MnDOT Pavement Design Manual

Chapter 4 – HMA (Hot-Mix Asphalt)
Contents

Introduction........................................................................................................................................................ 1

400 – New/Reconstructed HMA Pavements................................................................................................ 2

410 - Reclamation/Recycling of Existing HMA Pavement................................................................. 4

420 – Rubblization and Crack and Seat................................................................................................. 8

430 - Pavement Design using MnPAVE-Flexible ............................................................................... 11

440 - HMA Overlay of Existing Pavement......................................................................................... 25

450 - Materials and Specifications ..................................................................................................... 29
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.
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 subgrade 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 HMA pavement thickness of 4.0 inches 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.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA Pavement</td>
<td>4.0-inch minimum thickness</td>
</tr>
<tr>
<td>Aggregate Base</td>
<td>6.0-inch minimum thickness</td>
</tr>
</tbody>
</table>
| Granular Subbase  | • 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.  
• 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. |
| Soil              | See Note 2                                                            |

**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.
410 - Reclamation/Recycling of Existing HMA Pavement

Reclamation/Recycling of existing HMA pavement includes projects that pulverize the existing HMA pavement and re-use it as base material for new HMA pavement. This includes FDR, SFDR, and CIR. All of these methods are likely to result in an increase in road profile, however, using stabilized materials (SFDR, CIR) will likely result in less of an increase than with using an unstabilized material (FDR). If the existing HMA material is removed from the roadway, then use Section 400 – New/Reconstructed HMA Pavements.

For more information and/or assistance on FDR, SFDR or CIR, contact the Pavement Reclamation, Grading and Base Unit (Office of Materials and Road Research) at http://www.dot.state.mn.us/materials/gbacontacts.html

1. Evaluate the existing materials.

   A. Because it is critical to establish the thicknesses of the existing HMA and aggregate base layers, it is recommended to use (in addition to cores) Ground Penetrating Radar (GPR) on these types of projects (see Section 240 - GPR).

   B. Perform a mechanical analysis (gradation) on the existing aggregate material obtained from borings (see Section 220.3.B – Mechanical analysis) to help establish if it will be suitable material to incorporate into the reclaimed material. Note any change in gradation with depth of the cores.

   C. Collect cores for the project according to Section 230 – Cores. Use the cores to determine HMA depths to establish if the existing HMA has an unusually fine gradation.

   D. Because reclamation/recycling projects typically are not intended to improve the existing 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, may appear as weak areas in falling-weight deflectometer (FWD) data or may appear as areas of wet or poor foundation soils in a soils survey (see Chapter 2 - Investigation).

2. Full-depth reclamation (FDR)/stabilized full-depth reclamation (SFDR) design
FDR involves using a reclaiming machine to pulverize and blend together the existing HMA pavement and aggregate. The blended material is compacted and shaped and will then act as an aggregate base for new HMA pavement.

SFDR is a layer of FDR (typically, 6.0 inches thick) that has a stabilizing agent added, usually asphalt cement. After the roadway has been reclaimed, the reclaiming machine typically makes a second pass to apply and blend-in the stabilizer. This layer will then be compacted and allowed to cure before being paved with new HMA pavement.

Design the FDR/SFDR section using the following:

A. Reclaiming

(1) Include only existing HMA and sound aggregate in the reclaimed material. Existing class 5 and class 6 is optimal, class 3 and 4 are also acceptable. Avoid including any material that contains more than 15% material by weight passing the No. 200 (75 μm) sieve.

(2) Choose a reclaiming depth that is at least 2.0 inches above existing soils to avoid the introduction of fine particles into the reclaimed material. Note: In areas of weak soils, decrease the reclaiming depth to leave a thicker layer of undisturbed aggregate base which will aid the compaction process of the reclaimed material.

(3) The maximum depth that typical reclaiming machines can reclaim and produce a uniform material is 12.0 inches, although, equipment that can reclaim up to 18.0 inches is available.

(4) The existing HMA pavement may be milled prior to reclaiming to:

- Reduce any raise in grade of the proposed pavement section as compared to the existing section.
- Reduce the amount of HMA pavement in the reclaimed material.

(5) Where little or no aggregate base is present, aggregate or rock (100% passing the 1.0 inch sieve) can be placed on the surface of the existing HMA pavement prior to reclaiming. This can improve the gradation of the reclaimed blend and increase the amount of aggregate in the reclaimed material.

(6) Depth of reclaiming for FDR projects

a. Set a reclaiming depth that is at least a 1.0 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 base layer.
b. Try to set a reclaiming depth so that the reclaimed material will have a ratio of 50% pulverized HMA pavement to 50% aggregate, although up to 75% pulverized HMA is acceptable.

(7) Depth of reclaiming for SFDR projects

a. The reclaiming depth must be least a 1.0 inch deeper than the HMA pavement.

b. Try to set a reclaiming depth so that the material to be stabilized (typically, 6.0 inches thick) will contain approximately 80%-90% pulverized HMA pavement and 10%-20% aggregate. The intention is for the stabilization use approximately 2%-3% asphalt cement (or 3%-4.5% emulsion). In addition, consider incorporating a small amount of aggregate into the reclaimed material, as this will limit the fines content and subsequently the stabilizing agent requirement.

B. Minimum HMA pavement thicknesses

- **FDR** - The minimum HMA pavement thickness is 4.0 inches.
- **SFDR** - A minimum HMA pavement thickness of 2.0 inches may be used if placed on a minimum of 6.0 inches of SFDR.

C. Design the pavement thickness using **MnPAVE-Flexible** according to Section 430 - Pavement Design Using MnPAVE-Flexible.

D. Specify the HMA mix type, ride specification, lift thicknesses, and compaction requirement using Section 450 - Materials and Specification.

E. For SFDR, it is recommended to perform a SFDR mix design (according to the MnDOT Grading and Base Manual Section 5-692.290 at [http://www.dot.state.mn.us/materials/gbmanual.html](http://www.dot.state.mn.us/materials/gbmanual.html)) on samples of roadway material and stabilizing agents prior to letting the project. This may help to determine the method of stabilization (foaming or emulsion), asphaltic cement (AC) type and amount of additives needed.

3. CIR

CIR involves milling a layer of existing HMA, mixing the milled material with emulsified or foamed asphalt with additives, and placed and compacted on the roadway. These activities are all performed in one pass of a CIR “train.” After suitable curing time, HMA is paved on the CIR layer.
A CIR mix design is recommended to determine the method (Foaming or Emulsion), AC type and amount of additives needed to construct CIR. See Mix Design Criteria for CIR in the MnDOT Grading and Base Manual Section 5-692.291.

A. Design a CIR layer that is a maximum of 4.0 inches thick.

B. Adjust the milling depth to remove any stripped or debonded layers. If the debonded or stripped layers are too deep to be removed, adjust the milling depth to leave at least 3.0 inches of competent HMA remaining over the debonded or stripped layer.

C. Provide good support for the heavy CIR train during construction by leaving a sufficient amount a pavement in place, such as leaving 3.0 inches of existing HMA pavement and 6.0 inches of aggregate base on plastic soils.

D. 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 remaining existing, cracked pavement (by milling).

E. Specify a minimum HMA pavement thickness of 2.0 inches.

F. Design the pavement using MnPAVE-Flexible according to Section 430 - Pavement Design Using MnPAVE-Flexible.

G. Specify the mix type, ride specification, lift thicknesses, and compaction requirement using Section 450 - Materials and Specification.

H. Require that the contractor perform a CIR mix design on samples of roadway material and stabilizing agents/foamed AC during the first day of construction.
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

(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) The pavement must be designed 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.

2. Crack and seat (2231 Pavement Cracking Special Provision (S-107) and 2231 Pavement Seating in Special Provision (S-109))

The crack and seat process involves cracking the existing PCC pavement into 3 to 4-foot pieces, 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.

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.

(5) 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.
MnPVE-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.

MnPVE-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).

MnPVE-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.

MnPVE-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. MnPVE-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 at: [http://www.dot.state.mn.us/app/mnpave](http://www.dot.state.mn.us/app/mnpave). Left-click on the “Download MnPAVE” icon and follow the instructions in the following installation/popup windows:

   A. The first install window contains version and contact information.

   B. Clicking "Setup" in the Winzip Self-Extractor window initiates the installation process.

   C. The welcome window contains brief setup instructions.

   D. Update information is included in this window. This information can also be viewed using the “Development History” link on the MnPAVE-Flexible website.

   E. The executable MnPAVE.exe and Help files will be placed in “Program Files\MnDOT\MnPAVE” unless a different location is specified.

   F. A MnPAVE folder will be added to the Windows Start Menu, unless a different folder is specified.

   G. 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 430.1 – 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 430.2 - Project Information Module**
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**

In some windows, such as this one, the initial view shows only the details necessary for a basic pavement design. To view more details click this button.
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. If “show details” is chosen, the percent binder content and gradation may be specified. 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.
(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.

MnPave–Flexible is limited to modeling only 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.

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 specified 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, enter this number by checking the layer checkbox and entering the value. Use the average R-value of any testing. The engineered soil is always the second to the last layer.

v. MnPAVE–Flexible always applies ½ 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 430.8) 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 into 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) 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.

(3) The Quick Reliability simulation may be initiated prior to the Monte Carlo simulation to further refine the trial pavement design.

(4) 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

- ≥85% for less than 1 million flexible ESALs
- ≥90 % for 1 million to 15 million flexible ESALs
- >95% for more than 15 million flexible ESALs

(5) 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.

(6) 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.
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/feet) 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) in order 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 standard deviations, 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

<table>
<thead>
<tr>
<th>Surface Condition</th>
<th>MEDIUM (2-4&quot;) OVERLAY</th>
<th>20 Year Flexible ESALS</th>
<th>MILL &amp; MEDIUM (2-4&quot;) OVERLAY</th>
<th>20 Year Flexible ESALS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Med</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Good</td>
<td>LIFE</td>
<td>10</td>
<td>12</td>
<td>14</td>
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<tr>
<td></td>
<td>RANGE</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Fair</td>
<td>LIFE</td>
<td>8</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>RANGE</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Poor</td>
<td>LIFE</td>
<td>7</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>RANGE</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Surface Condition</th>
<th>THICK (≥4&quot;) OVERLAY</th>
<th>20 Year Flexible ESALS</th>
<th>MILL &amp; THICK (≥4&quot;) OVERLAY</th>
<th>20 Year Flexible ESALS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Med</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Good</td>
<td>LIFE</td>
<td>13</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>RANGE</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Fair</td>
<td>LIFE</td>
<td>11</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>RANGE</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Poor</td>
<td>LIFE</td>
<td>9</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>RANGE</td>
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</tr>
</tbody>
</table>

**Surface Condition Key**

- **GOOD** - Minimal Stripping & No Rutting
- **FAIR** - Severe Transverse Cracking Or Minimal Rutting Or Some Stripping
- **POOR** - Severe Rutting Severe Stripping Or Severe Multiple Cracking

<table>
<thead>
<tr>
<th>TRAFFIC</th>
<th>20 Year Flexible ESALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIGH</td>
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</tr>
<tr>
<td>MED</td>
<td>1-5M</td>
</tr>
<tr>
<td>LOW</td>
<td>&lt;1M</td>
</tr>
</tbody>
</table>
Table 440.2 - Design lives of HMA overlays of existing PCC

<table>
<thead>
<tr>
<th>Surface Condition</th>
<th>MEDIUM (2-4”) OVERLAY</th>
<th>20 Year Flexible ESALS</th>
<th>MILL &amp; MEDIUM (2-4”) OVERLAY</th>
<th>20 Year Flexible ESALS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>HIGH</td>
<td>MED</td>
<td>LOW</td>
</tr>
<tr>
<td>GOOD</td>
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<td>12</td>
</tr>
<tr>
<td>FAIR</td>
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<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>POOR</td>
<td></td>
<td>5</td>
<td>6</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Surface Condition</th>
<th>MILL &amp; THICK (≥4”) OVERLAY</th>
<th>20 Year Flexible ESALS</th>
<th>20 Year Flexible ESALS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HIGH</td>
<td>MED</td>
<td>LOW</td>
</tr>
<tr>
<td>GOOD</td>
<td>11</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>FAIR</td>
<td>10</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>POOR</td>
<td>8</td>
<td>10</td>
<td>12</td>
</tr>
</tbody>
</table>

Surface Condition Key

GOOD - Minimal Stripping & No Rutting

FAIR - Severe Transverse Cracking Or Minimal Rutting Or Some Stripping

POOR - Severe Rutting Severe Stripping Or Severe Multiple Cracking

<table>
<thead>
<tr>
<th>TRAFFIC</th>
<th>20 Year Flexible ESALS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIGH</td>
<td>&gt;5M</td>
</tr>
<tr>
<td>MED</td>
<td>1-5M</td>
</tr>
<tr>
<td>LOW</td>
<td>&lt;1M</td>
</tr>
</tbody>
</table>
450 - Materials and Specifications

Use this section to help determine HMA materials and 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) or visit their website at http://www.dot.state.mn.us/materials/bituminouscontacts.html.

1. Mix designation

Specify the mix designations used for all HMA 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. 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. An explanation of the meaning of the different portions of the designation is included in Specification 2360 of the “MnDOT Materials Lab Supplemental Specifications for Construction.”


C. Guidelines for choosing the PG Binder is provided in the “PG Binder Guidelines” document provided on the MnDOT Bituminous Engineering website Document and Aids page at http://www.dot.state.mn.us/materials/bituminousdocaids.html
2. HMA compaction designation

The Materials Lab Supplemental Specifications for Construction specification 2360 designates the HMA compaction method as the Maximum Density Method (2360.3.D1) but Ordinary Compaction (2360.3.D2) may also be specified.

A. Maximum density is tested by collecting cores from the completed pavement and determining their density in a laboratory. This is the standard and should always be specified for mainline pavement (unless the total HMA quantity is less than 500 tons).

B. Ordinary compaction uses a control strip to determine the rolling pattern for compaction of the HMA pavement. This is typically designated for small areas or areas that will be difficult to collect cores from. Designate ordinary compaction for the following:

- 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.

4. HMA lift thickness

The MDR designates the thickness of the individual lifts that will be used to construct the HMA pavement. Use the following to help choose lift thicknesses:

- Guidelines for minimum lift thicknesses with regard to aggregate size are provided in the “Design Criteria” document available on the MnDOT Bituminous Engineering website Document and Aids page at http://www.dot.state.mn.us/materials/bituminousdocaids.html

- The maximum HMA lift thickness is 3.0 inches but HMA lift thicknesses of 2.5 inches or less are recommended.

5. Smoothness

The MDR designates the ride requirement, if any, that will be applied to the project. Guidelines for choosing the ride quality is provided in the “Ride Guidelines” document available on the MnDOT Bituminous Engineering website Document and Aids page at http://www.dot.state.mn.us/materials/bituminousdocaids.html
6. Longitudinal joint enhancements

Specify longitudinal joint enhancements in the MDR for inclusion in a project. 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. The following joint enhancements are available for inclusion in projects and their specifications can be found on the MnDOT Bituminous Engineering website at http://www.dot.state.mn.us/materials/bituminous.html

A. Emulsion 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 joint sealer (similar to crack seal). The material is designed to provide a better bond between HMA passes and produce a better, more durable longitudinal joint.