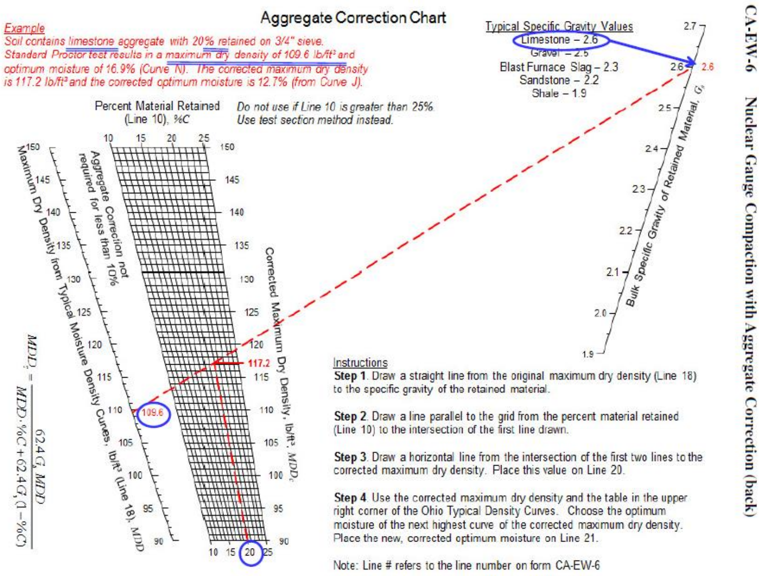


Figure 1015.S - Aggregate correction chart

5.D. Determine a Corrected Optimum Moisture Content

The corrected optimum moisture content is determined by locating the corrected maximum dry density in the maximum density values listed in the upper right hand corner of Figure 1015.T, the Ohio Typical Moisture-Density Curves.

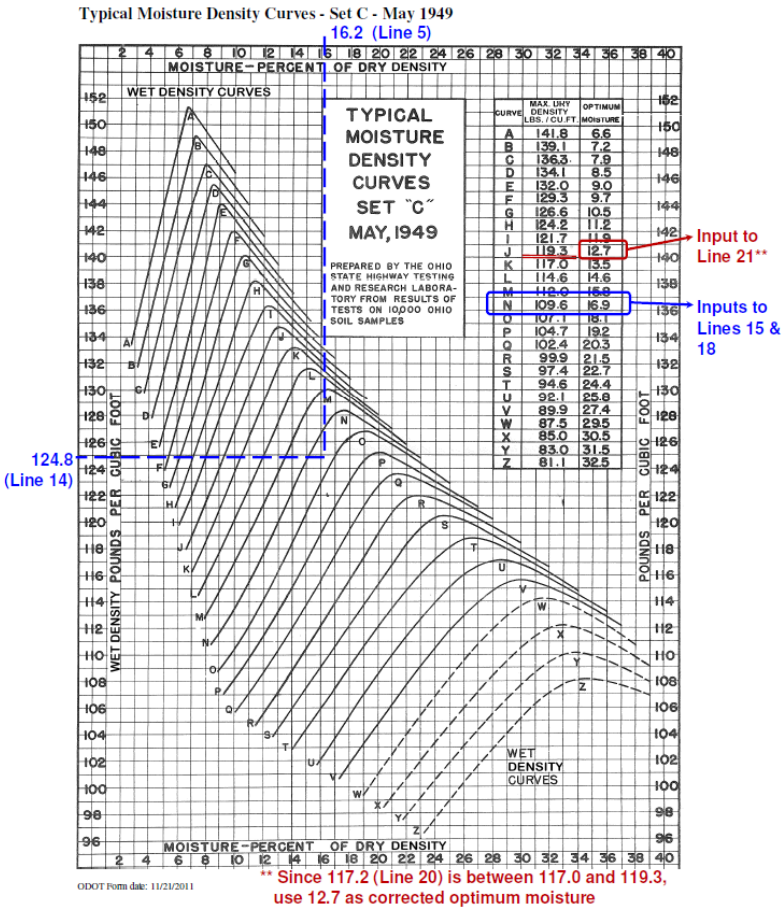


Figure 1015.T - Moisture correction for an aggregate correction

For example, the maximum dry density on Line 20 is 117.2 lbs/ft^3. This value is between Curve J (119.3) and K (117.0). The new optimum value is 12.7 percent which is the moisture corresponding to the next higher curve which is Curve J.

5.E. Calculating Percent Compaction, Difference from Optimum Moisture Content and Maximum Moisture Content from Zero Air Voids Curve

Percent compaction, difference from optimum moisture content, and the maximum moisture content from the zero air voids curve are calculated on Lines 22 to 24 using the corrected maximum density and the corrected moisture values.

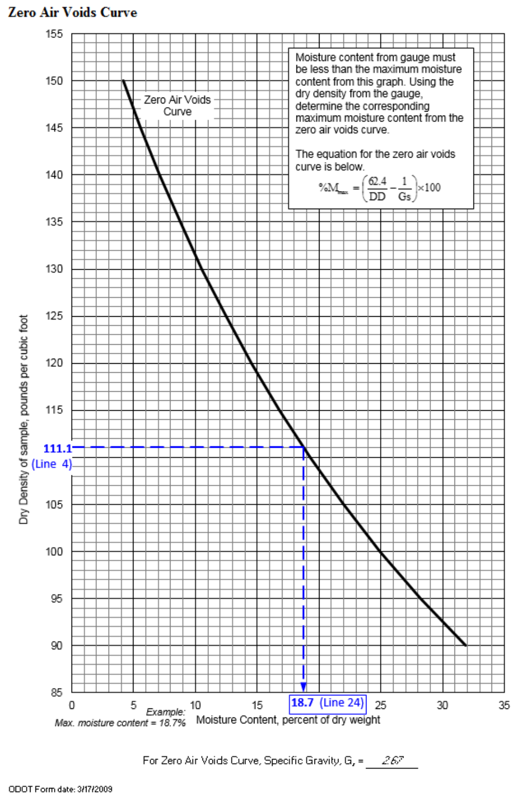


Figure 1015.U - Zero air voids curve

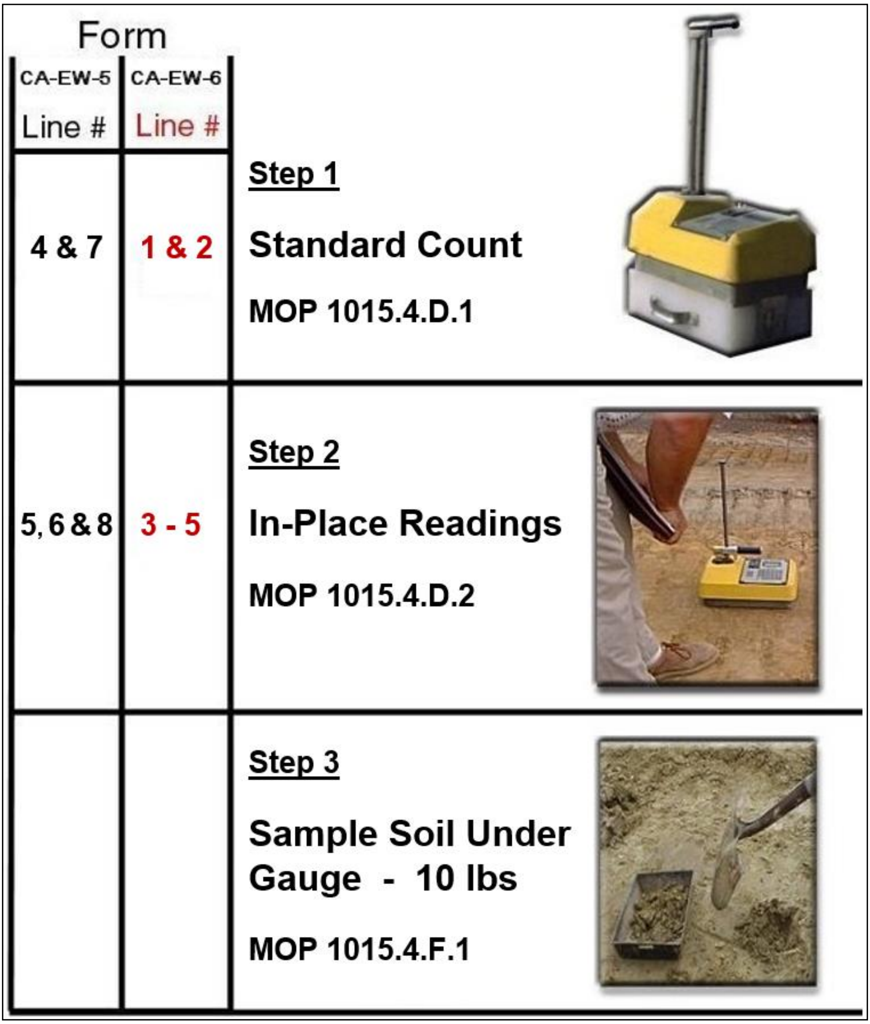


Figure 1015.V - Outline for using Forms CA-EW-5 and CA-EW-6 (1 of 2)

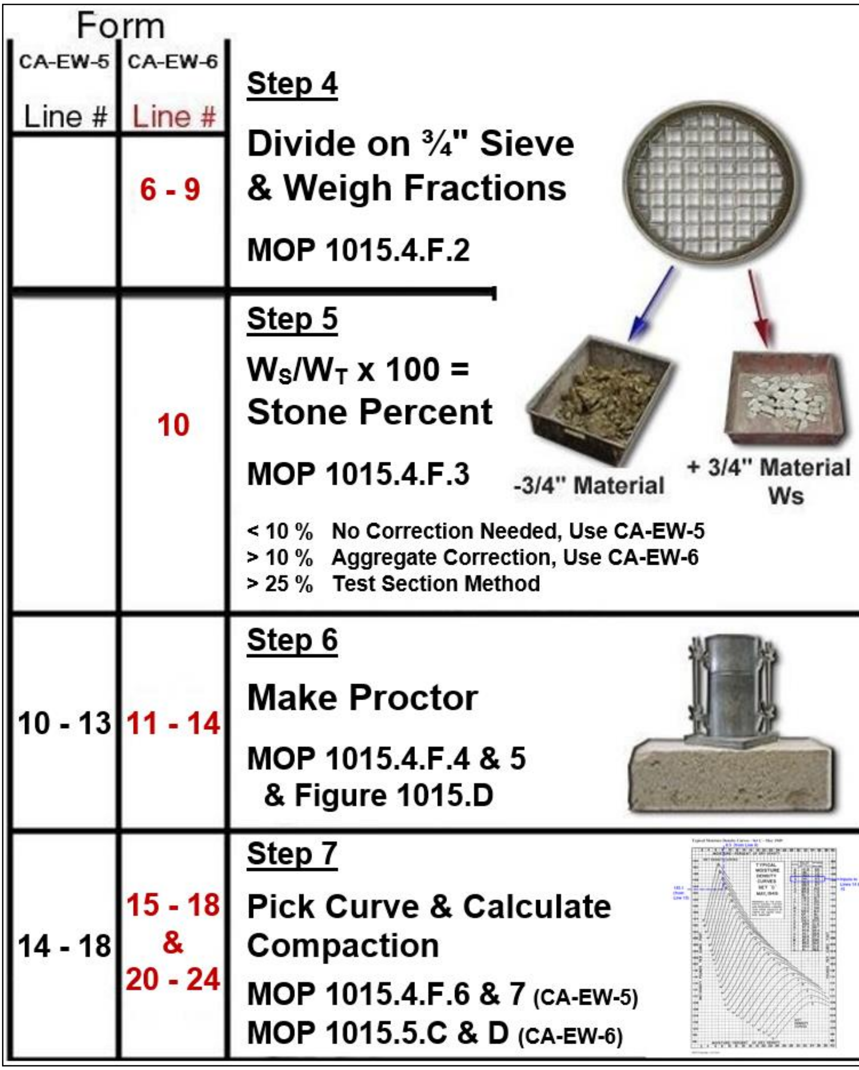


Figure 1015.W - Outline for using forms CA-EW-5 and CA-EW-6 (2 of 2)

1 Soil > 35% Passing No.200 Sieve	8" lifts	3/4" Sieve < 10% Retained > 10% Retained > 25% Retained	• One Point Proctor • Aggregate Correction ⇨ Granular Material
2 Granular Material < 35% Passing No.200 Sieve	8" lifts	M-D Curve Avaiable Not Available/None Variable Material	Test Section Method • Method A • Method B • Method C
3 Rock Limestone Sandstone Siltstone Durable Shale	3' lifts or Largest Particle or 18" at Bridges	Track Material with Dozer to Fill Voids	Compact with: Minimum Roller Size & No. of Passes (No density testing)
4 Rock & Shale Mixtures >15% Shale	8" lifts	Compact & Test Like Shale	
5 Shale	8" lifts	Bucket Durability Test (6" piece soaked 48 hrs)	
	1.	3/4" Sieve < 25% Retained 25-75% Retained > 75% Retained	 • One Point Proctor • Test Section Method A • Test Rolling
	2.	Test Rolling > 40% Breaks Down < 40% Breaks Down	 • Test Section Method A • Roller Size & Passes

Figure 1015.X - Compaction and testing guide

6. Compaction Testing for Granular Materials

6.A. General Explanation

Compaction testing for materials used as Granular Embankment, sand, Structural Backfill Type 1 or 2, 304, 411, Select Granular Backfill for MSE walls, Granular Material Type A, B, C, D or F, or any materials that requires a test section, is described in this section.

The dry density of the material is always used for compaction control. Using the wet density for comparison will give incorrect results.

Moisture-density Proctor curves were originally developed for cohesive (clays and silts) soils. Errors or complications arise when trying to extrapolate these principles to predominantly granular soils. For these materials, the Engineer or Inspector should determine density requirements from test section results.

Granular materials must have a moisture-density curve made before the Contractor proposes to use the material. Curves may be made in the field or by the Laboratory.

Making a moisture-density curve for these materials is the same procedure explained in Section 1015.3.A.2. A typical moisture-density curve for a granular material is shown in Figure 1015.Y.

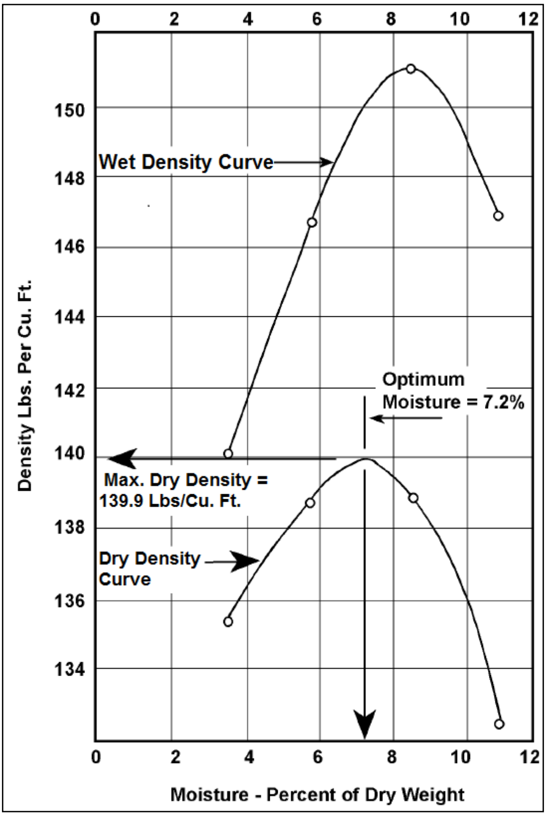


Figure 1015.Y - Typical granular Moisture-Density curve

The district may contact the Office of Geotechnical Engineering to have a moisture-density curve made.

The maximum dry density and optimum moisture content data obtained from this curve may or may not work in the field. The following are examples and further explanation of some of the problems associated with the density control of granular materials.

6.B. Examples of Density Problems

6.B.1. Using a Sandy Material

It may not be possible to obtain the maximum density of the curve no matter how or with what equipment the Contractor uses to compact the material. This is particularly true for sandy material with silt fines.

Reason

The Proctor mold used to produce the moisture-density curve confines the sand in all directions. In the field, since sand doesn't interlock or knit together well without being

confined, the roller will squeeze the material laterally. The laboratory maximum densities may not be obtained in the field.

The sand may not even support the weight of the roller. The lab and field confining pressures and compactive effort are not compatible in this case. A potential maximum dry density in the field for a sandy material may be only 135 lbs/ft^3, as compared to 140 lbs/ft^3 from the laboratory test.

Solution

Use the test section maximum dry density.

6.B.2. Using a Well Graded Granular Material like 304

In this case, the maximum dry densities obtained in the field, using the test section method, often exceed the maximum dry density obtained from the laboratory moisture-density curve.

Reason

The 304 type material is well interlocked and allows the roller to transfer more energy, compactive effort, or load to the material.

This roller load or energy is much larger than the Proctor hammer load of 5.5 lbs (2.5 kg) dropped 12 inches (305 mm) in three lifts. The potential maximum dry density in the field for 304 material may be up to 145 lbs/ft^3, as compared to the laboratory test value of only 140 lbs/ft^3.

Solution

Use the test section maximum density.

6.B.3. Compacting on a Soft Foundation

If the material is being compacted on a soft foundation, then the maximum laboratory density cannot be achieved. Excessive rolling will only result in pumping and creating an unstable foundation.

This applies to all types of materials. You cannot compact good material over bad material and expect to achieve a maximum density. The maximum density from a test section would be less than the laboratory maximum value.

6.B.4. Compacting in Confined Spaces

There are a variety of locations where light equipment is used to compact material. Some examples are for:

1. Pipe backfill.
2. Manhole backfill.
3. Around abutments.
4. MSE walls.

The potential maximum density is limited to the type of equipment used to compact this material in these confined spaces.

Throughout the specifications for these items, ODOT requires minimum compaction equipment weight for these areas where a test section is used for compaction acceptance.

The maximum density that can be achieved is proportional to the heaviest equipment that can be used in these locations. The maximum density that can be achieved in these locations is usually less than the laboratory value.

6.C. Moisture Problems

The granular material should be brought on site at or near optimum moisture. When this is not the case and the material is too dry, moisture should be added before rolling occurs. This is particularly important for 304 gradation materials since this material cannot readily absorb water once rolled.

In C&MS 304.03, it is required that the stockpile of 304 material have a moisture content of at least 2 percent below optimum.

Optimum moisture from the Proctor moisture-density curve of granular materials is not always correct. Sometimes the granular material begins to roll or pump when the material is compacted at or near optimum moisture obtained from the moisture-density curve. This is caused by excess water in the material and the difference between the field and curve confining forces. In this case, dry the material until stability is achieved; usually 1 to 3 percent below optimum will work.

6.D. Summary of the Moisture-Density Problems

A laboratory moisture-density curve for a granular material should be used to estimate the maximum dry density and optimum moisture content. For these materials, the laboratory moisture-density curve is used as a guide; a more precise maximum dry density and optimum moisture content can be determined by test section methods in the field.

The test section method of compaction acceptance compensates for:

1. Material differences.
2. Moisture problems.
3. Soft foundations.
4. Confined construction.

6.E. Equipment and Compaction Testing (S-1015.04)

The equipment used for compaction testing is listed in Supplement 1015.04.

The compaction testing is the same as in Section 1015.4.D, except for the following:

1. A one-point Proctor is not taken for every test. A laboratory Proctor test is only used to estimate the initial optimum moisture content.
2. The “Backscatter Mode” on the gauge is used.
   a. Ensure that the surface voids are all filled or the surface texture is the same.
3. Use form CA-EW-5. Aggregate corrections are not made.

6.F. Minimum Roller Weights for Test Sections

Throughout the specifications, you will find minimum roller weight requirements when a test section method is used for acceptance.

The following is from C&MS 203.06.A:

> "For soil or granular material, when a test section is used, use a minimum compactive effort of eight passes with a steel drum roller having a minimum effective weight of 10 tons (9 metric tons)."

The maximum potential density obtained in the field is relative to the effective weight of the roller used in the test section. Therefore, minimums were established to fit the field conditions. You will notice that confined areas have a much lower minimum effective weight and less maximum acceptance value.

Do not be confused by the word centrifugal force. It is only the equivalent additional weight caused by the vibration of the equipment.

7. Procedure for Constructing a Test Section Method A (S-1015.06.C.3)

Method A is used when the moisture-density curve is available to estimate the optimum moisture content. Use form CA-EW-13 (see Figure 1015.Z) to record the nuclear gauge readings. The following is an outline of the procedure:

1. Test section sizes are:
    a. 400 square yards for embankment, subgrade, or aggregate base.
    b. 10 square yards for trench backfill or other confined backfill.
    c. 40 square yards for select granular backfill for MSE walls.
2. Spread the material at the specified lift thickness.
    a. Usually 6 to 8 inches.
3. Moisture content at - 1 to + 1 percent of optimum as determined from the moisture-density curve.
    a. Water or dry throughout the lift.
    b. Reduce moisture if unstable.
4. Compact with two roller passes. One pass is each time the roller travels over a point.
5. Take a nuclear gauge density test.
    a. Mark the location with paint.
    b. Record the dry density and percent moisture on form CA-EW-13.
6. Compact with one more pass, take a density test, and repeat until:
    a. No further increase in density is measured.
    b. Or the density decreases.
7. Once a maximum density value is obtained:
    a. Make two additional passes and take one additional test.
    b. Verifies the maximum value (Verification Test).
8. Record the minimum number of passes and the maximum dry density on form CA-EW-13.
9. Use this number of passes or the specification minimum in the production area.
10. Compact the production area to at least 98 percent of the test section maximum.

Example test section densities are shown in Table 1015.7.A. The maximum density for Section 1 occurred on the 5th pass when the densities from next pass and after the verification passes were lower. The maximum density for Section 2 occurred on the 6th pass (condition 6.a. above) and the density after the verification passes was lower. Although the density for Section 3 decreased from the 4th to the 5th pass, the density after the verification passes was higher so more passes and testing are needed.

Table 1015.7.A – Test Section Value Examples ('X' denotes Maximum Used)

Test Section Value Examples ('X' denotes Maximum Used)						
Passes	2	3	4	5	6	Verification Passes (2 additional)
Section 1	126	134	135	140 X	122	125
Section 2	110	108	112	116	116 X	109
Section 3	120	129	132	130		145 (Take more Tests)

There are statements throughout the specifications that require a minimum number of passes. Experience has shown that these minimum passes for the different materials result in more uniform compaction in the production areas.

If the specification calls for 8 passes, use the 8 passes even though the test section may show that 6 passes are needed to obtain a maximum.

There are also statements throughout the specifications that allow a decrease in minimum number of passes, such as:

> "The Engineer may reduce the minimum passes if the passes are detrimental to compaction."

There are also statements about making a new test section when conditions change.

> "Construct a new test section if the pipe type, bedding material, backfill material, or trench conditions change."

All of these statements allow the Engineer to control the work to meet the field conditions and to obtain maximum densities.

CA-EW-13 Test Section Construction Compaction Form (S-1015.06.C.3)

Contract ID # ______________ Co-Rte-Sec ______________ Date Tested ______________
ALTID # ______________ Proposal Line # ___________ Contractor ________________
Item No. and Description ____

Inspector ID: ______________ Producer Code: ______________ Material Code: ______________

Material (*check one*): ☐ Embankment ☐ Subgrade ☐ Aggregate Base ☐ MSE Select Granular
☐ 503 Backfill Type___ ☐ 611 Pipe Backfill ☐ Other ______________

Location of Use: ☐ Entire Project ☐ Structure/Abutment ______________ ☐ Wall Number ______________
☐ Roadway (Sta, offset, name) ____

Test Section Method: ☐ Method A Laboratory Optimum Moisture Content ___________ %
☐ Method B
☐ Method C

Pass No.	Dry Density	Moisture (%)	Dry Density	Moisture (%)	Dry Density	Moisture (%)	Dry Density	Moisture (%)	Dry Density	Moisture (%)
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
V										
MDD										

V = Verification pass number
MDD = Maximum Dry Density for this test section

Test Section Compaction Control Results:
Minimum Number of Passes _________
Maximum Dry Density _________ pcf
Optimum Moisture Content _________ %

Computed By: ______________________ Checked By: ______________________

Figure 1015.Z – Test section construction compaction form

8. Test Section Method B (S-1015.06.C.3)

This type of test section is used when a moisture-density curve cannot be made or is not available at the time of construction. Recycled materials, such as some foundry sands or fly ash can be tested this way. Since the maximum density or optimum moisture are unknown, we have to create the curve in the field. Use multiple columns on form CA-EW-13 to record the nuclear gauge readings.

Use the same procedure as in Section 1015.7, except for the following.

1. Use material that is "bone dry," moisture content of 0 to 3 percent.

2. Place the material in the required lift thickness.
3. Compact, test, and record readings after each pass until:
    a. A maximum density is reached.
    b. Use form CA-EW-13 to record the dry density and moisture content after each pass.
    c. Record the maximum dry density and verification pass number.
4. Place new material in required lift thickness.
    a. At an adjacent location.
    b. At a moisture content 2 percent higher.
5. Compact and test after each pass to a maximum density (step 3).
6. Repeat the procedure from steps 4 and 5.
    a. At higher moistures until:
        i. Maximum value is achieved.
        ii. Two test sections have the same maximum density or stops increasing.
        iii. Material becomes unstable.
7. Use this maximum dry density, optimum moisture content, and minimum number of passes in the production areas. Record on form CA-EW-13.

9. Test Section Method C (S-1015.06.C.3)

This test section method may be used for materials that have a large amount of void spaces or for highly variable, non-uniform materials. Use multiple columns on form CA-EW-13 to record the nuclear gauge reading averages.

The test section procedure is the same as detailed in Section 1015.8 except for the following:

1. Place and compact the material at 1.5 percent above saturated surface dry (SSD) determined by Supplement 1031.
2. Construct each test section:
    a. 400 square yards.
    b. Mark three locations for nuclear gauge testing.
    c. Take nuclear gauge readings at the three locations.
    d. Average the readings and record on form CA-EW-13.
    e. Use the averages.
3. The maximum dry density is reached when:
    a. A maximum density average is achieved.
    b. The aggregate breaks.
    c. Whichever comes first.
4. Record the number of roller passes.
5. Take 10 in-place tests in the test section and average these dry density values.
6. For compaction acceptance, use the minimum number of roller passes and:
    a. Take five tests in a 5,000 square yard lot.
    b. This average of these readings must be greater than 98 percent of the test section maximum.

10. Compaction Testing for Shale (S-1015.07)

Compaction testing for shale will depend on the durability of the shale. Perform the durability test (Bucket test) outlined in C&MS 703.16.D. The compaction testing is directly associated with the results that are noted in Figure 1015.X. It provides a ready means to determine what test method to use for compaction acceptance.

In practice, different materials will always be mixed together in a fill situation. However, the durability test gives a good indication of how the material should break down during compaction and is an excellent way to determine how to test the compaction of the shale.

11. Compaction Acceptance (S-1015.08)

Compaction acceptance is always based on the dry density of the material. After the material is compacted, the dry density does not change with the addition or reduction of water, while the wet density does increase with the addition of water and decrease as the material dries.

12. Number of Tests (S-1015.09)

Use Forms CA-EW-5 and CA-EW-6 for recording and reporting results of compaction tests. Do not put different material items on the same form; use separate forms. File these test reports with the associated items of work.

The frequency of testing of each lift is based on the maximum lot size for the material item and are provided in S-1015 in Table 1015.09-1. Typically, the frequency of density and moisture testing may be higher during the start-up of the work when the behavior of the project materials are being learned. Under normal field conditions, the number of density and moisture tests required should return to the minimum frequency, assuming that the work is proceeding smoothly and materials being compacted are uniform.

The Engineer and Inspector will learn to judge the moisture content of the material quickly by appearance and feel. If adequate densities are obtained and the proper moisture content is maintained, the job of inspection may consist of deciding on the number of passes of the roller required for satisfactory compaction and ensuring that this number of passes is made.

Under such conditions, only one or two density checks per day may be required. Where conditions are more variable, density and moisture checks may be needed as often as once an hour. The Engineer and Inspector can determine the exact number of checks required.

1015 Appendix – Alternate Tests for Moisture

Oven Drying Method

This method of determining moisture content is applicable to all types of soils. The time required to dry the sample depends on the size and moisture content of the sample and the type of soil.

This method should be used for any recycled material. This can be used to apply a moisture correction to the nuclear gauge readings when the material is uniform. This is particularly true for fly ash.

Equipment

1. Two-burner stove. Either oil stove or a camp stove using white gasoline.
2. Portable camp oven. It sets on and is heated by the stove.
3. Several baking pans approximately 12 inches × 8-1/2 inches × 2-1/2 inches (300 mm × 200 mm × 63 mm).
4. Masonry trowel or putty knife.
5. Can of fuel. The can has tight stoppers and is painted red if used for gasoline.
6. Scale of 25 pound (12 kilogram) capacity sensitive to 0.01 pound (1 gram).
7. Piece of flat glass or pieces of bond paper with texture similar to the compaction forms.

Procedure

1. Weigh the pan to the nearest 0.01 pound (1 gram). Record the weight.
2. Place approximately 1 pound (0.5 kilograms) of representative sample of wet soil in the pan on the scale.
    a. Record the combined weight.
3. Break-up all lumps of soil with the putty knife or trowel and avoid any loss of the sample.
4. Place the pan with the sample in the oven with the stove on. Stir the soil every 3 to 5 minutes.
5. After the soil has changed to a lighter color and appears to be dry, remove the soil sample from the oven and test to determine if it is completely dry by using one of the following methods:
    a. Lay a piece of bond paper approximately 2 inches × 3 inches (50 mm × 75 mm) on the sample.
        i. If the paper curls immediately when laid on the sample, the soil contains moisture.
        ii. The paper used for this test must be bond of hard surface texture like the paper used for the compaction forms.
    b. Hold a piece of clean glass or a mirror in a horizontal position about 1 inch (25 mm) above the soil sample.
        i. If the glass steams up, this is an indication of further moisture in the sample.
    c. Keep the glass away from the heat of the stove or direct rays of hot sun prior to the test since this test depends upon condensation of moisture in the hot air onto the cooler glass.
6. If the test indicates further moisture in the sample, stir the sample and continue drying.
    a. Test the soil every 3 to 5 minutes until the test indicates the soil is dry.
7. Weigh the dried sample and pan to the nearest 0.01 pound (1 gram). Record this weight.
8. Subtract the weight of the pan from the weight of the pan and the dry sample to obtain the weight of the dried sample.

9. Subtract the weight of the dried sample from the weight of the wet sample. This is the weight of water in the original sample.
10. Divide the weight of the water by the weight of the dried sample. Multiply this result by 100. This gives the percentage of moisture in the sample. The equation is:

$$\text{Percent Moisture} = \frac{\text{Weight of wet soil} - \text{Weight of dry soil}}{\text{Weight of dry soil}} \times 100$$

Microwave Oven Drying Method (ASTM D4643)

This method is quick and simple. The moisture content is determine by incrementally drying the soil in a microwave oven. This method of determining moisture content is applicable to most types of soils. Soils containing large amounts of organic matter, mica, gypsum, or other hydrated materials may lead to inaccurate results.

Equipment

1. Microwave oven, about 70 watt, with variable power controls.
2. Scale of 25 lbs (12 kg) capacity sensitive of 0.01 lbs (1 gram).
3. Nonmetallic, nonabsorbent specimen containers. For example, paper plate, glass or porcelain dish, laboratory glassware.
4. Hot glove for removing hot containers from oven.
5. Heat sink (glass beaker with water or moist brick) to absorb excess microwaves after the soil has dried.
6. Glass rod, putty knife, or spatula, for breaking up and stirring the soil.

Procedure

1. Weigh the container to the nearest 0.01 pound (1 gram). Record the weight.
2. Place approximately 1 pound (500 grams) of representative sample of wet soil in the container on the scale. If less than 10 percent of the soil is retained on the No. 10 sieve (2.0 mm), the sample size may be reduced to 0.2 pounds (200 grams).
    a. Record the combined weight.
3. Break-up all lumps of soil with the rod, putty knife or trowel and avoid any loss of the sample.
4. Place the container with the sample in the oven with the heat sink and turn the oven on for 3 minutes. Do not overheat the soil. Experience with particular soils may indicate that a shorter or longer initial drying time is appropriate.
5. Remove the container and soil from the oven and weigh. Record weight to the nearest 0.01 lbs (1 g).
6. Stir the soil with the rod, putty knife or trowel and avoid any loss of the sample.
7. Return the container with the sample to the oven with the heat sink and turn the oven on for 1 minute.
8. Repeat Steps 5 through 7 until the change in weight between consecutive weighing’s is less than 0.1 % of the initial wet weight of the specimen.
9. Weigh the dried sample and pan to the nearest 0.01 lbs (1 g). Record this weight.
10. Calculate moisture content as shown in Steps 8 and 10 of the Oven Drying Method.

Precautions

The following cautions should be taken to avoid introducing errors into the test.

1. Avoid overheating the soil.
2. Highly organic soils and soils with oil or coal may ignite and burn in the oven.
3. Soils containing metallic materials may cause arcing in the oven.
4. Ensure that no soil is lost during the test.

Open-Pan Drying Method

This method is quick, simple, and obtains accurate results for granular material. This method should not be used for fine-grained soils (silts or clays) because the high temperatures may burn away the organic material if it happens to be present. This method can be used for fine-grained soils where limited accuracy is satisfactory and approximate moisture results are acceptable.

This method should not be used for any recycled material. It has been found to give lower moisture contents than is really in the material. This is particularly true for fly ash.

Equipment

1. Scale of 25 lbs (12 kg) capacity sensitive of 0.01 lbs (1 gram).
2. Several baking pans approximately 12 inches × 8-1/2 inches × 2-1/2 inches (300 mm × 200 mm × 63 mm).
3. Putty knife or other device for breaking up and stirring the soil.
4. Two-burner stove burning white gasoline.
5. Piece of flat glass or pieces of hard surface bond paper with texture similar to the compaction forms.

Procedure

Follow steps outlined in the Oven Drying Method, Steps 1 through 10, except place the pan directly over the burner instead of in the oven.

Precautions

The following cautions should be taken to avoid introducing errors into the test.

1. Avoid overheating the soil.
    a. Use two pans, one inside the other, to avoid hot spots that may occur when a single pan is used.
2. Avoid baking the soil.
    a. Baking can be prevented by testing the material with a paper or glass test at sufficiently close intervals, so that further heating can be discontinued after all the moisture has been evaporated.
3. Ensure that no soil is lost during the test.

Alcohol-Burning Drying Method

This method is quick and simple. The alcohol burns at a low enough temperature 286 ºF to 320 ºF (140 ºC to 160 ºC) so that it can be used with accuracy for most soil types.

This method should be done outside or in a well-ventilated area.

Equipment

1. Scale of 25 lbs (12 kg) capacity sensitive of 0.01 lbs (1 gram).
2. 12 × 8.5 × 2.5 inches (300 × 200 × 63 mm) baking pan.
3. Pan or can with perforated bottom and filter paper to fit bottom.
    a. A 10 oz (300 mL) round sample can is suitable for this purpose.
4. Glass stirring rod.
5. Supply of alcohol in tightly sealed can.

Procedure

1. Weigh perforated pan or can with filter paper in the bottom. Record weight.
2. Place sample of wet soil in perforated pan or can; weigh and record weight.
3. Place perforated pan or can in larger pan and stir alcohol into the soil sample with a glass rod until the mixture has the consistency of a thin mud or slurry.
    a. When stirring, do not disturb the filter paper on the bottom.
    b. Clean the rod.
4. Ignite the alcohol in the other pan and in the sample and burn off all alcohol.
5. Repeat the process three times or until successive weighing's indicate no reduction in weight after each time burning.
6. After final burning, weigh perforated can or pan and dry soil, and record weight.
7. The weight of dry soil equals the weight minus weight of perforated pan or can and filter.
8. Calculate moisture content as shown in Steps 9 and 10 of the Oven Drying Method.

Gasoline-Burning Drying Method

Application

This is a quick and simple method of drying. However, the gasoline burns at such a high temperature that it should be used only to dry granular materials. This method should only be conducted outside.

Equipment and Procedures

This method of drying is similar to the alcohol-drying method with the exception that the perforated pan and filter are not used. The gasoline can be mixed with the sample in the baking pan and burned in the pan. Except for this, the test is run exactly the same as the alcohol-burning method, described above.

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