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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 Statewide Planning and Research. 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 <u>volume</u> 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 <u>loading</u> 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.

B-ESALs = ADT * %T_{24} * %D * %LF * %B * CF
C-ESALs = ADT * %T_{24} * %D * %LF * %C * CF

B-ESALs + C-ESALs = Total Daily ESALs

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. The units for resilient modulus are pounds per square inch (psi).

$$M_r = 1200 * CBR$$

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. Questions regarding subgrade stabilization should be directed to the Office of Geotechnical Engineering.

203.4.1 Global Chemical Stabilization

When the entire subgrade is chemically stabilized without exception (global chemical stabilization), the subgrade resilient modulus of the native soil is increased. Research has shown that global chemical stabilization increases the stiffness of the subgrade and the effects are long lasting. The increased resilient modulus is calculated using the following formula:

$$M_{r\text{-}GCS} = 1.36 * M_r$$

Where:

$M_{r\text{-}GCS}$ = Improved subgrade resilient modulus due to global chemical stabilization (psi)
M_r = Subgrade resilient modulus of the native soil (psi)

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 nearly all projects that consist of constructing new pavement on subgrade or rubblizing the existing pavement. The exception is projects built on granular subgrade may not require subsurface drainage.

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.

205.1 Types of Drainage Systems

There are three means of draining the pavement subsurface - pipe underdrains, prefabricated edge underdrains, and aggregate drains. Pipe underdrains are the primary method to provide drainage and are generally used with paved shoulders and curbed sections. Occasionally, when an existing pavement is being overlaid, prefabricated edge underdrains are installed to provide drainage. Aggregate drains are generally used with aggregate shoulders, bituminous surface treated shoulders, and for spot improvements. In the past, another type of subsurface drainage, free draining base (FDB), was used but is no longer approved for use on ODOT projects and the specifications have been rescinded.

Figures 205-1 to 205-10 provide details on the placement of subsurface drainage systems. Additional examples are found in the Sample Plan Sheets.

205.1.1 Pipe Underdrains

Pipe underdrains are required when constructing new pavement on subgrade for all Interstates, freeways, expressways, and multi-lane divided facilities. Pipe underdrains are generally used with paved shoulders and curbed pavements.

Pipe underdrains generally follow the profile grade of the roadway as long as the pipe underdrain maintains a positive or zero slope. In the case of a zero slope, hydrostatic pressure is sufficient to ensure the proper drainage of the base and subgrade.

Underdrain depth is measured from the top of the subgrade elevation to the bottom of the underdrain trench. Base pipe and shallow pipe underdrains are typically 4 or 6 inches (100 or 150 mm) in diameter. The 4 and 6 inch (100 and 150 mm) pipes are considered equivalent in hydraulic capacity for the base pipe and shallow pipe underdrains. Use a 6-inch (150 mm) pipe if the outlet interval is greater than 500 feet (150 m) or if the subgrade is saturated.

Base pipe underdrains have a constant depth of 18 inches (450 mm). There may be locations where base pipe underdrains at less than 18 inches (450 mm) deep are needed but this is rare. Shallow pipe underdrains have a depth greater than 18 inches (450 mm) with a maximum of 30 inches (760 mm). Where a dual underdrain system is provided (shoulder width greater than or equal to 8 feet (2.4 m)), the underdrain at the outside edge of shoulder is supplemental to the underdrain at the edge of the travelled lane and is typically a base pipe underdrain with a depth of 18 inches (450 mm). If dual underdrains are provided on a superelevated section, the underdrain at the edge of the travelled lane is not required on the high side.

Deep pipe underdrains have a constant depth greater than 30 inches (760 mm) with a maximum depth of 50 inches (1.3 m) below the top of subgrade elevation. Deep pipe underdrains are typically 6 inches (150 mm) in diameter and are used in cut sections or areas of high water table.

Unclassified pipe underdrains are those having a variable depth below the profile grade within a single continuous longitudinal run. Designers are not to use variable depth (unclassified) pipe underdrains where underdrains of constant depth can be provided.

Rock cut underdrains are used in cut sections where rock, shale, or coal subgrade exists. The depth of rock cut underdrains should be 6 inches (150 mm) below the cut surface of the rock (see Figure 205-9).

Where necessary, the depth of underdrains may vary slightly.

When a pipe underdrain spans the trench of a lower conduit (utility, storm sewer, culvert, etc.) and the vertical distance between the lower conduit and the underdrain is less than or equal to 12 inches (300 mm), use a Type F conduit to span the lower trench. Use a minimum of 10 feet (3 m) of the Type F conduit, centered over the lower trench.

A filter fabric wrap should be used when the surrounding soil consists of a sandy or sandy-silt composition.

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. See SCD DM-1.2 for prefabricated edge underdrain details.

205.1.3 Underdrain Outlets

Underdrains that outlet to a slope should be provided with an outlet conforming to SCD DM-1.1. Additional details for underdrains and outlets are provided in SCD DM-1.2.

Underdrain outlets should be provided at a desirable interval of 500 feet (150 m) with a maximum interval of 1000 feet (300 m). It is desirable to outlet underdrains at least 12 inches (300 mm) above the flow line of a receiving ditch; and 12 inches (300 mm) above the flow line of a receiving catch basin, manhole, or pipe with 6 inches (150 mm) as a minimum. Underdrain outlets shall be type F conduit.

Underdrain outlet pipes flowing into a roadway ditch or fill slope should maintain a minimum slope of one percent.

Outlets should not be located at the top of high (over 20 feet [6 m]) 2:1 fill slopes. If this cannot be accomplished by adjusting the outlet spacing, special outlet treatments are required. Contact the Office of Hydraulic Engineering for special outlet treatments.

205.1.4 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 that 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) longitudinally 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 205-7 and 205-8; and Location & Design Manual, Volume 3 - Highway Plans, Sample Plan Sheets for details depicting aggregate drains with the various pavement-shoulder treatments.

205.1.5 Construction Underdrains

In fine-grained soils, excess water in the subgrade is the principal cause of unstable soil conditions during construction. Adequate subgrade drainage can be achieved by using temporary pipe underdrains. These underdrains are sacrificial in nature and are intended to perform throughout the construction process. Construction underdrains are usually placed along the centerline of the roadway. They may also be placed along the ditch line if water is coming into a cut section from a higher elevation.

The outlets for construction underdrains are the same pipe material and backfill as the construction underdrains (not Type F). The outlets should be discharged into a catch basin, manhole, pipe, or ditch. If discharging into a ditch, a precast concrete reinforced outlet is not required.

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.

200 Pavement Design Concepts

List of Figures

Serviceability & Reliability	201-1 July 2016 Reference Section 201 & 204

SERVICEABILITY FACTORS		
	Rigid	**Flexible**
Initial Serviceability	4.2	4.5
Terminal Serviceability	2.5	2.5
Design Serviceability Loss	**1.7**	**2.0**

RELIABILITY LEVELS (%)		
Functional Classification	**Urban***	**Rural***
Interstate and Freeway (01, 02)	95	90
Principle Arterial, Minor Arterial (03, 04)	90	85
Collectors (05, 06)	90	85
Local (07)	80	80

* The designer must determine if the location is urban or rural in character. The ODOT Highway Functional Classification System Concepts, Procedures and Instructions document available from the Office of Program Management should be used as a guide.

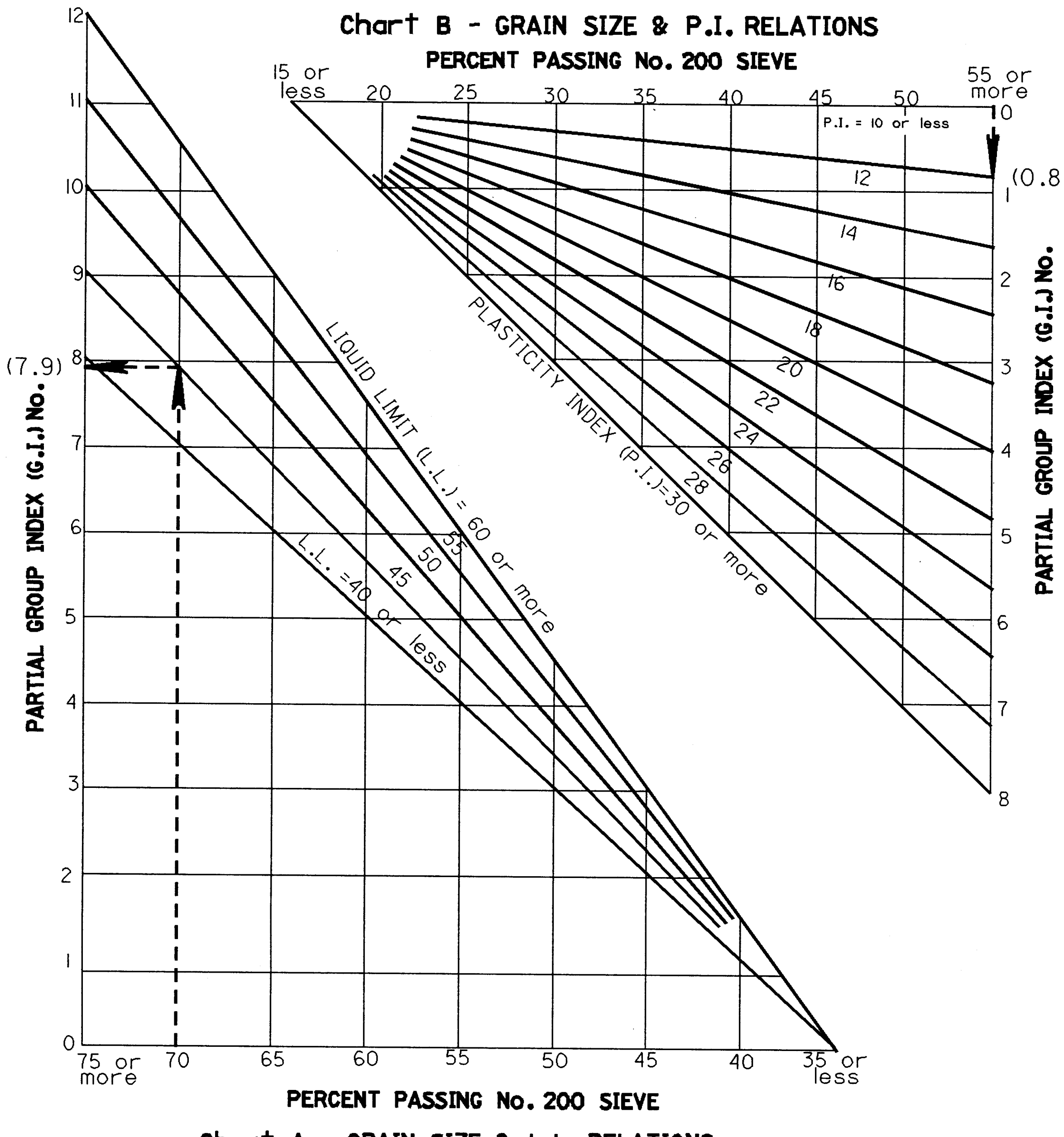
OVERALL STANDARD DEVIATION	
Flexible Pavement	0.49
Rigid Pavement	0.39

RATIO OF B:C COMMERCIAL VEHICLES		
Functional Classification	B:C Ratio	
	Urban*	Rural*
Interstate (01)	4:1	7:1
Other Freeway or Expressway (02)	3:1	
Principal Arterial (03)	2:1	5:1
All Other (04, 05, 06, 07)	1:1	2:1

ESAL CONVERSION FACTORS				
Functional Classification	Rigid		Flexible	
	B	C	B	C
Interstate (01), rural*	1.53	0.37	0.98	0.29
Principal Arterial (03), rural*	1.67	0.44	1.06	0.33
All Other (04, 05, 06, 07), rural*	1.26	0.76	0.79	0.48
Interstate (01), urban*	1.46	0.46	0.93	0.34
Expressway & Freeway (02), urban*	1.38	0.72	0.90	0.47
All Other (03, 04, 05, 06, 07), urban*	1.64	0.53	1.04	0.41

* The designer must determine if the location is urban or rural in character. The ODOT Highway Functional Classification System Concepts, Procedures and Instructions document available from the Office of Program Management should be used as a guide.

DESIGN LANE FACTORS		
Number of Lanes per Direction	Lane Factor (LF) (%)	Directional Distribution (D) for two-way traffic (%)
1 - Lane	100	50
2 - Lanes	95	50
3 - Lanes	80	50
4 (or more) - Lanes	70	50

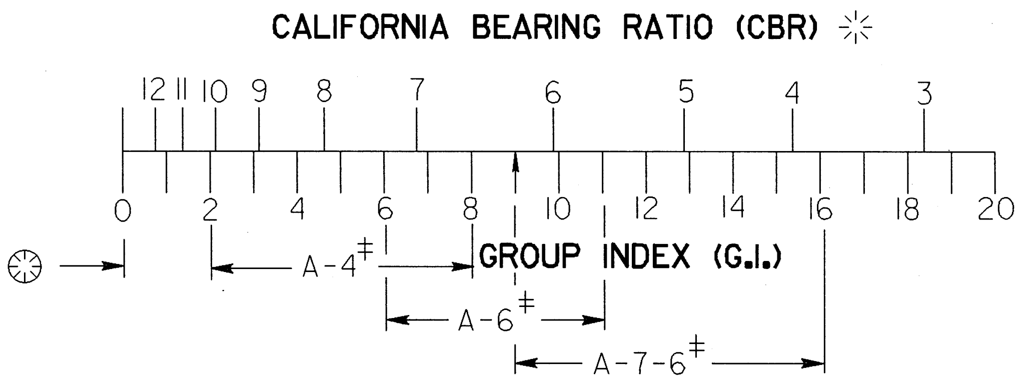


GROUP INDEX EQUALS SUM OF READINGS ON BOTH VERTICAL SCALES

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

Chart A=7.9; Chart B=0.8

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



⊛ AASHTO Classes A-1, A-2 & A-3. K=200+.

‡ 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.

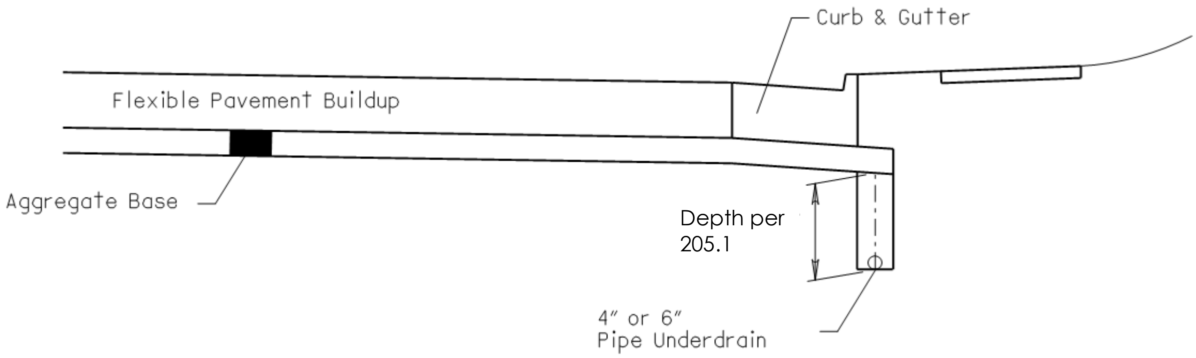
Example: G.I.=9 (Figure 203-2) CBR=6 (Rounded, from above)

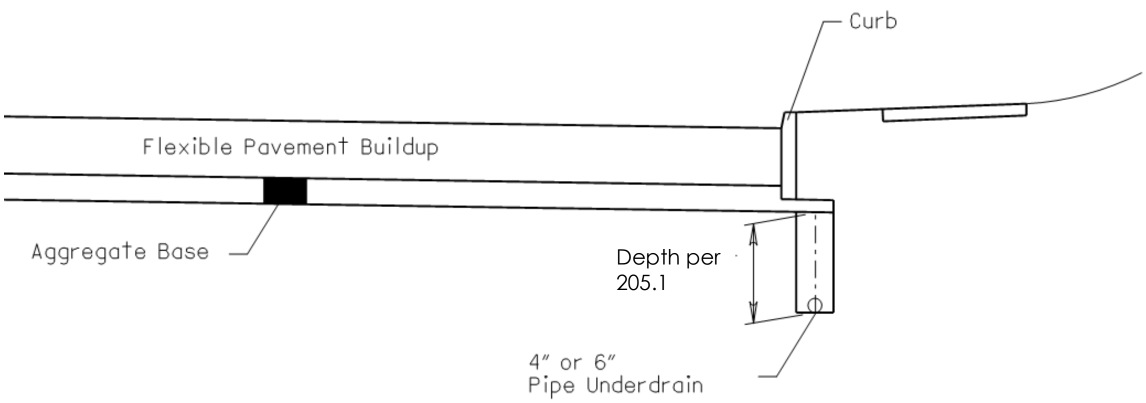
RESILIENT MODULUS (M_R) = 1200 × CBR

M_R = 1200 × 6 = 7200 psi

Typical Pipe Underdrain Locations	**205-1** July 2016
	Reference Section **205**

FLEXIBLE PAVEMENTS WITH CURB OR CURB AND GUTTER
SHOULDER WIDTH < 8 FEET (2.45 m)



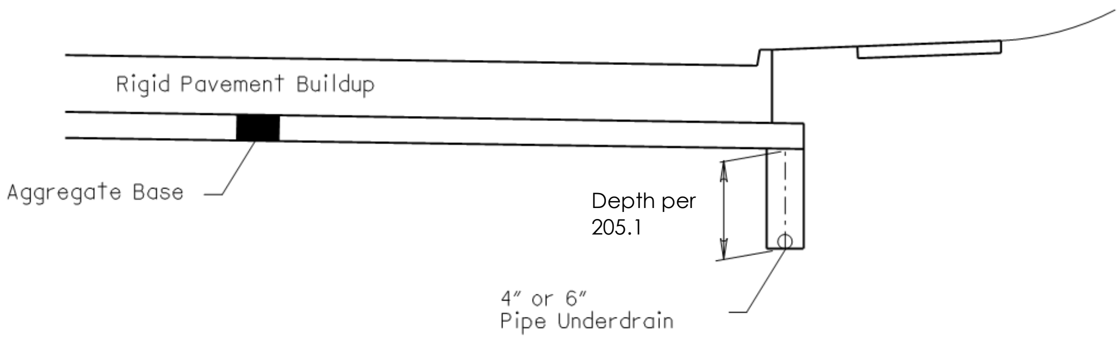


Notes:
Drawing is not to scale.

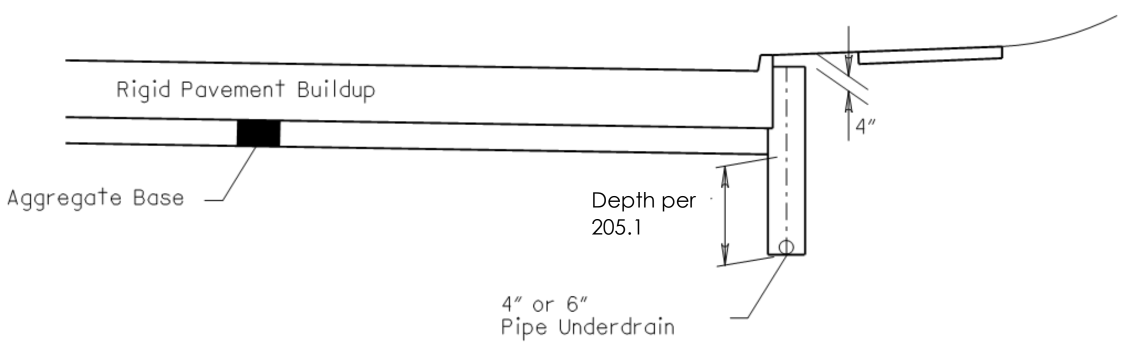
Drawing is not intended to depict allowable pavement buildups.

Typical Pipe Underdrain Locations	**205-2** July 2016 **Reference Section** **205**

RIGID PAVEMENTS WITH INTEGRAL CURB OR CURB AND GUTTER
SHOULDER WIDTH < 8 FEET (2.45 m)



PREFERRED UNDERDRAIN LOCATION



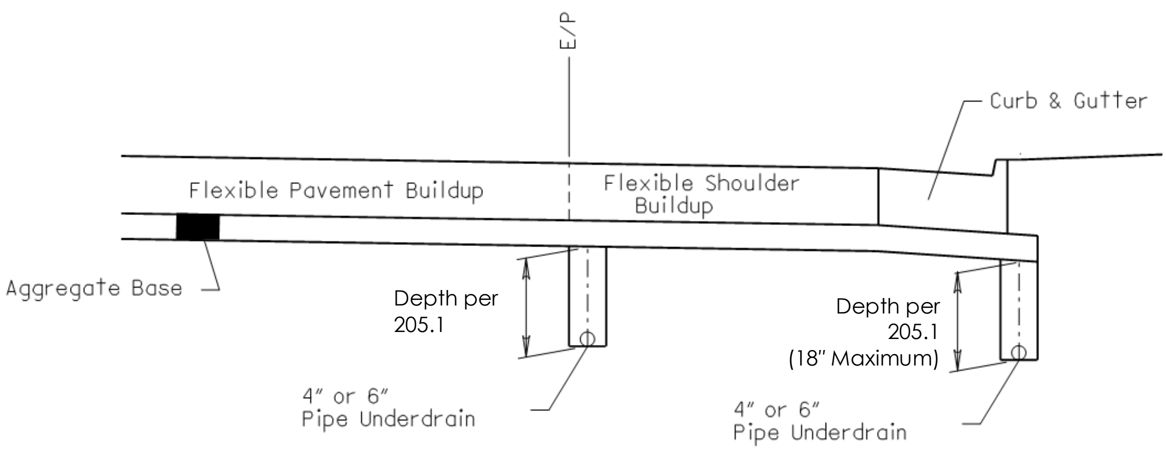
ACCEPTABLE UNDERDRAIN LOCATION

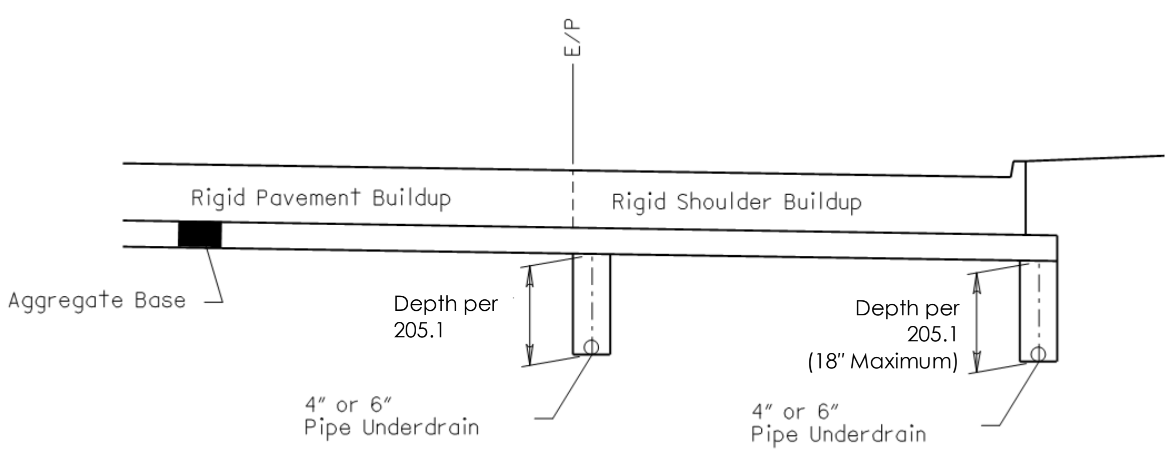
Notes:
Drawing is not to scale.

Drawing is not intended to depict allowable pavement buildups.

Typical Pipe Underdrain Locations	205-3 July 2016
	Reference Section 205

PAVEMENTS WITH CURB OR CURB AND GUTTER
SHOULDER WIDTH ≥ 8 FEET (2.45 m)





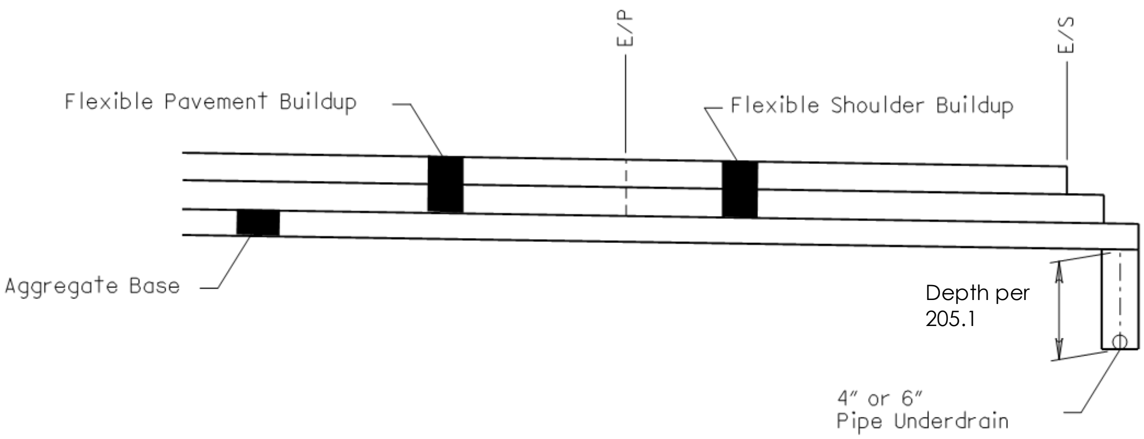
Notes:
Drawing is not to scale.

Drawing is not intended to depict allowable pavement buildups.

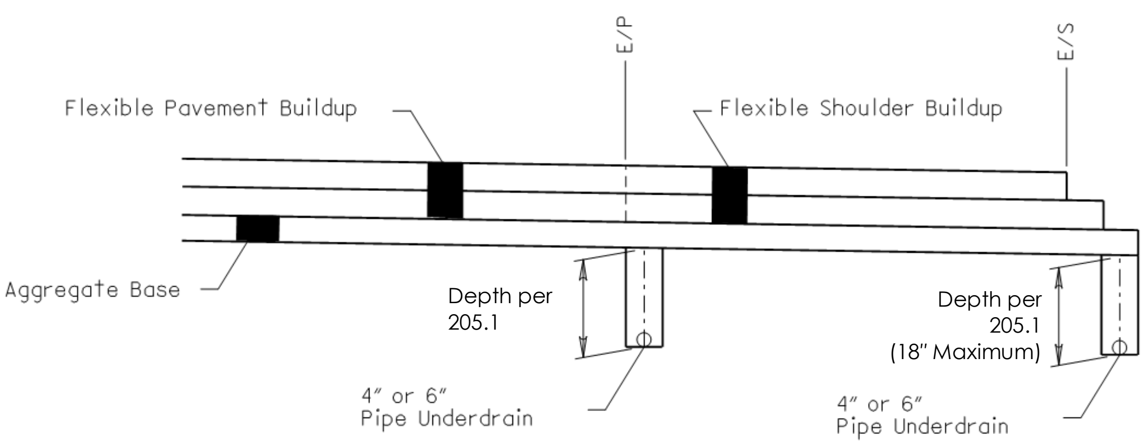
Typical Pipe Underdrain Locations

205-4
July 2016
Reference Section
205

FLEXIBLE PAVEMENTS WITH PAVED SHOULDER



Shoulder width < 8 feet (2.45 m)



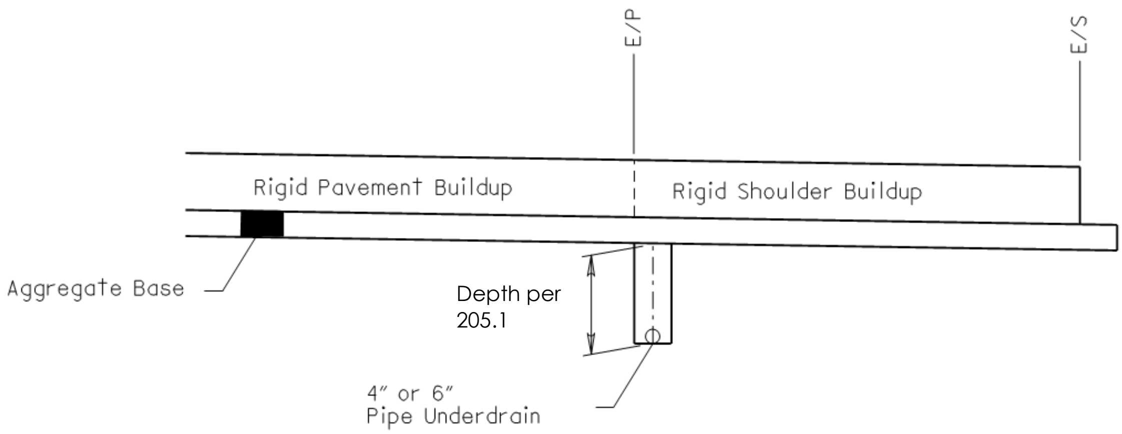
Shoulder width ≥ 8 feet (2.45 m)

Notes:
Drawing is not to scale.

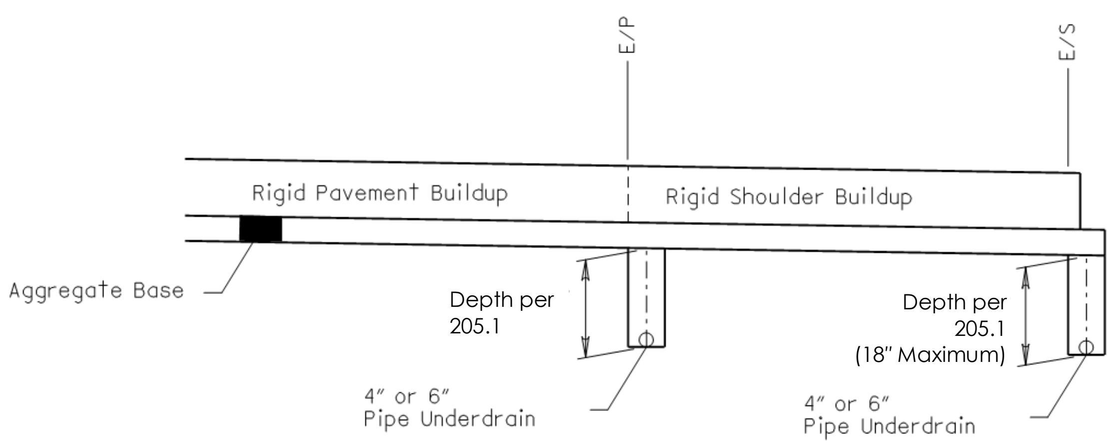
Drawing is not intended to depict allowable pavement buildups.

Typical Pipe Underdrain Locations	205-5 July 2016
	Reference Section 205

RIGID PAVEMENTS WITH PAVED SHOULDER



Shoulder width < 8 feet (2.45 m)

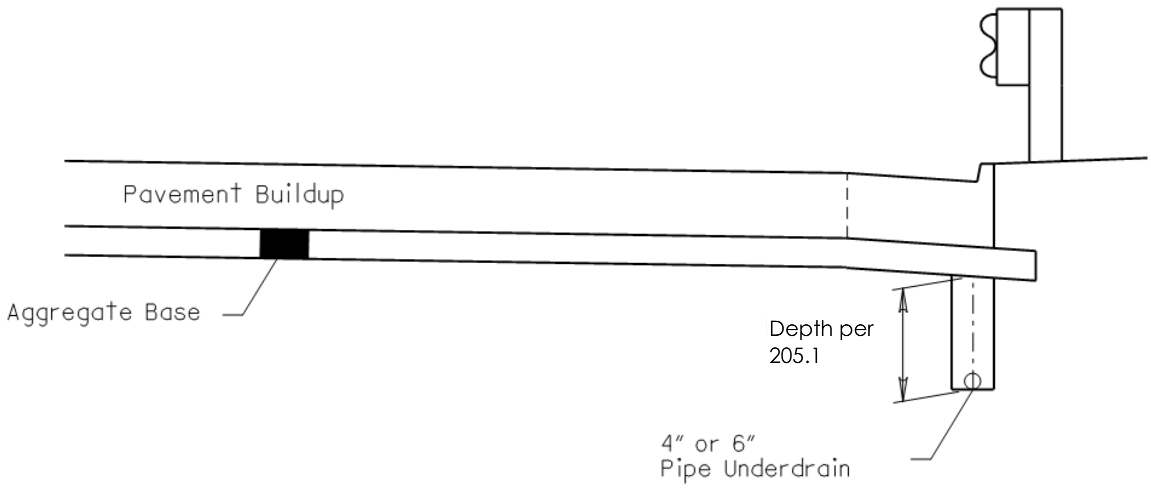


Shoulder width ≥ 8 feet (2.45 m)

Notes:
Drawing is not to scale.

Drawing is not intended to depict allowable pavement buildups.

MISCELLANEOUS LOCATION



Underdrain concurrent with guardrail

Notes:
Drawing is not to scale.

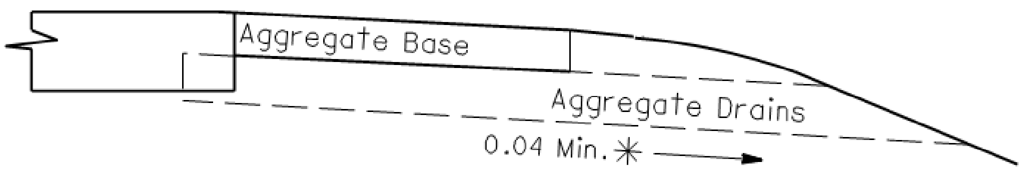
Drawing is not intended to depict allowable pavement buildups.

Typical Aggregate Drain Locations	205-7 July 2016
	Reference Section 205

AGGREGATE SHOULDER

Less than 250 B & C Trucks in Design Year ADT

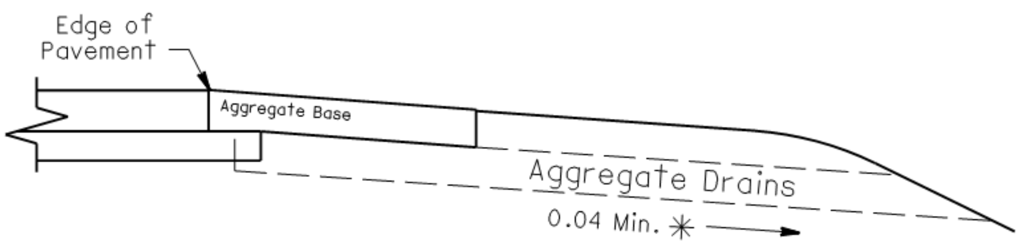
WITH FLEXIBLE OR RIGID PAVEMENT



BITUMINOUS SURFACE TREATED

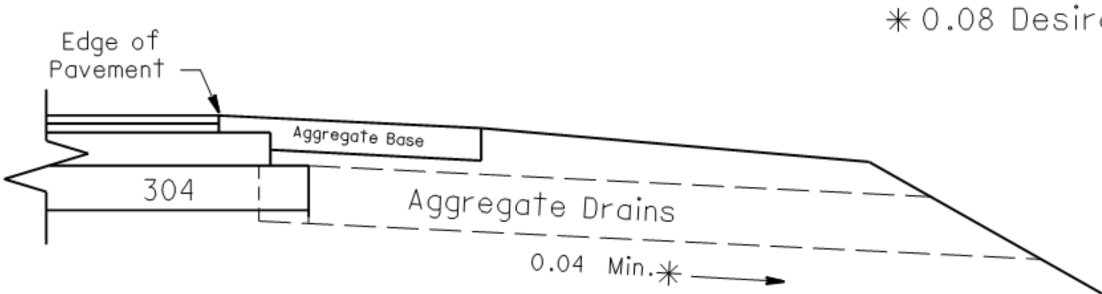
250 to 500 B & C Trucks in Design Year ADT

WITH RIGID PAVEMENT



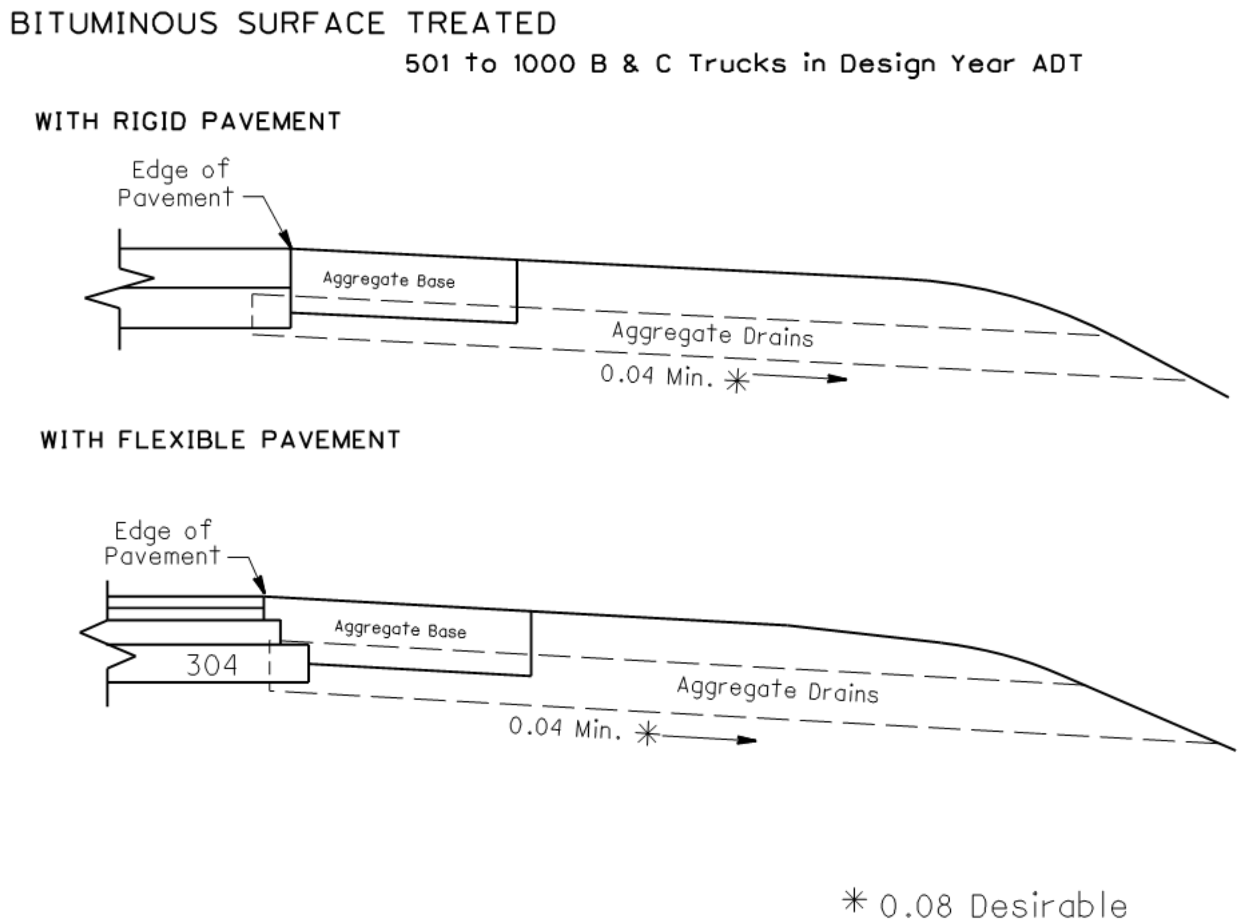
WITH FLEXIBLE PAVEMENT

✳ 0.08 Desirable



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.

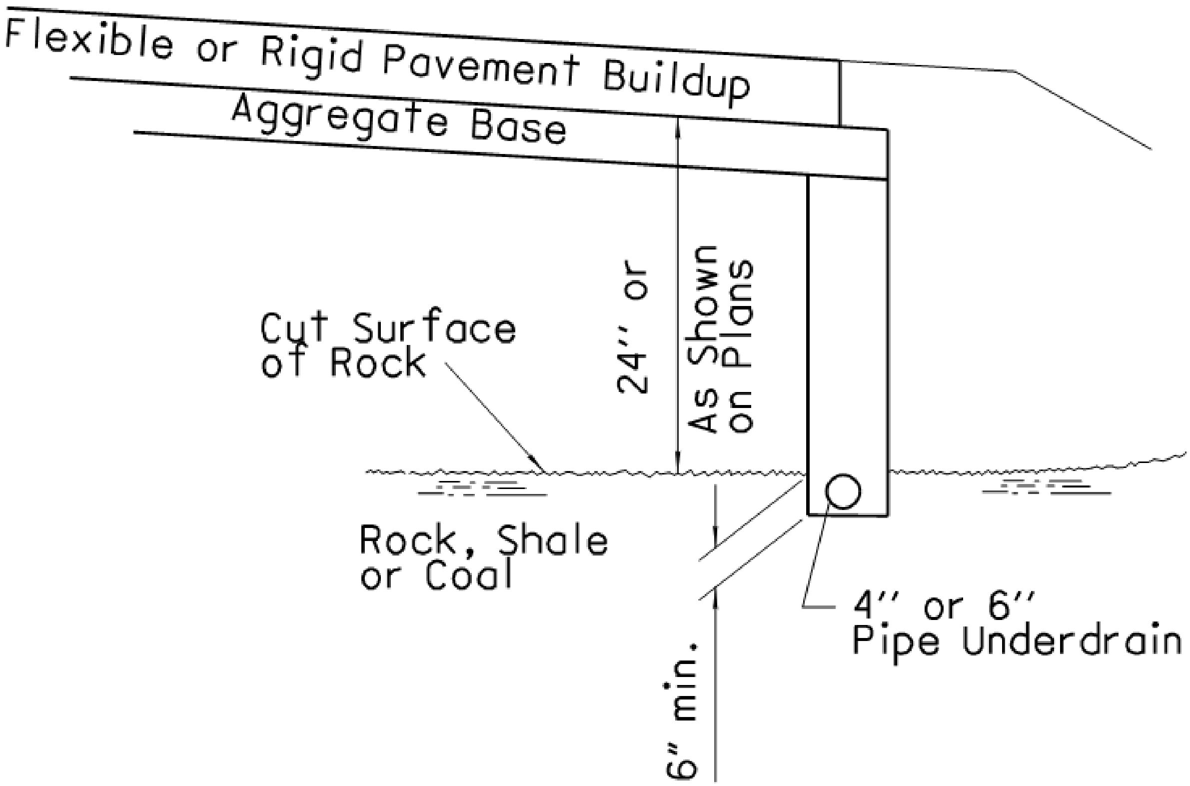
The top of the aggregate drains shall be no higher than the bottom of the shoulder's aggregate base at the point of contact.



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.

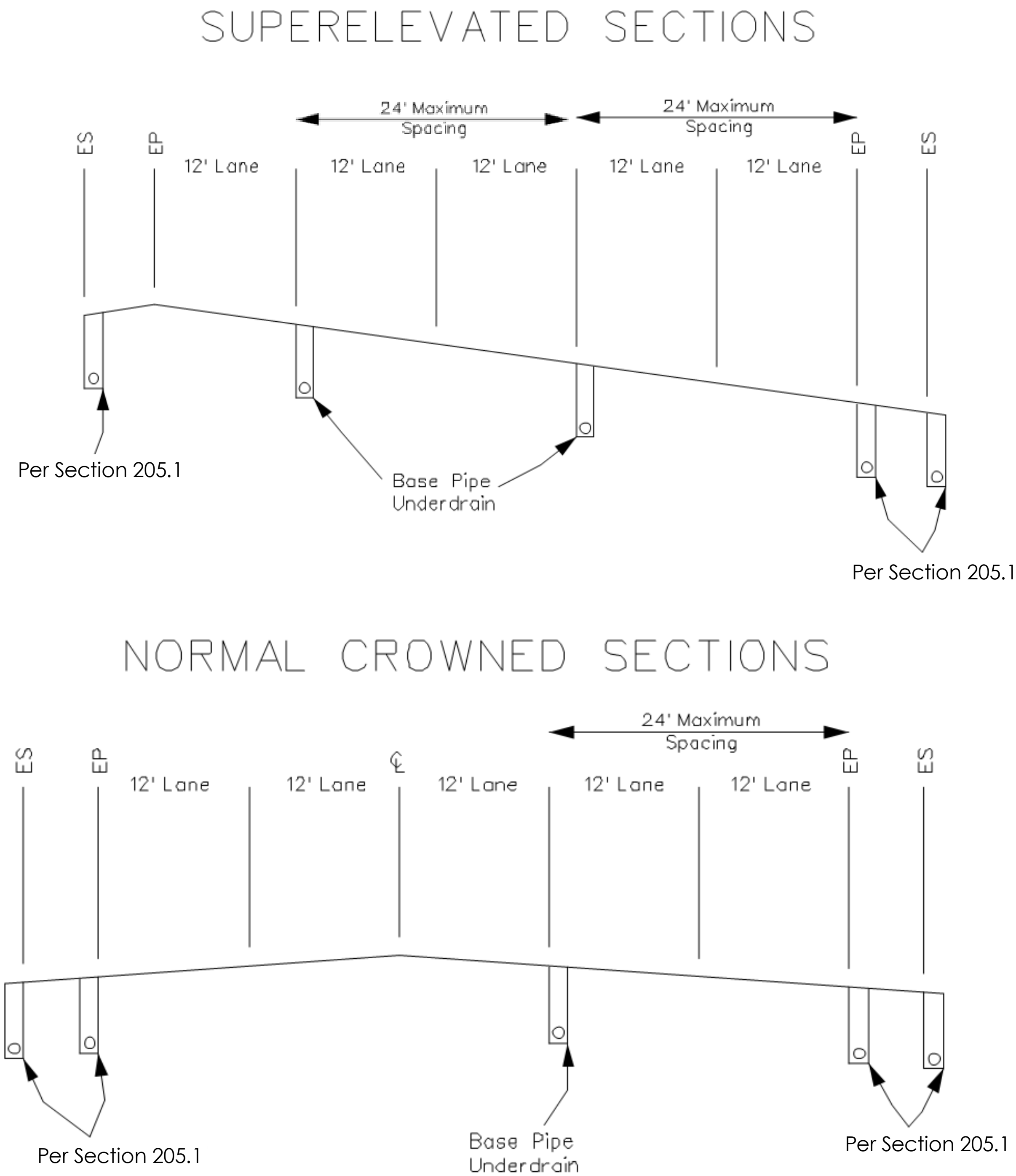
Typical Rock Cut Underdrain



Notes:
Drawing is not to scale.

Drawing is not intended to depict allowable pavement buildups.

# Typical Pipe Underdrain Locations	**205-9** July 2016
	Reference Section **205**



Notes:
Drawing is not to scale.

Drawing is not intended to depict required cross-slope or crown location.