Preface

Name

The name of this manual is the Pavement Design Manual (PDM). It was previously known as the Pavement Design & Rehabilitation Manual. All references to the Pavement Design & Rehabilitation Manual shall be considered to reference the PDM.

Purpose

Many manuals, policies, guides, standards, etc., have been published regarding pavement design and rehabilitation. Many of these have been written using wide ranges of design recommendations (minimums and maximums) since the contents were intended to apply nationally. Furthermore, the Ohio Department of Transportation's pavement design and rehabilitation procedures have been scattered among many different publications, poorly documented or in some cases existed only in the minds of a select few engineers. The purpose of this manual is to bring all the information together in one document, reduce the selection of design variables to those most appropriate for the State of Ohio, to document Ohio's interpretation of various policies and to include design criteria which may be unique to Ohio.

Application

The pavement engineering concepts described herein are intended for use with all new or reconstruction projects, major and minor rehabilitation projects, and all surface treatment projects, which are under the jurisdiction of the Ohio Department of Transportation (ODOT). The information contained in this manual has been taken from and based on the results of the AASHO Road Test, the AASHTO Guide for Design of Pavement Structures, Federal Highway Administration (FHWA) guidelines and technical advisories, industry publications, various training course manuals, ODOT research reports, as well as from the experience of the authors. In addition, the application of other studies, experiences, and engineering judgments have been included to fit Ohio's conditions.

The pavement design procedures relate the performance of a pavement to its structural design and the loading applied to the pavement. Failure mechanisms derived from poor mix design, poor material quality, or poor construction practices are not addressed in this manual.

This manual is neither a textbook nor a substitute for engineering knowledge, experience or judgment. It is intended to provide uniform procedures for implementing design decisions, assure quality and continuity in design of pavements in Ohio, and assure compliance with Federal criteria. The recommendations given are intended to improve pavement performance.

Consideration must be given to design standards adopted by city, county, or other local governments when designing pavements under their jurisdiction.

Distribution

The manual is distributed electronically through the Design Reference Resource Center on the ODOT website at http://www.dot.state.oh.us/drc. This manual is intended primarily for ODOT personnel who have received training from the Office of Pavement Engineering. It is made available to cities, counties, consultants, etc., to use at their own risk.

Preparation

The PDM has been developed by the Office of Pavement Engineering. Errors or omissions should be reported to the Ohio Department of Transportation, Office of Pavement Engineering, 1980 West Broad Street, Mail Stop 5200, Columbus, Ohio 43223.
Format and Revisions

The PDM is provided exclusively in electronic format through the Design Reference Resource Center. The online manual is the official version. Users may print all or part of the manual but are responsible for keeping it up to date.

Revisions to the PDM are distributed through the Design Reference Resource Center with notification through the e-mail subscription list. Revisions will be issued as necessary on the quarterly release dates.

Although pages are individually numbered within each section, new pages may be added and identified with letter suffixes after the page number. Each page has the latest revision date shown in the lower left hand corner. Figures do not have page numbers but are numbered to coincide with the section number in the text. The revision date for figures is located in the upper right corner. Figures are located at the end of each section and, if printed, are best printed on colored paper for easy reference.
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Pavement Design Approval and Responsibility

All pavement design buildups pertaining to roadways designated as Interstates, US Routes, National Highway System (NHS) routes, State Routes, or otherwise under the jurisdiction of the Ohio Department of Transportation (ODOT) must be approved by ODOT prior to incorporation into a set of construction plans. Those Agencies, Municipalities, or Consultants seeking pavement design buildup or approval from ODOT should make the request through the appropriate ODOT District Office.

A formal request for pavement design buildup or approval should include the following:

- A schematic drawing of the project;
- Typical sections showing the existing pavement buildup and the lane and shoulder configurations and widths, if applicable;
- Proposed typical sections with no pavement buildup but showing the number and width of lanes and shoulders and all cross-slopes;
- Plan and profile sheets if changes are being made;
- Certified traffic data showing the current and design year ADT and the 24-hour truck percentage; and,
- All required soils information as determined by the Office of Geotechnical Engineering

For projects which require Pavement Selection Committee approval (see Section 100), the above items, including the GB1 spreadsheet, must be submitted to the Office of Pavement Engineering.
Glossary of Terms

Analysis Period: The number of years included in a life-cycle cost analysis.

California Bearing Ratio (CBR): The quotient of a laboratory soil penetration test compared to a standard crushed rock penetration test. The test is performed on a saturated soil sample and is designed to represent the lowest bearing capacity of the soil.

Composite Modulus of Subgrade Reaction (Kc): A value used in rigid pavement design determined by dividing the load on a subgrade by the deflection, corrected for the effect of a base.

Composite Pavement: A pavement structure consisting of an asphalt concrete wearing surface on top of a hydraulic cement concrete slab.

Concrete Elastic Modulus (Ec): A measure of the rigidity of a pavement slab and its ability to distribute loads.

Concrete Pavement Restoration (CPR): Work performed on a concrete pavement consisting of any combination of diamond grinding, full or partial depth repair, dowel bar retrofit, etc., that preserves the concrete surface. A CPR project may be considered a surface treatment or minor rehabilitation.

Construction Joint: A transverse joint necessitated by an interruption in paving.

Contraction Joint: A joint at the end of a rigid pavement slab to control the location of transverse cracks.

Design Period: The number of years used in traffic loading predictions to design the new or rehabilitated pavement structure.

Design Serviceability Loss (ΔPSI): The change in the serviceability index of a pavement from the time it is constructed to the end of its design life.

Differential Costs: Costs that can be reasonably calculated, based on the information available at the time, that are different between the various alternatives in a life-cycle cost analysis.

Discount Rate: An economic factor to account for the effects of interest and inflation.

Drainage Coefficient: A factor used to modify structural layer coefficients in flexible pavements or stresses in rigid pavements as a function of how well the pavement structure can handle the effect of water infiltration.

Edge of Traveled Way: The intersection of the mainline pavement (driving lanes) with the shoulder (treated or turf) or the curb and gutter.

Effective Modulus of Subgrade Reaction (K): The composite modulus of subgrade reaction modified by loss of support.

Equivalent Single Axle Load (ESAL): Truck traffic loading expressed as the number of equivalent 18,000 lb (80 kN) single axle loads.

Expansion Joint: A transverse joint located to provide for the expansion of a rigid slab in the longitudinal direction without damage to itself or adjacent slabs. Generally placed near bridges or used to isolate mainline pavement from side road pavement at intersections.

Flexible Pavement: A pavement structure consisting of asphalt concrete, with or without an aggregate base, placed on a prepared subgrade.
**Functional Characteristics:** Those characteristics that affect the highway user but have little effect on the load carrying capacity of the pavement. Ride quality is the predominant functional characteristic. Others include skid resistance and surface oxidation.

**Functional Classification:** The grouping of highways by the character of service they provide.

**Group Index:** A number derived from the gradation, liquid limit and plasticity index of a soil.

**Life-cycle cost analysis (LCCA):** An economic analysis tool to quantify the differential costs of alternative pavement options by analyzing initial costs and discounted future costs over a defined period of time.

**Liquid Limit:** The water content, in percent, of a soil at the arbitrarily defined boundary between the semi-liquid and plastic states.

**Load Transfer Coefficient (J):** A factor used in rigid pavement design to account for the ability of a concrete pavement to distribute load across joints and cracks.

**Longitudinal Joint:** A pavement joint, in the direction of traffic flow, used to control longitudinal cracking on a rigid pavement or the joint formed between adjacent passes of a paver on a flexible pavement.

**Loss of Support (LS):** A factor included in the design of rigid pavement to account for the potential loss of support arising from base erosion and/or differential vertical soil movements.

**Major Rehabilitation:** Work performed on a pavement intended to restore structural and functional characteristics. Major rehabilitation includes such work as complete replacement, rubblizing with an asphalt overlay, unbonded concrete overlay, whitetopping, and possibly others.

**Mean Concrete Modulus of Rupture (S'_c):** The flexural strength of concrete derived from a beam test with third point loading.

**Minor Rehabilitation:** Work performed on a pavement intended to restore functional characteristics and protect structural characteristics. Minor rehabilitation consists primarily of asphalt overlays of varying thickness or CPR.

**Multi-Lane Pavements:** Pavements with four or more lanes. Continuous two-way left turn lanes are considered lanes in this definition.

**New Pavement:** Pavement built on a new alignment where no pavement existed before, pavement replacing existing pavement that has been removed, and pavement built next to existing pavement to increase capacity (widening).

**Overall Standard Deviation:** A statistical measure to account for the error in the prediction of traffic and pavement performance.

**Pavement Condition Rating (PCR):** A numerical rating of pavement distresses on a 0 to 100 scale based on visual inspection. A PCR of 100 signifies a perfect pavement with no distress.

**Plastic Limit:** The water content, in percent, of a soil at the boundary between the plastic and semi-solid states.

**Present Serviceability Index (PSI):** A numerical index which correlates roughness measurements on a scale of 0 to 5. A PSI of 5 indicates an exceptionally smooth pavement.

**Pressure Relief Joint:** Similar to expansion joint but placed exclusively near bridges to prevent damage to the bridge from pavement expansion.

**Reliability (R):** A statistical measure of the probability that a section of pavement will meet or exceed the predicted performance.
Rigid Pavement: A pavement structure consisting of hydraulic cement concrete, with or without an aggregate base, placed on a prepared subgrade.

Salvage Value: The remaining value of an investment alternative at the end of the analysis period.

Serviceability: The ability of a pavement to serve traffic as measured by the present serviceability index.

Slab Length: The distance between adjacent transverse joints.

Structural Deduct: A part of the PCR indicating distresses that may be related to the structural characteristics of the pavement.

Structural Characteristics: Those characteristics related to the load-carrying capacity of the pavement.

Structural Coefficient (Layer Coefficient): A measure of the relative ability of a material to function as a structural component of a flexible pavement structure and used to convert a design structural number to actual thickness.

Structural Number (SN): A regression coefficient derived from an analysis of traffic, soil conditions, and environment which may be converted to thickness of flexible pavement layers using structural coefficients related to the type of material being used in each layer of the pavement structure.

Subbase Elastic Modulus: A measure of the ability of a subbase to carry a load.

Subgrade Resilient Modulus ($M_r$): A measurement of the stress dependency of a subgrade soil, determined by the LTPP P46 test procedure.

Surface Treatment: Work performed on a structurally sound pavement intended to preserve the pavement, retard future deterioration, and maintain or improve the functional characteristics without substantially increasing the structural capacity. Surface treatments include such things as chip seals, microsurfacing, thin overlays and diamond grinding.

Terminal Serviceability Index ($P_t$): The lowest present serviceability index used in the design equations; the point at which rehabilitation is anticipated.

Transverse Joint: A pavement joint perpendicular to the centerline alignment of the pavement, designed to control cracking, provide for load transfer, and allow for the contraction and expansion of the pavement. Transverse joints may be construction, contraction, or expansion joints.

User Costs: The increased cost incurred by the highway user, such as vehicle operating costs and value-of-time delay costs, due to construction activities during the analysis period.
Reference Documents

Circular Number A-94 (Office of Management and Budget - 1992), Appendix C (OMB - Current Revision)


Construction and Material Specifications (ODOT - Current Edition)


Geotechnical Bulletin GB1: Plan Subgrades (ODOT - Current Revision)

Guide for Design of Pavement Structures (AASHTO - 1993)


Location and Design Manual, Volume One - Roadway Design (ODOT - Current Revision)

Location and Design Manual, Volume Two - Drainage Design (ODOT - Current Revision)

Location and Design Manual, Volume Three - Highway Plans (ODOT - Current Revision)

Location and Design Manual, Volume Three - Highway Plans, Sample Plan Sheets (ODOT - Current Revisions)

Pavement Condition Rating System (ODOT - Current Revision)


Specifications for Geotechnical Exploration (ODOT - Current Revision)

Standard Construction Drawings (ODOT - Current Revisions)

Effectiveness of Chip Sealing and Micro Surfacing on Pavement Serviceability and Life (ODOT – 2010)

Effectiveness of Crack Sealing on Pavement Serviceability and Life (ODOT – 2011)

Effectiveness of Thin Hot Mix Asphalt Overlay on Pavement Ride and Condition Performance (ODOT – 2008)


An Efficient and Accurate Genetic Algorithm for Backcalculation of Flexible Pavement Layer Moduli (ODOT - 2012)

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100 Pavement Requirements

100 Pavement Requirements

The requirements in this section replace ODOT policies 20-007(P) Pavement Design Policy and 22-009(P) Pavement Type Selection Policy, and standard procedure 520-001(SP) Pavement Type Selection Standard Procedure. Pavement designs for Interstate, US, and State routes, and other Federal-aid routes are to follow the requirements of this section and the procedures set forth in this Manual.

101 Design Responsibility

The districts are responsible for the pavement design for all priority system surface treatments, and general system minor rehabilitations and surface treatments. The districts or the local governing agency is responsible for pavement design for all urban system minor rehabilitations and surface treatments. The local governing agency is responsible for pavement design for Federal-aid routes off the state system. The Office of Pavement Engineering is responsible for the pavement design for all priority system minor rehabilitation.

Pavement design responsibility for all new pavements and major rehabilitations on the state system depends on the size of the project. The pavement design for projects in excess of four lane-miles of mainline driving lanes is the responsibility of the Office of Pavement Engineering. The pavement design for projects less than four lane-miles is the responsibility of the district or local governing agency.

102 Structural Design Period

Pavements must be structurally designed to accommodate the current and predicted traffic needs in a safe, durable, and cost effective manner. Pavement structural design is based on a projection of the anticipated traffic loading. The design period is the number of years in the traffic loading prediction. The design period for pavements is based in part on the geometric design period and the construction material quality specifications.

The design periods listed below are exact values, not maximums or minimums. A shorter design period would result in thin pavements more likely to fail prematurely. A longer design period would not be achievable without corresponding changes to the geometric standards, material quality specifications, and construction procedures.

Other roads not part of the priority, general, or urban systems should use the design period for the most similar roadway and rehabilitation type.

102.1 Priority System Design Period

- New Pavement: 20 years
- Major Rehabilitation: 20 years
- Minor Rehabilitation: 12 years
- Surface Treatments: n/a

Surface treatments are applied to structurally sound pavements to correct or reduce deterioration of non-structural surface distresses. They are also used occasionally as short term, stopgap measures on structurally deficient pavements in advance of minor or major rehabilitation; this practice is discouraged however, as patching or spot paving may be more cost effective.

Sound engineering judgment should be used when determining where to apply surface treatments. Output from the pavement management system can assist in identifying appropriate locations and treatment types.
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102.2 General System Design Period

- New Pavement: 20 years
- Major Rehabilitation: 20 years
- Minor Rehabilitation: n/a
- Surface Treatments: n/a

Because of the variability of the existing pavement buildup on general system routes, no structural design is required for minor rehabilitation and surface treatments. Output from the pavement management system should be used to assist in the timing and treatment for minor rehabilitation and surface treatments. A 12-year structural design may be used for minor rehabilitation where the existing pavement buildup is known and is relatively uniform.

102.3 Urban System Design Period

- New Pavement: 20 years
- Major Rehabilitation: 20 years
- Minor Rehabilitation: n/a
- Surface Treatments: n/a

Urban system minor rehabilitations and surface treatments are determined by or in conjunction with the local governing agency. The guidelines of the urban paving program apply (see the ODOT Program Resource Guide). Output from the pavement management system can assist in identifying appropriate treatments.

103 Subgrade Strength Parameters

The subgrade strength parameters for designing new pavement shall be determined in accordance with the Office of Geotechnical Engineering guidance.

104 Pavement Type Selection

Pavement type selection for new pavement and major rehabilitation projects on the state system in excess of four lane-miles of mainline driving lanes is subject to the requirements of this section. Pavement type selection for all ramps is subject to the requirements of Section 104.7.

Pavement type selection for minor rehabilitation and surface treatment projects of any length, and new pavement and major rehabilitation projects less than four lane-miles is the responsibility of the district, the Office of Pavement Engineering, or the local governing agency as appropriate.

The requirements of this section do not apply to any roads off the state highway system.

104.1 Pavement Designs Considered

For all pavements built along new alignments, both rigid and flexible pavement shall be considered. Composite pavement may be considered if there is a district or local preference to do so. Neither rigid nor flexible pavement shall be eliminated without justification in accordance with this section.

For all projects on existing alignment, all major rehabilitation techniques shall be considered. Current major rehabilitation techniques include complete replacement with rigid, flexible, or possibly composite pavement; rubblizing with an asphalt overlay; unbonded concrete overlay; and whitetopping. New or other techniques may be considered as well if applicable. Replacement is applicable to all
existing pavement types. Rubblize projects and unbonded concrete overlays are applicable to existing rigid or composite pavements. Whitetopping is applicable to existing flexible pavements. No major rehabilitation technique is to be eliminated without justification in accordance with this section.

104.2 Principal Factors

After the potential pavement designs are identified, an engineering review and analysis of the principal selection factors shall be conducted. Application of the principal factors may eliminate some pavement designs from further consideration. If only one pavement design exists after the analysis of the principal factors, it is selected and no further analysis is required.

104.2.1 Research

The Department may wish to conduct research on a new or specific pavement type or treatment. If a project is identified for the research, the pavement type selection and design parameters will be based on the requirements of the research.

104.2.2 Adjacent Existing Sections

When systematically building or rehabilitating multiple pavement sections along a corridor, a single pavement type or treatment may be selected to provide continuity throughout the corridor. Also, short sections adjacent to or between pavements with the same surface type, may be selected to continue the same surface material for continuity. Short sections are generally considered to be less than three centerline miles.

104.2.3 Geotechnical Concerns

The subgrade conditions may eliminate the use of some pavement designs. For example, there is a minimum blow count requirement for rubblize and roll to be considered.

104.2.4 Geometrics

Correcting deficient geometrics and adapting to existing constraints (e.g. bridges) may require replacing much of the existing pavement. When the percentage of pavement requiring replacement becomes large, consideration will be given to eliminating the rehabilitation treatments and proceeding with complete replacement only. Adapting to the existing conditions may also require typical section configurations that do not conform to the design assumptions or could result in premature deterioration.

104.2.5 Amount of New Pavement

On projects with lane additions or other widening, the percentage of new pavement versus the percentage of salvaged pavement may become so large that it is preferable to replace the existing and have all new pavement. New, full depth pavement next to rehabilitated pavement may or may not perform the same and may want to be avoided in some cases.

When the existing pavement can be salvaged and performance differences are not a concern, the new pavement may be selected to match the existing. It is standard practice to maintain one pavement surface type transversely across all adjacent driving lanes.

104.3 Life-Cycle Cost Analysis

A life-cycle costs analysis (LCCA) is prepared if more than one pavement design remains after the principal factors have been applied. The LCCA is prepared by the Office of Pavement Engineering
with unit price estimated provided by the Office of Estimating. The analysis period for the LCCA is 35 years.

The future rehabilitation timing and treatments used in the LCCA shall be in accordance with Section 700.

A draft version of the completed LCCA is sent to the district and representatives of both paving industries for review. The purpose of the review is to identify any errors and provide comments when applicable. The Office of Pavement Engineering will submit the final LCCA and selection package along with any comments to the Pavement Selection Committee.

If there is no pavement design within 10% of the lowest cost design, the Pavement Selection Committee shall select the lowest cost design.

104.4 Secondary Factors

Secondary factors are evaluated by the Pavement Selection Committee when one or more pavement design is within 10% life-cycle cost of the lowest cost pavement design. The committee may use the secondary factors to pick a single pavement design, or they may select two or more designs for optional bidding. Alternate bidding may also be selected but optional bidding is preferred.¹

104.4.1 Principal Factors

The committee may reconsider any of the principal factors as secondary factors.

104.4.2 Maintenance of Traffic

The Maintenance of Traffic Alternative Analysis (MOTAA) report details possible maintenance of traffic scenarios and the associated costs. This report should be available for the committee to evaluate as a secondary factor.

104.4.3 Smoothness

Smoothness is very important to the travelling public and to the Department. The Department collects ride quality data on a regular basis for new and existing pavements of all types. The initial and ongoing smoothness of a pavement yet to be constructed cannot be predicted but the collected data can indicate trends. The committee may consider expected smoothness as a secondary factor.

104.4.4 Initial Cost

There may be significant differences in the initial costs even when the total life-cycle costs are close. The committee may use differences in the initial costs to select one pavement design.

104.5 Pavement Selection Committee

Pavement type selection for new pavement and major rehabilitation projects in excess of four lane-miles of mainline driving lanes is by the Pavement Selection Committee. The committee is comprised of the following individuals:

- Assistant Director of Transportation Policy
- Deputy Director of Engineering

¹ Optional bidding requires a bidder to submit a bid for only one of two or more options. Alternate bidding requires a bidder to submit bids for all the alternatives.
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- District Deputy Director (of the applicable district)

The committee may call on additional subject matter experts as needed such as for geotechnical or maintenance of traffic issues.

104.6 Reanalysis of Selections

Pavement selections are considered final and not required to be reanalyzed. Projects may be reanalyzed at any time, however. Likely reasons for reanalysis include delays in the project schedule, changes in the project scope, and changes in pavement market conditions.

104.7 Ramp Pavement Type

All new ramps and ramps replaced in their entirety shall follow the requirements of this section. When part of a ramp is being replaced, the requirements of this section should be considered when selecting pavement type. System and service interchanges are defined in the L&D Manual, Volume 1, Section 502 Interchange Design Considerations.

All service interchange ramps, from the crossroad to the nose of the physical gore area, are to be constructed using concrete pavement. The longitudinal joints on concrete ramps are to be constructed in accordance with Standard Drawing BP-6.1 and should never be located in the wheelpaths.

For all system interchange ramps, districts may select the appropriate pavement type.

Pavement thickness design for all ramps is to be in accordance with the Pavement Design Manual. Acceleration and deceleration lanes shall match the pavement surface type of the adjoining mainline pavement.
200 Pavement Design Concepts

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200 Pavement Design Concepts

200.1 Introduction

Perhaps the most widely used pavement design method in the United States and throughout the world is the American Association of State Highway and Transportation Officials (AASHTO) Guide for Design of Pavement Structures. A long history of pavement studies has led to the current edition. The ODOT method for the design of pavement structures is almost identical to the 1993 AASHTO method, but ODOT has simplified some parts of the AASHTO Guide since it needs to apply only to the conditions encountered in Ohio.

The AASHTO/ODOT pavement design equations have some variables common to both rigid and flexible pavement, including serviceability, traffic loading, reliability, overall standard deviation, and roadbed soil resilient modulus. These common variables are detailed in this section. The remaining variables needed for the design of a pavement structure are presented in the rigid and flexible pavement design sections, respectively.

201 Serviceability

The AASHTO pavement design method was developed around the concept of serviceability. Serviceability is defined as the ability of a pavement to serve traffic. The present serviceability rating (PSR) was developed to measure serviceability. PSR is a rating of pavement ride based on a scale of zero, for impassible, to 5, for perfect. For the development of the original AASHTO pavement design equation, individuals (the raters) would ride the pavements and assign a PSR value. To avoid riding and rating every pavement by all raters to determine serviceability, a relationship between PSR and measurable pavement attributes (roughness and distress) was developed. This relationship is defined as the present serviceability index (PSI).

201.1 Initial Serviceability

The initial serviceability for design is 4.2 for rigid pavements and 4.5 for flexible pavements. Figure 201-1 shows initial serviceability.

201.2 Terminal Serviceability

Terminal serviceability is the minimum level of serviceability the agency allows in design. Once built, pavements may or may not actually degrade to that level but the design terminal serviceability remains the same. ODOT pavements are designed for a minimum PSI (terminal serviceability) of 2.5. Figure 201-1 shows terminal serviceability.

201.3 Design Serviceability Loss

The design serviceability loss is the amount of serviceability the agency will tolerate losing before rehabilitation. The design serviceability loss is the difference between the terminal serviceability and the initial serviceability. Figure 201-1 shows design serviceability loss.

202 Traffic Considerations

Estimating the design traffic loading is a critical step in designing a pavement. Overestimation of the design traffic results in a thicker pavement than necessary with higher associated costs. Underestimation results in pavements thinner than needed and susceptible to premature failure resulting in increased maintenance and impact on the user.
202.1 Traffic Loading

For design purposes, truck traffic is converted to loading which is normalized by the concept of an equivalent 18,000 lb (80 kN) single axle load (ESAL). The conversion of traffic to the ESAL is accomplished with the use of axle load equivalency factors. Equivalency factors are a function of pavement type and thickness, among other factors. Equivalency factors are provided in the AASHTO Guide.

202.1.1 B:C Ratios

Truck counts can be broken down into two truck type categories. Multi-unit vehicles such as semi-tractor trailers are classified as B-type trucks. Single unit trucks and buses are classified as C-type trucks. The Office of Technical Services collects this data on a sampling basis and reports the data using statewide averages by functional classification. B:C Ratios are presented in Figure 202-1. These ratios should be used only where current project counts are not available. Actual B & C counts are always more accurate than the B:C ratio provided in Figure 202-1.

202.1.2 Conversion Factors

In order to simplify the process of converting each truck expected on the roadway to an ESAL, ODOT uses average ESAL conversion factors for B and C trucks. The Office of Technical Services monitors truck counts and axle weights. Conversion factors are calculated for both truck types for the different functional classifications monitored. The conversion factors printed in this Manual are ten-year averages to smooth out year-to-year fluctuations. Refer to Figure 202-1 for ODOT’s most current ESAL conversion factors.

202.1.3 Traffic Data

Basic traffic data should be forecasted and certified by the Office of Technical Services. This data must include the average daily traffic (ADT) for the current year as well as the design year and the 24-hour truck percentage. This data is typically found in the design designation for the project. It is important to ensure the truck percentage is a 24-hour percentage and not a peak-hour percentage. When only the peak-hour truck percentage is available, it should be multiplied by 1.6 to estimate the 24-hour percentage.

202.1.4 Design Lane Factors

There are two design lane factors. One is the directional distribution factor (D) and the other is the lane factor (LF). The ADT counts always include all lanes and both directions of travel. In order to design the required pavement thickness, the ADT needs to be adjusted to represent the loading on the design lane. This is done by applying the directional distribution, which defines the loading in each direction of travel, and the lane factor, which distributes the trucks into the different lanes in a given direction.

The directional distribution listed in the design designation is the peak-hour volume distribution and is for capacity analysis. For pavement structural design, a directional distribution of 50% should be used in all cases. If the designer has specific, credible information indicating unequal loading on the two directions, and this imbalance is expected to continue throughout the design life of the pavement, a directional distribution other than 50% may be used but caution is advised as this can have significant impact on the pavement thickness required. Figure 202-1 shows directional distribution.

Where there are multiple lanes in the same direction, not every truck travels in the same lane. To account for variability across multiple lanes, a lane factor is applied. Refer to Figure 202-1 for ODOT’s most current lane factors.
202.2 Calculation of ESALs

The calculation of ESALs is very simple once all the data is available. The following equations are used. All percentages are to be expressed as a decimal.

\[
\begin{align*}
B-\text{ESALs} &= \text{ADT} \times \%T_{24} \times \%D \times \%LF \times \%B \times \text{CF} \\
C-\text{ESALs} &= \text{ADT} \times \%T_{24} \times \%D \times \%LF \times \%C \times \text{CF} \\
B-\text{ESALs} + C-\text{ESALs} &= \text{Total Daily ESALs}
\end{align*}
\]

Where:

- ADT = Average Daily Traffic
- \%T_{24} = 24-hour truck percentage of ADT
- \%D = Directional Distribution (50%)
- \%LF = Lane Factor
- \%B, C = % B or C trucks of the total trucks
- CF = Appropriate truck conversion factor

To calculate the design ESALs, the total daily ESALs are multiplied by 365.25 days per year and then by the number of years in the design period.

Examples of the calculation of design ESALs are provided in Figures 302-1 and 402-1.

202.2.1 Design Period

The design period is the number of years over which the pavement is expected to deteriorate from its initial condition to its terminal serviceability. It is the number of years for which the ESALs are predicted. The design period is established in Section 100 Pavement Requirements.

202.3 ESAL11

Another method for the calculation of ESALs is available for locations where historical traffic data is available. This method takes into account growth rates in numbers of trucks, changes in the conversion factors associated with the trucks, and changes in the B:C ratio. The method relies on the practice of forecasting the future based on trends of the past. However, trends of past traffic data may not be an accurate indication of future traffic projections.

The ESAL11 procedure calculates the daily ESALs for each year of truck count data entered. ESAL conversion factors corresponding to the year of the truck counts are used in the calculations instead of using ten-year averages. The daily ESALs are then used to calculate the cumulative ESALs from the first year of data to the most recent year of data. Finally, regression analysis is performed on the cumulative ESALs to develop equations used to predict the future ESALs.

The ESAL11 procedure is the preferred method for predicting ESAL loading. For more information regarding this method, contact the Office of Pavement Engineering.

203 Subgrade Soil Characterization

The subgrade is the foundation for all pavements. Trying to characterize the stiffness of this foundation for a particular pavement is a very difficult task because of the variability found in nature and during construction. The AASHTO pavement design equations used by ODOT characterize the subgrade stiffness using the roadbed soil resilient modulus. For pavement design, subgrade soil type is determined directly from soil tests made in conjunction with the soil profile or bridge foundation explorations. Information on subgrade explorations, soil classification, soil profiles, etc., can be found in the
Specifications for Geotechnical Explorations published by the Office of Geotechnical Engineering. Additional information on soil boring analysis, stabilization and treatment methods, and design procedures, can be found in Geotechnical Bulletin 1: Plan Subgrades (GB1) also published by the Office of Geotechnical Engineering.

General planning information about soil types and properties can be found in the Soil Survey books, which are published for every county in Ohio. Additional information on soils and proper construction practices can be found in the Construction Inspection Manual of Procedures published by the Office of Construction Administration. The ODOT soil classification method is presented in the Specifications for Geotechnical Exploration.

ODOT’s pavement design procedure uses a statistical reliability factor (see Section 204) to account for variability in subgrade stiffness. Because of this, the average CBR is to be used for pavement design. Often designers want to use the lowest CBR value to add an additional safety factor but this results in unnecessarily thick, wasteful designs.

203.1 Subgrade Resilient Modulus

The subgrade resilient modulus is a measure of the ability of a soil to resist elastic deformation under repeated loading. Many soils are stress dependent. As the stress level increases, these soils will behave in a non-linear fashion. Fine-grained soils tend to be stress-softening, whereas granular soils tend to be stress-hardening. The laboratory resilient modulus test, AASHTO T 307 or NCHRP 1-28A, is designed to determine the strain due to a repeated load (deviator stress) which simulates the effect of loads passing over a section of pavement.

Based on limited research and several current publications, ODOT has adopted a standard relationship between modulus of resilience \( M_r \) and the California bearing ratio (CBR) shown below.

\[
M_r = 1200 \times CBR
\]

203.2 California Bearing Ratio

The California bearing ratio (CBR) is a value representing a soil’s resistance to shearing under a standard load, compared to the resistance of crushed stone subjected to the same load. The CBR is obtained by performing a laboratory penetration test of a soaked sample of soil. The load required to produce a penetration at each 0.1 inch depth in the soaked sample is divided by a standard, which has been developed for crushed stone, then multiplied by 100.

203.3 Group Index

In order to reduce the amount of laboratory testing required to characterize the soil stiffness, ODOT developed a relationship between CBR and group index. This relationship was developed in the 1950's by testing hundreds of soil samples. Group Index is a function of a soil’s Atterberg Limits and gradation. The equation for group index is given in Appendix A of the Specifications for Geotechnical Exploration published by the Office of Geotechnical Engineering. Figure 203-1 contains a nomograph that solves the group index equation. Group index is then correlated to CBR using the chart in Figure 203-2.

203.4 Subgrade Stabilization

Undercutting or chemical stabilization of the subgrade should be determined in accordance with GB1. Although there is research to show that chemical stabilization results in higher subgrade stiffness, ODOT’s current design methods do not provide for reduced pavement section as a result of modified subgrade. Questions regarding subgrade stabilization should be directed to the Office of Geotechnical Engineering.
204 Reliability

AASHTO defines reliability as the probability that the load applications a pavement can withstand in reaching a specified minimum serviceability level is not exceeded by the number of load applications that are actually applied to the pavement. Reliability is a statistical tool used in pavement design that assumes a standard normal distribution exists for all pavement design parameters and allows the designer to account for deviation from the average equally for all parameters. Reliability can be thought of as a safety factor. Figure 201-1 lists the reliability factors to be used in pavement design for various classifications of highways.

204.1 Overall Standard Deviation

The overall standard deviation (variance) is a measure of the spread of the probability distribution for ESALs vs. Serviceability, considering all the parameters used to design a pavement. Figure 201-1 lists the overall standard deviation to be used in pavement design.

205 Subsurface Pavement Drainage

Subsurface pavement drainage is required on all projects. Lack of adequate pavement drainage is a primary cause of distress in many pavements. Excess moisture in the base and subgrade reduces the amount of stress the subgrade can tolerate without permanent strain. Strain in the subgrade transfers stress into the upper pavement layers resulting in deformation and ultimately distress. Trapped moisture in flexible pavement systems leads to stripping, raveling, debonding, and rutting. Excess moisture in rigid pavement systems leads to pumping, faulting, cracking, and joint failure.

Pipe underdrains are the primary method to provide drainage. Occasionally, when an existing pavement is being overlayed, prefabricated edge underdrains are installed to provide drainage. On pavements with and without any subsurface drainage, crack sealing can be done to reduce the infiltration of water. Another type of subsurface drainage, free draining base (FDB), has been used in the past. Free draining bases are not approved for use on ODOT projects.

205.1 Types of Drainage Systems

There are four means of draining the pavement subsurface - pipe underdrains, prefabricated edge underdrains, aggregate drains and free draining base systems.

205.1.1 Pipe Underdrains

Pipe underdrains must be used for all Interstate, freeways, expressways, and multi-lane facilities. Pipe underdrains are generally used with paved shoulders and curbed pavements. Refer to Figures 1009-1 to 1009-5 of the Location & Design Manual, Volume 2 - Drainage Design; and Location & Design Manual, Volume 3 - Highway Plans, Sample Plan Sheets for locations of pipe underdrains with the various pavement-shoulder treatments.

In rock cut, a pipe underdrain should be placed 6 inches (150 mm) into the rock to drain water that collects at the top of the rock. This drain can be one of the standard underdrains or an additional one. Refer to Figure 1009-10 of the Location & Design Manual, Volume 2 - Drainage Design for more information.

205.1.2 Prefabricated Edge Underdrains

Prefabricated edge underdrains may be placed at the edge of existing concrete pavement on resurfacing projects where the existing pavement and asphalt shoulders are being retained and the existing drainage is inadequate. If existing asphalt shoulders are being replaced, a 4 inch (100 mm) shallow pipe underdrain at the edge of the concrete should be used in lieu of the prefabricated edge...
underdrain. On resurfacing projects, where prefabricated edge underdrains already exist, existing outlets should be inspected and replaced where they no longer function.

205.1.3 Aggregate Drains

Aggregate drains are used with bituminous surface treated shoulders, aggregate shoulders, and for spot improvements. Aggregate drains are primarily for lower volume roadways with an aggregate base or as a retrofit for any pavement system with an aggregate base which does not have pipe underdrains or prefabricated edge underdrains.

Aggregate drains should be located at 50-foot (15 m) intervals on each side of the pavement and staggered so each drain is 25 feet (7.5 m) from the adjacent drain on the opposite side. If used on rigid pavements, the spacing should be adjusted to match up to the end of a transverse joint. For superelevated pavements, spacing should be at 25 feet (7.5 m) and drains should be located on the low side only.

Aggregate drains should be physically cut into the edge of the pavement - shoulder system, preferably the aggregate base. Refer to Figures 1009-8 and 1009-9 of the Location & Design Manual, Volume 2 - Drainage Design; and Location & Design Manual, Volume 3 - Highway Plans, Sample Plan Sheets for details depicting aggregate drains with the various pavement - shoulder treatments.

205.1.4 Free Draining Bases

Free draining bases (FDB) are not approved for use on ODOT projects. Use of FDB's was discontinued based on performance and research data from in-service FDB's. Performance data, including PCR and roughness on flexible pavements, and cracking and roughness on rigid pavements, indicate no difference between pavements built on an FDB and pavements built on an aggregate base. Some FDB types have caused worse performance in rigid pavements versus rigid pavements built on an aggregate base. Moisture probes on the Ohio SHRP Test Road have indicated little difference in the degree of subgrade saturation under pavements with or without a FDB. Finally, the cost of FDB is approximately twice that of the same amount of aggregate base.

205.2 AASHTO Drainage Coefficient

The AASHTO pavement design equations attempt to consider the effects of drainage on pavement performance. The nomographs used in this Manual are reprinted from AASHTO and allow for the use of the drainage coefficient for rigid pavement design. The flexible design method in this Manual does not include the drainage factor. For ODOT pavement design the drainage coefficient shall always be 1.0 for design of both rigid and flexible pavements.
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<td>4.5</td>
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<tr>
<td>Terminal Serviceability</td>
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<td>2.5</td>
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<tr>
<td>Design Serviceability Loss</td>
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### Reliability Levels (%)

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<th>Rural</th>
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<td>Interstate and Freeway</td>
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<td>90</td>
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<tr>
<td>Principle Arterial, Minor Arterial</td>
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<tr>
<td>Collectors</td>
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<td>Local</td>
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### Overall Standard Deviation

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<th>Standard Deviation</th>
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<td>Rigid Pavement</td>
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### RATIO OF B:C COMMERCIAL VEHICLES

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<td>Rural Principal Arterial (02)</td>
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<tr>
<td>All Other Rural (06, 07, 08, 09)</td>
<td>2:1</td>
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<tr>
<td>Urban Interstate (11)</td>
<td>4:1</td>
</tr>
<tr>
<td>Urban Freeway &amp; Expressway (12)</td>
<td>3:1</td>
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<tr>
<td>Urban Principal Arterial (14)</td>
<td>2:1</td>
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<td>All Other Urban (16, 17, 19)</td>
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### ESAL CONVERSION FACTORS

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### DESIGN LANE FACTORS

<table>
<thead>
<tr>
<th>Number of Lanes per Direction</th>
<th>Lane Factor (LF) (%)</th>
<th>Directional Distribution (D) for two-way traffic (%)</th>
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<td>1 - Lane</td>
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<td>2 - Lanes</td>
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<tr>
<td>3 - Lanes</td>
<td>80</td>
<td>50</td>
</tr>
<tr>
<td>4 (or more) - Lanes</td>
<td>70</td>
<td>50</td>
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</table>
**Chart B - Grain Size & P.I. Relations**

**Percent Passing No. 200 Sieve**

**Chart A - Grain Size & LL Relations**

Group Index equals sum of readings on both vertical scales.

Example: The G.I. of soil having 70% of its particles passing a No. 200 sieve, with a LL = 45 and a P.I. = 12.

Chart A: Δ = 7.9; Chart B: Δ = 0.8

G.I. = 7.9 + 0.8 = 8.7 (rounded off to 9).
Subgrade Resilient Modulus

\[ w_5 \text{ DEFLECTION } + 2 \text{ STD. DEVIATIONS} \]

\[
\begin{array}{cccccc}
0.15 & 0.2 & 0.3 & 0.4 & 0.5 & 0.6 \\
12 & 11 & 10 & 9 & 8 & 7 \\
6 & 5 & 4 & 3 \\
\end{array}
\]

CALIFORNIA BEARING RATIO (CBR) ★

\[
\begin{array}{cccccccc}
0 & 2 & 4 & 6 & 8 & 10 & 12 & 14 & 16 & 18 & 20 \\
12 & 11 & 10 & 9 & 8 & 7 & 6 & 5 & 4 & 3 \\
\end{array}
\]

Group Index (G.I.)

- ♦ Usual range of AASHTO Classes.
- ★ 5-1/2 LB. hammer, 12" drop, 4 layers, 45 blows per layer, compacted at optimum moisture as determined by AASHTO T-99.

Example: G.I.=9 (Figure 203-2) CBR=6 (Rounded, from above)

\[
\text{RESILIENT MODULUS } (M_R) = 1200 \times \text{CBR} \\
M_R = 1200 \times 6 = 7200 \text{ psi}
\]
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300 Rigid Pavement Design

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300 Rigid Pavement Design

300.1 Introduction

Rigid pavements can be constructed with contraction joints or no joints, with dowels or without dowels, and with reinforcing steel or without steel. For jointed concrete pavements, regardless of whether reinforced or non-reinforced, the AASHTO/ODOT method of pavement design calculates the same required thickness. The required thickness is a function of loading, material properties including subgrade, and type of load transfer, if any. Alterations to rigid pavement material specifications, jointing considerations, and mesh provisions to something other than those provided in ODOT’s Construction and Material Specifications (C&MS) or ODOT’s Standard Construction Drawings may require adjustments to the procedures described herein.

The Construction Inspection Manual of Procedures published by the Office of Construction Administration contains additional information on rigid pavement and proper construction practices.

300.2 Types of Concrete Pavement

ODOT has two basic types of concrete pavement: reinforced and non-reinforced. There are currently three different specifications for concrete pavement and one for concrete base. All of the concrete specifications relate back to either reinforced or non-reinforced. The current specifications are: Item 451 Reinforced Concrete Pavement, Item 452 Non-Reinforced Concrete Pavement, Item 884 Portland Cement Concrete Pavement (7 Year Warranty), and Item 305 Concrete Base. All of the concrete pavements included in the C&MS and Supplemental Specifications are jointed. Continuously reinforced concrete pavement is no longer used and the specification item has been removed from the C&MS.

Item 451 Reinforced Concrete Pavement is the basic specification referred to by all other concrete pavement specifications. Reinforced concrete contains steel wire mesh intended to tightly hold together any cracks that occur. The steel mesh does not add any structural capacity and does not impact the thickness design. A reinforced pavement is the same thickness as a non-reinforced one. The reinforcing steel allows longer joint spacing with the expectation that mid-panel cracks will form but the steel will hold them tightly together and not allow further deterioration. Hairline cracks (less than approximately 1/8 inch (3 mm) wide) are common, even expected, in reinforced pavements and are little cause for concern. Wider cracks likely mean the steel has failed and the cracks are going to deteriorate and need repair. Throughout the 1950's, 60's, 70's, 80's, and early 90's ODOT built mainly reinforced pavements.

Item 452 Non-Reinforced Concrete Pavement is nearly identical to Item 451 but does not contain the steel reinforcing mesh. Non-reinforced pavements use shorter joint spacing in an attempt to eliminate mid-panel cracking. Any cracks in non-reinforced pavement, even hairline, are likely to deteriorate and require repair. In the late 1990's, ODOT began using more non-reinforced pavements. Currently, non-reinforced is the preferred concrete pavement type.

Item 884 Portland Cement Concrete Pavement (7 Year Warranty) requires the contractor to choose either 451 or 452 pavement and warrant it against specific distresses for seven years. As of publication, in most cases contractors have elected to use 452. The warranty requirements allow hairline cracks in 451 but not in 452.

Item 305 Concrete Base is non-reinforced concrete used when constructing a composite pavement. Because this item is intended to be overlayed with asphalt, the surface texture, curing, and smoothness requirements are less than for exposed concrete pavement surfaces. Item 305 is never to be used as a permanent pavement surface. Throughout this Manual, references to concrete or rigid pavement include item 305 unless stated otherwise.
301 Design Parameters

ODOT’s method for the design of rigid pavement limits the designer to prescribed input parameters. The input values prescribed are based on Ohio materials and ODOT Specifications.

301.1 Modulus of Rupture

Modulus of rupture, as determined under a breaking load, measures the flexural strength or extreme fiber stress, of the concrete slab. There are many ways to determine the modulus of rupture and each way will give slightly different results, however, each method can be correlated to the measure defined for use in the AASHTO/ODOT method. The modulus of rupture used in ODOT’s pavement design method is the 28-day, third-point loading test as defined by ASTM C 78. All rigid pavement designs should use a modulus of rupture of 700 psi, as shown in Figure 301-1. Average values obtained through beam breaks performed as part of C&MS requirements for opening to traffic should not be used directly for design purposes, as this test is defined by ASTM C 293 as center-point loading, and is generally done as early as 5 days.

301.2 Modulus of Elasticity

The modulus of elasticity of concrete is a function of the strength, age, aggregate properties, cement properties, and type and size of the specimen tested as well as the rate of loading during the test. Furthermore, there are various methods used to determine the modulus of elasticity. ODOT's method for rigid pavement thickness design is not highly sensitive to the value used for modulus of elasticity. Based on values obtained by ODOT research, a modulus of elasticity of 5,000,000 psi should be used for all rigid pavement designs. The modulus of elasticity is shown in Figure 301-1.

301.3 Load Transfer Coefficient

The load transfer coefficient (J) is a factor used in rigid pavement design to account for the ability of a concrete pavement to distribute (transfer) load across discontinuities, such as longitudinal and transverse joints. Load transfer devices, aggregate interlock, widened lanes, and the presence of tied concrete shoulders all have an influence on this value. J factors are listed in Figure 301-1.

301.4 Composite Modulus of Subgrade Reaction

The composite modulus of subgrade reaction ($k_c$) represents the combined effect of the subgrade stiffness or subgrade modulus of resilience, as discussed in Section 203.1, and the stiffness, or elastic modulus, and thickness of the subbase material. The pavement design process requires the designer to choose the subbase prior to determination of the required slab thickness. The values for elastic modulus of the subbase for ODOT materials are listed in Figure 301-1. Figure 301-2 is a nomograph that determines the composite modulus of subgrade reaction.

A 6 inch (150 mm) granular base, item 304, is recommended as a subbase under all concrete pavements to prevent pumping. The granular base is required for concrete pavement built over a chemically stabilized subgrade. For very low traffic situations (less than 500,000 design ESALs) or on non-stabilized granular subgrades, consideration may be given to eliminating the granular base.

301.5 Loss of Support

Loss of support (LS) is included in the design of rigid pavements to account for the potential loss of support arising from subbase erosion or differential vertical soil movements. The potential of a material to pump is an indication support may be lost. Loss of support is treated in the design procedure by reducing the composite modulus of subgrade reaction. Figure 301-1 lists the LS factors to be used for ODOT materials.
301.6 Effective Modulus of Subgrade Reaction

The effective modulus of subgrade reaction (k) is the composite modulus of subgrade reaction as modified by the loss of support. Figure 301-3 is a nomograph that determines the effective modulus of subgrade reaction.

302 Thickness Determination

All of the design input information is required prior to determination of design thickness. Design thickness is determined using the nomographs found in Figures 302-2 and 302-3. An example rigid pavement design is provided in Figure 302-1. Concrete pavement thicknesses should be rounded to the nearest 0.5 inch (10 mm) increment.

Adequate concrete cover is needed to transfer stresses between the concrete and the dowel bars. Because of the required concrete cover, the minimum thickness of concrete pavement is 8 inches (200 mm). In special situations where the standard specifications are modified to eliminate the dowels, the minimum recommended thickness for concrete pavement is 6 inches (150 mm).

302.1 Ramps and Interchanges

If traffic and soils data is available, ramps, collector-distributor lanes, directional roadways, etc., may be designed individually. More common is to use the same thickness as the mainline or reduce the mainline thickness by 1-inch (25 mm).

303 Jointing and Shoulder Considerations

303.1 Transverse Joints

Transverse joints are provided to control cracking. The closer the joint spacing, the less likely a mid-panel crack will develop. Ohio uses 15-foot (4.6 m) joint spacing for non-reinforced concrete. For reinforced concrete, 60-foot (18.3 m) joint spacing was used before about 1967 when it was reduced to 40 feet (12.2 m), then in the early 1980’s it was further reduced to 27 feet (8.2 m) for several more years and then to the current standard of 21 feet (6.5 m).

Load transfer is the critical element at joints. In undoweled pavements, load transfer is provided by aggregate interlock. Aggregate interlock is lost when slabs contract and the joints open up. Interlock is also slowly destroyed by the movement of the concrete as traffic passes over. Given the high temperature variations and heavy truck traffic in Ohio, aggregate interlock alone is not effective and faulting is the primary result. To provide load transfer at the joints, 18-inch (460 mm) long, smooth dowels are used which allow for expansion and contraction. ODOT specifications require dowels in all transverse joints in all mainline concrete pavements and bases. Transverse joint design and spacing requirements are shown in the Standard Construction Drawings.

303.2 Expansion and Pressure Relief Joints

As slabs contract due to seasonal temperature changes, joints and cracks open allowing incompressible materials into the pavement system. Subsequently, the pavement can grow in length and create pressure. Pressure can lead to spalling, blowups, or damage to bridge back-walls. Having a small amount of pressure in a pavement may be good since lack of pressure allows joints and cracks to open which reduces load transfer. Slight pressure buildup in rigid pavement seldom creates pavement distress. Nonetheless, when distresses are found, they tend to require some type of maintenance, and may require immediate care in the case of a blowup.
To control pressure buildup, expansion joints and pressure relief joints are used. The most common need for an expansion joint or a pressure relief joint is to protect bridge back-walls. Four types of pressure relief joints are detailed in the Standard Construction Drawings. For new pavement construction, the Type A joint should be provided at all bridge approaches where the bridges are over 300 feet (90 m) apart. Where bridges are less than 300 feet (90 m) apart, the standard expansion joints as required by C&MS Item 451 and detailed in the Standard Construction Drawings are considered adequate. Use of pressure relief joints for pavements being rehabilitated is discussed in Section 500.

303.3 Longitudinal Joints

Longitudinal joints are required whenever the pavement width exceeds 18 feet (5.4 m) and are recommended whenever the width exceeds 15 feet (4.5 m). Joints in mainline pavement are to be located at the lane lines. Where project geometrics permit, 14-foot (4.3 m) wide slabs striped at 12 feet (4.2 m) are recommended to provide additional edge support for the outside, truck lane.

All lanes, shoulders, and ramps for traffic moving in the same direction should be tied together using a standard longitudinal joint as detailed in Standard Construction Drawing BP-2.1. Anytime traffic is expected to cross a longitudinal joint (between lanes, from lane to shoulder, etc.) the joint should be tied. Anytime traffic is not intended or expected to regularly cross a longitudinal joint (from shoulder to a barrier foundation, from shoulder to a paved gore area, anytime two shoulders meet, etc.) the joint should not be tied. Project specific details dictate exactly which joints need to be tied and which do not. The designer should consider the needs of traffic when deciding what type of joint to use. There is no strict limit on the maximum width that may be tied together. On undivided, bi-directional roadways, the centerline joint may or may not need to be tied depending on the project specifics.

On 16-foot (4.9 m) wide ramps, a tied longitudinal joint down the middle is required as shown in Standard Construction Drawing BP-6.1. This will guard against longitudinal cracking and may allow future repair work to be performed on half the ramp while traffic is maintained on the other half and shoulder.

At intersections, where two independent pavements meet, a longitudinal joint without tie bars is required to separate the two pavements and allow for independent movement.

303.4 Intersection Jointing Details

Intersections require careful consideration of the joint layout, and dowel and tie bar placement. In order to provide load transfer, control cracking, and prevent intersecting pavements from hindering the movement of one another, jointing diagrams should be provided as part of the plans. Joint diagrams should be designed with ease of construction in mind, as well as consideration of future rehabilitation and maintenance of traffic needs. The number of longitudinal joints should be kept to a minimum, and all slabs should be the same width, if possible. Examples of jointing diagrams are included in the Location & Design Plan Preparation Sample Plan Sheets-Volume Three. In addition, there are various publications provided by the American Concrete Pavement Association (ACPA) that provide guidance for intersection joint layout.

303.5 Shoulder Considerations

Shoulders are used to provide an area for accommodation of disabled vehicles, for lateral support of the base and surface courses, to improve the safety of a highway, and for maintenance of traffic operations during maintenance and rehabilitation work.

Shoulders for concrete pavements should be constructed of concrete with the same thickness as the driving lanes’ pavement whenever a paved shoulder is required. Having the same thickness allows extensive use of the shoulder for maintenance of traffic with little, if any, risk of failure and reduces the
300 Rigid Pavement Design

complexity of construction. Tying concrete shoulders to the driving lanes provides lateral support and spreads the load over a greater area.

Concrete shoulders should use non-reinforced concrete even if the driving lanes are reinforced. The plans should include a note modifying the transverse joint spacing of the non-reinforced shoulders if tied to reinforced driving lanes. In all cases, the shoulder joints should match the spacing and alignment of the driving lanes to form one continuous joint across the pavement. Do not place any intermediate joints in the shoulder.

Transverse joints in shoulders are not dowelled except within 500 feet (150 m) of a pressure relief joint. Dowels may be added by plan note if the shoulders will be used to carry traffic during extended (9 months or more) maintenance of traffic operations. The amount of truck traffic using the shoulder should be evaluated prior to requiring dowels.

Using other types of shoulders, such as flexible, surface treated, stabilized aggregate, or turf shoulders should be in accordance with the Location & Design Manual, Volume One - Roadway Design. Regardless of the type of shoulder used, the base and subgrade should be designed to drain water away from the pavement, rather than towards it. Examples of typical sections depicting rigid pavement with different types of unpaved shoulders are shown in Figure 303-1.

303.6 Edge Course Design

The aggregate base for a rigid pavement should extend 18 inches (450 mm) beyond the edge of the travelled way, or to the outside edge of the porous backfill over the pipe underdrain, or to 6 inches (150 mm) beyond the outside edge of the paved shoulder, whichever is greater.

Where curb and gutter or integral curb is used, subbase should extend 12 inches (300 mm) beyond the back of the curb or to the outside edge of the porous backfill over the pipe underdrain, whichever is greater. Refer to Location & Design Manual, Volume 2 - Drainage Design and Sample Plan Sheets.

304 Concrete Pavement Usage Guidelines

304.1 Item 451 Reinforced Concrete Pavement

The use of item 451 is seldom if ever recommended. It is most commonly used when new concrete is being tied to reinforced concrete constructed by a previous project. It is also used in intersection work or near skewed bridges where long or odd shaped slabs may exist.

304.2 Item 452 Non-Reinforced Concrete Pavement

Item 452 is recommended for all large-scale concrete pavement projects. Item 452 is also recommended for small projects as long as the proper joint spacing can be achieved. Projects that have numerous irregular shaped slabs may be better suited to item 451.

304.3 Item 884 Warranty Concrete

The use of warranty concrete is allowed only with permission of the Division of Construction Management. Requests to use warranty concrete should be directed to the warranty coordinator.

304.4 Item 305 Concrete Base

Item 305 is used anytime a composite pavement is being constructed. The most common use of 305 is widening next to an existing composite pavement.
304.5 Class of Concrete

Class QC1 is recommended for all mainline, shoulder, and ramp concrete in excess of 250 feet (75 m) of continuous pavement.

Class QC MS or QC FS may be used for smaller, repair-type areas. These mixes are intended for joint and crack repairs or individual slab replacements. They are not intended for long stretches of continuous pavement and are not expected to perform well if used in such applications.

The QC/QA designation is to be added if any single concrete pavement pay item exceeds 10,000 square yards (8500 square meters). The QC/QA designation may be added to all concrete pavement items if any single item meets the threshold.

305 Warranty Concrete

The use of warranty concrete does not change the thickness design in any way. The same inputs are used and the same thickness is determined regardless of whether warranty concrete will be used or conventional Item 451 or 452 concrete. More information on concrete pavement warranties is available in the Warranty Application Guidelines in the Innovative Contracting Manual published by the Office of Construction Administration and in the Item 884 Portland Cement Concrete Pavement (7 Year Warranty) specification.

306 Smoothness Specifications

Incentive/disincentive for smoothness is specified using Proposal Note 420 Surface Smoothness Requirements for Pavements. PN 420 is recommended for all eligible projects. The Designer Note details the eligibility requirements. Smoothness incentives generally result in better attention to detail by the contractor and higher quality pavement overall. Smooth, high quality pavements are expected to perform better for a longer time, potentially resulting in cost savings to the Department.

The designer should ensure the contractor has a reasonable opportunity to achieve the incentive. Projects that may otherwise be eligible but have numerous manholes, drainage structures, business or residential driveways, etc., are usually not good candidates for smoothness incentive.

307 Composite Pavement

Composite pavement herein refers to a rigid base with an asphalt surface. Composite pavements are rarely designed and built on ODOT projects. When they are used it is often at the request of a local government agency. Where local preference is strong and there has been good performance, consideration may be given to the design and specification of a composite pavement.

307.1 Composite Pavement Design

Composite pavements are designed as rigid pavements. Once the required thickness is determined, the concrete thickness is reduced by one inch (25 mm) and replaced with 3 or 3.25 inches (75 mm - 83 mm) of asphalt. This ratio of 1 inch (25 mm) of concrete to 3 inches (75 mm) of asphalt holds true only for the first inch (25 mm) of concrete removed and is an approximation at best.

The minimum asphalt overlay thickness on a rigid pavement or base is 3 inches (76 mm). Lift thickness requirements for specific asphalt materials may require a 3.25 inch (83 mm) minimum overlay thickness. The minimum concrete thickness of 8 inches (200 mm) still applies.
300 Rigid Pavement Design

307.2 Composite Pavement Typical Section Design

Composite pavement should be constructed using Item 305 Concrete Base. The width of the concrete base should be extended beyond the wearing surface by 3 inches (75 mm). Item 409 Sawing and Sealing Asphalt Concrete Pavement Joints is recommended for most newly constructed composite pavements.

307.3 Composite Pavement Warranty

There is not a seven year warranty specification for composite pavements. The only warranty that could be used on a composite pavement is a three year warranty, Supplement 1059, on the asphalt concrete surface course. The use of Supplement 1059 is allowed only with permission of the Division of Construction Management. Requests to it should be directed to the warranty coordinator.

307.4 Composite Pavement Smoothness Specifications

Proposal Note 420 Surface Smoothness Requirements for Pavements may be used with composite pavements for smoothness incentive/disincentive. The guidelines in Section 306 apply.
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<td>700 psi</td>
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<tr>
<td>Modulus of Elasticity ($E_c$)</td>
<td>5,000,000 psi</td>
</tr>
<tr>
<td>Load Transfer Coefficient (J) - Doweled, Edge Support*</td>
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* Edge support includes tied concrete shoulders, integral curb, widened lane, etc. Widened lane refers to concrete slabs built 14 feet (4.2 m) wide or wider, but striped for a standard 12-foot (3.6 m) lane, leaving 2 feet (0.6 m) outside the traveled lane to provide edge support.

### SUBBASE FACTORS

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<td>300,000</td>
<td>0</td>
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<tr>
<td>Item 304 Aggregate Base</td>
<td>6</td>
<td>30,000</td>
<td>1</td>
</tr>
<tr>
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<td></td>
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<td>2</td>
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** Not recommended for most applications. See Section 301.4
Composite Modulus of Subgrade Reaction ($k_c$)

Subbase Elastic Modulus, $E_{SB}$ (psi)

Subbase Thickness, $D_{SB}$ (inches)

Composite Modulus of Subgrade Reaction, $k_c$ (pci)
( Assumes Semi-infinite Subgrade Depth )

Subgrade Resilient Modulus, $M_R$ (psi)
Given:

- Pavement of choice: Doweled, jointed concrete
- Subbase: 6 inches Item 304 Aggregate Base
- Shoulders: Tied, jointed, concrete
- Number of Lanes: 4
- Functional Classification: Rural Principal Arterial
- 2016 Traffic: 15,800 ADT
- 2036 Traffic: 22,450 ADT
- 24 hour truck %: 18%
- Design Period: 20 years
- Open to Traffic: 2017
- Subgrade CBR: 5 (from GB1 analysis)

Problem: Solve for the thickness of the concrete slab.

Solution:

**Step 1** - Determine the 18-kip equivalent single axle loading (ESAL).

Since the project is expected to open to traffic in 2017, the ESAL projection should be for 2017 to 2037. Calculate the mid-year (2027) ADT, rounded to nearest ten:

\[
2027 \text{ ADT} = 15,800 + (22,450 - 15,800)(11/20) \\
2027 \text{ ADT} = 19,460
\]

The equations in Section 202.2 are used with

- Directional distribution, \(D = 50\%\) (Figure 202-1)
- Lane factor = 90\% (Figure 202-1)
- B:C ratio = 5:1 (Figure 202-1)
- ESAL conversion factor for B trucks = 1.67 (Figure 202-1)
- ESAL conversion factor for C trucks = 0.44 (Figure 202-1)

Using the equations given in Section 202.2:

- ESAL’s from B trucks = 19,460(0.18)(0.50)(0.90)(5/6)(1.67) = 2,194
- ESAL’s from C trucks = 19,460(0.18)(0.50)(0.90)(1/6)(0.44) = 116

Total daily ESAL’s = 2,194 + 116 = 2,310 ESAL/day

Design period ESAL’s = 2,310 ESAL/day \* 365.25 days/yr. \* 20 years = 16,874,550

use 16.9x10^6 ESAL’s
Step 2 - Determine the subgrade resilient modulus ($M_r$) using the formula given in Section 203.1.

$$M_r = 1200 \times \text{CBR}$$

$$M_r = 1200 \times 5$$

$$M_r = 6000 \text{ psi}$$

Step 3 - Determine the composite modulus of subgrade reaction ($k_c$) using Figure 301-2.

Starting with the given subbase thickness ($D_{SB}$) of 6", a line is projected up to the subbase elastic modulus ($E_{SB}$) curve of 30,000 psi (Item 304 Aggregate Base from Figure 301-1). From this point on the 30,000 psi curve, a line is projected to the right for future intersection. Similarly, from the 6" subbase thickness ($D_{SB}$), a line is projected down to the subgrade resilient modulus ($M_r$) curve of 6000 psi. From this point on the 6000 psi curve, a line is projected to the right to the turning line and then projected up to intersect with previously projected line. This intersection results in a composite modulus of subgrade reaction ($k_c$) of 350 pci.

Step 4 - Determine the effective modulus of subgrade reaction ($k$) using Figure 301-3.

Using the composite modulus of subgrade reaction ($k_c$) determined in Step 3, enter the chart on the bottom. Project a line from 330 pci up to $LS = 1.0$ (from Figure 301-1 for Item 304 Aggregate Base). Then project a line straight across to the vertical axis. This results in an effective modulus of subgrade reaction ($k$) of 110 pci.

Step 5 - Determine the thickness of the concrete slab using Figures 302-2 and 302-3.

Figure 302-2 is used to solve for the match line number using the following information:

- Effective modulus of subgrade ($k$) = 110 pci (Step 4)
- Concrete elastic modulus ($E_c$) = 5,000,000 psi (Figure 301-1)
- Concrete modulus of rupture ($S'_c$) = 700 psi (Figure 301-1)
- Load Transfer Coefficient ($J$) = 2.7 (Figure 301-1)
- Drainage coefficient ($C_d$) = 1.0 (Section 205.2)

The resulting match line number is then used on Figure 302-3, along with the following information, to solve for the design slab thickness ($D$).

- Design serviceability loss (PSI) = 1.7 (Figure 201-1)
- Reliability = 85% (Figure 201-1)
- Overall standard deviation = 0.39 (Figure 201-1)
- 18-kip equivalent single axle load = $16.9 \times 10^6$ ESAL (Step 1)

Therefore: design slab thickness ($D$) = 10 inches
NOTE: Application of reliability in this chart requires the use of mean values for all input variables.
Surface Treated Shoulder and Stabilized Aggregate Shoulder
Typical Sections

AGGREGATE SHOULDER
Less than 250 B & C Trucks in Design Year ADT

BITUMINOUS SURFACE TREATED
250 to 500 B & C Trucks in Design Year ADT

BITUMINOUS SURFACE TREATED
501 to 1000 B & C Trucks in Design Year ADT

WITH PIPE UNDERDRAIN

Notes:

The bottom of the aggregate drains shall be at or below the bottom of the pavement's aggregate base at the point of contact. The top of the aggregate drains shall be no higher than the bottom of the shoulder's aggregate base at the point of contact.

See Figure 403-1 for additional shoulder details.
# 400 Flexible Pavement Design

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400 Flexible Pavement Design

400.1 Introduction

Flexible pavement design is based on the concept of structural number. The structural number is a regression coefficient expressing the structural strength of a pavement required for given combinations of soil support \( (M_r) \), traffic loading, and terminal serviceability. Flexible pavements can be constructed with stone mastic mixes, contractor designed mixes, or ODOT mixes; however, regardless of the mix design method used, the ODOT/AASHTO method of pavement design calculates the same required structural number. Once the structural number is determined, the flexible buildup is determined by using the appropriate structural coefficient for ODOT specification materials. Alterations to ODOT’s Construction and Material Specifications (C&MS) for asphalt concrete may require adjustments to the procedures described herein.

The Construction Inspection Manual of Procedures published by the Office of Construction Administration contains additional information on flexible pavement and proper construction practices.

401 Design Parameters

Flexible pavement design is based on relatively few input parameters. Serviceability, traffic loading (ESAL), subgrade stiffness \( (M_r) \), reliability and overall standard deviation have all been discussed in Section 200. Structural coefficient is the only new parameter. Structural coefficients for ODOT asphalt concrete material specifications are found in Figure 401-1.

402 Structural Number Determination

All of the design input information is required prior to determination of design thickness. Structural number \( (SN) \) is determined using the nomographs found in Figures 402-2 and 402-3. An example flexible pavement design is provided in Figure 402-1.

402.1 Ramps and Interchanges

If traffic and soils data is available, ramps, collector-distributor lanes, directional roadways, etc., may be designed individually. More common is to use the same thickness as the mainline or reduce the mainline thickness by 1-inch (25 mm).

403 Typical Section and Buildup Considerations

403.1 Typical Section Design

Regardless of the SN required, a buildup that includes an aggregate base (Item 304) will generally provide better performance than an asphalt-on-subgrade buildup. The aggregate base is less sensitive to moisture than the subgrade and it separates the pavement further from the subgrade. An aggregate base is recommended under all flexible pavements and particularly when the thickness of a full depth flexible design is very thin, approximately 5 inches (130 mm) \( \text{(SN ~ 1.8)} \) or less.

All surface and intermediate courses should be specified in 0.25-inch (5 mm) increments. Items 301 and 302 should be specified in 0.5-inch (10 mm) increments. Item 304 is typically placed at 6 inches (150 mm) thick. The minimum thickness for Item 304 is 4 inches (100 mm) and it should be specified in 1-inch (25 mm) increments.
When designing a flexible pavement, some consideration should be given to reducing the total number of separate lifts required. This can be accomplished by keeping in mind the maximum and minimum lift thicknesses for all of the materials involved. Maximum and minimum lift thicknesses can be found in the C&MS, or Section 406 or Figure 406-1 of this Manual.

403.2 Shoulder Buildups

Shoulders are used to provide an area for the accommodation of disabled vehicles, for the lateral support of the base and surface courses, to improve the safety of a highway, and for future maintenance of traffic operations during maintenance and rehabilitation work.

Shoulders for flexible pavements should be constructed of the same materials and thicknesses as the driving lanes’ pavement whenever a paved shoulder is required. This provides for the ability to have a hot longitudinal joint at the pavement-shoulder interface, provides a stable temporary pavement for maintenance of traffic lane shifts, and reduces the complexity of construction. Using other types of shoulders, such as surface treated, stabilized aggregate, or turf shoulders should be in accordance with the Location & Design Manual, Volume One - Roadway Design. Regardless of the type of shoulder used, the base and subgrade should be designed to drain water away from the pavement, rather than towards it. Examples of typical sections depicting flexible pavement with different types of unpaved shoulders are located in Figure 403-1. Also, refer to the Location & Design Manual, Volume 2 - Drainage Design and the Sample Plan Sheets.

403.3 Edge Course Design

For proper quantity calculations, each lift of pavement and base below the intermediate course must be shown wider than the lift above, creating a stair step look. A lift is the thickness of material placed in one pass. Maximum lift thicknesses for the various materials are found in the C&MS, or Section 406 or Figure 406-1 of this Manual. When a layer of material exceeds the maximum lift thickness, it will be placed in two lifts. The designer should assume the two lifts will be approximately equal thickness. If a layer requires three lifts, it should be assumed that the lifts will be approximately equal thickness.

Surface and intermediate courses should be shown ending in a vertical plane at the outside edge of the surface course. The lift immediately below the intermediate course should be shown extending 4 inches (100 mm) beyond the edge of the intermediate course or a distance equal to the combined thickness of the surface and intermediate course, whichever is greater. All other lifts of Items 301, 302, and 304 should be shown extending 6 inches (150 mm) beyond the overlying lift or extending the thickness of the overlying lift, whichever is greater.

For concrete curbed sections, the asphalt is paved to the face of the curb. Where the bottom courses of the asphalt pavement buildup lie below the depth of the curb base, those lifts should be placed as a foundation for the curb and should have the proper edge course design as discussed above.

404 Asphalt Concrete Acceptance

One of the most important concepts to understand when selecting asphalt concrete materials is the acceptance method used in construction. There are three different acceptance methods hereinafter referred to as 403 acceptance, 446 acceptance and 448 acceptance. It is important that the designer understand the different acceptance methods and when they apply. In many cases, the materials required in two different pay items are identical, the only difference being the acceptance method. For example, Item 441 Asphalt Concrete Surface Course, Type 1, PG64-22 is the exact same material whether the acceptance is 446 or 448. The acceptance method for most surface and intermediate courses is specified by the number in parentheses in the pay item description.
The 403 acceptance is the default acceptance for all asphalt concrete items not using 446 or 448 acceptance. It is never explicitly specified in the plans or the item descriptions, as it is inherent to the specifications. The 403 acceptance is based on asphalt binder content and gradation only and does not include density. The C&MS details the method the contractor must use to compact the pavement. If the method is followed, the pavement is accepted regardless of the actual density achieved. The 403 acceptance is used for all asphalt concrete base items.

The 446 acceptance is a density acceptance method. It requires cores be taken and measured for density. If the pavement is over or under compacted, the contractor is assessed a penalty or, in some cases, forced to remove and replace the material.

Proper density is important to the long-term performance of the pavement. Items with 446 acceptance give ODOT more assurance that proper density will be achieved. However, in order to give the contractor the opportunity to achieve proper density, items with 446 acceptance must be placed on a level surface and at a uniform thickness. If the surface is not level and/or the thickness not uniform, it is impossible to evenly compact the material and achieve the proper density.

A level surface is a surface placed previously as part of the same contract or a surface planed under the same contract. An existing, aged surface is rarely, if ever, a level surface. Pavement planing must be included before requiring 446 acceptance on an existing surface. A level surface is required to place a uniform thickness layer of asphalt.

The 448 acceptance includes asphalt binder content and gradation and usually density acceptance. It automatically requires density acceptance using Supplement 1055 under certain conditions. When Supplement 1055 is not required, 448 acceptance defaults to 403 acceptance.

When 448 acceptance is specified, Supplement 1055 is automatically invoked on surface and intermediate courses if the project exceeds the minimum length and the material being placed exceeds the minimum thickness and is being placed at a uniform thickness. Supplement 1055 is a less stringent density requirement than 446 acceptance. It assures the department of a minimum level of compaction but does not challenge the contractor to achieve optimum compaction or avoid over-compaction like 446 acceptance. For thin courses, variable depth courses, and courses placed on non-level surfaces, 448 acceptance does not invoke Supplement 1055. When Supplement 1055 is not required, 448 acceptance defaults to 403 acceptance.

Items with 448 acceptance, with or without Supplement 1055, are typically used in lower traffic volume situations where the risk of pavement distresses resulting from lack of density is not as great.

### 404.1 Acceptance Guidelines

The following guidelines are provided to assist in selecting materials with the proper acceptance type for all surface and intermediate courses. All surface and intermediate courses require either 446 or 448 acceptance. Small projects and thin or variable depth surface and intermediate courses specifying 448 acceptance will automatically default to 403 acceptance. The 446 acceptance should not be used with variable depth courses except in the limited situations described below. All asphalt concrete base courses, Items 301 and 302, use 403 acceptance and the following guidelines do not apply. Choose 446 or 448 acceptance as follows:

- Specify 446 acceptance for all lifts placed at a uniform thickness on priority, general and urban system projects requiring Item 442 with greater than 500 cubic yards (500 cubic meters) of surface course.

- Specify 446 acceptance for all designed priority system minor rehabilitation projects where a uniform thickness is placed.
Specify 446 acceptance for all lifts placed at a uniform thickness on priority system projects where the combined surface and intermediate course quantities exceed 2000 cubic yards (1500 cubic meters).

Specify 446 acceptance for all lifts placed at a uniform thickness on general and urban system projects requiring Item 442 where the combined surface and intermediate course quantities exceed 2000 cubic yards (1500 cubic meters).

Specify 448 acceptance for all projects where 446 acceptance is not required.

For projects that require 446 acceptance, it is permissible to use variable thickness at bridges and ramps to taper down to the required elevation. ODOT construction and testing staff will test only the areas constructed as uniform thickness and skip testing the short areas with variable thickness. This eliminates any need for an additional pay item yet still allows the proper material with the proper acceptance to be used.

When 446 acceptance is specified for the surface course, it is recommended the intermediate course also use 446 acceptance except where a uniform lift thickness is not possible such as a variable depth course for crown correction. It is permissible to use a variable depth course with 448 acceptance below a surface and/or intermediate course with 446 acceptance. The 448 acceptance on the variable depth course will default to 403 acceptance.

Superpave Asphalt Concrete

Superpave mixes are required on all projects with greater than 1500 trucks in the opening day traffic. Superpave mixes are not necessary on projects with lower truck traffic although some districts have been instructed to use Superpave mixes due to localized material problems.

Superpave Type A and B requirements are found in C&MS 442. They control gradation bands and aggregate angularity. Type A has higher crush requirements that may mean the importation of aggregate in some areas of the state but provides the most rut resistance. Type B has less restrictive crush requirements. Type A mixes are preferred except where superior rut resistance is not necessary and importation of aggregate would be cost-prohibitive. District testing and construction personnel knowledgeable in materials should be consulted prior to selection of Type A or B.

Pay item descriptions for Superpave items contain a reference to the nominal maximum aggregate size used in the mix. Accordingly, the 9.5mm, 12.5mm, and 19mm designations are used for Superpave mixes. This reference to the nominal maximum aggregate size replaces the reference to Type 1 and Type 2 used in Item 441 mixes, has nothing to do with any other measurement, and is used in English and metric plans.

The pay item descriptions for Superpave items indicate the acceptance method by the number in parentheses. The designer should follow the guidance in Section 404 to select the proper acceptance method.

Lift Thickness and Usage Guidelines

ODOT asphalt concrete specifications contain gradation requirements for all items. For optimum performance of the pavement system, it is important to design the various lifts of asphalt concrete items in order to achieve maximum smoothness, durability, and densification. In order to do this, some constraints are required regarding maximum and minimum lift thicknesses in relation to the gradation of the item specified. Due to lift thickness restrictions, typical sections using Item 442 should avoid specifying overlay thicknesses between 2.5 inches (65 mm) and 3.25 inches (83 mm).
There are many different asphalt concrete specification items available. The differences between the items are sometimes subtle but always important. Understanding these subtleties and their importance can help the designer select the proper item for the proper application. The specifications themselves and any designer notes should also be consulted for additional guidance.

To select mixes for use in high stress locations the designer should refer to Appendix B: Pavement Guidelines for Treatment of High Stress Locations. High stress locations occur where heavy vehicles are operating under low speed or stopped conditions.

406.1 Surface Courses

The designation of surface course refers to the layer’s relative position in the pavement buildup. Surface courses are the top layer of asphalt concrete placed in a flexible pavement, with rare exceptions. In general, surface courses have the finest gradation, highest binder content, and strictest quality control requirements to provide a dense, smooth, durable surface. As a result, surface courses are typically the most expensive layer in the flexible pavement structure.

There are two instances where a surface course is not the top layer: 7-year warranty asphalt concrete and open graded friction courses. In 7-year warranty asphalt concrete, the entire pavement structure is specified as Item 880 Asphalt Concrete (7-year Warranty) although the top layer is still generally referred to as the surface course. When using an open graded friction course, Item 803, it is placed on top of a surface course, making it the top layer.

All surface courses should be specified in 0.25-inch (5 mm) increments except Item 424 Type A that is specified at exactly five-eighths inches (0.625” [16 mm]).

406.1.1 Item 441 Asphalt Concrete Surface Course, Type 1, (446 & 448), PG64-22

This item is for roads with less than 1500 trucks in the opening day traffic. Lift thickness can be 1.25 inches (32 mm) or 1.5 inches (38 mm). A 1-inch (25 mm) lift may be used with 448 acceptance, however 1.25 inches (32 mm) is the preferred minimum. If 446 acceptance is specified a uniform thickness is required.

406.1.2 Item 441 Asphalt Concrete Surface Course, Type 1, (446 & 448), PG70-22M

This item is for districts that have been specifically instructed to use it on roads with less than 1500 trucks in the opening day traffic. Lift thickness can be 1.25 inches (32 mm) or 1.5 inches (38 mm). A 1-inch (25 mm) lift may be used with 448 acceptance, however 1.25 inches (32 mm) is the preferred minimum. If 446 acceptance is specified a uniform thickness is required.

406.1.3 Item 442 Asphalt Concrete Surface Course, 9.5mm, Type A & B (446 & 448)

This item is a Superpave surface course for roads with less than 1500 trucks in the opening day traffic. This item exists for those districts required to use Superpave mixes on lower truck traffic routes due to localized material problems. The requirements of Section 406.1.1 apply.

406.1.4 Item 442 Asphalt Concrete Surface Course, 12.5mm, Type A & B (446 & 448)

This item is for roads with greater than 1500 trucks in the opening day traffic. The 12.5mm mix is designed for maximum rut resistance at 1.5 inches (38 mm) thick. The surface course is generally the most expensive layer and an increased thickness may not be economical. In special situations where an intermediate course is not possible, the 12.5mm mix may be specified up to a maximum of 2.5 inches (65 mm). A 12.5mm mix cannot be placed properly at a thickness less than 1.5 inches (38 mm); durability
and constructability problems will result. Best practice is to use 1.5 inches (38 mm). If 446 acceptance is specified a uniform thickness is required.

406.1.5 Item 443 Stone Matrix Asphalt Concrete, 12.5mm, PG70-22M & PG76-22M (446)

Stone matrix asphalt (SMA) concrete is a highly rut-resistant mix intended as a surface course for high stress areas and is often used for Amish buggy routes. SMA uses 446 acceptance therefore a uniform lift thickness is required. The minimum lift thickness is 1.5 inches (38 mm). Maximum lift thickness is 2 inches (50 mm). SMA is not recommended for intermittent paving. The minimum recommended placement is one mile (1.6 km) of continuous paving or 250 cubic yards (250 cubic meters); however there may be situations where smaller quantities are justified.

406.1.6 Item 424 Fine Graded Polymer Asphalt Concrete, Type A & B

This item is intended primarily for use as a surface treatment. Use of this item should be in accordance with recommendations from the pavement management system. This item should not be placed over crack sealer that has aged less than one year.

Type A should not be used in locations with greater than 1500 trucks per day.

If Type B is specified and the project contains multiple road sections, some with greater than 1500 trucks and some with less, the mix design criteria for all the sections will be for greater than 1500 trucks.

406.2 Intermediate Courses

Intermediate courses are placed on top of base courses and below surface courses. Intermediate courses provide additional structural capacity and level the base course to allow a smooth surface course. Intermediate courses can be used for extended periods for maintenance of traffic.

All intermediate courses should be specified in 0.25-inch (5 mm) increments.

406.2.1 Item 442 Asphalt Concrete Intermediate Course, 19mm, Type A & B (446)

This item is for roads with greater than 1500 trucks in the opening day traffic. The gradation of this mix requires the lift to be at least 1.75 inches (45 mm) thick. Due to the 446 acceptance, this item is to be specified only in uniform thickness.

Caution is advised when determining the use and thickness of this item. ODOT C&MS specifies a maximum compacted lift of 3 inches (75 mm). For example, the contractor must place a 3.5-inch (90 mm) layer in two lifts of 1.75 inches (45 mm). It is best to avoid specifying layers between 3 inches (75 mm) and 3.5 inches (90 mm) due to the 1.75 inch (45 mm) minimum lift thickness requirement. For most situations, the total thickness should not exceed 4.5 inches (115 mm), as it would be better to introduce the additional thickness into the 301 or 302, or possibly the 304 base.

406.2.2 Item 441 Asphalt Concrete Intermediate Course, Type 2, (446)

This item is for roads with less than 1500 trucks in the opening day traffic. The requirements of Section 406.2.1 apply.

The PG binder is automatically designated in the C&MS and is not included as part of the pay item description.
406.2.3 Item 441 Asphalt Concrete Intermediate Course, Type 1, (448)

This item is intended primarily as a scratch course on roads with less than 1500 trucks in the opening day traffic. Uniform lift thickness for this item can be as thin as 1 inch (25 mm) and as thick as 1.5 inches (38 mm). This item can be used as a variable thickness course. For some rare occasions, when this lift is used as a leveling or wedge course, it may be practical to stretch the lift thickness past the 1.5 inch (38 mm) limit. For situations where the variability of the course thickness is excessive, say 0 inches to 2 inches (0 mm to 50 mm), consideration should be given to pavement planing to allow for the use of a Type 2 intermediate course which provides more stability than a Type 1 mix. This item can be tapered to 0 inches (0 mm) and placed at non-uniform thickness less than the minimum lift thickness.

For projects using 446 acceptance for the surface course but need this type of a leveling or wedge, there is nothing wrong with placing an intermediate course with 448 acceptance under a surface course with 446 acceptance. This item is not to be used as uniform thickness layer for projects with greater than 1500 trucks in the opening day traffic.

The PG binder is automatically designated in the C&MS and is not included as part of the pay item description.

406.2.4 Item 442 Asphalt Concrete Intermediate Course, 9.5mm, Type A & B (448)

This item is intended primarily as a scratch course on roads with greater than 1500 trucks in the opening day traffic. The requirements of Section 406.2.3 apply.

406.2.5 Item 442 Asphalt Concrete Intermediate Course, 19mm, Type A & B (448)

This item is the same as Item 442 Asphalt Concrete Intermediate Course, 19mm, Type A & B (446) (Section 406.2.1) except it can be used as a variable thickness course. The minimum and maximum lift thickness and maximum total thickness in Section 406.2.1 apply. For some rare occasions, when this material is used as a leveling or wedge course, it may be practical to stretch the maximum recommended thickness past the 4.5 inch (115 mm) limit. This item can be tapered to 0 inches (0 mm) and placed at non-uniform thickness less than the minimum lift thickness.

For projects using 446 acceptance for the surface course but needing this type of a leveling or wedge, it is acceptable to use this item for the intermediate course. Use of this item should be avoided, if possible, for high traffic volumes to minimize pavement densification under traffic.

406.2.6 Item 441 Asphalt Concrete Intermediate Course, Type 2, (448)

This item is for roads with less than 1500 trucks in the opening day traffic. The requirements of Section 406.2.5 apply.

The PG binder is automatically designated in the C&MS and is not included as part of the pay item description.

406.3 Base Courses

Asphalt concrete base courses provide the majority of the structural capacity in most flexible pavement buildups. All asphalt concrete base courses should be specified in 0.5-inch (10 mm) increments.

406.3.1 Item 301 Asphalt Concrete Base, PG64-22

This item is to be used in conjunction with both a surface and intermediate course.
The gradation of this mix requires the lift to be at least 3 inches (75 mm) thick. In special circumstances, it is possible to allow this lift to be as thin as 2.5 inches (65 mm), but this is discouraged. ODOT C&MS specifies a maximum compacted lift of 6 inches (150 mm). Layers thicker than 6 inches (150 mm) will automatically be placed in multiple lifts. This item may be placed in variable thicknesses.

For most situations, this material should have 304 underneath, and a minimum of 3 inches (75 mm) of surface and intermediate course above.

This material can handle traffic during construction but care should be taken to minimize high traffic volume contact. In high traffic volume situations, an intermediate course is preferred for maintenance of traffic, particularly over the winter.

406.3.2 Item 302 Asphalt Concrete Base, PG64-22

This item is to be used in conjunction with both a surface and intermediate course. This mix was developed for use with thick flexible pavements where high volume truck traffic exists. When lift thicknesses and maintenance of traffic operations allow, Item 302 is preferred over Item 301. Item 302 generally costs less than Item 301 and is a more stable, rut-resistant mix but is more susceptible to segregation problems during construction unless good construction practices are followed.

The gradation of this mix requires the lift to be at least 4 inches (100 mm) thick. ODOT C&MS specifies a maximum compacted lift of 7.75 inches (190 mm). Layers thicker than 7.75 inches (190 mm) will automatically be placed in multiple lifts. This item may be placed in variable thicknesses.

For most situations, this material should have 304 underneath, and a minimum of 3 inches (75 mm) of surface and intermediate course above. It is not necessary to put a 301 course above a 302 course. Placement of 301 below 302 is illogical.

Item 302 should not be used for maintenance of traffic for more than approximately 60 days and never over the winter. If it is necessary to maintain traffic for more than 60 days or over winter, the top 3 inches (75 mm) of the 302 could be changed to 301, or preferably, the project should be phased to allow the intermediate course to be used for maintenance of traffic.

406.4 Item 407 Tack Coat

A tack coat is used to glue an asphalt concrete layer to the layer below. Tack coats are required anytime a surface course is placed on an intermediate course (C&MS 407.06). The tack coat between a surface and an intermediate course placed as part of the same project should be specified using Item 407 Tack Coat for Intermediate Course. All other tack coats should be specified using Item 407 Tack Coat.

Tack coat is recommended anytime an asphalt concrete surface or intermediate course is being placed on pavement constructed in a previous project with one exception. Tack coat should not be used under a bondbreaker layer for an unbonded concrete overlay unless traffic will be maintained on the bondbreaker. All other situations a tack coat is recommended even if the old pavement has been planed.

A tack coat is not required below an intermediate course placed on an asphalt concrete base constructed as part of the same project. A tack coat is required below the intermediate course if the base course is used for maintenance of traffic operations. A tack coat below the intermediate course is recommended if project-specific details require the base course to be exposed for more than ten days.

A tack coat is required between the concrete and the intermediate course when building a composite pavement. When tack coat is placed on concrete or brick, C&MS automatically requires the use of rubberized asphalt emulsion conforming to 702.13.
Actual application rates of tack coat are set in the field. The most common application rate used for estimating quantities is 0.075 gallons per square yard (0.34 L/m²). Estimated application rate of Tack Coat for Intermediate Course is 0.04 gallons per square yard (0.18 L/m²).

406.5 Item 408 Prime Coat

Prime coats are rarely used and are never required. Before specifying a prime coat, the designer should check with construction personnel to see if prime coats are routinely non-performed. A prime coat should not be included in the plans if it will be non-performed.

Prime coats are applied to Item 304 Aggregate Base to seal and protect the 304 during construction. Prime coats help control dust and damage caused by construction traffic. They can also help reduce water infiltration while the 304 is exposed. The designer should consider the construction phasing and how long the 304 will be exposed to the elements and construction traffic when determining the use of prime coat.

Estimated application rate for prime coat is always 0.4 gallons per square yard (1.8 L/m²).

407 Warranty Asphalt Concrete

The use of warranty does not change the asphalt concrete thickness design in any way. The same inputs are used and the same SN determined regardless of whether warranty or conventional asphalt concrete will be used. To determine the thickness of a warranty asphalt pavement, the designer should assume conventional materials and lift thickness restrictions, then apply the appropriate structural coefficients. For asphalt pavements with a 7-year warranty, the entire thickness is specified as Item 880. For 3-year warranties, conventional items are specified for each layer and Supplement 1059 is added to the surface course pay item description.

More information on asphalt pavement warranties is available in the Warranty Application Guidelines in the Innovative Contracting Manual published by the Office of Construction Administration, in the Item 880 Asphalt Concrete (7 Year Warranty) specification, and in Supplement 1059 Asphalt Concrete Surface Course Warranty Requirements.

408 Smoothness Specifications

Incentive/disincentive for smoothness is specified using Proposal Note (PN) 420 Surface Smoothness Requirements for Pavements or PN 470 Thin Lift Asphalt Surface Smoothness Requirements. PN 420 is recommended for all eligible projects. The designer note details the eligibility requirements. For projects not eligible for PN 420, PN 470 is recommended in accordance with the designer note.

PN 470 is incentive only. The minimum smoothness requirements when PN 470 is used are contained in C&MS 401.19.

Smoothness incentives generally result in better attention to detail by the contractor and higher quality pavement overall. Smooth, high quality pavements are expected to perform better for a longer time, potentially resulting in cost savings to the Department.

The designer should ensure the contractor has a reasonable opportunity to achieve the incentive. Projects that may otherwise be eligible but have numerous manholes, drainage structures, business or residential driveways, etc., may not be good candidates for smoothness incentive depending on the maintenance of traffic and sequence of operations.
409 Special Use Asphalt Concrete Items

The following items are used for surface treatments, high stress areas and other situations where specialized material is desired.

409.1 Item 803 Rubberized Open Graded Asphalt Friction Course

This item is intended for use in areas with poor skid resistance, where surface drainage is a concern, or where reduced tire-pavement noise is desired. Air-cooled slag is required, which may not be economically available in all areas of the state.

ODOT has had trouble with snow and ice removal on open graded friction courses (OGFC). According to FHWA Technical Advisory T 5040.31, an OGFC “requires special snow and ice control methods and generally remains icy longer.” An OGFC is effective in reducing potential for hydroplaning, reducing splash and spray, and reducing tire-pavement noise as much as 3 to 5 decibels.

An OGFC does not add any structural capacity and therefore should be considered on structurally sound pavements only.

409.2 Item 826 AC Surface and Intermediate Course, Type 1 & 2, Fiber A or B

These items are intended primarily for high stress areas to reduce the potential for rutting. Use of these items should be coordinated with the Offices of Pavement Engineering and Materials Management.

409.3 Item 857 AC with Gilsonite, Surface Course, Type 1 and Intermediate Course, Type 2

These items are intended primarily for high stress areas to reduce the potential for rutting. Use of these items should be coordinated with the Offices of Pavement Engineering and Materials Management.

409.4 Item 859 AC with Verglimit

This item is intended as an anti-icing pavement. It is not recommended for roads with greater than 1500 trucks per day. Verglimit is a linseed oil-coated multi-component chemical deicer additive consisting of calcium chloride flakes and other chemicals. ODOT has very limited experience with this item. Use of this item should be coordinated with the Offices of Pavement Engineering, Maintenance Administration, Materials Management, and Structural Engineering if used on bridges.

409.5 Item 874 Ultrathin Bonded Asphalt Concrete

This item is intended primarily for use as a surface treatment. It consists of sealing the pavement with a polymer modified emulsion followed immediately with a thin asphalt overlay. The asphalt overlay requires crushed aggregate to provide rut resistance. This item should not be placed over fresh, less than one year old, crack sealer. Placement of this item requires a special paving machine. This item should be used on structurally sound pavements only.

410 Small Quantity Guidelines

Numerous asphalt concrete mixes exist for use in various situations on projects large and small. It is desirable to minimize the number of different mixes specified on a project to reduce complexity and receive the best price for the items specified. These guidelines are intended to simplify and reduce the
cost of paving on bridge and culvert replacement projects, bridge deck overlays, turn lane additions, landslide repairs, etc.

410.1 Transition to Structures

Bridge replacement and rehabilitation projects often include a small amount of paving to transition to the structure. Culvert replacement projects include a small quantity of asphalt to replace the pavement over the culvert. When these small quantities are the only asphalt paving on a project, the guidelines in this section should be used to select the proper asphalt concrete items.

If the road carries less than 1500 trucks per day, use Item 441 Asphalt Concrete Surface Course, Type 1, (448), PG64-22 for both the surface and intermediate courses. Include a plan note restricting the 441 to two-inch (50 mm) maximum lift thickness. Use either Item 301 Asphalt Concrete Base, PG64-22 or Item 302 Asphalt Concrete Base, PG64-22 for the base course.

If there are more than 1500 trucks per day, use Item 442 Asphalt Concrete Surface Course, 12.5mm, Type A or B (448) for both the surface and intermediate courses. Include a plan note requiring PG64-22 binder and restricting the 442 to two-inch (50 mm) maximum lift thickness. If the project is on an interstate and the adjoining pavement is less than seven years old, use PG70-22M binder for the 442. Use Item 302 Asphalt Concrete Base, PG64-22 for the base course.

If the transition area is a high stress location, the asphalt concrete should be selected in accordance with the High Stress Guidelines (Appendix B). Include a plan note restricting the asphalt concrete selected for the surface and intermediate courses to two-inch (50 mm) maximum lift thickness. Use Item 302 Asphalt Concrete Base, PG64-22 for the base course.

410.2 Overlaying Pavement and Bridges Simultaneously

When continuing a pavement overlay across a bridge, use the same asphalt concrete items on the bridge as used on the pavement. If a leveling course is needed on the bridge but not used on the pavement, use an additional lift of the surface course mix as the leveling course. Include a plan note restricting each lift of surface course on the bridge to two inches (50 mm) maximum.

410.3 Bridge Deck Overlays with Transitions

Some new bridges may include an asphalt concrete wearing surface. The items to be used for the wearing surface are specified in the Bridge Design Manual. Use the same items as used on the bridge for any required transition to the pavement. If a surface course mix is used for both the surface and intermediate course, include a plan note restricting each lift of surface course to two inches (50 mm) maximum. Use either Item 301 Asphalt Concrete Base, PG64-22 or Item 302 Asphalt Concrete Base, PG64-22 for the base course, if needed.

410.4 Turn Lane Additions

These guidelines are to be used any time a turn lane is added or other minor widening is performed without a resurfacing project and the adjoining asphalt concrete surface is more than three years old. If the adjoining surface is less than three years old, the materials in the widening should match the adjoining pavement so the performance is similar. If the widening is greater than the equivalent of one lane wide and 0.25 miles (0.50 km) long, standard materials and lift thicknesses should be used.

If the road carries less than 1500 trucks per day, use Item 441 Asphalt Concrete Surface Course, Type 1, (448), PG64-22 for both the surface and intermediate courses. Include a plan note restricting the 441 to two-inch (50 mm) maximum lift thickness. Use either Item 301 Asphalt Concrete Base, PG64-22 or Item 302 Asphalt Concrete Base, PG64-22 for the base course.
If there are more than 1500 trucks per day, use Item 442 Asphalt Concrete Surface Course, 12.5mm, Type A or B (448) for both the surface and intermediate courses. Include a plan note requiring PG64-22 binder and restricting the 442 to two-inch (50 mm) maximum lift thickness. If the project is on an interstate and the adjoining pavement is less than seven years old, use PG70-22M binder for the 442. Use Item 302 Asphalt Concrete Base, PG64-22 for the base course.

If the widening is a high stress location, the asphalt concrete should be selected in accordance with the High Stress Guidelines (Appendix B). Include a plan note restricting the asphalt concrete selected for the surface and intermediate courses to two-inch (50 mm) maximum lift thickness. Use Item 302 Asphalt Concrete Base, PG64-22 for the base course.

410.5 Landslides, Washouts, Collapses, etc.

Repairing landslides, washouts or other collapses may require small quantities of new pavement. If the adjoining pavement is less than three years old, the materials used in the repair should match the adjoining pavement so the performance is similar. If the repair length is less than 0.25 miles (0.50 km), these guidelines apply; otherwise, standard materials and lift thicknesses apply.

If the road carries less than 1500 trucks per day, use Item 441 Asphalt Concrete Surface Course, Type 1, (448), PG64-22 for both the surface and intermediate courses. Include a plan note restricting the 441 to two-inch (50 mm) maximum lift thickness. Use either Item 301 Asphalt Concrete Base, PG64-22 or Item 302 Asphalt Concrete Base, PG64-22 for the base course.

If there are more than 1500 trucks per day, use Item 442 Asphalt Concrete Surface Course, 12.5mm, Type A or B (448) for both the surface and intermediate courses. Include a plan note requiring PG64-22 binder and restricting the 442 to two-inch (50 mm) maximum lift thickness. If the project is on an interstate and the adjoining pavement is less than seven years old, use PG70-22M binder for the 442. Use Item 302 Asphalt Concrete Base, PG64-22 for the base course.

If the repair is in a high stress location, the asphalt concrete should be selected in accordance with the High Stress Guidelines (Appendix B). Include a plan note restricting the asphalt concrete selected for the surface and intermediate courses to two-inch (50 mm) maximum lift thickness. Use Item 302 Asphalt Concrete Base, PG64-22 for the base course.
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<td>Item 803 Rubberized Open Graded Asphalt Friction Course</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Items 822, 886 - Hot In Place Recycling</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

* Free Draining Bases are not approved for use on ODOT projects.

Asphalt Concrete Drainage Factor = 1.0
Given:

- Number of Lanes: 4
- Functional Classification: Rural Principal Arterial
- 2016 Traffic: 15,800 ADT
- 2036 Traffic: 22,450 ADT
- 24 hour truck %: 18%
- Design Period: 20 years
- Open to Traffic: 2017
- Subgrade CBR: 5 (from GB1 analysis)

Problem: Solve for the Structural Number and determine an acceptable flexible buildup

Solution:

Step 1 - Determine the 18 Kip Equivalent Single Axle Loading (ESAL)

Since the project is expected to open to traffic in 2017, the ESAL projection should be for 2017 to 2037. Calculate the mid-year (2027) ADT, rounded to the nearest ten:

2027 ADT = 15,800 + (22,450 - 15,800)(11/20)
2027 ADT = 19,460

Directional distribution, D = 50% (Figure 202-1)
Lane factor = 90% (Figure 202-1)
B:C ratio = 5:1 (Figure 202-1)
ESAL conversion factor for B trucks = 1.06 (Figure 202-1)
ESAL conversion factor for C trucks = 0.33 (Figure 202-1)

Using the equations given in Section 202.2:

ESAL’s from B trucks = 19,460(0.18)(0.50)(0.90)(5/6)(1.06) = 1392
ESAL’s from C trucks = 19,460(0.18)(0.50)(0.90)(1/6)(0.33) = 87

Total daily ESAL’s = 1392 + 87 = 1479 ESAL/day

Design period ESAL’s = 1479 ESAL/day * 365.25 days/yr. * 20 years = 10,804,095
use 10.8x10^6 ESAL

Step 2 - Determine the subgrade resilient modulus (M_r) using the formula given in Section 203.1.

M_r = 1200 * CBR
M_r = 1200 * 5
M_r = 6000 psi
Step 3 - Determine the design structural number (SN) using Figures 402-2 and 402-3. In Figure 402-2, solve for the match line number using the following information:

- Reliability = 85% (Figure 201-1)
- Overall Standard Deviation = 0.49 (Figure 201-1)
- 18-kip Single Axle Loads = $10.8 \times 10^6$ ESAL (Step 1)
- Subgrade Resilient Modulus = 6,000 psi (Step 2)

The resulting match line number is then used in Figure 402-3, along with the design serviceability loss of 2.0 (Figure 201-1), to solve for the design structural number (SN).

Therefore: design structural number (SN) = 5.04

Step 4 - Design the typical section using the layer coefficients found in Figure 401-1. The total structural number for the pavement buildup must equal or exceed the design structural number (SN) = 5.04 (Step 3).

Check the number of trucks in the opening day traffic.

\[
2017 \text{ ADTT} = (15,800 + (22,450 - 15,800)/(1/20)) \times 0.18 \\
2017 \text{ ADTT} = 2900
\]

Since the opening day truck traffic is greater than 1500, Item 442 Asphalt Concrete Surface Course, 12.5mm is required.

The following buildup is the recommended solution in accordance with the guidance in Section 406.

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness</th>
<th>Coefficient</th>
<th>SN</th>
</tr>
</thead>
<tbody>
<tr>
<td>442 AC Surface Course, 12.5mm, Type A</td>
<td>1.5&quot;</td>
<td>0.43</td>
<td>0.65</td>
</tr>
<tr>
<td>442 AC Intermediate Course, 19mm, Type</td>
<td>1.75&quot;</td>
<td>0.43</td>
<td>0.75</td>
</tr>
<tr>
<td>302 Asphalt Concrete Base, PG64-22</td>
<td>8&quot;</td>
<td>0.36</td>
<td>2.88</td>
</tr>
<tr>
<td>304 Aggregate Base</td>
<td>6&quot;</td>
<td>0.14</td>
<td>0.84</td>
</tr>
</tbody>
</table>

Total SN = 5.12

Since the total SN equal to 5.12 of the proposed buildup is greater than the required SN of 5.04, the design is acceptable.
Notes:

The bottom of the aggregate drains shall be at or below the bottom of the pavement's aggregate base at the point of contact. The top of the aggregate drains shall be no higher than the bottom of the shoulder's aggregate base at the point of contact.

* 0.08 Desirable

** A flexible shoulder (Item 301) could be used in lieu of the Surface Treatment
<table>
<thead>
<tr>
<th>Item</th>
<th>Minimum Lift</th>
<th>Maximum Lift</th>
<th>Taper to 0&quot;*</th>
<th>Uniform Thickness Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>301 Asphalt Concrete Base</td>
<td>3&quot;</td>
<td>6&quot;</td>
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<td>No</td>
</tr>
<tr>
<td>302 Asphalt Concrete Base</td>
<td>4&quot;</td>
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<tr>
<td>424 Fine Graded Polymer Asphalt Concrete, Type A</td>
<td>0.625&quot; (5/8&quot;)</td>
<td>0.625&quot; (5/8&quot;)</td>
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<tr>
<td>441 AC Surface Course, Type 1 (448)</td>
<td>1&quot;</td>
<td>1.5&quot;</td>
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<tr>
<td>441 AC Surface Course, Type 1 (446)</td>
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<tr>
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<td>No</td>
</tr>
<tr>
<td>441 AC Intermediate Course, Type 2 (446)</td>
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<td>3&quot;</td>
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<tr>
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<td>2.5&quot;</td>
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<tr>
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<tr>
<td>443 Stone Matrix Asphalt Concrete, 12.5mm (446)</td>
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<td>2&quot;</td>
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<tr>
<td>Item</td>
<td>Minimum Lift</td>
<td>Maximum Lift</td>
<td>Taper to 0&quot;**</td>
<td>Uniform Thickness Required</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>--------------</td>
<td>--------------</td>
<td>---------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>803 Rubberized Open Graded Asphalt Friction Course</td>
<td>0.75&quot;</td>
<td>0.75&quot;</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>826 AC Surface Course, Type 1, Fiber A or B</td>
<td>1&quot;</td>
<td>1.5&quot;</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>826 AC Surface Course, Type 2, Fiber A or B</td>
<td>1.75&quot;</td>
<td>3&quot;</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>826 AC Intermediate Course, Type 1, Fiber A or B</td>
<td>1&quot;</td>
<td>1.5&quot;</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>826 AC Intermediate Course, Type 2, Fiber A or B</td>
<td>1.75&quot;</td>
<td>3&quot;</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>857 AC with Gilsonite, Surface Course, Type 1 (designed for &lt;1500 trucks)</td>
<td>1&quot;</td>
<td>1.5&quot;</td>
<td>No</td>
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</tr>
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<td>857 AC with Gilsonite, Surface Course, Type 1 (designed for &gt;1500 trucks)</td>
<td>1.5&quot;</td>
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</tr>
<tr>
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<td>1.75&quot;</td>
<td>3&quot;</td>
<td>No</td>
<td>**</td>
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<tr>
<td>859 AC with Verglimit</td>
<td>1&quot;</td>
<td>2.5&quot;</td>
<td>No</td>
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<tr>
<td>874 Ultrathin Bonded AC</td>
<td>0.625&quot; (5/8&quot;)</td>
<td>1.5&quot;</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

* A "Yes" value in this column indicates the material can be specified at a 0" minimum in variable depth applications such as a rut fill course or it can be feathered to 0" at the beginning and end of paving. A "No" value indicates the minimum lift thickness is required at all times and a butt joint is required at the beginning and end of paving (intermediate courses may taper and end as shown in the butt joint detail in BP-3.1).

** Acceptance and the need for a uniform lift thickness for Item 857 depends on the total quantity of material used. If the total quantity is 250 tons (250 metric tons) or greater, 446 acceptance is used and a uniform lift thickness is required. Less than 250 tons (250 metric tons), 448 acceptance is used and a variable lift thickness is allowed.
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500 Pavement Design Procedures for Minor Rehabilitation

500.1 Introduction

Minor rehabilitations should occur when the pavement has deteriorated beyond the point at which preventive maintenance is effective but does not yet require major rehabilitation. Minor rehabilitations usually consist of some combination of milling, repair, and overlay. ODOT designs minor rehabilitation overlays using a deflection-based procedure and twelve-year traffic projections.

501 Deflection Measuring Equipment

Deflection measuring equipment imposes a load on the pavement and measures the response. The deflections can be correlated to the structural condition of the pavement and the subgrade. Designers can interpret the deflections and provide recommendations for pavement rehabilitation. ODOT has two kinds of deflection measuring equipment or Non-Destructive Testing (NDT) devices: the Dynaflect, and the Falling Weight Deflectometer. Both are described below; however, this manual is written specifically for use with the Dynaflect.

501.1 Dynaflect

The Dynaflect is an electro-mechanical device used for measuring pavement deflection. It is trailer-mounted and can be towed by a standard vehicle. A static weight of 2000 pounds (~908 kg) is applied to the pavement through a pair of 4-inch wide by 16-inch (~406 mm) diameter rubber-coated steel wheels placed 20 inches (~508 mm) apart. Two counter-rotating eccentric weights produce a dynamic force of 1000 pounds (~454 kg), peak-to-peak, at a frequency of eight cycles per second. The dynamic force is superimposed on the static force and the deflections are measured by five velocity transducers (geophones). The first geophone is located between the steel wheels with the rest spaced twelve inches (~305 mm) apart. The deflections are recorded on a computer in the tow vehicle.

501.2 Falling Weight Deflectometer

The Falling Weight Deflectometer (FWD) is an impact load response device used to measure pavement deflection. The impact force is created by dropping a weight of 110, 220, 440, or 660 pounds (~50, 100, 200, 300 kg) from a height of 0.8 to 15 inches (~20 to 380 mm). By varying the drop height and weight, a peak force ranging from 1500 to 24,000 pounds (~6.7 to 106.8 kN) can be generated. The load is transmitted to the pavement through a loading plate, 11.8 inches (~300 mm) in diameter, to provide a load pulse in the form of a half sine wave with a duration from 25 to 30 ms. The actual magnitude of load applied may depend on the stiffness of the pavement and is measured by a load cell. The deflections are measured by seven velocity transducers. One transducer is located at the center of the loading plate while the remaining six can be placed at locations up to 7.4 feet (~2.25 m) from the center. The deflections are recorded on a computer located in the tow vehicle.

502 Deflection Testing and Analysis

502.1 General

Deflection measurements taken when the subgrade is frozen are meaningless for design. The testing season in Ohio runs approximately April through November. Requests for Dynaflect testing should be made to the Research and Development Section of the Office of Materials Management with a copy of the request to the Pavement Design Section in the same Office. Requests are honored on a first-come, first-served basis, subject to scheduling considerations. Requests made too late in the season may not be tested until the following year. Research testing needs take priority during many of the summer months. The best time to submit requests is just prior to and early in the testing season. All requests must include the exact limits of the project using the current English straight-line diagrams issued by the Office of Technical Services, even for projects being developed in metric units.

Deflection measurements represent a snapshot of the pavement at that time. As the pavement continues to deteriorate, the snapshot changes. Therefore, deflection data should not be obtained more than four years prior to construction. If the project is delayed such that the data will be more than four-years old, new deflection measurements should be requested and the design checked against the new measurements to ensure validity.
502.2 Analysis

Deflection measurements yield a great deal of information about the pavement when properly interpreted. This Manual is not intended to make the reader an expert in analyzing deflection data. A training course is available which discusses the data analysis in much greater detail.

502.2.1 Edwards Ratio

One of the more useful parameters derived from the Dynaflect data is called the Edwards Ratio. Named after William F. Edwards, former Bureau Chief of Research and Development at ODOT. The Edwards Ratio states that if the $w_1$ sensor reading divided by the $w_5$ sensor reading is greater than three, the pavement is acting as a flexible pavement and should be analyzed as such. If it is less than three, the pavement is acting as a rigid pavement and should be analyzed as such. This is very useful when trying to decide how to analyze a brick pavement or an existing break & seat or crack & seat.

502.2.2 $w_5$ vs. CBR

The $w_5$ sensor provides an estimate of the subgrade strength. The chart in figure 203-3 shows the relationship between the average $w_5$ sensor reading plus two standard deviations and the CBR value. The average $w_5$ reading and the standard deviation are given on the Dynafect printout.

502.2.3 Load Transfer

The Load Transfer factor can indicate joints which have deteriorated and are no longer effectively transferring the load. Load Transfer factors less than 0.70 indicate poor load transfer. Factors greater than 0.70 do not necessarily indicate good joints. If the pavement is warm, the joints may be locked up and showing better load transfer than actually exists. The Load Transfer factor is the $w_2$ sensor divided by the $w_1$ sensor, both from the joint approach reading. A graph of Load Transfer values is given by the UTPlot program (Section 503.1).

502.2.4 Joint Support Ratio

The Joint Support Ratio is another measure of the joint’s effectiveness. Joint Support Ratio is the $w_1$ sensor from the joint leave reading divided by the $w_1$ sensor from the joint approach reading. Joint Support Ratios between 0.50 and 1.50 are considered good. Ratios outside this range indicate probable voids under the joint. Voids are also likely anytime the $w_1$ sensor reading is above 1.0. The UTPlot program provides a graph of the Joint Support Ratio.

502.3 Factors Affecting Deflections

The major factors that influence deflections include loading, climate and pavement conditions. These factors must be carefully considered when conducting nondestructive tests.

502.3.1 Loading

The magnitude and duration of loading have a great influence on pavement deflections. It is desirable that the NDT device applies a load to the pavement similar to the actual design load, e.g., a 9000 pound (~4086 kg) wheel load. Unfortunately, not every commercially available NDT is capable of simulating the design load. Some can simulate the magnitude of the design load but not its duration or frequency.

Due to the nonlinear or stress-sensitive properties of most paving materials, pavement deflections are not proportional to load. Test results obtained for light loads must be extrapolated to those for heavy loads. Because extrapolation may lead to significant error for nonlinear paving materials, the use of NDT devices that produce loads approximating those of heavy truck loads is recommended by most researchers.

In 1989, FHWA/ODOT published Technical Report No. FHWA/ OH-89/020 titled: Implementation of a Dynamic Deflection System for Rigid and Flexible Pavements in Ohio. This research study looked into the non-linearity problems associated with NDT using light loading as compared to normal truck loads. The relevant conclusion was: “on the average, pavement deflections obtained by the Dynaflect and the FWD correlated quite well and pavement non-linearity was not as significant as was anticipated.”

502.3.2 Climate

Temperature and moisture are the two climatic factors that affect pavement deflections. For asphalt pavements, higher temperatures cause the asphalt binder to soften and increase deflections. For concrete pavements, temperature in the form of overall change or thermal gradient has a
significant influence on deflections near joints and cracks. The slab expands in warmer temperatures causing tighter joints and cracks and resulting in greater efficiency of load transfer and smaller deflections. The curling of the slab due to temperature gradients can cause a large variation in measured deflections. Measurements taken at night or early morning, when the top of the slab is colder than the bottom, will result in higher corner and edge deflections than those taken in the afternoon, when the top of the slab is much warmer than the bottom.

The season of the year has a great effect on deflection measurements. In cold regions, four distinct periods can be distinguished. The period of deep frost occurs during the winter season when the pavement is the strongest. The period of spring thaw starts when the frost begins to disappear from the pavement system and the deflection increases rapidly. The period of rapid strength recovery takes place in early summer when the excess free water from the melting frost leaves the pavement system and the deflection decreases rapidly. The period of slow strength recovery extends from late summer to fall when the deflection levels off slowly as the water content slowly decreases. For pavements that do not experience freeze-thaw, the deflection generally follows a sine curve with the peak deflection occurring in the wet season when the moisture contents are high.

502.3.3 Pavement Conditions

Pavement conditions have significant effects on measured deflections. For asphalt pavements, deflections obtained in areas with cracking and rutting are normally higher than those free of distress. For concrete pavements, voids beneath the concrete slabs will cause increased deflections, and the absence or deterioration of load transfer devices will affect the deflections measured on both sides of the joint.

503 Overlay Design Procedure

503.1 Introduction

The overlay design procedure for minor rehabilitations is based on the UTOVER computer program. A great deal of preparatory work and research must take place before the computer program is run. The Dynaflect readings must be completed (Section 202). Finally, the history of the pavement must be known.

The history is required to determine the actual buildup of the pavement at the time the Dynaflect measurements were taken. There are many sources for this information such as historical plans, the pavement management system database, the joint repair database, etc. On past overlay projects where existing asphalt was milled, it is necessary to determine the depth of milling or at least a reasonable estimate. The UTOVER program requires the total thickness of asphalt and/or concrete at the time the Dynaflect readings were taken. If the thickness changes within the project, the user must split the data and run UTOVER separately for each of the different thicknesses.

Once all the required information is collected, the first step is to run the UTPLOT.BAT program. UTPLOT converts the raw Dynaflect file to a format which can be read by UTOVER. Next is to run the UTOVER.EXE program. The input files for UTOVER are the output files created by UTPLOT and not the raw Dynaflect file.

Most of the user inputs for UTOVER are self-explanatory and many provide default values. Some inputs are common to all pavement types: the title is the users choice, the design traffic input comes from the ESAL99 program (Section 202.3), reliability factors are given in Figure 201-1, the traffic standard deviation is always the default value of 0.10, the file name containing the Dynaflect data is one of the files created by UTPLOT, and the output file name is the users choice. Inputs specific to each pavement type are discussed in the following sections. The information given here is not intended to fully explain the UTOVER procedure or Dynaflect analysis. A training course is available which goes over the procedures in detail.

All of the inputs and outputs for UTOVER are exclusively in English units.

503.2 Rigid Pavements

Rigid pavement refers to all types of exposed concrete pavement with no asphalt on top. The minimum overlay thickness for rigid pavements is three inches. Pavements which require an overlay of about one inch or less are candidates for diamond grinding instead of an overlay.
Most of the rigid pavement inputs to UTOVER use the default values. The thickness of the existing pavement is obtained from the history. Use the default value for Poisson's Ratio of the existing concrete. Use the default values for elastic modulus, initial PSI, terminal PSI, modulus of rupture, and the drainage coefficient. The load transfer coefficient (J) is dependent on the specifics of the existing pavement. A list of J-factors for existing pavements is given in Figure 503-1. A rigid pavement with the majority of the joints replaced with flexible repairs, should use a J-factor for a pavement with no load transfer at the joints.

503.3 Flexible Pavements

Flexible pavements are made up entirely of asphalt with or without an aggregate or macadam base. Previously rubblized pavements are considered flexible pavement. Previous break & seat and crack & seat projects may be flexible pavement but are more likely acting as composite pavement. The Edwards Ratio can help in determining pavement type in questionable cases.

Most of the inputs for flexible pavement require the user to enter values. The whole thickness of flexible pavement above subgrade is exactly what the name implies: the thickness of the aggregate base, macadam base, or rubblized concrete plus the entire thickness of asphalt on top. The thickness of the surface AC layer is required for temperature adjustment. It is not a sensitive input. Best practice is to use the thickness of the existing surface and intermediate courses combined. Pavement surface temperature is recorded on the Dynaflect printout. Where additional temperatures were recorded for the same data, a weighted average should be used. The 5-day mean air temperature should be obtained from meteorological records, if available. In the absence of actual temperature data, the morning pavement surface temperature should be used as the basis for the 5-day mean temperature. Some adjustment is allowed if the user is aware of specific temperature conditions in the days just prior to the Dynaflect readings. Initial and terminal PSI are always 4.5 and 2.5, respectively.

503.4 Composite Pavements

Composite pavements are concrete overlaid with asphalt. Most old break & seat and crack & seat projects should be analyzed as composite pavements. Any asphalt-surfaced road with some sort of concrete underneath, that is acting like a rigid pavement according to the Edwards Ratio, should be analyzed as a composite pavement.

The inputs for composite pavement are nearly identical to rigid pavement with the addition of asphalt on top (Section 503.2). Thickness of existing AC layer is the thickness of all the asphalt on top of the concrete. The default values should be used for Poisson’s Ratio and the resilient modulus of the asphalt. The thickness of existing PCC slab is obtained from the history or coring. Use default values for Poisson’s Ratio, new concrete elastic modulus, initial PSI, terminal PSI, new concrete modulus of rupture, and drainage coefficient. The load transfer coefficient (J) is dependent on the specifics of the existing pavement. A list of J-factors for existing pavements is given in Figure 503-1. A composite pavement with the majority of the joints replaced with flexible repairs, should use a J-factor for a pavement with no load transfer at the joints.

503.4.1 Brick Pavements

Most brick pavements in Ohio were built on a concrete base and have since been overlayed with asphalt and thus are a special kind of composite pavement. The UTOVER program was not designed for use on brick pavements. The Edwards Ratio can help the user decide which type of pavement to use to analyze the brick. When inputting the thicknesses, it is up to the user to decide if the bricks count as concrete or as asphalt.

Since brick pavements occur mostly in urban areas, there are likely to be geometric problems such as curb reveal, driveways, etc. A possible solution is to design a crack and seat overlay (see Section 600) with removal of both the asphalt and the bricks. This should only be done if the section has been cored to determine the condition and thickness of the existing concrete. The actual cracking and seating operation should not be
performed as the concrete is likely already well cracked. This method merely eliminates the need to run UTOVER on a brick pavement which it was not intended for and can sometimes result in excessive overlay thicknesses.

504 Minor Rehabilitation Strategies

As stated before, minor rehabilitations generally consist of some combination of milling, repair, and overlay. The structural overlay thickness needed is determined from the Dynaflect and the UTOVER program. Even if UTOVER says that no additional structure is needed, an overlay may still be required to correct functional deficiencies. The thickness of a functional overlay is selected based on factors such as milling depth, lift thickness requirements, vertical clearance, curb reveal, etc. A functional overlay with milling should never result in thinner pavement than existed beforehand. The other minor rehabilitation actions are at the designer’s discretion based on the condition of the pavement. The actions selected should be those required to reach the full design period for minor rehabilitation projects.

504.1 Asphalt Considerations

All asphalt items used in minor rehabilitation overlays should conform to the guidelines given in Section 404. Prior to completion of the plans, all asphalt items specified should be discussed with the District Engineer of Tests or his designee. This is important to ensure proper binder grades and mix specifications are specified.

A minimum of 3 inches (~75 mm) of asphalt is required over any concrete or brick surface.

504.2 Milling

Milling is always recommended. A milled surface allows for mechanical interlock between the existing pavement and the overlay which helps prevent rutting and debonding. Milling removes the old, raveled, oxidized asphalt which, if left in place, would be a weak layer in the pavement structure and would tend to hold water due to the lower binder content. Milling reduces the overall elevation increase and thus helps reduce geometric problems. Milling removes ruts and other irregularities and provides a level surface for the contractor to achieve proper density for 446 mixes.

When old asphalt is removed, it is necessary to replace the structure removed with an equivalent structure of new asphalt. The structural ratio of new asphalt to old asphalt used in Ohio is 2:3. For example, if 3” (~75 mm) of asphalt are removed, 2” (~50 mm) of asphalt are required to replace the lost structure. Any required structural overlay is then placed in addition to the 2 inches (~50 mm). This ratio should not be used to make major reductions in the pavement thickness. In virtually all cases, the pavement thickness after rehabilitation should be equal to or greater than the thickness prior to rehabilitation.

On composite pavements, including brick, if all the asphalt is removed down to the concrete, or bricks, the minimum overlay thickness for rigid pavements of 3 inches (~75 mm) applies.

When milling down to a concrete surface, consideration should be given to lightly scarifying the top of the concrete if the total overlay is less than 5 inches (~125 mm) thick. The scarification should be specified by plan note. The roughened surface increases the bond between the asphalt and the concrete, therefore reducing the chances of rutting and debonding.

504.2.1 Brick Pavements

When milling asphalt over an existing brick base, it is recommended to leave about two inches (~50 mm) of asphalt on the bricks. Milling any closer can easily dislodge the bricks and pull them up with the asphalt. Dislodged bricks should be quickly repaired, preferably using Asphalt Concrete (Items 301 or 448 Type 2), to prevent adjacent bricks from moving. Repairs should be made prior to running any traffic over the area, including construction traffic.

504.3 Pavement Repair

504.3.1 Rigid and Composite Pavements

Pavement repairs in rigid and composite pavements most often occur at transverse joints and cracks and are generically referred to as joint repairs. Joint repairs can be made using either concrete or asphalt. The repairs can be at existing transverse joints or transverse cracks or any other place which requires full-depth repair. Rigid repairs per BP-2.5, using Item 255 Full Depth Pavement Removal and Rigid Replacement are recommended in almost every case. Prior to repair, coring is recommended to determine if solid
concrete exists near the joints to dowel into. Where solid concrete does not exist, flexible repairs are an option but more likely the pavement requires major rehabilitation. Only coring can reveal if the concrete near the joints is solid, Dynaflect analysis and visual inspection of the surface cannot reveal this.

Joint repair is considered economical for repair quantities up to ten percent of the pavement surface area. When more than ten percent repair is needed, a more thorough investigation is warranted. If not already done, the pavement should be cored to better determine exact repair needs. The required overlay thickness needs to be examined and the possibility of major rehabilitation should be considered. It should be remembered that minor rehabilitations are intended to last twelve years, not twenty. It may not be necessary to repair every joint, especially if the pavement is to receive a thick overlay.

When estimating repair quantities, it is important to correctly calculate the pavement sawing quantities. Transverse saw cuts are required across the pavement at the limits of the repair. A saw cut is also required along any tied longitudinal joint. For a typical six foot repair in one twelve foot wide lane on a four-lane divided highway with asphalt shoulders, the total sawing quantity would be 12' +12' +6' = 30' (3.6 m +3.6 m +1.8 m = 9 m).

In the past, due to concerns over pressure in concrete pavements, Type D pressure relief joints (per BP-2.4) were sawed at approximately 1000-foot (~300 m) intervals in many concrete pavements around the state. This not only relieved the pressure in the pavements but allowed the midpanel cracks to open up and thus lose aggregate interlock required for load transfer. These Type D joints should be repaired full depth with rigid joint repairs whenever they are encountered. To guard against pressure damage to the bridges, a Pressure Relief Joint, Type A per BP-2.3, may be installed at the approach slabs.

Some concrete pavements have had joints repaired with full depth flexible repairs. These asphalt repairs tend to hump up as the concrete expands, forming mini speed bumps which can be very detrimental to the ride and can be a maintenance headache. When a majority of the joints have been repaired with asphalt, it is generally impractical to re-repair them with concrete. However, if there are only a few flexible repairs or if the concrete is in excellent condition except for the flexible repairs, it may be practical to replace all the flexible repairs with rigid repairs.

504.3.2 Flexible Pavements

Flexible pavements may require full-depth repair due to potholes, severe alligator cracking, transverse thermal cracks, etc. Repairs in flexible pavements are done using Item 253 Pavement Repair. As with rigid and composite pavements, when repair quantities exceed about ten percent, further investigation is warranted and major rehabilitation should be considered. For construction purposes, the minimum practical repair size is 2 feet by 2 feet (~0.6 m x 0.6 m).

Transverse thermal cracks are similar to transverse joints in concrete pavement. As flexible pavements expand and contract with temperature, if the binder is too stiff the pavement will crack. These cracks can be random or can be regularly spaced just like joints in concrete. Thermal cracks are full-depth cracks through the entire thickness of the pavement and must be repaired full depth to correct them and prevent them from reflecting through the surface.

504.3.3 Brick Pavements

Brick pavements built on a concrete base typically do not have joints but often require full-depth repair. Full-depth repairs should be made using Item 305 Concrete Base, As Per Plan. A plan note needs to be written to handle all project specific concerns. In general, the note should eliminate the need for dowels, tie bars, joint forming, joint sealing, and texturing requirements. This assumes the brick has an asphalt overlay or is going to receive one.

Full-depth repair of brick pavements built on a flexible base should be made with materials similar to existing. Generally this means Item 304 Aggregate Base and/or Item 301 Bituminous Aggregate Base.

As many brick pavements occur inside municipalities, the agency responsible for maintenance should be contacted regarding their repair standards. This is particularly true for exposed brick pavements that will remain exposed.
504.4 Reflective Crack Control

Reflective cracks refer to cracks in the asphalt over transverse or longitudinal joints or cracks in the concrete below. Reflective cracks are inevitable with composite pavements.

504.4.1 Sawing and Sealing

Sawing and sealing, Item 413, consists of making a partial-depth saw cut in the asphalt overlay directly over existing transverse joints, immediately after paving. After the saw cuts are made, they are filled with a hot bituminous sealer. Sawing and sealing has proved very effective in controlling the location and deterioration of reflective cracks. Care must be taken to properly locate and align the saw cuts or the treatment will not be effective. Sawing and sealing is recommended anytime the concrete is exposed, either because it has never been overlayed or because the existing overlay has been removed.

504.4.2 Fabrics and Geogrids

Paving fabrics and geogrids have not been found to be cost effective in reducing transverse reflective cracking. However, studies have shown that fabrics can delay and sometimes reduce reflective transverse cracking, but not to the extent that future maintenance decisions are less costly or come at a later time. Paving fabrics can be effective in reducing reflective cracks over longitudinal joints. Fabrics may be considered for longitudinal joints, particularly widening joints and joints at concrete/asphalt interfaces. A Minimum overlay thickness of 1-1/2" (~38 mm) should be placed above fabric installations.

504.5 Concrete Pavement Restoration

Concrete Pavement Restoration (CPR) generally consists of some combination of full- and partial-depth repair, diamond grinding, joint resealing, crack sealing and undersealing. Experience has shown that adding tied concrete shoulders is not cost effective and is not recommended as part of a CPR. CPR is recommended as the first rehabilitation action for most existing concrete pavements. CPR maintains the concrete surface and avoids the reflective cracking that comes with composite pavements. CPR may not be the best choice for pavements built with slag aggregate as they tend to deteriorate on the surface first.

504.6 Geometric Issues

Many times there are geometric problems with the roadway such as vertical clearance, curb reveal, cross-slope, etc., that need to be addressed. Some geometric problems can be easily corrected as part of the pavement rehabilitation. Cross-slopes can be adjusted with either variable depth milling or a layer of asphalt with variable thickness or a combination of the two. Other problems are not fixed so easily.

To meet at-grade bridges and provide clearance under overhead bridges, the overlay is often thinned down or the milling depth increased. The minimum overlay thickness on concrete must still be maintained. If the minimum overlay thickness cannot be maintained, pavement must be removed or bridges raised. These areas with thinner pavement structure may exhibit more extensive and severe distresses as they age and will require more maintenance than the surrounding pavement. In some cases where a thick structural overlay is required, thinning down is not recommended and the pavement should be replaced or bridges raised.

Curb reveal is often a problem in urban areas. The structural needs of the pavement should not be compromised to save old curb. Where there is insufficient curb height for the required overlay, the curbs should be replaced. When only a functional overlay is needed, then it may be practical to increase the milling depth at the face of the curb to provide the full overlay thickness while still maintaining the curb height.

504.7 Pavement Widening

When widening a pavement, the best practice is to design the widening for the traffic and soils conditions present. When traffic and soils information is not available, match the existing pavement type, materials and thicknesses. In all cases the existing pavement and the widening should meet at the same subgrade elevation. The base under the widening should slope away from the existing pavement and drainage should be provided for the widening. Drainage can be achieved with pipe underdrains or possibly aggregate drains. Pipe underdrains should be tied into the existing outlets.

Pavement widening in this section refers to additional lanes or turn lanes, etc. Adding paved shoulders or widening shoulders does not fall...
under this definition. Rebuilt or widened shoulders should generally use asphalt. Widening projects in excess of four lane-miles must follow the Pavement Design and Selection Process.

504.7.1 Rigid Pavement

When widening existing rigid pavement with concrete, the new pavement should be the same type as the old (plain or reinforced) and should be tied to the existing concrete using a Type D Longitudinal Joint per BP-2.1. Prior to specifying a Type D joint, the existing concrete should be cored to determine soundness. Where coring discloses unsound pavement; pavement repair, pavement replacement, or the elimination of the Type D joint should be considered. Widening of concrete pavement without tying longitudinally may create separation and/or faulting depending on traffic.

The most important consideration when widening and tying rigid pavement is that transverse joints in the widening must be of the same type, placed at the same location, and in the same alignment as the existing. Mismatched transverse joints will induce cracking. Longitudinal joints are best located at lane lines. The worst location for a longitudinal joint is in the wheel path. If necessary, remove part of the existing pavement to prevent locating a longitudinal joint in the wheel path.

Rigid pavements which are to be overlaid as part of the widening project should be considered composite pavements and follow the widening guidelines given in Section 504.7.3.

When widening a rigid pavement with another pavement type, the widening should be designed for the conditions at hand. If necessary, the base under the widening should be thickened so that the subgrade elevations will match. If the widening is thicker than the existing, the subgrade should be sloped away from the existing and drainage provided.

504.7.2 Flexible Pavement

When widening existing flexible pavement with asphalt, the best practice is to make a saw cut at the edge of a lane and remove the outside edge of the existing asphalt. This not only removes the uncompacted asphalt at the edges, but ensures there will not be a longitudinal construction joint in the wheel path. When matching thickness with the existing, the exact buildup and lift thicknesses should follow the guidelines given in Section 404.

When widening a flexible pavement with another pavement type, the widening should be designed for the conditions at hand. If necessary, the base under the widening should be thickened so that the subgrade elevations will match. If the widening is thicker than the existing the subgrade should be sloped away from the existing and drainage provided.

504.7.3 Composite Pavement

When widening existing composite pavement with composite pavement, not only should the subgrade elevations match but the surface of the concrete must match as well. Because it will be overlayed immediately, use Item 305 Concrete Base for the concrete regardless what type the existing concrete is. However, if the existing concrete is reinforced, add a note requiring the 305 also be reinforced. Transverse joints should be the same location, alignment and type as the existing. Mismatched transverse joints will induce cracking. Tie the 305 to the existing concrete using a Type D Longitudinal Joint per BP-2.5. Prior to specifying a Type D joint, the existing concrete should be cored to determine soundness. If the existing concrete is too deteriorated at the edge, the widening should not be tied but simply butted up against. The longitudinal joint between the old and new concrete is best located at a lane line. It is recommended that some of the existing pavement be removed rather than placing the longitudinal joint in a wheel path.

When widening a composite pavement with another pavement type, the widening should be designed for the conditions at hand. If necessary, the base under the widening should be thickened so that the subgrade elevations will match. If the widening is thicker than the existing the subgrade should be sloped away from the existing and drainage provided.
## 500 Pavement Design Procedures for Minor Rehabilitation

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### UTOVER Design Inputs

**Parameter** | **Default Value** | **Recommended Value**
--- | --- | ---
Reliability - All | none | see Figure 201-1
Standard Deviation of Traffic - All | 0.10 | 0.10
Poisson’s Ratio - Concrete | 0.15 | 0.15
Poisson’s Ratio - Asphalt | 0.35 | 0.35
Elastic Modulus - Concrete | 5,000,000 | 5,000,000
Resilient Modulus - Asphalt | 450,000 | 450,000
Initial PSI - All | 4.5* | 4.5
Terminal PSI - All | 2.5 | 2.5
Modulus of Rupture - Concrete | 700 | 700
Load Transfer Coefficient - Concrete | 3.2 | See below
Drainage Coefficient - Concrete | 1.0 | 1.0

* Early versions of UTOVER list 4.2 as the default Initial PSI when analyzing Flexible pavements.

### Load Transfer Coefficient (J)

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<tr>
<td>Jointed Doweled</td>
<td>2.8</td>
<td>3.2</td>
</tr>
<tr>
<td>Jointed Undoweled</td>
<td>3.8</td>
<td>4.2</td>
</tr>
<tr>
<td>Continuously Reinforced</td>
<td>2.4</td>
<td>2.8</td>
</tr>
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** Edge support includes tied concrete shoulders, integral curb, widened lane, etc. Widened lane refers to concrete slabs built 14 feet (~4.2 m) wide or wider, but striped for a standard 12-foot (~3.6 m) lane, leaving 2 feet (~0.6 m) outside the traveled lane to provide edge support.
# 600 Major Rehabilitation Design

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# 601 Unbonded Concrete Overlay

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600 Major Rehabilitation Design

600.1 Introduction

Major rehabilitations are performed when the pavement condition is such that minor rehabilitation is no longer feasible. The Pavement Design and Selection Process, Appendix A, requires major rehabilitation when the PCR falls below 55. Minor rehabilitation projects may be bumped up to major because of specific conditions on the project. For example, project level analysis may reveal excessive repair quantities which make minor rehabilitation a poor choice economically.

Major rehabilitations are designed for twenty-year traffic projections using the ESAL99 procedure. All major rehabilitations require a life-cycle cost analysis using the procedures in Section 700. Major rehabilitations include the techniques given here, as well as complete removal of the existing pavement and replacement with either concrete or asphalt. The design of new concrete and asphalt is given in Sections 300 and 400.

600.2 Subgrade Determination

To design all major rehabilitations, including complete replacement, it is necessary to know the strength of the subgrade under the existing pavement. Subgrade strength can be estimated from historical subsurface investigations or by using the \( w_5 \) sensor readings from the Dynaflect. The chart in Figure 203-3 shows the relationship between the \( w_5 \) readings and CBR. The chart uses the average \( w_5 \) reading plus two standard deviations. This information is shown on the Dynaflect printout for each direction tested.

Once a major rehabilitation strategy is selected, additional soils investigation may be necessary. For all projects selected for complete replacement or rubblize and roll, soil borings or a soils profile is highly recommended. Projects selected for unbonded concrete overlay do not require additional soils information except possibly in areas where the pavement is being replaced because of bridges, etc. Projects selected for crack and seat generally do not need additional soils information but if the designer suspects soft subgrade it should be investigated as it can cause problems.

When additional soils information is received and reviewed, the pavement design should be checked for adequacy. If the actual subgrade conditions are different from what was estimated, the pavement design may have to be adjusted. Local areas of weak or wet subgrade should be considered unsuitable subgrade soil and treated per the recommendations in Section 203.4.1.

601 Unbonded Concrete Overlay

An unbonded concrete overlay is a new concrete pavement placed on top of an old, deteriorated concrete pavement with a thin layer of asphalt in between to act as a bond-breaker. The thickness of an unbonded concrete overlay is derived from the required thickness for a new concrete pavement reduced by an amount based on the effective thickness of the existing concrete.

The design of an unbonded concrete overlay begins with the design of a new rigid pavement according to the procedures in Section 300. Next an asphalt overlay is designed using the UTOVER computer program and the procedures given in Section 500. The equation for determining the thickness of an unbonded concrete overlay, developed by the U.S. Army Corps of Engineers, is given below:

\[
T_{UCO} = \sqrt{(T_N)^2 - (T_E)^2}
\]

where:

- \( T_{UCO} \) = Required thickness of the unbonded concrete overlay.
- \( T_N \) = Required thickness for a new concrete pavement.
- \( T_E \) = Effective thickness of the existing concrete.

The effective thickness of the existing concrete comes from the UTOVER printout. The column labeled “Deff (PCC)” must be manually averaged to find the effective thickness of the existing concrete. Best practice dictates averaging all the readings for the entire project, both directions, rather than averaging each direction separately and using the smaller or larger number. The design period used in the UTOVER analysis does not need to be twenty years as the Deff (PCC) does not change with different traffic inputs. An example of an unbonded concrete overlay design is given in Figures 601-1 and 601-2.
To minimize the elevation increase of an unbonded concrete overlay, removal of any existing asphalt overlay is recommended. Deteriorated joints and cracks do not need to be repaired prior to the overlay. Where existing pavement must be removed to meet the elevation of at-grade bridges or as a means of providing clearance at overhead bridges, it should be replaced with new concrete pavement. The thickness required is that which was calculated for new pavement when designing the unbonded concrete overlay, $T_N$. A base of at least 6 inches (~150 mm) of Item 304 should be placed under the concrete.

Item 452 Plain Concrete Pavement is recommended for all unbonded concrete overlays and the replacement areas. Because of the dowels and the required concrete cover, the minimum thickness is 8 inches (~200 mm).

**602 Fractured Slab Techniques**

Fractured Slab Techniques are for rehabilitation of existing rigid or composite pavements. They involve impacting the concrete to break it into smaller pieces. The intent being to retard or eliminate reflective cracking in the asphalt overlay. Fractured slab techniques involve placement of a thick asphalt overlay. The increased elevation due to the thick overlay requires full-depth replacement to meet at-grade bridges and possibly to provide clearance at overhead bridges. The pavement in these replacement areas should be designed as full-depth flexible pavement on an aggregate base.

The design of fractured slab techniques begins with the design of a new flexible pavement as described in Section 400. The structural number required for the new flexible pavement is the basis for all the fractured slab designs.

Because these techniques turn a rigid pavement into a flexible pavement, subgrade conditions take on increased importance. Weak or wet subgrade can hamper the fracturing operation and may make the seating or rolling operation impossible. Ohio has a very famous photograph of a 50 ton roller buried up to its axles in the pavement because of too soft subgrade. Prior to designing a fractured slab technique, the $w_s$ sensor readings from the Dynaflect should be carefully reviewed to try and determine local areas of soft subgrade that may require undercutting and replacement. Prior to constructing a fractured slab technique, soil borings should be taken and specific replacement and undercut quantities should be set up in the plans.

A third fractured slab technique, break and seat, was used extensively in Ohio in the past. While some sections had good performance, others performed very poorly. Break and seat is not to be used as a major rehabilitation strategy per the Pavement Design and Selection Process, Appendix A.

**602.1 Crack & Seat**

Crack and seat is for use on plain concrete pavements only. It is not for use on reinforced pavements whether jointed or continuous. The cracks induced are very light and are visible only with the application of water. Prior to cracking, any existing asphalt overlay must be removed.

To design a crack and seat, the thickness of the cracked concrete is multiplied by a structural coefficient, given in Figure 401-1. Asphalt layers are then added until the total structural number is equal to or greater than the structural number required for a new flexible pavement. Any existing subbase under the concrete is neglected. An example is shown in Figure 602-1.

**602.2 Rubblize & Roll**

Rubblize and roll can be used on all concrete pavements although it is primarily intended for reinforced concrete. The rubblizing process does just what the name implies, it reduces the concrete to rubble. All slab action is destroyed and the concrete is transformed into an aggregate base. Prior to rubblizing, any existing asphalt overlay must be removed.

Subgrade support is even more important for rubblize and roll than for crack and seat. Soil borings are strongly encouraged as early as possible in the design phase. Where subgrade conditions are very poor, analysis of the soil borings may reveal such large areas requiring replacement and undercutting that the decision to rubblize should be reconsidered. As a rule of thumb, areas three percent or more above
optimum water content will require undercutting and replacement. Another rule of thumb was developed to estimate optimum water content: the optimum water content is the Plastic Limit minus four. Plastic Limit is not to be confused with the Plasticity Index. The Plastic Limit is equal to the Liquid Limit minus the Plasticity Index.

To design a rubblize and roll, the thickness of the rubblized concrete is multiplied by a structural coefficient, given in Figure 401-1. Asphalt layers are then added until the total structural number is equal to or greater than the structural number required for a new flexible pavement. Any existing subbase under the concrete is neglected. An example is shown in Figure 602-1.

603 Whitetopping

Whitetopping is the construction of a new rigid pavement on top of an existing asphalt pavement. It is not to be confused with ultra-thin whitetopping which is a thin layer of concrete placed on top of asphalt to prevent rutting and shoving. Whitetopping is designed as a new rigid pavement using the existing asphalt pavement as the base for determining the modulus of subgrade reaction.
# 600 Major Rehabilitation Design

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Given:

- Rigid Pavement Design Example, Figure 302-1
- Existing pavement buildup: 3" Asphalt
  9" Reinforced Concrete
  6" Subbase
- UTOVER output, Figure 601-2

Problem:

Design an unbonded concrete overlay.

Solution:

Obtain required thickness for new rigid pavement.

\[ T_N = 9.6" \]  
(from Figure 302-1)

Obtain effective thickness of existing concrete.

\[ T_E = 8.69" \]  
(from Figure 601-2)

Calculate required thickness of unbonded concrete overlay.

\[ T_{UCO} = \sqrt{(9.6)^2 - (8.7)^2} \]

\[ T_{UCO} = \sqrt{92.16 - 75.69} \]

\[ T_{UCO} = \sqrt{16.47} \]

\[ T_{UCO} = 4.06" \]

Minimum thickness of unbonded concrete overlay = 8"

Items of work:

- 452 8" Plain Concrete Pavement
- 448 Asphalt Concrete Intermediate Course, Type 1, PG 64-22 (1" thick)
- 202 Wearing Course Removed
### Title: MIL-1-0.000 Lane 4 12-yr 4/29/98

**Project:** 099989  
**District:** 15  
**County:** MILLER  
**Route:** 001  
**Pave. Type:** COMPOSITE  
**Lane Tested/No. of Lanes:** 4/4  
**Test Date:** 4/1/97  
**Weather:** CLOUDY  
**Pave. Temp.:** 31F  
**Existing Pavement Type:** COMPOSITE  
**Overlay Pavement Type:** AC  

**Geometry of Existing Pavement:**  
**Overlay Design:**  
- **Thickness of AC Layer:** 3.00  
- **Poisson Ratio AC:** 0.35  
- **Elastic Modulus of New AC:** 450000.  
- **Thickness of PCC Slab:** 9.00  
- **Poisson Ratio of PCC:** 0.15  
- **Elastic Modulus of New PCC:** 5000000.  

**TOTAL DEPTH OF PAVEMENT:** 12.00  
**New PCC Modulus of Rupture:** 700.0  
**Equivalent Poisson Ratio:** 0.20  
**Equivalent Elastic Modulus:** 2436712.  
**Drainage Factor:** 1.00  
**Load Transfer Coefficient:** 3.20  
**Initial PSI:** 4.50  
**Terminal PSI:** 2.50  
**Traffic Standard Deviation:** 0.10  
**Initial PSI:** 4.50  
**Terminal PSI:** 2.50  

**Statistical Results Summary:**  
- **Number of Data Points:** 46  
- **Avg. Deff:** 8.69"
Crack & Seat Example

Given:

• Flexible Pavement Design Example, Figure 402-1
• Existing pavement buildup: 3" Asphalt
  8" Item 305 Concrete Base
  6" Subbase

Problem:
Design a Crack & Seat project.

Solution:
Obtain required structural number for a new flexible pavement
SN = 4.5 (from Figure 402-1)

Determine the required buildup using the structural coefficients given in Figure 401-1

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness</th>
<th>Coefficient</th>
<th>SN</th>
</tr>
</thead>
<tbody>
<tr>
<td>446 Surface</td>
<td>1.5&quot;</td>
<td>x 0.35</td>
<td>0.52</td>
</tr>
<tr>
<td>446 Intermediate</td>
<td>1.75&quot;</td>
<td>x 0.35</td>
<td>0.61</td>
</tr>
<tr>
<td>301</td>
<td>4&quot;</td>
<td>x 0.35</td>
<td>1.40</td>
</tr>
<tr>
<td>305 (cracked &amp; seated)</td>
<td>8&quot;</td>
<td>x 0.27</td>
<td>2.16</td>
</tr>
</tbody>
</table>

Total Structural Number = 4.69

Rubblize & Roll Example

Given:

• Flexible Pavement Design Example, Figure 402-1.
• Existing Pavement Buildup: 4" Asphalt
  9" Reinforced Concrete
  6" Subbase

Problem:
Design a Rubblize & Roll project.

Solution:
Obtain required structural number for a new flexible pavement.
SN = 4.5 (from Figure 402-1)

Determine the required buildup using the structural coefficients given in Figure 401-1.

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness</th>
<th>Coefficient</th>
<th>SN</th>
</tr>
</thead>
<tbody>
<tr>
<td>446 Surface</td>
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<td>x 0.35</td>
<td>0.52</td>
</tr>
<tr>
<td>446 Intermediate</td>
<td>2&quot;</td>
<td>x 0.35</td>
<td>0.70</td>
</tr>
<tr>
<td>302</td>
<td>6&quot;</td>
<td>x 0.35</td>
<td>2.10</td>
</tr>
<tr>
<td>Rubblized Concrete</td>
<td>9&quot;</td>
<td>x 0.14</td>
<td>1.26</td>
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</table>

Total Structural Number = 4.58
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700 Life-Cycle Cost Analysis

701 Introduction

Life-Cycle Cost Analysis (LCCA) is a process for evaluating the economic worth of a pavement segment by analyzing initial costs and discounted future costs such as surface treatment, resurfacing, rehabilitation, and reconstruction costs over a defined analysis period. This section outlines some of the requirements for preparing an LCCA. Other details about the LCCA are given in Section 100.

701.1 Discount Rate

ODOT uses the discount rate provided by the Office of Management and Budget (OMB) in Circular A-94. Specifically, the 30-year real interest rate is used. The current discount rate can be found on the OMB website at http://www.whitehouse.gov/omb/.

702 Initial Construction

All alternatives for initial construction are designed using the procedures outlined in this Manual. Initial construction is considered to take place in year zero.

All differential pavement items are to be included in the analysis such as excavation, stabilization, pavement removed, base, and pavement. Non-pavement items and items common to all alternatives can be neglected. Items such as striping, signing, lighting, guardrail, barrier, underdrains, culverts, bridges, embankment, etc., are not pavement items, are essentially equal for all alternatives and are not to be included in the analysis. On new locations, earthwork items including stabilization are common to all pavement alternatives and are essentially equal and are not to be included.

For rehabilitations that raise the elevation of the existing pavement, a cost needs to be included for maintaining clearance under overhead structures and for meeting elevations of at-grade bridges. This cost can be calculated in various ways, most common is to calculate the cost to remove the existing pavement, excavate down, and build back up with new pavement. Another way is to calculate the cost of jacking the bridges, including any approach work necessary on overheads. A third option could be a combination of the two.

It is not important which method is selected for computing cost of maintaining clearance. What is important is that the costs are included in the analysis. The same method of calculating the costs is to be used for all alternatives. The method used in the LCCA for computing cost of maintaining clearance does not have to be the actual method used in the plans and in construction.

703 Future Rehabilitation

703.1 Introduction

The future rehabilitation required to keep the pavement in serviceable condition for the next 35 years must be predicted. Routine and reactive maintenance performed by ODOT forces are not included in the analysis due in part to lack of dependable data. Only contract rehabilitation projects are considered.

ODOT does not use salvage value. The rehabilitation schedules listed below result in approximately equal condition at the end of the analysis period. The salvage values are considered equal and are not included in the analysis.
703.2 Rehabilitation Schedules

The rehabilitation schedules given below were developed from an analysis of ODOT pavement performance data. The analysis will be updated periodically and the rehabilitation schedules updated accordingly. The schedules below are to be used without deviation.

The schedules list only major items of work. The LCCA should include the specification items needed to complete the work described such as tack coats and pavement sawing.

703.2.1 Flexible Pavement

Flexible pavement includes new pavement on a new alignment and complete replacement of existing pavement.

Year 14: 1.5” overlay with planing (driving lanes only).

Year 24: 3.25” overlay with planing (driving lanes and shoulders) with 1% patching planed surface.

Year 34: 1.5” overlay with planing (driving lanes only).

703.2.2 Rigid Pavement

Rigid pavement includes new pavement on a new alignment and complete replacement of existing pavement.

Year 22: Diamond grinding (driving lanes plus one foot of each shoulder) and full dept rigid repairs of 4% of the driving lanes surface area.

Year 32: 3.25” asphalt overlay and full depth rigid repair of 2% of the driving lanes surface area.

703.2.3 Composite Pavement

Composite pavement includes new pavement on a new alignment and complete replacement of existing pavement. The performance of newly constructed composite pavements has not been studied as relatively few have been constructed. Since composite pavement is a hybrid of rigid and flexible pavements, a hybrid rehabilitation schedule may be derived from the rigid and flexible schedules.

The timing, width, and thickness of each rehabilitation shall be the same as the flexible pavement schedule given in Section 703.2.1. A quantity of full depth rigid repairs equal to 2% of the driving lanes surface area shall be included with the overlay at years 14 and 34, and 3% at year 24.

703.2.4 Unbonded Concrete Overlay

An unbonded concrete overlay is a new concrete pavement built on top of an old concrete pavement with a bondbreaker layer in between. The future rehabilitation schedule is the same as rigid pavement given in Section 703.2.2.

703.2.5 Fractured Slab Techniques

Fractured slab techniques include crack & seat, and rubblize & roll. The future rehabilitation schedule for all fractured slab techniques is the same as flexible pavement given in Section 703.2.1.
703.2.6 Whitetopping

Whitetopping is a new concrete pavement built on an old flexible pavement. The future rehabilitation schedule is the same as rigid pavement given in Section 703.2.2.

704 Total Cost

Once all the costs for initial construction and future rehabilitation have been calculated, they are summed to determine the net present value of each alternative. Future rehabilitation costs are discounted to account for and the time value of money.

704.1 Discounting

Discounting is a simple yet effective way to account for the time value of money. The discount rate can be thought of as the difference between market interest rates and the general rate of inflation. For example, if one-year Certificates of Deposit (CD) are paying 5.5% while inflation is running 2.0% per year, the discount rate would be 3.5%. Similarly, if CDs are paying 8.0% and inflation is running 4.5%, the discount rate is still 3.5%. Using a discount rate eliminates the need to predict what inflation will do for the next 35 years or what return one might get on an investment.

The formula for applying the discount rate is as follows:

\[
(P/F, i\%, n) = \frac{1}{(1+i)^n}
\]

where:

\( (P/F, i\%, n) \) = discount factor

\( i \) = discount rate from OMB Circular A-94

\( n \) = year costs occur

An example of how to use the discount rate and calculate total cost is shown in Figure 703-1.

705 Results Presentation

The Office of Pavement Engineering prepares all LCCAs and pavement selection packages. A standard format for presenting the information is still evolving. Once a standard is established, a general description will be added to this Manual.
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<th>Subject</th>
</tr>
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<tbody>
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<td>July 2014</td>
<td>Discounting Example</td>
</tr>
</tbody>
</table>
Discounting Example

July 2014

Reference Section
704.1

Given:

- Initial Construction (Year 0): $16,000,000
- First Rehabilitation (Year 14): $1,400,000
- Second Rehabilitation (Year 24): $2,300,000
- Third Rehabilitation (Year 34): $1,400,000

Problem:

Solve for the net present value using a discount rate of 1.9%.

Solution:

Calculate the discount factor for each year using the equation given in Section 704.1.

\[ (P/F, 1.9\%, 0) = \frac{1}{(1 + 0.019)^0} = 1.0 \]

\[ (P/F, 1.9\%, 14) = \frac{1}{(1 + 0.019)^{14}} = 0.7684 \]

\[ (P/F, 1.9\%, 24) = \frac{1}{(1 + 0.019)^{24}} = 0.6365 \]

\[ (P/F, 1.9\%, 34) = \frac{1}{(1 + 0.019)^{34}} = 0.5273 \]

Multiply costs by discount factors and sum to find Net Present Value (NPV).

\[
NPV = (16000000) \times (1) + (1400000) \times (0.7684) + (2300000) \times (0.6365) + (1400000) \times (0.5273)
\]

\[
= 19300000
\]

= $19,300,000
Appendix A

Reserved for future use
Appendix B

Pavement Guidelines for Treatment of High Stress Locations
PAVEMENT GUIDELINES FOR TREATMENT OF HIGH STRESS LOCATIONS

BACKGROUND:

These guidelines are intended to be used to reduce or eliminate rutting or shoving problems associated with the use of asphalt concrete pavement surfaces in high stress locations.

These guidelines are intended to be used by district office staff in making best practice decisions regarding pavement resurfacing and design considerations. Technical assistance with these guidelines is available by contacting either of the following individuals:

Dave Powers - Asphalt Materials Engineer, Office of Materials Management (614-275-1387)
Craig Landefeld – Construction Pavements Engineer, Office of Construction Administration (614-644-6622)
Aric Morse - Pavement Design Engineer, Office of Pavement Engineering (614-995-5994)

DEFINITIONS:

Rutting: Rutting is visually identified by vertical depressions in the pavement surface along the wheel tracks. Rutting is measured transversely across the depression using a string line or straight edge. Rutting is generally considered significant when it approaches 0.4 inches (~10 mm) in depth. The presence of significant rutting may or may not indicate a high stress location. Circumstances resulting in faulty mix design, production, or placement could contribute to rutting.

Shoving: Shoving is longitudinal displacement of a localized area of the pavement surface. It is generally caused by braking or accelerating vehicles and is usually located on hills, curves, or intersections. Shoving may also include vertical displacement. Shoving is generally considered significant when it affects ride quality. The presence of shoving may or may not indicate a high stress location. Circumstances resulting in faulty mix design, production or placement could contribute to shoving.

High Stress Location: High stress locations are found at areas of high acceleration and braking, at intersections, sharp curves, ramps, and where heavy vehicles frequent at slow speeds. High stress locations occur at intersections with forced stop control and one or more of the following criteria:

- The approach grade to the stop control is greater than or equal to 3.5 percent.
- Current Design Designation of 500 trucks per day or greater in the design lane.
- Current Design Designation of 250 trucks per day or greater in a turn lane.

High stress locations occur on ramps or sharp curves with or without forced stop control that have greater than 250 trucks per day or have exhibited significant repeated rutting problems in
the past. As truck counts on ramps are often unknown and the definition of a sharp curve depends upon the speed of the curve, some judgment is required on new locations.

High stress locations occur on stretches of roadway that continue to exhibit significant rutting after several trials of standard mixes. These stretches of roadway generally exhibit rutting due to some combination of long or steep grades; trucking/traffic patterns, counts, or weights.

High stress locations occur at standard bus stops on bus routes or at park and ride lots.

High stress locations occur at all truck and bus lots located in the Department's rest areas.

**TREATMENT OF HIGH STRESS LOCATIONS:**

I. **RIGID PAVEMENT:**

No consideration is made for high stress locations where rigid pavement exists or is proposed. When replacing a composite or flexible pavement with a rigid pavement at a high stress location, the following needs to be considered:

A. When new pavement is being constructed, the designer should try to match subgrade elevation at the high stress termini. For most situations, the rigid pavement should be placed on a minimum of 6 inches (~150 mm) of Item 304 Aggregate Base; however, if the surrounding flexible or composite pavement is constructed on subgrade, it would be acceptable to do the same with the rigid pavement. The thickness of the rigid pavement should be a minimum of 8 inches (~200 mm). The exact thickness should be determined by design calculations in accordance with the procedures specified in Section 300 of the Pavement Design Manual. Additional thickness of Item 304 may be used, if necessary, to match subgrade elevations.

B. For composite pavements where clearance requirements are not a concern, an unbonded concrete overlay may be placed. Unbonded concrete overlays should be constructed a minimum of 8 inches (~200 mm) thick with standard dowels using Item 452. If dowels are not used or non-standard smaller diameter dowels are used, the thickness may be reduced to 6 inches (150 mm).

C. For flexible pavements where clearance requirements are not a concern, conventional whitetopping may be used. Conventional whitetopping should be constructed a minimum of 8 inches (~200 mm) thick with standard dowels using Item 452. If dowels are not used or non-standard smaller diameter dowels are used, the thickness may be reduced to 6 inches (150 mm).
II. FLEXIBLE PAVEMENT:

A. There are several options available for the use of flexible pavement in high stress locations. For cost consideration, the 'Next Step' approach should be used. Next Step approaches are as follows:

1. In a high stress area with less than 1500 trucks that would normally use Item 441, specify a Superpave mix design using Item 442. All high stress areas using Item 442 shall use 446 acceptance regardless of the quantity limitations given in Section 404.1.

2. In a high stress area that would normally require a Superpave mix design, specify a non-standard modified asphalt concrete pavement mix design. A list of all available modified asphalt concrete mixes is on file with the Office of Materials Management. Contact the Asphalt Materials Section for a current list of available options. Item 443 Stone Matrix Asphalt Concrete may also be considered but not for small quantity applications.

B. For all high stress locations where rutting is evident, pavement planing should be specified to remove all deformed material.

1. For flexible pavement, planing should be specified to the bottom of the material responsible for the rutting. In order to determine the responsible layer, the comparison of pavement cores taken in the rutted area with cores taken outside of the rut may be helpful. Where this information is not available, best practice is to remove 3 inches (~75 mm) below the deepest portion of the rut. Standard practice concerning tack coat should be followed prior to the placement of the Next Step asphalt mixes.

2. For composite pavement, planing should be specified according to II.B.1. Where the surface of the rigid base pavement is within 2 inches (~50mm) of the required milled depth, best practice is to take the milling down to the concrete in order to provide a course of larger aggregate (301 or 302) material.

C. Lift combinations and thickness requirements will generally be the same as would be required for a standard flexible pavement or overlay.

LIMITS OF HIGH STRESS LOCATIONS:

The limits of the high stress treatment should be determined as follows:

A. A minimum of 250 feet (~75 m) back from the location of stop termini or traffic signal.

B. The length of the turn lane.
C. The limits of the existing problem condition.

In urban areas where several intersections exist within close proximity to each other and meet high stress criteria, best practice is to specify the required high stress mix the length of the section bounded at the outermost limits of the high stress locations.
Appendix C

Simplified Pavement Design for Short Projects
Simplified Pavement Designs for Short Projects

Many projects exist, such as bridge replacement projects, that include a short stretch of new pavement or pavement replacement. For projects in which the total length of new pavement or pavement replacement is less than 300 feet (100 m), the chart on the following page may be used in lieu of a complete pavement design according to Sections 200, 300 and 400 of this Manual. The buildups given on the chart are conservative and based on the amount of truck traffic expected for the opening day. The following procedures and precautions should be recognized:

1. The length of pavement replacement is exclusive of bridge length, where applicable.
2. The buildups given here are in accordance with the small quantity guidelines Section 410.
3. The designer should first evaluate the buildup of the existing pavement. If the strength of the existing pavement exceeds the chart value, then the existing design should be perpetuated.
4. Where opening day truck traffic exceeds 800, this chart is not to be used and the procedures described in Sections 200, 300 and 400 of this Manual are to be followed.
5. If it is known in advance that poor soils may be encountered at subgrade level or if the designer is unsure of proper subgrade or slope treatments, review by the Office of Geotechnical Engineering is recommended.
6. The designer is always welcome to do a complete design according to Sections 200, 300 and 400 rather than using the chart.
<table>
<thead>
<tr>
<th>Pavement Composition</th>
<th>Flexible Design</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Trucks in Opening Day ADT (ADT x T24)</td>
</tr>
<tr>
<td></td>
<td>&lt;=10</td>
</tr>
<tr>
<td></td>
<td>in.</td>
</tr>
<tr>
<td>441 AC Surface, Type 1, (448), PG64-22, As Per Plan**</td>
<td>1.25</td>
</tr>
<tr>
<td>301 Bituminous Aggregate Base</td>
<td>4</td>
</tr>
<tr>
<td>304 Aggregate Base</td>
<td>6</td>
</tr>
<tr>
<td><strong>Alternate Flexible Design</strong></td>
<td></td>
</tr>
<tr>
<td>441 AC Surface, Type 1, (448), PG64-22, As Per Plan**</td>
<td>3</td>
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<tr>
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<td>12</td>
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<tr>
<td><strong>Rigid Design</strong></td>
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</tr>
<tr>
<td>452 Plain Concrete Pavement</td>
<td>-</td>
</tr>
<tr>
<td>304 Aggregate Base</td>
<td>-</td>
</tr>
</tbody>
</table>

* Less than 300 linear feet (100 meters) of total pavement replacement
** Include a plan note restricting the 441 to 2-inch (50 mm) maximum lift thickness.
*** 7-inch (180 mm) concrete is allowed for short projects only. All other projects require 8-inch (200 mm) minimum in accordance with Section 302.