

Chapter 4: HMA (Hot-Mix Asphalt)

# MnDOT Pavement Design Manual



July 10, 2019

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# Introduction

For this manual, HMA refers to hot-mix asphalt or warm-mix asphalt layers of a pavement structure. HMA pavement may be constructed on new aggregate base, recycled material used as aggregate base, such as full-depth reclamation (FDR), or placed as an overlay on existing pavement. Other asphalt containing materials such as cold in-place recycling (CIR) or stabilized full-depth reclamation (SFDR) is considered as stabilized aggregate base material. Surface treatments, such as seal coats or microsurfacing, are considered as surface treatments and not pavement.

This chapter contains directions for designing HMA pavement on mainline highways, determining the HMA specification required for a Materials Design Recommendation (MDR), and evaluating existing pavement with regard to rehabilitation with a HMA overlay. The process for pavement-type selection is contained in **Chapter 7: Pavement-Type Selection**.

## Section 400: New/Reconstructed HMA Pavements

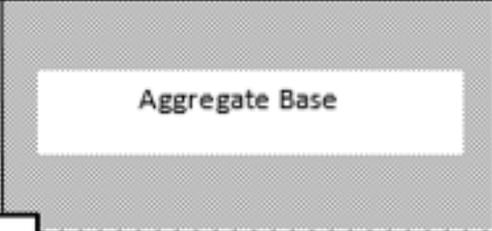
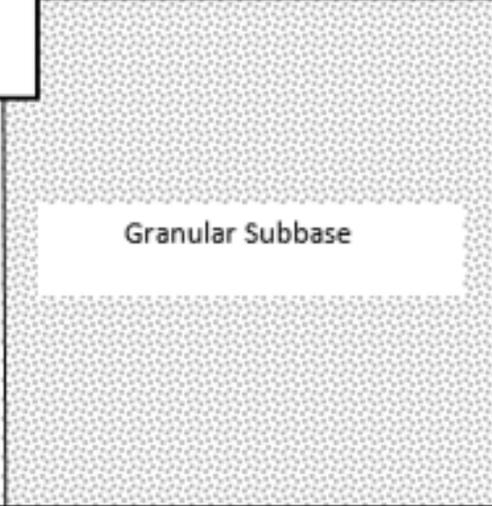
This section contains directions to design pavements for projects that include the complete removal of the existing pavement or construction on a new alignment.

New/reconstructed HMA pavements are built on aggregate base and granular subbase. The base and subbase provide a portion of the pavement's structure, a solid working platform for construction and improved engineering properties as compared to native, non-granular soils; such as higher strength, less reduction in strength during spring thaw, lower frost susceptibility, and improved drainage.

Use the following standards to design new/reconstructed HMA pavements:

1. Projects that involve working the existing soil must comply with **Figure 400.1** and its notes.
2. Projects that do not involve working the existing soil must comply with the following:
  - A. These projects must have existing soil, subbase, and/or aggregate base material in good condition, suitable to perform as a portion of the pavement structure and to remain in the pavement section. The designer must evaluate the existing materials and determine what material will remain and what treatment, if any, will be required.
  - B. These projects do not need to comply with all of the requirements shown in **Figure 400.1**. However, a minimum of 4.0 inches of HMA (a 5.0-inch HMA minimum may be used on urban sections) on a minimum of 6.0 inches of aggregate base must be used.
3. Design the pavement using MnPAVE-Flexible according to **Section 430: Pavement Design Using MnPAVE-Flexible**.
4. Specify the mix type, ride specification, lift thicknesses, and compaction requirement using **Section 450: Materials and Specification**.
5. Any construction beneath the typical shown in **Figure 400.1** is at the discretion of the District Materials/Soils Engineer. For guidance regarding the pavement subsurface design see **Chapter 3: Pavement Subsurface**.
6. For guidance on pavement cross sections consult the MnDOT Road Design Manual (Chapter 4 – Cross Sections and Chapter 7: Pavement Design).

Figure 400.1 – Pavement design standards for new/reconstructed HMA pavement for projects that involve working the existing soil.

Layer	Notes
 <p data-bbox="383 422 691 495">HMA Pavement</p>	<ul data-bbox="813 390 1360 499" style="list-style-type: none"> <li>• 4.0-inch minimum thickness</li> <li>• 5.0-inch HMA minimum may be used on urban sections</li> </ul>
 <p data-bbox="326 646 745 720">Aggregate Base</p>	<ul data-bbox="813 667 1208 699" style="list-style-type: none"> <li>• 6.0-inch minimum thickness</li> </ul>
<div data-bbox="152 789 326 911" style="border: 1px solid black; padding: 5px; width: fit-content;">See Note 1</div>  <p data-bbox="326 1010 745 1083">Granular Subbase</p>	<ul data-bbox="813 842 1406 1251" style="list-style-type: none"> <li>• For non-granular soils use select granular. Class 3 or class 4 can be substituted for a portion of the select granular material at the discretion of the District Materials/Soils Engineer.</li> <li>• For granular soils (percent passing ratio [no. 200 (75 μm)/1.0 inch (25 mm)] sieve ≤ 20), mix and compact the upper 12.0 inches (minimum) of the existing granular soils.</li> </ul>
 <p data-bbox="444 1409 664 1503">Soil</p>	<p data-bbox="867 1419 1005 1451">See Note 2</p>

**NOTE 1** For non-granular soils, the minimum pavement structure (i.e. pavement, aggregate base, and subbase) thickness required is:

- 30.0 inches for 20-year BESALs ≤ 7 million
- 36.0 inches for 20-year BESALs > 7 million

**NOTE 2** Any construction beneath the typicals shown above shall be at the discretion of the District Materials/Soils Engineer.

## Section 410: Reclamation/Recycling of HMA Pavement

Reclamation/Recycling of HMA pavement includes processes that grind the existing HMA pavement and re-use it in the new pavement section. This includes full-depth reclamation (FDR), stabilized full-depth reclamation (SFDR), cold in-place recycling (CIR), and cold central plant recycling (CCPR).

If the existing HMA material is removed from the roadway and then re-used as base, then use **Section 400: New/Reconstructed HMA Pavements**.

### 1. Pavement condition assessment

- A. Examine existing pavement to determine whether there are weak subgrade or base areas.
- B. Use Ground Penetrating Radar (GPR), to ascertain pavement and base thicknesses.
- C. Take cores samples for calibration purposes of the GPR and for evaluation of the HMA. Take at least 1 core per mile but increase that to 2 per mile if GPR testing wasn't performed.
- D. Analyze cores to discern the uniformity of gradation, crushing, and condition. Evaluate the sample's gradation and crushing along discontinuities by slicing the core, performing a burn extraction and analyzing the sample for crushing and gradation by depth of core.
- E. Sample the base and subgrade at each core location and determine:
  - (1) Base thickness, gradation, crushing and strength (perform DCP testing through base, subbase and subgrade).
  - (2) Subbase thickness and gradation
  - (3) Subgrade attributes

Establish the soil samples classification according to the triaxial chart and the soil's strength attributes (R-value or other). Consider repairing the subgrade where it is weak, as reclamation projects do not improve a weak subgrade; establish that the condition of the subgrade is adequate and requires, at the most, minimal repairs. Areas that require subgrade repair may be visually apparent (see **Section 270**), may appear as weak areas in FWD data (see **Section 200**), or may appear as areas of wet or poor foundation soils in a soils survey (see **Section 220.1.D**).

- F. Consider cement soil stabilization for weak areas. It can be cost effective, if an entire HMA section is being reclaimed. Soil stabilization will aid in the long term performance by not only providing a stable platform for the longevity of the project, but it will also increase compaction efforts during construction.

As an alternative to cement stabilization, the designer should consider the use of a fabric separator or a geogrid.

## 2. Reclamation selection

Use **Table 410.1** and the following as a guide to rehabilitation selection.

- A. CIR may be preferred for thicker existing HMA ( $\geq 7$  inches) and there are no underlying distresses.
- B. Consider CIR for an existing HMA overlay on a jointed concrete (BOC).
- C. FDR and SFDR are preferred for thinner ( $< 7$  inches) HMA sections.
- D. Consider SFDR if it is desirable to strengthen the base without raising the grade as much as a FDR. Consider cold central plant recycling (CCPR) for projects that involve stabilizing the subgrade. The CCPR process involves; removing all of the existing HMA, strengthening the subgrade, placing cold central plant mix and then paving new HMA.

**Table 410.1 – Recommended rehabilitation methods with regard to existing distresses.**

Existing Distress	CIR	SFDR	Soil Stabilization
Raveling			
Potholes	✓		
Rutting	✓		
Corrugations			
Shoving	✓		
Fatigue Cracking	✓	✓	
Block Cracking	✓	✓	
Longitudinal Cracking	✓		
Transverse Cracking	✓	✓	
Reflective Cracking	✓	✓	
Swells/Bumps/Sags			✓
Sags			✓
Depressions			✓
Poor Ride Quality	✓		
Weak Subgrade			✓

### 3. In-depth design

This section contains general reclamation guidelines for CIR, SFDR and FDR.

The three most important design attributes for CIR, SFDR and FDR to consider are:

- Crushing % (aim for a minimum of 20%).
- Gradation (aim for a minimum of 40% retained on the No. 4 (4.76mm) sieve and a maximum of 10% passing the No. 200 (75 µm) sieve).
- Having a firm platform to compact against.

#### A. Full-depth reclamation (FDR) design

FDR involves using a reclaiming machine to crush and blend-together the existing HMA pavement and aggregate. The blended material is moved as necessary to allow it to be compacted in 6-inch lifts. After compaction and shaping, it will then act as base for new HMA pavement. Therefore, staging should be considered during design.

As per above, the minimum goal should be to meet a gradation with a minimum of 40% retained on the No. 4 (4.76mm) sieve and a maximum of 10% retained on the No. 200 (75 µm) sieve. Excess crushing over 20% may be substituted for a deficiency in No. 4 (4.76mm) sieve gradation.

Do not over-mill the HMA, as often the existing HMA will provide needed crushing and rock for the reclaimed material. Consider correcting the grade after reclamation. Reclaiming first will provide good rock and crushing percentages for the reclaimed material. Excess reclaimed material may be used on shoulders and gravel roads to stabilize them. If the reclaimed material is expected to be deficient in crushing or gradation, provide additional rock placed in front of the reclaimer. One hundred percent crushed chip seal rock (FA -3 per MnDOT specification 3127) works well for this purpose. (Note that older HMA may be a very sandy mix and may not provide the needed rock or crushing).

Establish a reclaiming depth of at least 1 inch deeper than the HMA pavement. This will allow the teeth of the reclaiming machine to pass through the HMA and to be cooled by the aggregate layer. Alternatively, aggregate may be placed on top of the existing HMA to cool the teeth but is not preferred.

It is preferred to establish a reclaiming depth that will provide a structure to compact against and there is little potential to incorporate dirty (i.e. excess fine material) base, subbase, and subgrade into the final product. Therefore, deeper depths of reclamation are not recommended, unless a thick clean base, subbase and strong subgrade is present.

Consider compaction aids comprised of calcium chloride or other salt materials, which will aid in compaction and may provide some strength. However, note that when saturated, compaction aids will perform similar to reclaimed material without compaction aids during the spring thaw period.

When determining the reclaiming depth consider the following:

- Only existing HMA and sound aggregate should be included in the reclaiming section.
- The maximum depth that typical reclaiming machines can reclaim is 18 inches but a depth of 12 inches is typically used. **Note:** stay as far above weak soils as possible because bearing capacity is needed for compaction.
- If there is a definite change in the pavement section, design for multiple milling depths, added aggregate, or reclaiming depths within the project.

#### B. Stabilized full-depth reclamation (SFDR) design

SFDR is FDR that has had a stabilizing agent added. After the roadway has been reclaimed, a second pass of the reclaiming machine is made to apply and blend-in a stabilizer. The stabilizer is typically asphalt emulsion or foamed asphalt. This layer will then be shaped, compacted, and allowed to cure before being paved with new HMA pavement.

As with FDR, design SFDR with adequate rock and crushing and a good platform to compact against (see above).

It is recommended to use either an emulsion derived from PG 58-28 or foamed asphalt meeting PG 49-34.

An SFDR mix design is recommended to determine the method (foaming or emulsion), bituminous type and amount of additives needed. See the “Mix Design Criteria for SFDR” in the **Grading and Base Manual Section 5-692.290**.

##### (1) Reclaiming depth

Establish a reclaiming depth of 1 inch deeper than the HMA pavement. This will allow the teeth of the reclaiming machine to pass through the HMA and to be cooled by the aggregate layer. A greater amount of aggregate is not preferred for SFDR because the required emulsion percentage is increased and there is greater potential to incorporate dirty base, subbase, and subgrade into the final product.

- a. Only existing HMA and sound aggregate should be included in the reclaiming section.
- b. If there is a definite change in the pavement section, design for multiple milling depths, added aggregate or reclaiming depths for the project.

##### (2) Stabilization depth

The maximum stabilization depth is 6 inches, and the typical minimum depth is 4 inches. Design the stabilization depth to meet the design needs of the pavement.

### C. Cold in-place recycling (CIR) design

CIR is produced by grinding HMA and adding an emulsion or foamed asphalt in one process. It is less expensive than SFDR but does not fix a weak base. This layer will then be shaped, compacted, and allowed to cure before being paved with new a new HMA pavement or a surface treatment.

As with (S)FDR, design CIR to have adequate rock, % crushing and a good platform to compact against. Assess changes in gradation of the HMA throughout the cores during design.

A CIR mix design is recommended to determine the method (foaming or emulsion), bituminous type and amount of additives needed. See the “Mix Design Criteria for SFDR” in the **Grading and Base Manual Section 5-692.291**.

A benefit of using a CIR layer is that it retards reflective cracking. Reflective cracking may be further retarded by reducing the thickness of the existing cracked pavement (by milling).

It is recommended to use either an emulsion derived from PG 58-28 or foamed asphalt meeting PG 49-34.

#### (1) CIR grinding and stabilization depth.

- a. Only existing HMA should be included in the reclaiming section.
- b. The preferred design thickness for CIR is 4 inches, and the minimum thickness is 3 inches. To permit proper compaction, the maximum thickness is 5 inches.
- c. Ensure there is a minimum of 6 inches of existing aggregate base, PCC or an equivalent thickness in other materials under the existing HMA for support of the CIR train.
- d. If the existing HMA is on aggregate base, choose CIR and milling thicknesses to leave at least the bottom two inches of HMA undisturbed.
- e. If the existing HMA is on PCC pavement, mill and CIR to the top surface of the PCC pavement.

### D. Cold central plant recycling (CCPR)

CCPR is a method where asphalt millings are processed with asphalt then placed back onto a pavement surface. It is most applicable where all the pavement surface is removed to the subgrade, the subgrade is then stabilized and the CCPR material is placed directly onto the stabilized soil, which is topped with HMA.

A mix design is recommended to determine the bituminous type and amount of additives needed. See the Mix Design Criteria for CIR in the **Grading and Base Manual Section 5-692.291**.

For more information and/or assistance on FDR, SFDR or CIR, contact the [Reclamation - Grading and Base Unit of the Office of Materials & Road Research](#).

#### 4. Pavement Design

A. Design the pavement thickness of FDR, CCPR, SFDR, and CIR using MnPAVE-Flexible according to **Section 430: Pavement Design Using MnPAVE-Flexible**. Use the following minimum HMA pavement thicknesses for the pavement designs.

- **FDR** - The minimum HMA pavement thickness is 4.0 inches (a 5-inch HMA minimum may be used on urban sections).
- **SFDR** - A minimum HMA pavement thickness of 2.0 inches may be used if placed on a minimum of 6.0 inches of SFDR.
- **CIR or CCPR** - The minimum HMA pavement thickness is 2.0 inches, but a seal coat may be acceptable for shoulders not normally used for traffic.

B. Specify the HMA mix type, ride specification, lift thicknesses, and compaction requirement using **Section 450: Materials and Specification**.

#### 5. Use of intelligent compaction (IC) on SFDR, CIR, or CCPR projects

See **Section 450.5** to help evaluate if IC would be appropriate for one of these project.

## Section 420: Rubblization and Crack and Seat

Rubblization and crack and seat are two methods used to process existing PCC pavement to prevent reflective cracking and allow the fractured PCC to serve as a base for new HMA pavement.

### 1. Rubblization (2231 Pavement Breaking Special Provision (S-108))

Rubblization is intended to reduce the existing PCC modulus and obliterate the existing PCC joints in order to prevent reflective cracking of the HMA pavement and allow the rubblized PCC to act as new base.

Rubblization involves breaking the existing PCC slab into pieces (3.0 inches maximum at surface and 9.0 inches maximum at the bottom of pavement), compacting the rubblized material, and paving an HMA pavement.

#### A. Evaluation and pre-HMA paving repairs.

- (1) Rubblization projects require a minimum average R-value of 17 or a minimum of 1 foot of granular material under the existing PCC pavement. The R-value may be determined by performing laboratory tests on samples obtained from borings (see **Section 220: Borings**) or from FWD testing an existing HMA shoulder, if it was constructed with the mainline and it is not heavily cracked.
- (2) Establish the material and condition of the existing subgrade with borings (see **Section 220: Borings**). Roadways with wet subgrades are poor rubblization candidates. However, wet subgrades may be remedied by installing subsurface drains a year prior to rubblization.
- (3) Before rubblization, remove any existing HMA overlay.
- (4) Before rubblization, repair spot areas of poor subgrade support or bad PCC joints with full -depth HMA.
- (5) When edge-drains do not exist, install edge-drains prior to rubblization or remove the shoulders and daylight the base and subbase so that water may drain.

## B. Design the HMA pavement

Use a minimum HMA pavement thickness of 4.0 inches.

- (1) A layer of permeable asphalt stabilized base (PASB) or permeable asphalt stress relief course (PASSRC) (specification 2363) is recommended as the first layer of HMA to reduce or delay any reflective cracking. This layer does not contribute towards the minimum HMA requirement.
- (2) The pavement must be designed using MnPAVE-Flexible according to **Section 430: Pavement Design Using MnPAVE-Flexible**.
- (3) Specify the mix type, ride specification, lift thicknesses, and compaction requirement using **Section 450: Materials and Specification**.

## 2. Crack and seat ((2231) Pavement Cracking Special Provision and (2231) Pavement Seating Special Provision)

The crack and seat process involves cracking the existing PCC pavement, firmly seating the pieces, then paving a HMA pavement. The intention is to reduce the size of the PCC pieces to minimize movements at existing cracks and joints. This will minimize the frequency and severity of reflective cracking. It is an especially useful technique when moving or rocking panels have been identified. The pavement cracking special provision specifies cracking at 3 to 4-foot intervals but modifying the intervals to 1.5 feet has shown satisfactory performance.

## C. Evaluation and pre-HMA paving repairs.

- (1) Establish the material and condition of the existing subgrade with borings (see **Section 220: Borings**). Roadways with wet subgrades are poor crack and seat candidates. However, wet subgrades may be remedied by installing subsurface drains a year prior to performing the crack and seat.
- (2) Remove any existing HMA overlay of the PCC pavement before crack and seating.
- (3) Repair spot areas of poor subgrade support or bad joints and patch the pavement with full depth HMA.
- (4) When edge-drains do not exist, install edge-drains prior to crack and seating or remove the shoulders and daylight the base and subbase so that any water that gets into the PCC has a way to drain.

D. Design the HMA pavement.

- (1) Use a minimum HMA pavement thickness of 4.0 inches.
- (2) A layer of permeable asphalt stabilized base (PASB) or permeable asphalt stress relief course (PASSRC) (specification 2363) is recommended as the first layer of HMA to reduce or delay any reflective cracking. This layer does not contribute towards the minimum HMA requirement.
- (3) For crack and seat projects that use a PASB or PASSRC layer use a design life of 20 years. Otherwise, use the HPMA program to predict the performance of the crack and seat project (see **Section 280: Pavement Management System**, steps 1-7B for directions) in order to determine when a rehabilitation activity will occur. The number of years until a rehabilitation activity occurs is the design life. **Table 440.2** or experience may be used to determine the design life if it clearly demonstrates that a different value than derived from the HPMA program should be used.
- (4) Specify the mix type, ride specification, lift thicknesses, and compaction requirement using **Section 450: Materials and Specification**.

## Section 430: Pavement Design using MnPAVE-Flexible

MnPAVE-Flexible is a mechanistic-empirical (M-E) pavement thickness design program for HMA pavements. It calculates the stresses and strains in the roadway from traffic loading and material properties for the pavement layers. Then the calculated stresses and strains are used with empirically derived equations to predict fatigue cracking (bottom-up) and rutting in the roadway. The final output is the reliability that the pavement structure will successfully meet fatigue and rutting requirements when evaluated with a Monte Carlo simulation.

MnPAVE-Flexible is a computer program that combines known empirical relationships with a representation of the mechanics from layered elastic theory used in modeling flexible pavement behavior. The mechanistic portions of the program calculate the tensile strain at the bottom of the asphalt layer, the compressive strain at the top of the soil, and the maximum principal stress 6.0 inches from the top of the aggregate base layer (or at the bottom of the base if it is 6.0 inches or thinner).

MnPAVE-Flexible consists of three input modules: climate, traffic, and structure; and three design levels: basic, intermediate, and advanced. The level is selected based on the amount and quality of information known about the material properties and traffic data. In the basic mode, only a general knowledge of the materials and traffic data are required. The intermediate level corresponds to the amount of data currently required for MnDOT projects. The advanced level requires the determination of modulus values for all materials over the expected operating range of moisture and temperature.

MnPAVE-Flexible simulates traffic loads on a pavement using a layered elastic analysis (LEA) called WESLEA. It is a five-layer analysis program written in 1987 by Frans Van Cauwelaert at the Catholic Superior Industrial Institute Department of Civil Engineering in Belgium and modified in 1989 by Don R. Alexander at the U.S. Army Engineer Waterways Experiment Station in Vicksburg, Mississippi. All layers are assumed to be isotropic (same properties in all directions) and infinite in the horizontal direction. The fifth and final layer is assumed to be semi-infinite in the vertical direction. Material inputs include layer thickness, modulus, Poisson's ratio, and an index indicating the degree of slip between layers. MnPAVE-Flexible assumes zero slip at all layer interfaces. All stresses and strains are considered to be within the elastic range of the material (no permanent deformation). Other inputs include load and evaluation locations. Loads are characterized as being circular and are expressed in terms of pressure and radius. The LEA program calculates normal and shear stress, normal strain, and displacement at specified locations.

Output includes the expected life of the pavement, which is calculated using a damage factor based on Miner's Hypothesis. Reliability is estimated using Monte Carlo simulation. There is also a batch section for testing a range of layer thicknesses. In Research Mode (accessible from the "View" menu in the main MnPAVE-Flexible window), output includes various pavement responses for each season. **Note: DO NOT design projects in research mode!**

## 1. Installing MnPAVE-Flexible

**Note: An IT professional may be required for installation, if you do not have administrator rights.**

The installation file can be downloaded from the [MnPAVE-Flexible website](#).

- A. Left-click on “Download MnPAVE Flexible” and follow the prompts and instructions to start the MnPAVE Setup Wizard:
- B. Use the MnPAVE Setup Wizard to determine the location that MnPAVE files and folders will use and install MnPAVE-Flexible.
  - The executable MnPAVE.exe and Help files will be placed in “Program Files\MnDOT\MnPAVE” unless a different location is specified.
  - A MnPAVE folder will be added to the Windows Start Menu, unless a different folder is specified.
- C. Finish. At this point there will be a MnPAVE icon on the desktop and in the Windows Start menu under the folder name specified in **Step F**.

## 2. Using MnPAVE-Flexible

- A. Starting the program.

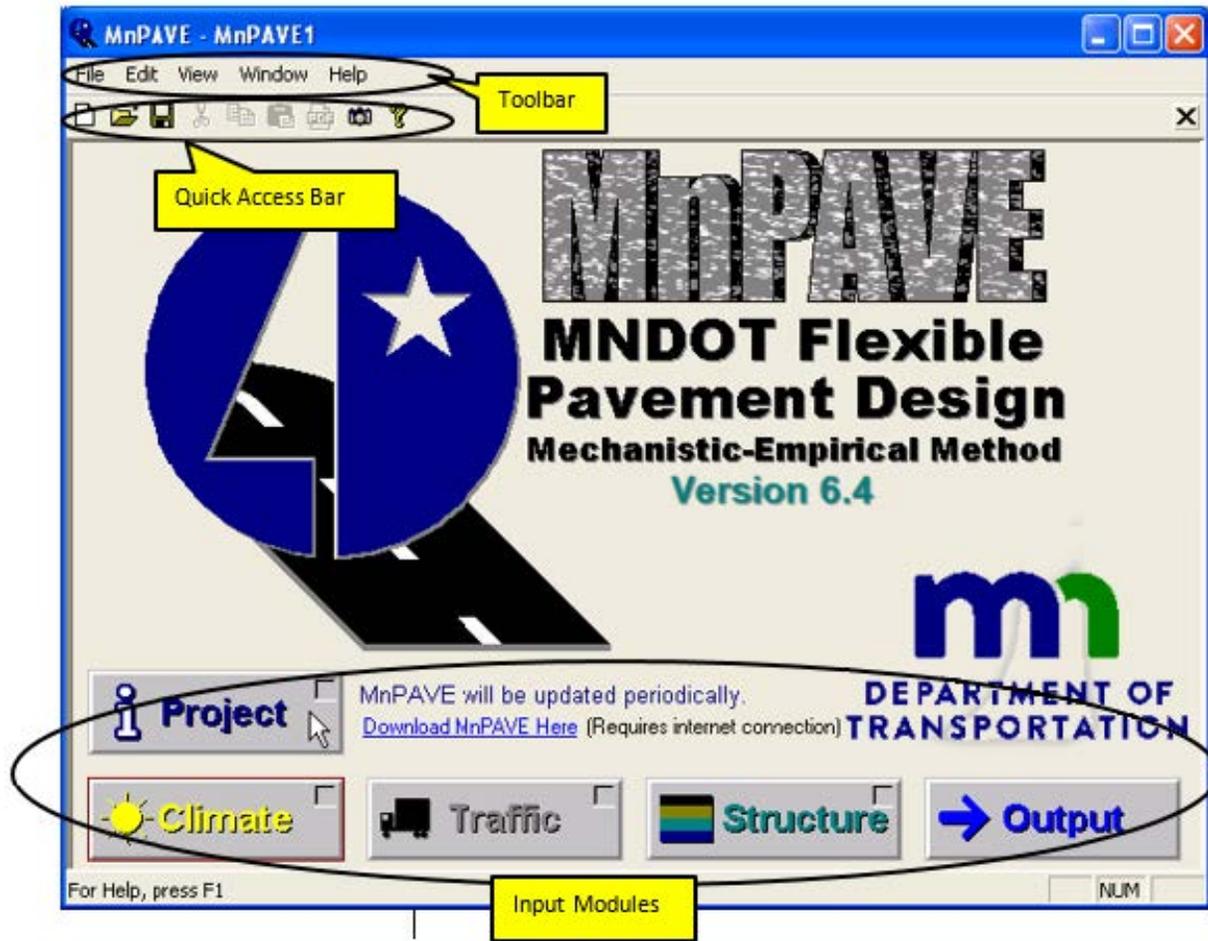
The program can be started by double-clicking on the MnPAVE icon on the desktop or selecting MnPAVE from the Windows Start, select programs, then selecting the folder name specified in **Step F** of **Section 430.1** (the default is MnPAVE).

- B. Main Control Panel.

MnPAVE-Flexible initially opens to the Main Control Panel (shown in **Figure 430.1**). The Main Control Panel contains 5 input modules, a toolbar and a quick access bar that contain several utilities.

MnPAVE-Flexible designs are performed by completing the modules in order from left to right. A module will not become available for input until the preceding module has sufficient inputs.

Figure 430.2 – MnPAVE-Flexible Main Control Panel



### C. Opening and saving a file.

MnPAVE-Flexible will automatically open to a new project. It is recommended to begin a design by saving the new project. MnPAVE-Flexible saves project files to an .mpv file format that is unique to MnPAVE-Flexible. A filename that includes the SP number is recommended.

The following commands can be used to open and save MnPAVE-Flexible files.

- (1) The current file can be **saved** by clicking on  , located on the quick access bar or by selecting "Save" from the "File" menu of the toolbar.
- (2) Changes can be **saved as** a new file name by selecting "Save As" from the "File" menu.
- (3) A **new** MnPAVE-Flexible file can be **opened** by clicking on the  icon or by selecting "New" from the "File" menu on the toolbar.
- (4) An **existing** MnPAVE-Flexible file can be **opened** by clicking on the  icon or by selecting "Open" from the file menu. A recently saved file can also be selected from the list at the bottom of the "File" menu of the toolbar.

#### D. Project Information Module

The Project Information Module is a form for entering information necessary to identify a MnPAVE-Flexible project. MnDOT district, county, city, highway, construction type, design engineer, and project notes are entered in this module. This data will be retained with the saved MnPAVE-Flexible file and it will appear on the final design printout.

Identifying the county of the project in the Project Information Module will also locate the project in the Climate Module. This may be the easiest and most convenient method to locate the project in the Climate Module. MnPAVE-Flexible will identify the location of the climate data as the center of the county. The Climate Module will still need to be accessed before proceeding to the next module will be allowed.

In the notes section,

- For full-depth reclamation (FDR), stabilized full-depth reclamation (SFDR), or cold-in-place recycling (CIR) projects, identify the existing pavement layers and any milling used in the pavement design.
- Identify any assumptions that were used for the pavement design.

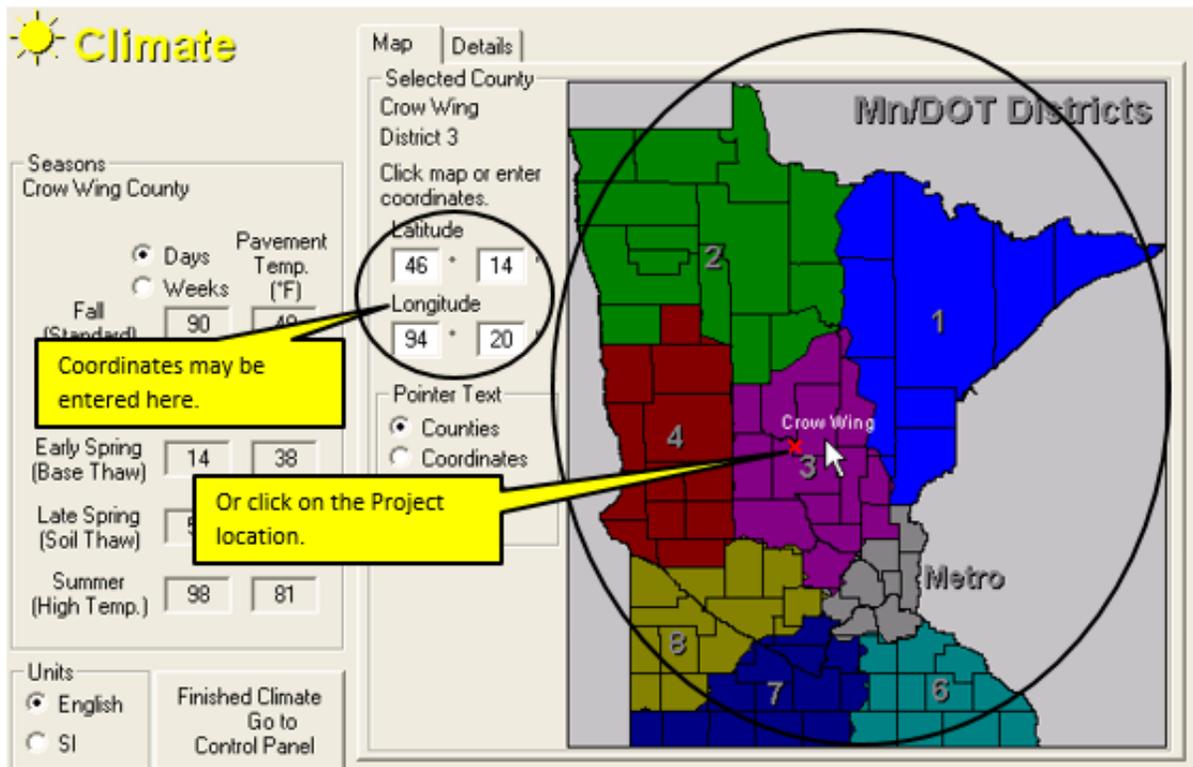
Figure 430.3 - Project Information Module

The screenshot shows a web-based form titled "Project Information" with an information icon on the left. The form contains several input fields and a text area. At the top, there are dropdown menus for "District" (value: 3) and "County" (value: Crow Wing), and a "View" section with radio buttons for "All Counties" and "By District" (selected). Below these are text boxes for "Project No." (100), "Route" (CR1331), and "City" (n/a). The "Reference Post (RP)" section has two boxes: "0.00" and "2.00" with "to" between them, and a "Letting Date" dropdown (7/ 2/2012). The "Construction Type" is a text box with "2360". There are two text boxes for "Designer" and "Soils Engineer", both containing "MnPAVE". At the bottom is a large text area labeled "Notes" with the placeholder text "(Type any project details here that should be documented in the report.)". At the very bottom, there is a "Go Back to Control Panel" button with a mouse cursor and a link "View Mn/DOT Bituminous Specifications (Requires internet connection)".

### E. Climate Input Module

The Climate Input Module is where the project location is specified so that MnPAVE-Flexible can determine the local climate. The Climate Input Module contains a set of coordinates and a Minnesota map and is shown in **Figure 430.3**. If the longitude and latitude are known, those coordinates can be directly inputted into the module. Otherwise, left click on the map at the project location.

Figure 430.3 - Climate Module

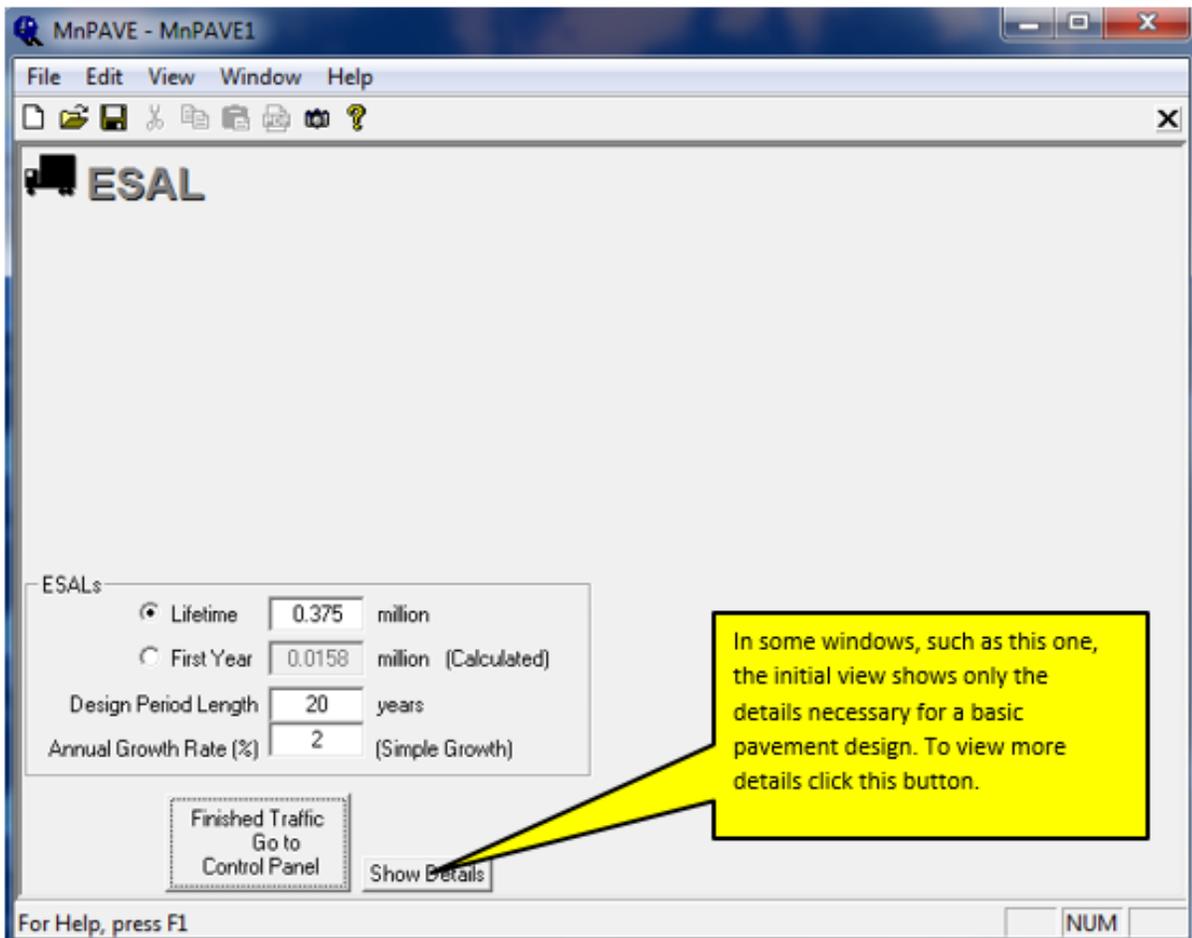


## F. Traffic Module

This module is where traffic data and design life is entered.

- (1) Select “Lifetime” and enter the 20-year flexible ESALs (BESALs) which can be found on the project traffic forecast. MnPAVE-Flexible also requires an ESAL annual growth rate which may also be found on the traffic forecast, although 2% is provided as a reasonable default.
- (2) Specify the design period length as “20” years.

Figure 430.4 - Traffic Module



## G. Structure Module

In the Structure Module, the layers of the pavement structure are identified, by up to five layers. The user defines the layer thicknesses and materials and may specify some material properties. MnPAVE-Flexible assigns material properties to the layers based on the user-defined materials and then creates a model of the pavement structure.

As a rule for MnPAVE-Flexible, **use average values for all material inputs.** MnPAVE-Flexible methodology is based on the expectation that any inputs are average and procedures are included to account for variability in the materials. Outliers may be removed prior to determining the averages but no reliability factor should be applied.

- (1) The HMA Mix Properties Form (see **Figure 430.5**) opens when the Structure Input Module is initially accessed. This form may also be accessed on the “select sub-type” section of the Structure Module at a later time. This input screen is where the HMA binder grade is specified. Click on “show details” to select the percent binder content and gradation. If there are layers (or in MnPAVE-Flexible “lifts”) of HMA with differing binder grades, binder content, or gradation then the properties of each layer may be specified here for up to three “lifts.”
  - a. The HMA Mix Properties Form is where the expected traffic speed is specified. This is an important input for MnPAVE-Flexible. HMA is a viscoelastic material and is sensitive to the rate of loading. HMA behaves much stiffer with shorter loading (i.e., faster traffic). Conversely, the slower traffic moves, the more time it has to load the HMA and the more it behaves as a liquid. The standard is to specify the posted speed limit as the expected speed.
  - b. When this form is completed, click “OK” to continue to the Structure Input Module.

**Figure 430.5 – HMA Mix Properties Form**

**MnPAVE - HMA Mix Properties**

Screen Capture Help

HMA Mix Properties

Layer   Expected traffic speed (mph)

Equivalent Thickness  HMA SN = 2.1

HMA Lift *	Binder Grade	Thickness (in.)	Binder content (% by wt. of mix)	Mn/DOT Spec.	Nom. Max. Size	Percent Passing				Advanced
						3/4"	3/8"	#4	#200	
<input type="radio"/> 1	PG58-34	4	5	2360 Fine	1/2"	100	85	63	5	Advanced
<input checked="" type="radio"/> 2	PG58-28	2	5	2360 Fine	1/2"	100	85	63	5	Advanced
<input type="radio"/> 3										

\* The term "Lift" is used here to differentiate between HMA layers.

Appears when the "Show Details" button is clicked.

- (2) The Structure Input Module (see **Figure 430.6**) opens to the Basic Inputs tab. Here the layer thicknesses and material types are defined.

In the edit structure area, the structure may be defined by up to 5 layers but may be as few as 3.

- a. The top layer is always HMA. You may click on the HMA layer in the “Select Subtype” area to edit the HMA Mix Properties form (See the previous section).

- b. Aggregate/granular layers.

Aggregate base (AggBase), subbase, rubblized portland cement pavement (RPCC), SFDR, and CIR may be selected as layers in the edit structure area. Aggregate base (AggBase) and subbase will need to be further defined in the “select subtype” area (on the right). FDR is available as a subtype of aggregate base.

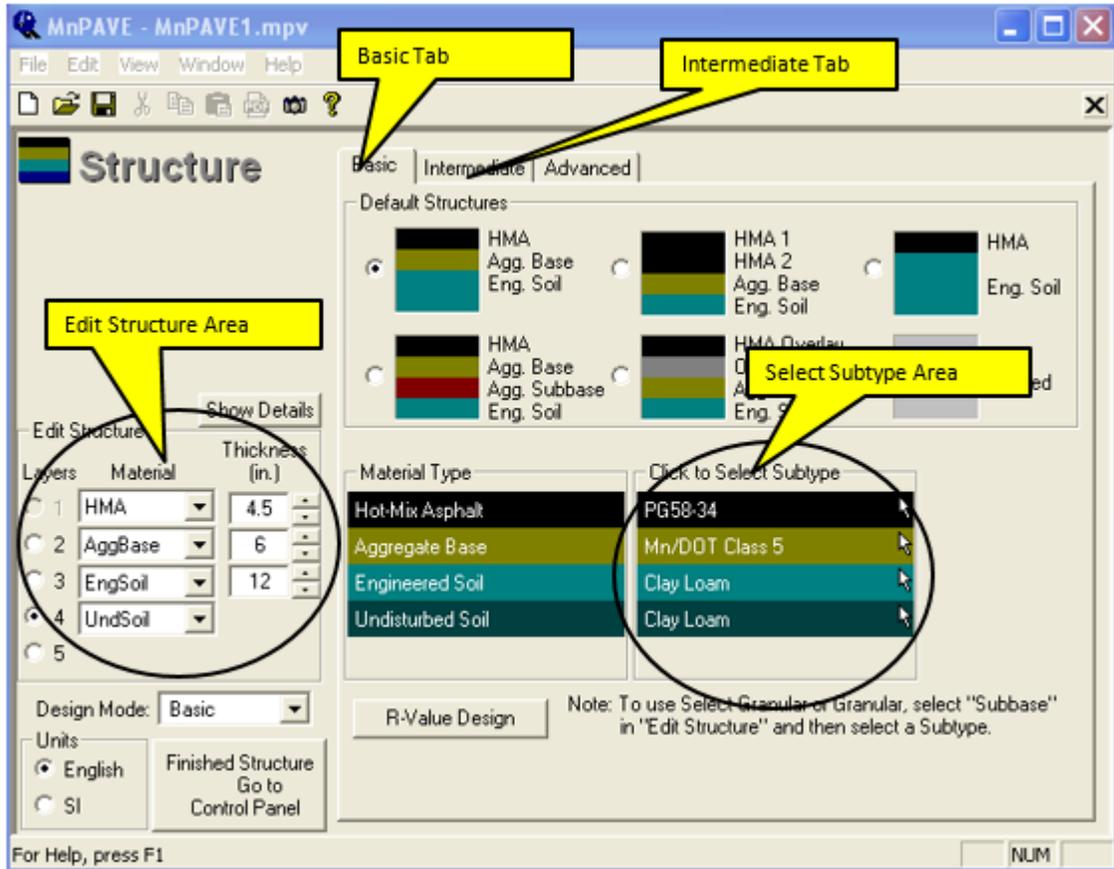
The pavement structure may only include two aggregate/granular layers. These include layers defined as AggBase, Subbase, RPCC, SFDR, and CIR. If the pavement structure includes more than two aggregate/granular layers then “Multi-Layer” may be selected as a subtype of an aggregate base or subbase layer. Within the “Multiple Aggregate Layers” form, the layer can be defined by up-to three layers of different aggregate/granular materials and MnPAVE-Flexible will combine their properties into one composite layer.

When performing a CIR pavement design, include the thickness of any remaining existing HMA with the thickness of the CIR layer. For example, 6 inches of existing HMA will have the top 4 inches recycled as CIR and 2 inches of existing HMA will remain undisturbed. Define this in the pavement structure as one 6-inch layer of CIR.

- c. Define the next to bottom layer as engineered soil and the bottom layer as undisturbed soil.

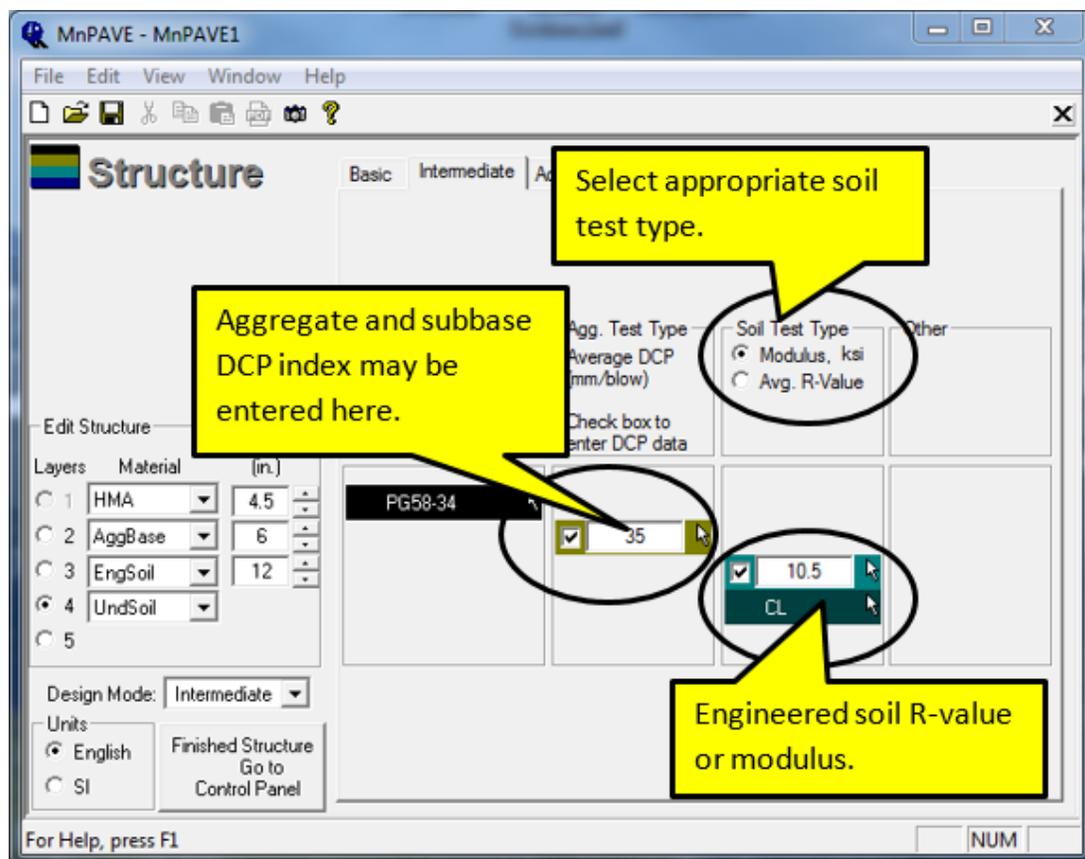
Engineered soil represents soil that has been blended and re-compacted. Its thickness is normally the depth of any subcut that is backfilled with select grading material or the depth of any subgrade preparation (see **Chapter 3: Pavement Subsurface**). If the project will not disturb the existing soil, the roadway soil is assumed to have been previously engineered or has been in place long enough to behave as an engineered soil; and the engineered soil layer is specifies as being 12.0 inches thick.

Figure 430.6 – Structure Input Module – Basic Tab



- i. Choose a soil type by clicking on the soil layers in the select subtype area.
- ii. The intermediate tab of the Structure Input Module allows you to enter strength parameters for aggregate, subbase, and engineered soil.
- iii. If DCP testing has been performed on the in-place material, the DCP index may be entered for an aggregate or subbase layer by checking the layer checkbox and entering the value. Do not check the check box without entering a value.
- iv. If the soil has a known R-value or subgrade modulus, apply this value to the engineered soil layer. Enter this number by selecting the appropriate soil test type, checking the layer checkbox and entering the value. Use the average value of any testing. The engineered soil is always the second to the last layer.
- v. MnPAVE–Flexible always applies  $\frac{1}{2}$  the engineered soils R-value to the undisturbed soil which must always be the bottom layer.

Figure 430.7 – Structure Module – Intermediate Tab



## H. Output Module

The Output Module (see **Figure 430.10**) is where the reliability and life expectancy of the pavement structure is shown. MnPAVE–Flexible models the effect of traffic and climate on the proposed pavement structure while taking in account variations in layer strengths and thicknesses.

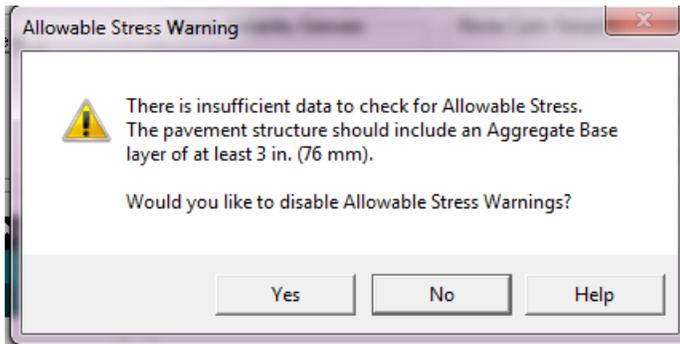
**Note:** All final designs must meet reliability requirements when using the Monte Carlo simulation.

(1) The following describes the three different ways that MnPAVE-Flexible models variations and reliability:

- a. The quickest way to model the thickness and strength of the layers is to use a 70% confidence level. This accounts for variations in the pavement structure and reliability by simply reducing the strength and thickness of the pavement layers. MnPAVE-Flexible is able to calculate the estimated years to failure, for fatigue and rutting, almost immediately using this method. The estimated life shown on the left side of the Output module is determined with this method.  
  
Allowable stress is also calculated using this method. The allowable stress is the maximum stress allowed in the aggregate base layer due to a single heavy load event. A warning will appear immediately if the allowable stress criteria are not met. The allowable stress warning will indicate the minimum HMA thickness required to meet the allowable stress criteria.
- b. Quick reliability is an estimate of a Monte Carlo simulation.
- c. The Monte Carlo simulation is the slowest calculation of the three methods. The time for running this process ranges from less than one minute to a few minutes. The Monte Carlo simulation calculates the life of the pavement many times over. Each time, it varies the pavement layers' strengths and thicknesses based on their averages and variances. The reported reliability is the percentage of these calculated lives that met or exceeded the required design life.

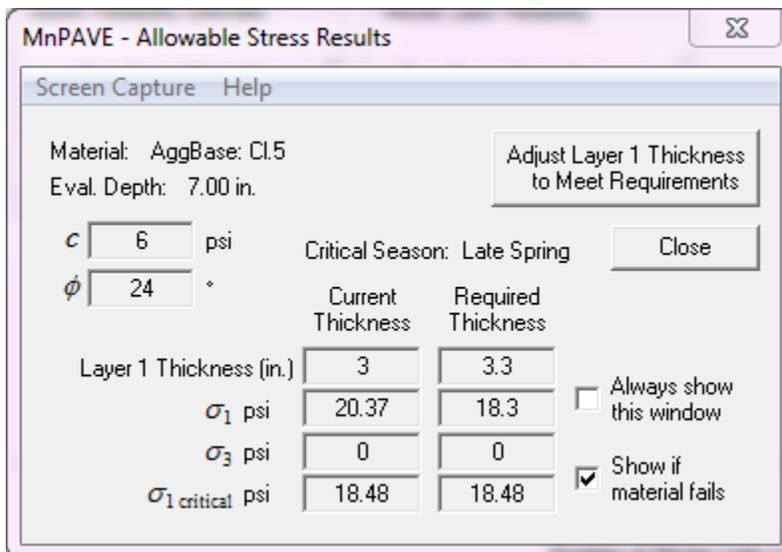
- (2) Upon opening the Output module an “Allowable Stress Warning” may appear, see **Figure 430.8**. This warning appears if the pavement structure has less than 3” of aggregate base material and consequently the stress in the aggregate layer cannot be calculated. If the pavement structure is intended to have less than 3” of aggregate base then disable the warning by clicking “Yes” and continue with the design output.

**Figure 430.8 – Allowable Stress Warning**



- (3) Upon opening the Output module an “Allowable Stress Results” message may appear, see **Figure 430.9**. This message appears when the allowable stress from a heavy, one-time load is calculated to exceed allowable stress in the base and indicates that the pavement structure must be improved. Clicking the “Adjust Layer 1 to Meet Requirements” button will close the message and add the minimum amount of thickness to the top layer so that allowable stress requirements are met. Otherwise, click “Close” and manually add pavement structure so that the requirements will be met.

**Figure 430.9 – Allowable Stress Results**



- (4) When the Output Module opens, it immediately calculates the estimated pavement life using a 70% confidence level. The “thickness goal seek” button can be used to optimize the layer thicknesses so that the lowest estimated life (fatigue or rutting) equals the design life. The user has the option to choose the layer to be optimized.

When “thickness goal seek” is used for non-HMA layers, the HMA layer will be adjusted for fatigue first (if necessary), and then the selected layer thickness will be adjusted. This is because adjusting underlying layers has a relatively small effect on fatigue life and may result in very thick layers.

The user may also manually change the thickness of the pavement layers. After any changes, the recalculate button must be clicked to recalculate the estimated lives with the new thicknesses.

- (5) The Quick Reliability simulation may be initiated prior to the Monte Carlo simulation to further refine the trial pavement design.
- (6) The final pavement design must meet the minimum reliability requirements of the Monte Carlo simulation for rutting and fatigue. According to the Monte Carlo simulation the final pavement design must have a reliability of
- $\geq 85\%$  for less than 1 million flexible ESALs
  - $\geq 90\%$  for 1 million to 15 million flexible ESALs
  - $> 95\%$  for more than 15 million flexible ESALs
- (7) Whenever possible, the fatigue and rutting years should be within 5 years of each other to optimize the HMA and granular material thicknesses.
- Fatigue life is largely an effect of HMA thickness.
  - Rutting life is largely an effect of granular material thickness.
- (8) Report the final pavement design.

#### I. Reports

A summary report can be saved as PDF file by clicking on the PDF icon on the quick access bar or by selecting "PDF Design Summary" from the "File" menu.

A screen shot of the output window can be saved by clicking on the camera icon on the quick access bar. Most other windows have a camera icon that can be clicked to print a screen shot.

Figure 430.10 – Output Module

The screenshot shows the Output Module interface with several callout boxes:

- Thickness Goal Seek:** Adjusts the selected layer thickness to provide a 20-year Estimated Life.
- Quick Reliability:** An estimate of the Monte Carlo Simulation.
- Monte Carlo Simulation:** The reliability of the pavement structure.
- Fatigue:** >50
- Rutting:** 21
- Estimated Life:** Base on 70% confidence.
- Adjust Materials:** Layer thicknesses may be adjusted here.
- Recalculate:** Click this button after adjusting any layer thicknesses to recalculate the Estimated Life.

The interface includes the following data and controls:

- ESAL: 375,000
- Preliminary Design: Thickness Goal Seek
- Layer 1 (selected) / 2
- Years: 20
- Run Quick Reliability (100%) and Run Monte Carlo Simulation (100%) buttons.
- Fatigue Estimate: 100% and Rutting Estimate: 85%.
- Fatigue Reliability: 100% and Rutting Reliability: 88.6%.
- Adjust Materials table:
 

Material	H (in.)
HMA: PG58-34	4.5
AggBase: CL5	6
EngSoil: CL	10
UndSoil: CL	
- Recalculate button.
- Units: English (selected) / SI.
- Go Back to Control Panel button.
- Number of Monte Carlo Cycles: 2500 (with Edit Cycles button).

## Section 440: HMA Overlay of Existing Pavement

HMA overlays are placed on existing, intact HMA or PCC pavement that has not been processed (e.g., FDR, CIR, or rubblization). Typically, HMA overlays are less than 5.0 inches thick.

The performance of an HMA overlay is dependent on the condition of the existing pavement. Existing cracks, especially transverse thermal cracks, will reflect through the new HMA overlay which commonly limits the life of HMA overlays. Additionally, frost heaves, subgrade failures, severe stripping, or rutting of the aggregate base layer may also limit the performance of any HMA overlay if not repaired. If the roadway has considerable distresses that will limit the life of an HMA overlay, then consider other rehabilitation techniques. Existing PCC pavements that exhibit movement (i.e., rocking) are not recommended for a HMA overlay. Instead, to eliminate any movement, use the crack and seat or rubblization processes (see **Section 420 – Rubblization and Crack and Seat**).

Use this section to design HMA overlays of intact HMA or PCC pavements.

### 1. Use of milling

HMA pavements are often milled prior to placement of a HMA overlay. Leave a sufficient thickness of existing HMA to support any traffic or construction activities until the HMA overlay is placed. Milling is used for the following reasons:

- A. Milling will help restore the profile of the existing pavement's surface, remove patching and sealing materials that may bleed through the overlay, and remove surface distresses that otherwise might have reflected through the overlay. Typically, milling more than 2.0 inches is not necessary to attain these benefits.
- B. Milling may be used to flatten any bumps or dips in the existing HMA.
- C. Milling may be used to remove any stripped or debonded layers in the existing HMA. If the debonded or stripped layers are too deep to be removed, adjust the milling depth to leave a sufficient thickness of existing HMA to support any traffic or construction activities until the HMA overlay is placed.
- D. Milling may also be used to lower the existing road surface profile to lessen the grade raise due to placing an overlay.

## 2. Establishing cross-slope

A proper pavement cross-slope (.02 feet/foot) may be constructed by either of these methods.

- A. Mill the existing HMA pavement at its existing cross-slope and pave the HMA overlay with variable thickness to produce the proper pavement cross-slope.
- B. Mill the existing HMA pavement at the proper pavement cross-slope and pave the HMA overlay at one consistent thickness.

## 3. HMA overlay design life and thickness

- A. The design life of an HMA overlay is the number of years until a rehabilitation activity will occur. Use the HPMA program to predict the performance of the HMA overlay (see **Section 280: Pavement Management System, steps 1-7B** for directions) to determine when a rehabilitation activity will occur; unless **Table 440.1** or **Table 440.2**, or experience, clearly demonstrates that a different value should be used.
- B. For HMA roads that have a seasonal load restriction of less than 10 tons, the thickness of the HMA overlay necessary to remove the restriction may be calculated using the TONN program and Falling Weight Deflectometer (FWD) data. See **Section 200: Falling-Weight Deflectometer (FWD)** for guidance in getting and processing FWD data.

## 4. Background of **Tables 440.1** and **440.2**

**Tables 440.1** and **Table 440.2** are the result of a survey, originally performed in 1993, of the District Materials Engineers and Central Office Pavement Engineers. Averages and standard deviations of the survey were calculated and outliers (more than 2 standard deviations away from the average) were eliminated. The averages and standard deviations were recalculated. The tables basically consist of these averages and ranges, with very minor modifications for uniformity.

These tables were compared to the historical performance of HMA overlays using MnDOT's pavement management system to verify that the design life averages and ranges in these tables are still applicable. It was determined that the design lives and ranges contained in the tables are reasonable and remain applicable.

**Table 440.1 - Design lives of HMA overlays of existing HMA**

Thickness/Milling	Surface Condition	High ESALs	Med ESALs	Low ESALs
Thin (≤2") Overlay	GOOD	5-9	6-12	8-14
Thin (≤2") Overlay	FAIR	4-8	6-10	6-12
Thin (≤2") Overlay	POOR	2-6	4-8	6-10
Mill & Thin (≤2") Overlay	GOOD	6-10	7-13	9-15
Mill & Thin (≤2") Overlay	FAIR	5-9	6-12	7-13
Mill & Thin (≤2") Overlay	POOR	3-8	5-9	6-12
Medium (2" - 4") Overlay	GOOD	8-12	10-14	11-17
Medium (2" - 4") Overlay	FAIR	6-10	8-12	10-14
Medium (2" - 4") Overlay	POOR	5-9	6-10	8-12
Mill & Medium (2" - 4") Overlay	GOOD	8-14	10-16	12-18
Mill & Medium (2" - 4") Overlay	FAIR	6-12	8-14	10-16
Mill & Medium (2" - 4") Overlay	POOR	5-11	7-13	9-15
Thick (> 4") Overlay	GOOD	11-15	13-17	14-20
Thick (> 4") Overlay	FAIR	9-13	11-15	12-18
Thick (> 4") Overlay	POOR	7-11	9-13	11-15
Mill & Thick (> 4") Overlay	GOOD	12-16	14-18	16-22
Mill & Thick (> 4") Overlay	FAIR	10-14	12-16	14-21
Mill & Thick (> 4") Overlay	POOR	9-13	11-15	13-19

**Table 440.1.x – Traffic Key for Table 440.1**

High ESALs	Med ESALs	Low ESALs
More Than 5 Million 20-year Flexible ESALs	1 to 5 Million 20-year Flexible ESALs	Less Than 1 Million 20-year Flexible ESALs

**Table 440.1.y – Surface Condition Key for Table 440.1**

GOOD	FAIR	POOR
Minimal Stripping & No Rutting	Severe Transverse Cracking or Minimal Rutting or Some Stripping	Severe Rutting, Severe Stripping or Severe Multiple Cracking

**Table 440.2 - Design lives of HMA overlays of existing PCC**

Thickness/Milling	Surface Condition	High ESALs	Med ESALs	Low ESALs
Thin ( $\leq 2''$ ) Overlay	GOOD	4-8	5-9	6-12
Thin ( $\leq 2''$ ) Overlay	FAIR	2-6	4-8	5-9
Thin ( $\leq 2''$ ) Overlay	POOR	1-5	2-6	4-8
Mill & Thin ( $\leq 2''$ ) Overlay	GOOD	4-8	5-11	6-14
Mill & Thin ( $\leq 2''$ ) Overlay	FAIR	3-7	5-9	5-11
Mill & Thin ( $\leq 2''$ ) Overlay	POOR	1-5	3-7	5-9
Medium (2'' - 4'') Overlay	GOOD	6-10	8-12	10-14
Medium (2'' - 4'') Overlay	FAIR	4-8	6-10	8-12
Medium (2'' - 4'') Overlay	POOR	3-7	4-8	6-10
Mill & Medium (2'' - 4'') Overlay	GOOD	7-11	9-13	10-16
Mill & Medium (2'' - 4'') Overlay	FAIR	5-9	7-11	8-14
Mill & Medium (2'' - 4'') Overlay	POOR	4-8	6-10	6-12
Thick ( $> 4''$ ) Overlay	GOOD	9-13	11-15	13-17
Thick ( $> 4''$ ) Overlay	FAIR	8-12	10-14	11-15
Thick ( $> 4''$ ) Overlay	POOR	6-10	8-12	10-14
Mill & Thick ( $> 4''$ ) Overlay	GOOD	10-14	11-17	13-21
Mill & Thick ( $> 4''$ ) Overlay	FAIR	9-13	10-16	11-19
Mill & Thick ( $> 4''$ ) Overlay	POOR	7-11	8-14	9-17

**Table 440.2.x – Traffic Key for Table 440.2**

High ESALs	Med ESALs	Low ESALs
More Than 5 Million 20-year Flexible ESALs	1 to 5 Million 20-year Flexible ESALs	Less Than 1 Million 20-year Flexible ESALs

**Table 440.2.y – Surface Condition Key for Table 440.2**

GOOD	FAIR	POOR
Minimal Stripping & No Rutting	Severe Transverse Cracking or Minimal Rutting or Some Stripping	Severe Rutting, Severe Stripping or Severe Multiple Cracking

## Section 450: Materials and Specifications

Use this section to help determine HMA materials (provided with a Mixture Designation Code) and other specifications that are included in a Materials Design Recommendation (MDR). For more information and/or assistance on HMA materials, contact the [MnDOT Bituminous Engineering Unit](#) (Office of Materials and Road Research).

### 1. Mixture Designation Code

The Mixture Designation Codes are used to specify HMA mixes and a Mixture Designation Code for each HMA mix on a project must be included in the project's MDR. There may be several different HMA mixes designated on a single project, although, judgment should be used to minimize the total number of different HMA mixes. Typically, it is not economical to specify another bituminous mixture for less than 2,000 tons. Examples of areas that may have different mixes on a project include; mainline wearing course, non-wearing course, shoulders, temporary pavements, local roads, multi-use trails, and others.

A. **The Mixture Designation Code** uses the following format:

**SP WE B 3 30 B**  
a b c d e f

- a. 1<sup>st</sup> two letters are the mix design procedure – **SP** (Superpave gyratory mix design) or **SM** (stone matrix).
- b. 2<sup>nd</sup> two letters are the course – **WE** (wear course) or **NW** (non-wear course).
- c. 5<sup>th</sup> letter is the maximum aggregate size – **A** through **D**.
- d. 6<sup>th</sup> digit is the design traffic level – **2** through **6**.
- e. 7<sup>th</sup> and 8<sup>th</sup> digits are the design air voids – **40** (4.0% for wear course) or **30** (3.0 for non-wear course and Low-Volume Non-Trunk Highway Wear Course).
- f. Last letter is the asphalt binder grade – **A, B, C, E, F, H, I, L** or **M**.

B. Begin with **Table 450.1** to determine the proper **Mixture Designation Code(s)**.

**Table 450.1 - Mixture Designation**

Mixture Course	Code Format
Non-wear (4.0 inches below pavement surface)**	<b>SPNW (1)*(2)*30(3)*</b>
Wear (top 4.0 inches of pavement)**	<b>SPWE (1)*(2)*40(3)*</b>
Shoulder Wear & Low Volume Non-Trunk Highway Wear	<b>SPWE (1)*(2)*30(3)*</b>
Stone Matrix Asphalt (SMA) >30 million ESALs	<b>SMWEE640H</b>

\* Select (1) Aggregate size, (2) Traffic Level and (3) Asphalt Binder Grade as shown below

\*\* The wearing course may be reduced to 3.0 inches for non-trunk highways with traffic levels <3 million ESALs.

(1) Aggregate size.

**Table 450.2 - Aggregate Size and Recommended Minimum Lift Thickness**

Code Letter	Maximum Aggregate Size, Superpave (mm)	Nominal Maximum Aggregate Size	Minimum Lift Thickness
A	SP 9.5	1/2 inch	1.5 inch
B	SP 12.5	3/4 inch	2.0 inches
C	SP 19.0	1 inch	3.0 inches
D	SP 4.75	3/8 inch	0.75 inch

Typically, aggregate size **A** or **B** is specified in asphalt paving mixtures. Aggregate size **A** provides a finer, tighter pavement surface and tighter longitudinal joints. Aggregate size **B** is coarser. Lift thickness should be considered when selecting aggregate size. Aggregate size **A** may be specified for the final lift only with aggregate size **B** used for all underlying lifts. However, aggregate size **A** may be placed on all lifts when it is economically feasible. With the approval of the Engineer, the Contractor may supply a gradation with a smaller maximum aggregate size than that specified (i.e. **A** instead of **B**).

(2) Design traffic level.

**Table 450.3 - Traffic Level**

Traffic Level	20-year Design ESALs
2	<1 million (AADT < 2,230)
3	1 - <3 million (AADT >2,300 to <6,000)
4	3 - <10 million
5	10 - ≤30 million
6	> 30 million

Note 1: Specify a minimum of Traffic Level 3 for mainline pavements of state highways.

Note 2: For slow traffic consider designating a higher traffic level. Contact the MnDOT Bituminous Engineer for guidance.

Note 3: SMA (Stone Mastic Asphalt) is a premium stone on stone mix intended only for the highest traffic volume facilities. Contact the MnDOT Bituminous Engineer for guidance regarding SMA.

(3) Asphalt binder grade letter

The asphalt binder grade letter is used to identify the PG Binder Grade. The MnDOT PG binder grades follow AASHTO M332 (MSCR) which includes the Multiple Stress Creep Recovery test to characterize high temperature performance. The standard MSCR PG grades for Minnesota are PG58, followed by the traffic loading designation and then the minimum pavement design temperature. For example: PG58S-XX, PG58H-XX, PG58V-XX, and PG58E-XX. The traffic loading designations are S (standard), H (high), V (very high) and E (extremely high). The asphalt binder grade letter and the PG grade (with and without MSRC designation) are shown in **Table 450.4** and the recommended asphalt binder grades for typical applications are shown in **Table 450.5** and **Table 450.6**.

Specify MSCR PG binder grades in all MDR's. Since, at the present time, there is a transition to MSCR PG binder grades **Table 450.4** shows both MSCR PG grading and the equivalent PG grade.

To use MSCR PG binder grading it is necessary for the MDR to contain instructions to include special provisions for (2360) Plant Mixed Asphalt Pavement (MSCR) and (3151) Bituminous Material (MSCR) in the contract documents. Special provisions are available in the "Boiler Plate" on the [MnDOT Special Provision website](#).

**Table 450.4 - PG Asphalt Binder Grade Letters**

Letter	MSCR PG Grade	Equivalent PG Grade
A	PG 52S-34	
B	PG 58S-28	PG 58-28
C	PG 58H-34	PG 58-34, PG 58-34(PMB)
E	PG 58H-28	PG 64-28, PG 64-28(PMB)
F	PG 58V-34	PG 64-34, PG 64-34(PMB)
H	PG 58V-28	PG 70-28, PG 70-28(PMB)
I	PG 58E-34	PG 70-34
L	PG 64S-22	
M	PG 49S-34	

**Table 450.5 - Recommended Asphalt Binder Grade for Mainline**

Type of Construction	<3 million 20-year ESALs	3 -10 million 20-year ESALs	>10 million 20-year ESALs
<b>Overlay</b> , wear course (Top 4.0 inches) <sup>3</sup>	<b>B</b> (PG 58S-28)	<b>B</b> (PG 58S-28) <sup>1</sup>	<b>E</b> (PG 58H-28) <sup>1</sup>
<b>New Construction</b> , <sup>2</sup> Wear course (Top 4.0 inches) <sup>3</sup>	<b>C</b> (PG 58H-34)	<b>C</b> (PG 58H-34) <sup>1</sup>	<b>F</b> (PG 58V-34) <sup>1</sup>
<b>All non-wear course</b> <sup>3</sup>	<b>B</b> (PG 58S-28)	<b>B</b> (PG 58S-28)	<b>B</b> (PG 58S-28)

1. Selecting a higher PG will provide increased resistance to rutting. Contact the MnDOT Bituminous Engineer for guidance.
2. New construction includes: reconstruction, rubblization, CIR, full-depth reclamation (FDR), and stabilized full-depth reclamation (SFDR).
3. The wearing course may be reduced to 3.0 inches for non-trunk highways with traffic levels <3 million ESALs.

**Table 450.6 - Recommended Binder Grade for Shoulders**

Traffic Allowed	Traffic Prohibited	Next to Concrete Mainline and Concrete Curb and Gutter
Generally, the same binder grade as mainline, but not to exceed PG 58H-xx.	<b>B</b> (PG 58S-28) or <b>A</b> (PG 52S-34) (Match the mainline low PG number)	<b>B</b> (PG 58S-28) or <b>E</b> (PG 58H-28)

Asphalt binder grade notes:

- a. Use SMA on the final wearing surface only (top 1.5" – 2" lift). Specify a minimum PG 70-28 (H) for SMA mixtures. Contact the MnDOT Bituminous Engineer for guidance.
- b. With the agreement of the MnDOT Bituminous Engineer, the designer may allow, by Special Provision, the Contractor's option to use PG 64S-22 on overlay construction when both of the following conditions are met:
  - Overlay thickness of 3.0 inches or less and
  - Average in-place crack/joint spacing of 30-feet or less.

The Special Provision will limit the allowable RAP usage to 15% for mixtures specifying PG 64S-22.

- c. For temporary construction (2 years or less) consider using PG64S-22 when PG 58H-28 or PG 58V-34 is otherwise recommended.
- d. For special or unique design considerations contact the MnDOT Bituminous Engineer.

## 2. HMA compaction designation

MnDOT Standard Specifications for Construction Specification 2360 include Maximum Density (2360.3.D1) and Ordinary Compaction (2360.3.D2).

- A. Maximum Density Method (2360.3.D1) is the default compaction method and tests if the pavement's density meets minimum requirements by cutting cores from the completed pavement. The bulk density of the cores from the pavement is compared to the maximum specific gravity of the mixture to determine in-place density. If the designer does not want Maximum Density as the compaction requirement on a project it must be written out in the project Special Provisions. Maximum Density should not be specified for temporary work or on projects with 500 tons or less total tonnage.
- B. Ordinary Compaction (2360.3.D2) requires a control strip to be developed to determine the optimal rolling pattern for compaction and acceptance of the HMA pavement. Specification 2360 defaults to Ordinary Compaction for the following situations:
- Layers identified in the typical sections with a minimum planned thickness less than 1½ in.
  - Thin lift leveling.
  - Wedging layers.
  - Patching layers.
  - Driveways.
  - Areas the Contractor cannot compact with standard highway construction equipment and practices.
  - Bike paths, walking paths, and other similar non-traffic paving areas.

## 3. HMA lift thickness

The MDR designates the thickness of the individual lifts that will be used to construct the HMA pavement. The following items should be considered when establishing the lift thicknesses:

- The recommended minimum lift thickness for each aggregate size is shown in **Table 450.2**.
- Improved density is the greatest benefit of specifying thicker lifts.
- Improved ride is the greatest benefit of paving more lifts (see the following section on specifying smoothness). However, the ride improvement from 2 to 3 lifts is less than the improvement from 1 to 2 lifts.

#### 4. Smoothness

The MDR designates the ride equation or percent ride improvement to apply to HMA paving on the project. Use the following guidelines to determine which ride equation or percent ride improvement is appropriate. Consult the MnDOT Bituminous Engineer for other construction types not covered.

A. For the following construction types, use **Equation HMA-A**:

- New construction with a minimum of 3 lifts.
- Overlay with a minimum of 3 lifts and lift thicknesses of at least 1.5 inches.
- Construction with a minimum of 3 lifts, with curb and gutter and at least 8 feet separating the traffic lane from the curb and gutter (i.e. a shoulder at least 8-feet wide).

B. For the following construction types use **Equation HMA-B**:

- New construction with 2 lifts.
- Construction with a minimum of 3 lifts, with curb and gutter adjacent to at least one driving lane.
- 2-lift overlays with 1.5 inch minimum lift thickness.
- Winter-carry-over, wearing course on 2 lifts.
- FDR or SFDR with 2 lifts.
- Cold-in-place recycled pavements with 2 lifts.
- Two lifts over concrete pavement.

C. For single-lift overlay construction on bituminous choose either **Equation HMA-C** or **Percent Ride Improvement**. **Percent Ride Improvement is used only on single lift overlay projects that do not include milling** (See Note 1 below for single-lift overlay on concrete). The Percent Ride Improvement provision compares the smoothness of the roadway before any construction activities have taken place to the smoothness of the roadway after construction activities are finished. Incentive/disincentive is determined by the percent ride improvement. Percent Ride Improvement is intended to be used in situations where the existing roadway is in poor condition. Data from pilot projects show that the rougher the road segment to begin with the greater the relative improvement possible. For instance, a road segment with a starting smoothness of 150 in/mile is more likely to be reduced to a smoothness of 75 in/mile than a road segment starting at 75 in/mile is to be reduced to a Smoothness of 37.5 in/mile. Contact the Special Provisions Unit to insert the Percent Ride Improvement in a Contract.

For the following construction types, use **Percent Ride Improvement (1) (2)**:

- Single-lift bituminous over bituminous (BOB) overlays on a roadway surface with an overall Ride Quality Index (RQI) < 2.8 (MRI greater than 120 in/mi)\*.

For the following construction types, use **Equation HMA- C (1)**:

- Single lift bituminous over bituminous (BOB) overlays on a roadway surface with an overall RQI > 2.8 (MRI 120 in/mi or less)\*.

\* This information is available in the District’s Pavement Management Condition Rating Reports.

**Note 1:** Table 2399-2 of the MnDOT Standard Specification excludes smoothness testing of single-lift overlays on concrete, but requires evaluation of “Areas of Localized Roughness” (ALR) and the 10-foot straightedge. However, there may be unique situations on single-lift BOC construction where a smoothness evaluation requirement is appropriate. Consult the MnDOT Bituminous Engineer for guidance in those considerations.

**Note 2:** The original smoothness and final smoothness values should be obtained by calendar date as close to one another as possible. Do not run the original smoothness in one year and the final smoothness in a different year (i.e. carryover projects).

The following “typical” smoothness values and the equivalent RQI are given for a perspective of various pavement smoothness numbers:

**Table 450.6 - Typical Smoothness Values**

Pavement Type and Lifts	MRI	RQI
New pavement (3-lifts)	37 in/mile	4.1
New pavement (2-lifts)	47 in/mile	3.9
New pavement (1-lift)	60 in/mile	3.6
Aged pavement (10 years)	110 in/mile	2.9

Table 2399-2 of the MnDOT Standard Specifications lists pavement surfaces that are excluded from smoothness testing but subject to evaluation of “Areas of Localized Roughness” (ALR) and the 10-foot straightedge 2360.3E (Surface Requirements). There may be other instances where you feel the ride specification is not appropriate on a project. In those instances make note in the Special Provisions that ride will be verified by MnDOT Standard Specification 2360.3E.

#### 4. Longitudinal joint enhancements

These products are intended to improve the long-term performance of longitudinal “cold” joints in HMA paving that are often the source of early pavement distress. Specify in the MDR any longitudinal joint enhancements that will be included with the project.

The following joint enhancements are available and their specifications can be found on the [MnDOT Bituminous Engineering website](#).

- A. **Fog Sealing:** This consists of treating the longitudinal construction joint with a light application of bituminous material to seal the surface. This treatment is recommended for use on newly constructed HMA longitudinal joints and can also be used to maintain an existing longitudinal joint. The fog seal must be applied before permanent pavement markings are placed or before re-striping of an existing pavement.
- B. **Joint Adhesive:** This is a thick, rubberized asphalt material applied to the vertical face of the cold joint before the adjacent lane is placed. The material is designed to provide a better bond between HMA passes and produce a better, more durable longitudinal joint that minimizes the potential for water infiltration.
- C. **Joint Stabilization:** This consists of applying a fog seal of a bituminous material composed of petroleum oils and resins emulsified in water over the longitudinal construction joint of a Hot Mixed Asphalt (HMA). Show in the plans.

5. Use of Paver Mounted Thermal Profile (PMTP) and intelligent compaction (IC)

Paver Mounted Thermal Profiling (PMTP) is the process of continuously monitoring and recording the location and temperature of the asphalt mat immediately behind the paver screed during placement operations. This identifies any thermal segregation in the uncompacted asphalt which may affect the pavement’s performance and durability.

Intelligent Compaction (IC) refers to the compaction of road materials, such as soil, aggregate base, or asphalt, using self-propelled rollers integrated with a position monitoring system and an onboard documentation system that can display real-time, color coded maps of roller location, number of passes, roller speeds, amplitudes and vibration frequencies of the roller drum. Some systems are also equipped with drum vibration instrumentation, infrared temperature sensors, and/or automatic feedback control. The onboard documentation system on these rollers also displays real-time, color-coded maps of stiffness response or pavement surface temperatures, or both. This improves monitoring and recording of the compaction process to ensure that the material is properly and uniformly compacted.

PMTP and/or IC are recommended for projects when the following project/site conditions are met:

- A. Net lane miles are greater than or equal to 4 lane miles for the given specification and route and on associated routes within the plan set, with a minimum, continuous length of 2 lane miles.
- B. The project uses one or more of the following specifications

**Table 450.7 – Specifications that are appropriate for IC or PMTP**

Specification	Intelligent Compaction (IC) Method	Paver Mounted Thermal Profile (PMTP) Method
HMA - Specification 2360	✓	✓
SMA - Specification 2365	✓	✓
Ultrathin Bonded Wearing Course (UTBWC)	✓	
SFDR - Specification 2215	✓	
CIR - Specification 2390	✓	
CCPR - Specification 2390	✓	

C. Cellular coverage, to allow for automatic transfer of data to the cloud, at least one time per day. Areas with intermittent locations of limited to no cellular coverage are allowed within the project limits, since the systems can store data until adequate data cellular coverage is available.

D. Adequate global navigation satellite system (GNSS) coverage through the project limits is required for recording of the real-time, spatial location of equipment. Table 450.8 lists the required accuracies.

**Table 450.8 - Required GNSS Accuracy**

<b>Technology</b>	<b>Accuracy</b>
Intelligent Compaction (IC) Method— SP 2016 Quality Management Special	± 2 in (50 mm) in the X and Y Direction
Paver Mounted Thermal Profile (PMTP) Method — SP 2016 Quality Management	± 4 feet (1.2 m) in the X and Y Direction