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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) (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. A lift is the thickness of material placed in one pass. Maximum and minimum lift thicknesses can be found in the C&MS, or Section 406 or Figure 406-1 of this Manual.

403.1.1 Phase Joints

Longitudinal phase joints due to maintenance of traffic and construction phasing on multi-lane pavement replacement projects require details in the plans to ensure proper construction. The asphalt placed near the existing pavement at the phase line generally does not receive the desired level of compaction. This location often ends up in or near a wheelpath in the final configuration. The maintenance of traffic plans need to allow sufficient width for proper joint construction.

It is recommended to have a detail in the plans showing cutting back 6 inches (150 mm) of the first lift of asphalt concrete base at the phase line. Cut back any second lift of asphalt concrete base a sufficient amount to create a 6-inch (150 mm) horizontal step in the first lift. Keep the edge of the intermediate course at least 3 inches (75 mm) away from what will be the trimmed edge of the asphalt concrete base lift immediately below.

Consideration should be given to placing a construction underdrain at or near the phase joint to provide drainage during construction.

Two-lane roads, low volume roads, and short sections of replacement due to bridge, culvert, or intersection work generally do not require the details described in this section but adequate space for some stepping of the phase joint should be provided.

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 four different acceptance methods hereinafter referred to as 403 acceptance, 446 acceptance, 447 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 (441, 442, and 443 items) 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, 447, 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 method 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 method is used for all asphalt concrete base items.

The 446 acceptance method 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 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, aged surface. A level surface is required to place a uniform thickness layer of asphalt.

The 447 acceptance method is similar to 446 acceptance but with extra requirements for density along cold longitudinal joints. The 447 acceptance method is intended for limited access, multi-lane facilities with controlled grades and cross slopes, and is for surface courses only. It is not for use on 2-lane facilities or any facility with numerous driveways or intersections, or anywhere the maintenance of traffic plan does not allow continuous paving. The 447 acceptance method requires a minimum of 10,000 feet (3000 m) of cold longitudinal paving joint(s) after removing areas excluded by the specification.

With 447 acceptance, SS 875 Longitudinal Joint Adhesive is required on all cold longitudinal joints and is incidental to the surface course pay item. Do not include SS 875 as a pay item when using 447 acceptance.

The 448 acceptance method includes asphalt binder content and gradation and may include 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, 447 or 448 acceptance, as applicable. The 447 acceptance method is the highest standard of the available acceptance methods and is to be specified whenever the project criteria for use are met. Small projects and thin or variable depth surface and intermediate courses specifying 448 acceptance will automatically default to 403 acceptance. The 446 and 447 acceptance methods 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 guidelines below do not apply.

Choose 446, 447, or 448 acceptance as follows:

- Specify 446 acceptance for all surface and intermediate courses placed at a uniform thickness on a level surface on priority, general, and urban system projects using Item 442 with greater than 1500 trucks in the opening day traffic and greater than 500 cubic yards (500 cubic meters) of surface course material (approximately two lane-miles [3.2 lane-km]).

- Specify 446 acceptance for all priority system minor rehabilitation projects structurally designed from deflection measurements 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 using Item 442 with greater than 1500 trucks in the opening day traffic and the combined surface and intermediate course quantities exceed 2000 cubic yards (1500 cubic meters).

- Specify 447 acceptance for surface courses meeting all of the following criteria and that would otherwise have 446 acceptance:

    - Limited access, multi-lane facilities with controlled grades and cross slopes.

    - Few, if any, driveways and intersections.

    - Maintenance of traffic operations that allow for continuous paving.

- A minimum of 10,000 feet (3000 m) of cold longitudinal paving joint(s) after removing areas excluded by the specification.

- Projects with late season completion dates may not be good candidates for 447 acceptance. Instead use SS 872 VRAM for cold longitudinal joints and 446 as per plan acceptance as described in the designer note for SS 872. Do not use SS 872 with 447 acceptance.

- Specify 448 acceptance for all projects where 446 or 447 acceptance is not applicable.

For projects that use 446 or 447 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 or 447 acceptance is specified for the surface course, it is recommended the intermediate course 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 with 446 or 447 acceptance or below an intermediate course with 446 acceptance. The 448 acceptance on the variable depth course will default to 403 acceptance.

405 Superpave Asphalt Concrete

Superpave mixes, Item 442, 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.

406 Lift Thickness and Usage Guidelines

ODOT asphalt concrete specifications contain aggregate 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. A lift is the thickness of material placed in one pass. 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 and Section 406.7. 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 can be specified as thin as 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, 447, & 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. If 446 or 447 acceptance is specified, a uniform thickness is required.

406.1.4 Item 442 Asphalt Concrete Surface Course, 12.5mm, Type A & B (446, 447, & 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 or 447 acceptance is specified a uniform thickness is required.

406.1.5 Item 443 Stone Matrix Asphalt Concrete, 12.5mm, PG70-22M & PG76-22M (446 & 447)

Stone matrix asphalt (SMA) concrete is a highly rut-resistant mix intended as a surface course for high stress areas. SMA uses 446 or 447 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 has the finer gradation and can be placed as thin as 5/8-inches (16 mm) up to 1-inch (25 mm) thick. Type A uses 403 acceptance and thus never has any density testing. Type A is not for use in any location with high friction demand or legal speed limit greater than 40 miles per hour. Type A should not be used in locations with greater than 1500 trucks per day regardless of friction demand or speed.

Type B can be placed at thicknesses from 0.75 inches (19 mm) to 1.25 inches (32 mm). When placing Type B less than 1 inch (25 mm) thick, Item 897 Fine Planing is recommended. 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. Type B uses 448 acceptance.

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.

Any time an intermediate course is used as a variable depth, scratch, or leveling course, the legend on the typical section sheets should include the word “variable” or “leveling” in parentheses at the end of the item description.

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 bond pavement layers together to create a monolithic pavement structure. A tack coat is required between all lifts of asphalt concrete; surface and intermediate, intermediate and base, and between multiple lifts of asphalt concrete base (C&MS items 301 and 302). When following the small quantity guidelines (Section 410), a tack coat is required between all lifts, even if the same material is used for multiple lifts.

A tack coat is required anytime asphalt concrete is placed on pavement constructed by a previous project, even if the old pavement has been planed. The one exception is, when constructing an unbonded concrete overlay, tack coat should not be used under the bondbreaker layer unless traffic will be maintained on the bondbreaker.

A tack coat is required anytime asphalt concrete is placed on Portland cement concrete or brick with the exception of a bondbreaker layer mentioned above. When tack coat is placed on concrete or brick, C&MS automatically requires the use of rubberized asphalt emulsion conforming to 702.13. It is recommended the designer use the tack coat pay item that references 702.13 where the plans show placing tack on concrete or brick.

Tack coat application rates are specified in the C&MS. It is recommended that the designer use the mid-point of the application rate ranges shown in C&MS Table 407.06-1 for determining plan quantity. When multiple tack coats exist on a project, such as below an intermediate course and below a surface course, one total quantity for all the tack coat is listed in the general summary. It is not necessary to show in the plans the estimated application rate(s).

406.4.1 Non-Tracking Tack Coat

Non-tracking tack coat does not require as long of a cure time as standard tack coat to prevent tracking onto adjacent roadways. Non-tracking tack coat should be considered when project conditions do not allow for adequate cure time for standard tack coat. The designer should evaluate the potential for safety-related issues that would arise from tracking tack coat material onto adjacent roadways. Project conditions that may warrant the use of non-tracking tack include short construction zones, particularly in urban areas, and when night paving is required.

Non-tracking tack coat is not allowed on concrete or brick.

Non-tracking tack coat is not recommended for very small quantities. A minimum quantity of 800 gallons (3000 L) is recommended.

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/m^2).

406.6 Anti-Segregation Equipment

Items 441 and 442 have a pay item for anti-segregation equipment. This item requires the contractor to provide equipment to remix the asphalt concrete after discharging from the trucks.

Anti-segregation equipment is to be specified for surface and intermediate courses of uniform thickness on all large-scale priority system paving projects. Large-scale paving projects generally consist of at least one mile (1.6 km) of paving. Other projects such as bridge projects that may include small amounts of paving do not need to specify anti-segregation equipment.

The cubic yards (cubic meters) calculated for this item should include the total quantity of surface and intermediate course on the priority system route driving lanes, C-D lanes, ramps, etc., but not including shoulders.

406.7 Asphalt Binder Grades

ODOT uses the Performance Grade (PG) binder grading system to designate the grade of asphalt binder in all asphalt concrete items. Most asphalt concrete items contain a default binder grade given in the specification. Other items list the binder grade as part of the pay item description. The binder grades used and available in Ohio are: PG64-22, PG64-28, PG70-22M, PG76-22M, and PG88-22M.

The numbers in the PG designation relate to the temperature range the binder is expected to perform. A PG64-22 binder is expected to resist deformation at a high pavement temperature of 64 ºC and to resist cracking at a low pavement temperature of -22 ºC. PG64-22 is pronounced PG sixty-four minus twenty-two.

In most cases, the default binder grade is sufficient for normal traffic loading and patterns. In high stress locations (see Appendix B), the designer should consider using a binder with the ability to resist deformation at higher temperatures.

The most common binder for 441 items is PG64-22. Some districts are required to use PG70-22M in 441 surface courses. In high stress locations, PG64-22 surface course binders should be changed to PG70-22M and for districts already using PG70-22M for surface courses it should be changed to PG76-22M. In extreme conditions, all districts should use PG76-22M or even PG88-22M and the asphalt concrete should be changed to a 442 mix as well.

Item 441 intermediate courses use PG64-22 binder in all districts. If the surface course binder grade is changed due to a high stress location, the binder grade for any intermediate course may be changed to match the surface binder grade but this is usually not necessary.

The surface course binder for 442 items is PG70-22M. In high stress locations, the binder should be changed to PG76-22M or PG88-22M.

The intermediate course binder for 442 items is PG64-28. If the surface course binder grade is changed due to a high stress location, the binder grade for any intermediate course may be changed to match the surface binder grade but this is usually not necessary.

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.

Use of Item 880 and Supplement 1059 currently require pre-approval from the Division of Construction Management.

408 Smoothness Specifications

Incentive/disincentive for smoothness is specified using Proposal Note (PN) 420 Surface Smoothness Requirements for Pavements. PN 420 is recommended for all eligible projects as described in the designer note.

The minimum smoothness requirements when PN 420 is not 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 Type A, B, or C

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.

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 the standard 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) and Section 406.7. 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 the standard 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) and Section 406.7. 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 the standard 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) and Section 406.7. 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.

400 Flexible Pavement Design

List of Figures

Flexible Pavement Structural Coefficients

401-1
January 2019
Reference Section
401

ASPHALT CONCRETE STRUCTURAL COEFFICIENTS		
Material	**English Coefficient**	**Metric Coefficient**
Items 424, 441, 442, 443, 826, 857, 859 AC Surface Courses	0.43	0.0169
Items 441, 442, 826, 857 AC Intermediate Courses	0.43	0.0169
Item 880 Warranty Asphalt - top 3" (75 mm)	0.43	0.0169
Items 301, 302 Asphalt Concrete Base Courses	0.36	0.0142
Item 880 Warranty Asphalt - below top 3" (75 mm)	0.36	0.0142
Item 321 Cracked & Seated Plain Concrete	0.27	0.0106
Existing Asphalt Concrete - old, oxidized, & weathered	0.23	0.0092
Item 304 Aggregate Base*	0.14	0.0055
Item 320 Rubblized Concrete	0.14	0.0055
Items 421 Microsurfacing	0.0	0.0
Item 803 Rubberized Open Graded Asphalt Friction Course	0.0	0.0
Items 822 Hot In Place Recycling	0.0	0.0

* When the entire subgrade is chemically stabilized (global chemical stabilization), the coefficient for Item 304 Aggregate Base is increased to 0.17 (0.0067).

Asphalt Concrete Drainage Factor = 1.0

Given:

- Number of Lanes: 4 (2 per direction)
- Functional Classification: Principal Arterial (Rural)
- 2018 Traffic: 15,800 ADT
- 2038 Traffic: 22,450 ADT
- 24 hour truck %: 18%
- Design Period: 20 years
- Open to Traffic: 2019
- 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 2019, the ESAL projection should be for 2019 to 2039. Calculate the mid-year (2029) ADT, rounded to the nearest ten:

2029 ADT = 15,800+(22,450-15,800)(11/20)
2029 ADT = 19,460

Directional distribution, D = 50% (Figure 202-1)
Lane factor = 95% (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)(0.95)(5/6)(1.06) = 1470
ESAL's from C trucks = 19,460(0.18)(0.50)(0.95)(1/6)(0.33) = 92

Total daily ESAL's = 1470+92 = 1562 ESAL/day

Design period ESAL's = 1562 ESAL/day * 365.25 days/yr. * 20 years = 11,410,410
use 11.4×10^6 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 = 11.4×10^6 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) = 5.07

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 ADTT = (15,800+(22,450-15,800)(1/20))*0.18
2017 ADTT = 2900

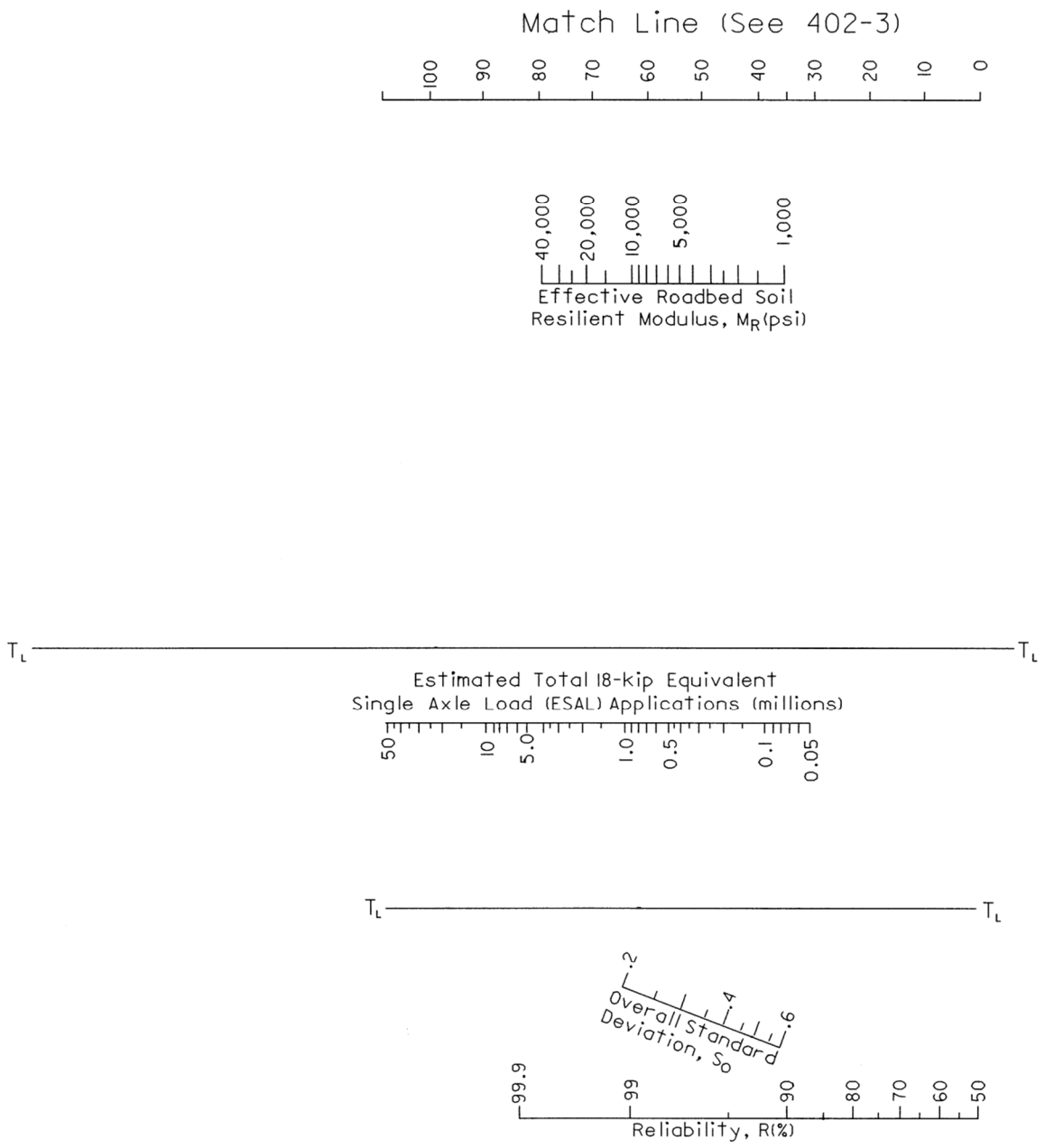
Since the opening day truck traffic is greater than 1500, Item 442 Asphalt Concrete Surface Course, 12.5mm is required.

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

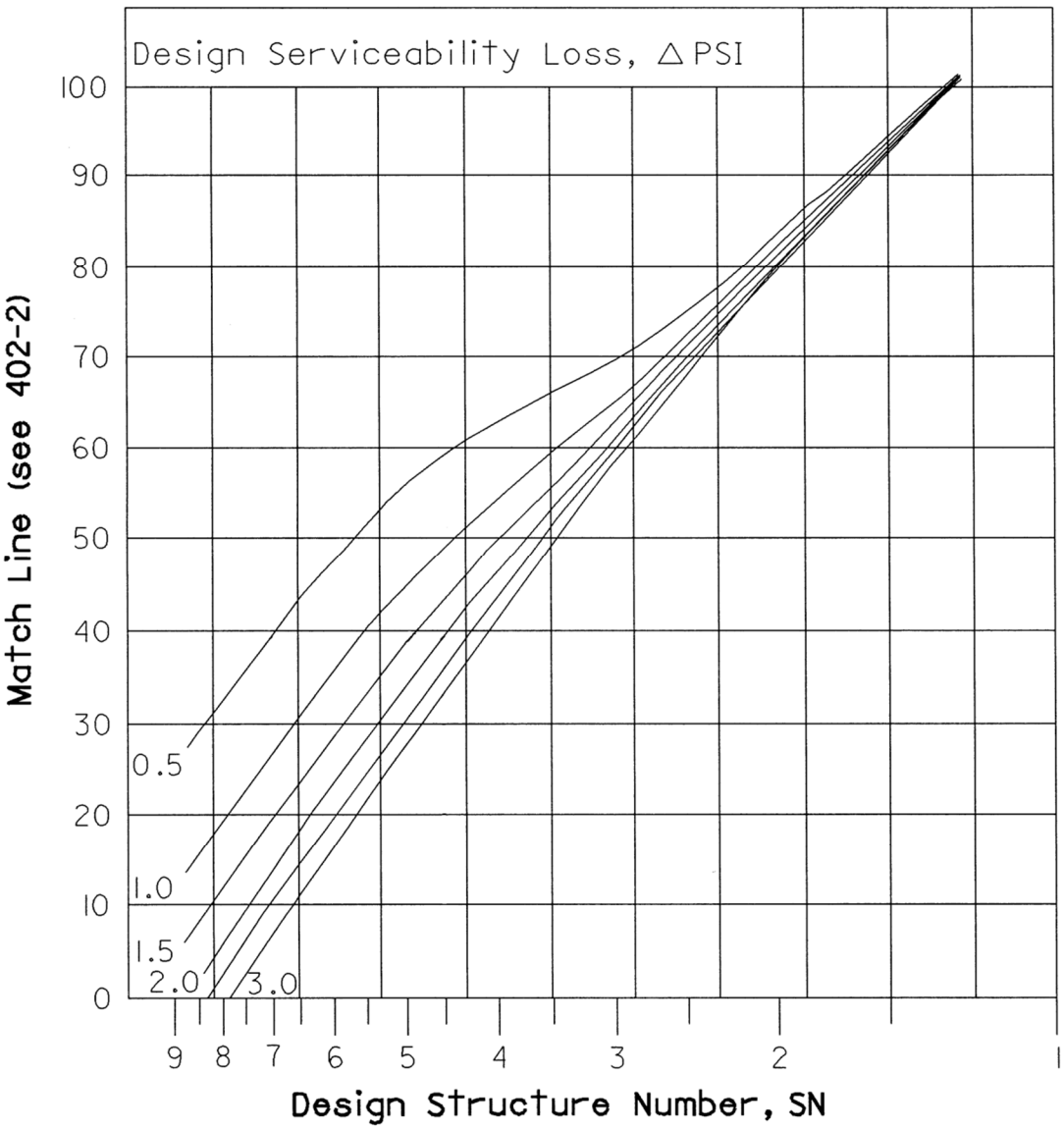
Material	Thickness	Coefficient	SN
442 AC Surface Course, 12.5mm, Type A (446)	1.5"	0.43	0.65
442 AC Intermediate Course, 19mm, Type A (446)	1.75"	0.43	0.75
302 Asphalt Concrete Base, PG64-22	8"	0.36	2.88
304 Aggregate Base	6"	0.14	0.84
		Total SN =	5.12

Since the total SN equal to 5.12 of the proposed buildup is greater than the required SN of 5.07, the design is acceptable.

Flexible Pavement Design Chart Segment 1	402-2 July 2008 Reference Section & Figure 402, 402-1(step 3)

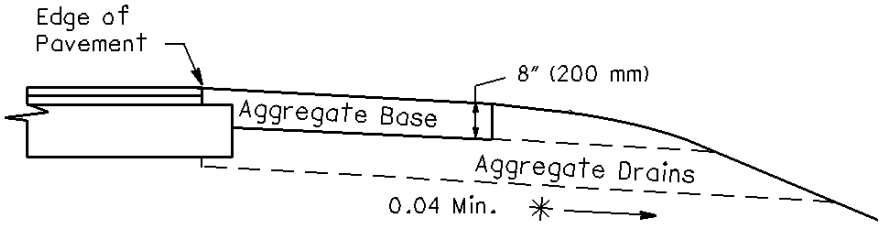


Flexible Pavement Design Chart Segment 2	402-3 July 2008 Reference Section & Figure 402, 402-1(step 3)

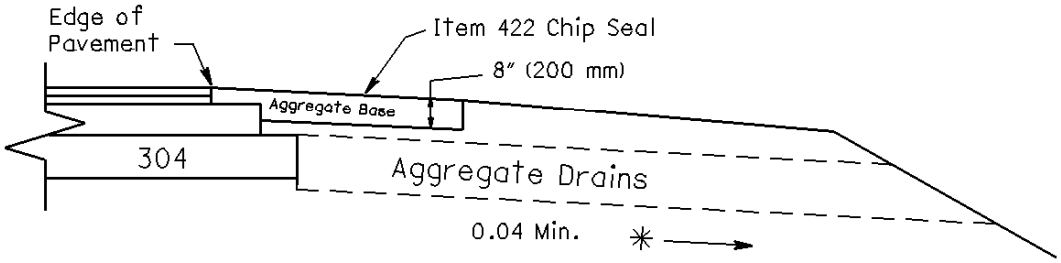


Surface Treated Shoulder and Stabilized Aggregate Shoulder Typical Sections	403-1 July 2008 Reference Section 205.1, 403.3 & 403.4

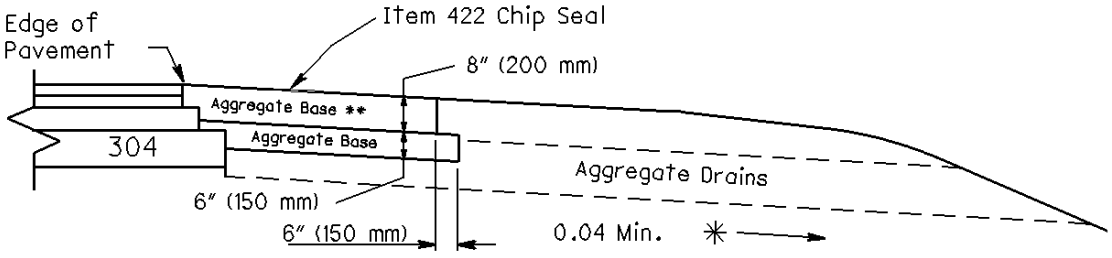
AGGREGATE SHOULDER



SURFACE TREATED



SURFACE TREATED (Greater than 500 trucks in Design Year ADT)



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

Asphalt Concrete
Quick Reference Guide

406-1
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406

Item	Minimum Lift	Maximum Lift	Taper to 0"*	Uniform Thickness Required
301 Asphalt Concrete Base	3"	6"	No	No
302 Asphalt Concrete Base	4"	7.75"	No	No
424 Fine Graded Polymer Asphalt Concrete, Type A	0.625" (5/8")	1"	No	Yes
424 Fine Graded Polymer Asphalt Concrete, Type B	0.75"	1.25"	No	Yes
441 AC Surface Course, Type 1 (448)	1"	1.5"	No	No
441 AC Surface Course, Type 1 (446)	1"	1.5"	No	Yes
441 AC Intermediate Course, Type 1 (448)	1"	1.5"	Yes	No
441 AC Intermediate Course, Type 2 (448)	1.75"	3"	Yes	No
441 AC Intermediate Course, Type 2 (446)	1.75"	3"	No	Yes
442 AC Surface Course, 12.5mm, Type A or B (446)	1.5"	2.5"	No	Yes
442 AC Surface Course, 9.5mm, Type A or B (446)	1"	1.5"	No	Yes
442 AC Surface Course, 12.5mm, Type A or B (447)	1.5”	2.5”	No	Yes
442 AC Surface Course, 9.5mm, Type A or B (447)	1”	1.5”	No	Yes
442 AC Surface Course, 12.5mm, Type A or B (448)	1.5"	2.5"	No	No
442 AC Surface Course, 9.5mm, Type A or B (448)	1"	1.5"	No	No
442 AC Intermediate Course, 19mm, Type A or B (446)	1.75"	3"	No	Yes
442 AC Intermediate Course, 19mm, Type A or B (448)	1.75"	3"	Yes	No
442 AC Intermediate Course, 9.5mm, Type A or B (448)	1"	1.5"	Yes	No
443 Stone Matrix Asphalt Concrete, 12.5mm (446)	1.5"	2"	No	Yes
443 Stone Matrix Asphalt Concrete, 12.5mm (447)	1.5”	2”	No	Yes

Item	Minimum Lift	Maximum Lift	Taper to 0"*	Uniform Thickness Required
803 Rubberized Open Graded Asphalt Friction Course	0.75"	0.75"	No	Yes
826 AC Surface Course, Type 1, (448), Fiber A, B, or C	1"	1.5"	No	No
826 AC Intermediate Course, Type 2, (448), Fiber A, B, or C	1.75"	3"	No	No
826 AC Surface Course, 442 12.5mm, (448), Fiber A, B, or C	1"	1.5"	Yes	No
826 AC Intermediate Course, 442 19mm, (448), Fiber A, B, or C	1.75"	3"	Yes	No
857 AC with Gilsonite, Surface Course, Type 1 (designed for <1500 trucks)	1"	1.5"	No	**
857 AC with Gilsonite, Surface Course, Type 1 (designed for >1500 trucks)	1.5"	2.5"	No	**
857 AC with Gilsonite, Intermediate Course, Type 2	1.75"	3"	No	**
859 AC with Verglimit	1"	2.5"	No	Yes

* 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.