Chapter 5 – PCC (Portland Cement Concrete)
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Introduction

This chapter contains directions for designing portland cement concrete (PCC) mainline pavements and evaluating existing pavement with regard to rehabilitation with a PCC overlay. The process for deciding which pavement type to use on a project is described in Chapter 7 – Pavement-Type Selection.
500 - New/Reconstructed PCC Pavements

This section contains directions for the design of new/reconstructed PCC pavements which are projects that include the complete removal of the existing pavement or construction on a new alignment.

These pavements are built on aggregate base and granular subbase. The base and subbase layers provide a solid working-platform for construction of the PCC pavement 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. Base layers may also be constructed of drainable materials, which require either edge drains or daylighting the drainable layer to the ditches.

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

1. Projects that involve working the existing soil must follow Figure 500.1 and its notes.

2. Projects that do not involve working the existing soil the subgrade must meet the following:

   A. These projects must have existing soil, subbase, and/or aggregate base material in good condition, suitable as a platform for construction and to remain as part of 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 meet all of the requirements shown in Figure 500.1. However, the minimum thickness for the PCC is 6.0 inches (7.0 inches to include dowel bars) and the PCC must be constructed on a minimum of 4.0 inches of drainable or aggregate base (either new or existing). The aggregate base may be class 5, class 5Q or class 6.

3. If open graded aggregate base (OGAB) is used then edge-drains must be provided for its drainage. If drainable stable base (DSB) is used then it must be daylighted to the ditch or edge-drains must be provided for its drainage.

4. The PCC pavement thickness must be designed with the MnPAVE-Rigid program according to Section 540 – PCC Thickness Design Using MnPAVE-Rigid.

5. Use Section 530 – Joint Design to determine joint spacing, joint designations, dowel, and tie bar requirements.
6. For guidance on pavement cross sections consult the **Road Design Manual** (Chapter 4 – Cross-Sections and Chapter 7 – Pavement Design).

7. Any construction beneath the typical shown in **Figure 500.1** is at the discretion of the District Materials/Soils Engineer. For more guidance see **Chapter 3 – Pavement Subsurface**.
**Figure 500.1** – Pavement design standards for New PCC Pavement for projects that involve working the existing Soil.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCC Pavement</td>
<td>6.0-inch minimum thickness</td>
</tr>
<tr>
<td>Drainable or Aggregate Base</td>
<td>• 4.0-inch minimum thickness aggregate base (class 5, Class 5Q, Class 6).</td>
</tr>
<tr>
<td></td>
<td>• Or 4.0 inches of drainable base (OGAB or DSB).</td>
</tr>
<tr>
<td>Granular Subbase</td>
<td>• When using aggregate base:</td>
</tr>
<tr>
<td></td>
<td>o For non-granular existing soils use a minimum of 12.0 inches of select granular materials, class 3 or class 4.</td>
</tr>
<tr>
<td></td>
<td>o 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.</td>
</tr>
<tr>
<td>Existing Soil</td>
<td>• When using a drainable base, place it on a minimum of 4.0 inches of aggregate base (class 5, class 5Q or class 6).</td>
</tr>
<tr>
<td></td>
<td>Any construction beneath the granular subbase shall be at the discretion of the District Materials/Soils Engineer.</td>
</tr>
</tbody>
</table>
510 - PCC Overlay of Existing HMA - Whitetopping

MnDOT uses two procedures to design PCC overlays of existing HMA. One procedure uses the BCOA-ME (bonded concrete overlay of asphalt – mechanistic-empirical) program to design bonded PCC overlays of existing HMA. MnDOT uses PCC thicknesses ranging between 4.0 and 6.0 inches with this program. The relatively thin design thickness is made possible by taking advantage of a bond between the new PCC overlay and the existing HMA pavement. All designs with this procedure use a 20-year design life.

The second procedure uses the MnPAVE-Rigid program to design PCC overlays of existing HMA with PCC thicknesses 6.0 inches and greater. This program does not consider any bonding with the existing HMA. Designs with this procedure use a 35-year design life or may be used with a 20-year design life when using the BCOA-ME program wouldn’t be appropriate.

The following steps outline the data collection and design process (including the design of construction details) for whitetopping.

1. Survey of existing HMA pavement.

   Collect the following data to evaluate the suitability of the existing HMA for use with a bonded PCC overlay:

   A. Perform a visual condition assessment of the existing HMA Surface and note:

      • The amount of fatigue cracking.
      • The frequency of thermal cracks, their condition and widths.
      • Any areas that may not provide uniform support such as widenings within the travel lane, cracked or uneven pavement edges, frost heaves, or subgrade failures.
      • The depth of rutting.
      • Any local distresses that may need to be repaired prior to placing the PCC overlay.
      • Areas of patching or evidence of maintenance activities.
      • The condition of the existing shoulders.

   B. Collect project ride, surface rating, and rut depth information from the pavement management system (see Section 280 – Pavement Management System).
C. Collect HMA pavement cores away from cracks and on (or near) cracks in the existing HMA (see Section 230 - Cores) to determine the pavement thickness and the subsurface condition of the cracks.

D. Contact area maintenance personnel to determine if there are any areas of high maintenance, frost heaves or other areas of concern.

2. Design the PCC overlay

Use Table 510.1 to determine which design program to use, either BCOA-ME (Section 550 - Whitetopping Thickness Design Using BCOA M-E) or MnPAVE – Rigid (Section 540 - PCC Thickness Design Using MnPAVE-Rigid). Design the PCC overlay with the appropriate program.

<table>
<thead>
<tr>
<th>Program</th>
<th>Design Life</th>
<th>BCOA-ME Candidate*</th>
<th>MnPAVE-Rigid Candidate**</th>
<th>Min. PCC Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCOA-ME</td>
<td>20</td>
<td>✓</td>
<td></td>
<td>4.0 Inches</td>
</tr>
<tr>
<td>MnPAVE-Rigid</td>
<td>20</td>
<td>✓</td>
<td>✓</td>
<td>6.0 Inches</td>
</tr>
<tr>
<td>MnPAVE-Rigid</td>
<td>35</td>
<td>✓</td>
<td>✓</td>
<td>6.0 Inches</td>
</tr>
</tbody>
</table>

* Candidate for BCOA-ME design

- The existing pavement has uniform support conditions with only localized weak areas that must be repaired prior to placing the PCC overlay.
- The primary distresses in the existing HMA pavement are surface distresses.
- Thermal cracks in the HMA pavement are predominately non-deteriorated thermal cracks. Deteriorated thermal cracks will require repair prior to placing the PCC overlay.
- There is a sufficient existing HMA thickness so that after any proposed milling:
  - 85% of the cores are 4.0 inches or thicker.
  - Any individual core must be a minimum of 3.0 inches thick. Any areas with less than 3.0 inches of HMA may be treated by removing the existing HMA pavement and constructing a 6.0-inch (minimum) PCC section.
** Candidate for MnPAVE-Rigid design

- The existing HMA pavement has significant structural deterioration and areas of uneven support conditions.
- Existing HMA overlay of PCC Pavement.
- The existing pavement exhibits evidence of significant foundation movement due to settlements, frost heave, swelling soils, etc.
- The existing HMA has been widened, or will require widening, within the area of the driving lane.
- The HMA pavement that will remain after any milling exhibits stripping and/or debonded layers.
- HMA pavements with predominately deteriorated thermal cracks that will require repair prior to placing the PCC overlay.
- There is an insufficient existing HMA thickness so that after any proposed milling:
  - More than 15% of the cores are less than 4.0 inches thick.
  - There are individual cores less than 3.0 inches thick. However, any areas of less than 3.0 inches of HMA may be treated by removing the existing HMA pavement and constructing a 6.0-inch (minimum) PCC section.

3. Milling and pre-overlay repairs of the existing HMA pavement.

- Mill HMA pavements that exhibit shoving and/or rutting prior to placing the PCC overlay. The milling depth should be at least one half inch below the rutting and shoving.
- The existing HMA pavement may be milled to reduce the rise in pavement grade caused by the placement of the PCC overlay.
- If the PCC overlay is thinner than 5.0 inches then the surface of the existing HMA pavement must always be milled prior to placing the PCC overlay.
- When milling, avoid leaving a thin layer of existing bituminous that may debond. Adjust the milling depth to leave at least one half inch of thickness of an existing lift.
- Provide for full-depth patching (including foundation repair) of any areas of subgrade failure or bottom-up cracking (alligator cracking).
- Subgrade repair and full-depth patch any area that exhibits differential frost heave
- Patch or fill depressions (potholes).
- Patch or fill cracks that are wide, deteriorated cracks.
4. Design joints according to Section 530 – Joint Design.

5. PCC overlays wider than the existing mainline pavement (PCC Overlay 6.0 inches and thicker).

   A. When the PCC overlay is wider than the existing HMA pavement and the outside edge of the existing pavement is *not under* the new driving lane (as marked), follow the details of Figure 510.2.

**Figure 510.2** - PCC overlay wider than the existing HMA pavement and the outside edge of the existing pavement is *not under* the new driving lane (PCC overlay 6.0 inches or thicker).

**NOTES:**

A. This area may be compacted aggregate base or a material that will provide equal or better support.

B. If the PCC overlay extends 2 feet, or less, beyond the existing HMA Pavement, then no tie bar is required.

C. If the PCC overlay extends more than 2 feet beyond the existing HMA Pavement, then saw a joint in the PCC overlay at the extent of the existing HMA Pavement and include a tie bar.
B. When the PCC overlay is wider than the existing HMA pavement and the outside edge of the existing pavement is *under* the new driving lane (as marked), follow the details of *Figure 510.3*.

**Figure 510.3** - PCC overlay wider than the existing HMA pavement and the outside edge of the existing pavement is *under* the new driving lane (PCC overlay 6.0 inches or thicker).

**NOTES:**

A. This area must be HMA or PCC.

B. If the PCC overlay extends 2 feet, or less, beyond the existing HMA Pavement, then no tie bar is required.

C. If the PCC overlay extends more than 2 feet beyond the existing HMA Pavement, then include a tie bar but do not saw a joint (because it would be in the driving lane).

6. PCC overlay wider than existing mainline pavement (PCC overlay less than 6.0 inches thick)

A. When the PCC overlay is wider than the existing pavement and the outside edge of the existing pavement *not under* the new driving lane (as marked) follow the details of *Figure 510.4*.

B. PCC overlays that are wider than the existing HMA pavement and the outside edge of the existing pavement is under the driving lane (as marked) are poor candidates for a PCC overlay designed with BCOA-ME (i.e. <6.0 inches thick) and should be designed with MnPAVE-Rigid (see Section 540 - PCC Thickness Design Using MnPAVE-Rigid).
7. Reinforcing steel

For pavements 6.0 inches or greater in thickness, place tie bars over any changes in underlying support that are more than 2 feet from the edge of the PCC overlay. If this location is in the driving lane, place the tie bars but do not cut a joint.

Do not include reinforcing steel in PCC overlays that are less than 6.0 inches thick, unless using the configuration of Figure 510.4.

**Figure 510.4** - PCC overlay wider than the existing pavement and the outside edge of the existing pavement is *not under* the new driving lane (PCC overlay Less than 6.0 inches thick).

**NOTES:**

A. This area may be compacted aggregate base or a material that will provide equal or better support.

B. Widening must be a minimum of 1.5 feet wide.

C. Provide a 36.0-inch long, No. 4 tie bar by stapling it to the surface of the existing HMA; saw a joint in the PCC overlay at the extent of the existing HMA Pavement.
8. Transitions

Transitions between whitetopping and adjacent pavement are areas of high stresses. A thickened section in this area is recommended to prevent future distresses. Figure 510.5 and Figure 510.6 show the typical transition details for HMA and PCC pavements. Figure 510.7 shows the typical transition for paving on grade or full depth repair sections.

9. Fibers

PCC pavement used in whitetopping may be reinforced by the addition of fibers. Consult the MnDOT Concrete Engineer for the use of fibers.

10. Additional information


Figure 510.5 - Transition from whitetopping to adjoining HMA pavement.
Figure 510.6 - Transition from whitetopping to existing PCC pavement.

Figure 510.7 - Transition from whitetopping to New PCC.
Figure 510.8 – Supplemental steel reinforcement

C1D-D or C2H-D
C1U or C2H joint cut perpendicular to C/L at end of transition taper
Center of Panel
C1D-D or C2H-D

13-15 typical
16 #6 Bars
Equally spaced
6"

13-14 typical
16 #6 Bars
Equally spaced
6"

3-#4 Bars
@ 2’ C-C
1’
1’
3-#4 Bars
@ 2’ C-C

12 or 15’
To match the project joint spacing

**Note:**
All supplemental steel must be epoxy coated and comply with MnDOT spec. 3301.

Dowel bar assembly (see Standard Plate 1105)
Unbonded PCC overlays are used to rehabilitate distressed PCC pavements. They are constructed by placing a new PCC overlay on an interlayer that separates the new overlay from the existing pavement. The interlayer may be made of permeable asphalt stabilized stress relief course (PASSRC), new or existing HMA, or a geotextile that is designed for this purpose. The interlayer is intended to prevent a bond developing between the existing pavement and the new PCC overlay and, in the case of PASSRC and geotextile, to also provide drainage.

The following steps outline the data collection and design process (including the design of construction details) for unbonded concrete overlays of existing PCC pavement.

1. Document the condition of the existing PCC pavement and shoulders.

   Unbonded PCC overlays may be used to rehabilitate most existing PCC pavements. Collect the data required by this section to help design the PCC overlay and to determine the necessary pre-overlay repairs.

   A. Core the pavement to determine the thickness of the existing PCC pavement and shoulders.

   B. Determine the height of faulting from the MnDOT pavement management system data or field measurements.

   C. Visually examine the pavement for any Distress-cracking (D-cracking) or alkali-silica reaction (ASR).

   D. Visually examine the pavement to determine the number and extent of slabs that are:

      - Shattered
      - Rocking
      - Moving
      - Heaving
      - Settling

   E. If the unbonded overlay will require widening beyond the existing PCC roadway, evaluate the existing shoulders to determine if they are stable enough to support the widening or need to be repaired or replaced.
2. Pre-overlay repairs

In the design procedures, pre-overlay repair refers to minor repairs and milling of an existing asphalt overlay. One major advantage of an unbonded overlay is the amount of repair to the existing pavement prior to overlay is minimized. Unbonded overlays are not intended to bridge localized areas of non-uniform support but locations of unstable support or movement should be repaired. The following tables (Table 520.1 and 520.2) should be reviewed and repaired prior to placement of the overlay:

A. Existing jointed concrete pavements (JPCP and JRCP)

Most of the serious deterioration in existing jointed plain concrete pavement (JPCP) and jointed reinforced concrete pavement (JRCP) that requires pre-overlay repair occurs at joints and cracks. The following table (Table 520.1) describes common distresses and recommended repair for these types of pavements.
<table>
<thead>
<tr>
<th>Distress Type</th>
<th>Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working crack</td>
<td>No repair is needed for non-spalled cracks.</td>
</tr>
<tr>
<td>Spalling</td>
<td>Remove loose material &amp; patch with HMA or PCC.</td>
</tr>
<tr>
<td>Faulting &lt; 0.25 inches</td>
<td>No repair of the joint or crack for faulting will be necessary.</td>
</tr>
<tr>
<td></td>
<td>Use 1.0 inch of PASSRC or standard HMA as the interlayer. Fabric may also be used.</td>
</tr>
<tr>
<td>Faulting &gt; 0.25 inches</td>
<td>Use 1.5 inches of PASSRC or standard HMA as the interlayer instead of using fabric or remove the faulting with grinding/milling and use fabric.</td>
</tr>
<tr>
<td>Pumping/free water</td>
<td>Use PASSRC as the interlayer; install interceptor drains and/or edge drains.</td>
</tr>
<tr>
<td>PCC Durability (D-cracking and ASR problems)</td>
<td>Remove loose pieces of concrete pavement and patch with a HMA or PCC before placing the interlayer.</td>
</tr>
<tr>
<td>Rocking or unstable slab with high deflection or pumping problems</td>
<td>Repair the subbase and/or subgrade if soft or eroded material is responsible for the loss of support. Replace the pavement with full-depth PCC or HMA.</td>
</tr>
<tr>
<td>Badly shattered slab with working cracks</td>
<td>Repair the subbase and/or subgrade if it is soft or eroded. Replace the pavement with full-depth PCC or HMA.</td>
</tr>
<tr>
<td>Settlement</td>
<td>Level-up with HMA or PCC.</td>
</tr>
<tr>
<td>Severe Frost Heave</td>
<td>Subgrade correction and full-depth PCC or HMA replacement.</td>
</tr>
</tbody>
</table>
B. Existing continuously reinforced concrete pavement (CRCP)

The most serious distresses in CRCP that require repair are punch-outs and ruptured steel. The following table describes common distresses and recommended repair for this type of pavement.

<table>
<thead>
<tr>
<th>Distress Type</th>
<th>Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Punch-out, blowups, high severity D-cracking</td>
<td>Full-depth PCC removal (repair area should extend at least 18.0 inches beyond the area of distress). Excavate and re-compact the subbase and subgrade. Replace full-depth with concrete.</td>
</tr>
<tr>
<td>Deteriorated or working Transverse cracks with ruptured steel and construction joints with high-severity spall</td>
<td>Repair full-depth with PCC or HMA. Saw joints in the existing PCC every 100 feet to sever the steel reinforcement.</td>
</tr>
</tbody>
</table>

3. Interlayer design

A. PASSRC – permeable asphalt stabilized stress relief course

PASSRC is an open-graded HMA that prevents the PCC overlay from bonding to the existing PCC and provides drainage.

Provide edge-drains when using PASSRC. Details for PASSRC with edge drains are shown in Standard Plan 5-297.432.

The typical design thickness of PASSRC is 1.0 inch. This may be increased to 1.5 inches if faulting greater than 0.25 inch is present.

**NOTE:** Perform any crown corrections with the PCC overlay rather than the interlayer to prevent difficulties with anchoring dowel bar baskets. Other corrections may require adjustments to the interlayer.
B. Non-woven geotextile fabric

A specially designed geotextile fabric may be used as an interlayer. This fabric provides drainage and prevents the PCC overlay from bonding to the existing PCC. Geotextile fabric is an acceptable alternate for most candidate PCC pavements. However, the use of geotextile fabric is not advised if joint faulting is greater than 0.25 inch because of concerns that the overlay may “lock onto” the fault which will cause a stress concentration.

Geotextile fabric requires drainage, either by daylighting (shown in Figure 520.1 & Figure 520.2), or edge drains (replace the PASSRC layer with a geotextile interlayer in Standard Plan 5-297.432).

Figure 520.1 - Geotextile interlayer with daylighting detail for HMA or aggregate shoulders.

NOTES:

A. If this area will be under the driving lane (as marked) then this area must be HMA or PCC; otherwise, this area may be compacted aggregate base material or material with equal or better support.

B. If the PCC overlay will extend more than 2 feet beyond the existing PCC then include tie bars.

C. If the PCC Overlay will extend more than 2 feet past the outside edge of the existing PCC and the outside edge of the existing PCC won’t be under the driving lane; saw a longitudinal joint in the PCC overlay at the outside edge of the existing PCC.
Figure 520.2 - Geotextile interlayer with daylighting detail for PCC shoulders.

C. New HMA

New HMA may be used as an interlayer. It will prevent the PCC overlay from bonding to the existing PCC but it will not provide drainage.

The typical design thickness is 1.0 inch but should be increased to 1.5 inches if faulting greater than 0.25 inches is present.

**NOTE:** Perform any crown corrections with the PCC overlay rather than the interlayer to prevent difficulties with anchoring dowel bar baskets. Other corrections may require adjustments the interlayer.

D. Existing HMA overlay over PCC Pavement

An existing HMA overlay may be used as all or part of the interlayer. If badly deteriorated, it should be removed and replaced with some other interlayer. Otherwise, it should be milled to provide a smooth surface profile and to establish the cross-slope on which to build the overlay.

4. Transitions

Transition from an unbonded overlay to on-grade pavements should be in accordance with Figure 520.3 or Figure 520.4.
5. Thickness design

Design unbonded PCC overlays of existing PCC pavements using the MnPAVE-Rigid program according to Section 540 - PCC Thickness Design Using MnPAVE-Rigid. Use 20-year and 35-year design lives as required by Chapter 7 – Pavement-Type Selection.

6. Additional information

1. Joint spacing, dowel bars, and tie bars

Joint spacing and dowel bars in concrete pavements must comply with Table 530.1. In any case, longitudinal joints must not be placed near the wheel paths (such joints lead to increased degradation and decreased service life).

The required number of dowel bars in a 12-foot lane is defined as either a “Full-Set” or “Wheel Path.” A “Full-Set” is 11 dowel bars spaced 1 foot apart (on center) and shown in MnDOT Standard Plate 1103. “Wheel Path” is 4 dowels in each wheel path for a total of 8 dowels per 12-foot lane. For the placement of “Wheel Path” dowels with a “Full-Set” basket, see Figure 530.1.

Typically, dowel bars are only included on pavements that will receive traffic and shoulders or other paved areas outside the travel lane are normally undoweled. However, the standard is to dowel the full-width of PCC ramps, including outside the marked travel lane.

<table>
<thead>
<tr>
<th>PCC Thickness</th>
<th>Joint Spacing</th>
<th>Dowel Bars</th>
<th>All Longitudinal Joints</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Longitudinal (Panel Width)</td>
<td>Transverse (Panel Length)</td>
<td>Size</td>
</tr>
<tr>
<td>≥ 10 ½ inches</td>
<td>12’ – 14’</td>
<td>15’</td>
<td>1 ½” dia. Dowels</td>
</tr>
<tr>
<td>8-10 inches</td>
<td>12’ – 14’</td>
<td>15’</td>
<td>1 ¾” dia. Dowels</td>
</tr>
<tr>
<td>7 &amp; 7.5 inches</td>
<td>12’ – 14’</td>
<td>15’</td>
<td>1” dia. Dowels</td>
</tr>
<tr>
<td>6 &amp; 6.5 inches</td>
<td>6’ – 8’</td>
<td>6’</td>
<td>Un-Doweled</td>
</tr>
<tr>
<td>4 -5.5 inches</td>
<td>6’ – 8’</td>
<td>6’</td>
<td>Un-Doweled</td>
</tr>
</tbody>
</table>

* Do not include tie bars on pavements less than 6.0 inches thick, unless using the arrangement of Figure 510.4.

**Use Wheel Path (8 dowels) dowels bars for UBOL or whitetopping.
2. Joint designation

Specify in the Materials Design Recommendation (MDR), the typical contraction (transverse) and longitudinal joints on a project.

A. Contraction joints

Use the following steps to determine the joint designation of the contraction joints. Contact the MnDOT Concrete Unit (Office of Materials and Road Research) if varying from the recommendations.

**STEP 1.** Use Table 530.1 to determine if the contraction joints will or will not include dowel bars.

**STEP 2.** Use Table 530.2 to determine, based on joint sealing recommendations, which joint references may be designated.

**STEP 3.** Using the determinations of the previous steps, designate the PCC contraction joints as one of the joint references in Table 530.3 (based on MnDOT Standard Plan 5-297.221).
### Table 530.2 – Concrete Joint Sealing Guidelines

<table>
<thead>
<tr>
<th>Type of Construction</th>
<th>Speed Limit</th>
<th>Base Material</th>
<th>Joint Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Roadways, excluding</td>
<td>≤ 45 mph</td>
<td>All</td>
<td>C2H</td>
</tr>
<tr>
<td>ramps and loops</td>
<td></td>
<td></td>
<td>C2H-D</td>
</tr>
<tr>
<td>PCC Overlay on Existing HMA</td>
<td>&gt; 45 mph</td>
<td>Existing HMA</td>
<td></td>
</tr>
<tr>
<td>(Whitetopping) &lt; 6” thick</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Construction</td>
<td>&gt; 45 mph</td>
<td>All</td>
<td>C1U</td>
</tr>
<tr>
<td>Unbonded PCC Overlay of</td>
<td></td>
<td></td>
<td>C1U-D</td>
</tr>
<tr>
<td>Existing PCC (UBOL)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCC Overlay on Existing HMA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Whitetopping) ≥ 6” thick</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ramps and Loops</td>
<td>All</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* For future concrete pavement rehabilitation (CPR) projects, follow the same recommended practices as original construction. Contact the MnDOT Concrete Unit with questions.

### Table 530.3 – Contraction Joint Reference, Detail & Sealer Spec. (MnDOT Standard Plan 5-297.221)

<table>
<thead>
<tr>
<th>Joint Reference</th>
<th>Joint Sealant Material &amp; Spec.</th>
<th>Joint Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without Dowels</td>
<td>With Dowels</td>
<td></td>
</tr>
<tr>
<td>C1U</td>
<td>C1U - D</td>
<td>Unsealed</td>
</tr>
<tr>
<td>C2H</td>
<td>C2H - D</td>
<td>Hot Pour – 3725</td>
</tr>
<tr>
<td>C3P</td>
<td>C3P - D</td>
<td>Preformed Elastomeric - 3721</td>
</tr>
<tr>
<td>C4S</td>
<td>C4S - D</td>
<td>Silicone - 3722</td>
</tr>
<tr>
<td>C5H</td>
<td>C5H - D</td>
<td>Hot Pour – 3725</td>
</tr>
</tbody>
</table>
B. Longitudinal joints

Use the following steps to determine the joint designation of the longitudinal joints. Contact the MnDOT Concrete Unit (Office of Materials and Road Research) if varying from the recommendations.

**STEP 1.** Determine the type of longitudinal joint

- **L1** – This is a sawed joint down the center of a roadway or section, either tied or untied.
- **L2** – Tied/keyed construction joint (i.e. PCC on one side of the joint is placed with a keyway formed in it and/or tie bars; the abutting pavement is placed later).
- **L3** – This is a construction joint between two concreting operations, which are not tied to one another, essentially a butt joint.

**STEP 2.** Determine if the joints should be tied

1. **Tied joints**
   - L1 and L2 joints are generally recommended to be tied.

2. **Untied joints**
   - When a roadway is 5 or more lanes wide, include a L3 joint so that no more than 4 lanes are tied together.
   - Pavements less than 6.0 inches thick, unless using the arrangement of Figure 510.4.
   - L3 joints don’t have the option to include tie bars.

**STEP 3.** Specify a joint without a keyway. However, it is the contractor’s option to use a keyway for formed PCC pavements or for PCC pavements 10 inches or thicker.

**STEP 4.** Determine if the joints must be sealed.

- Do not seal L2 or L3 joints.
- Seal L1 joints if the contraction joints will be sealed.
STEP 5. Designate the PCC longitudinal joints as one of the joint references in the Table 530.4 (based on MnDOT Standard Plan 5-297.221) using the determinations of the previous steps.

<table>
<thead>
<tr>
<th>Joint Reference</th>
<th>Without Tie Bars</th>
<th>With Tie Bars</th>
<th>With Keyway with Tie Bars</th>
<th>Joint Sealant Material &amp; Spec.</th>
<th>Joint Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1U</td>
<td>L1TU</td>
<td></td>
<td>Unsealed</td>
<td></td>
<td>1/8 inch</td>
</tr>
<tr>
<td>L1H</td>
<td>L1TH</td>
<td></td>
<td>Hot Pour – 3725</td>
<td></td>
<td>1/8 inch</td>
</tr>
<tr>
<td>L2TU</td>
<td>L2KTU</td>
<td></td>
<td>Unsealed</td>
<td></td>
<td>3/8 inch</td>
</tr>
<tr>
<td>L2TH</td>
<td>L2KTH</td>
<td></td>
<td>Hot Pour – 3725</td>
<td></td>
<td>3/8 inch</td>
</tr>
<tr>
<td>L3U</td>
<td></td>
<td></td>
<td>Unsealed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3H</td>
<td></td>
<td></td>
<td>Hot Pour – 3725</td>
<td></td>
<td>3/8 inch</td>
</tr>
</tbody>
</table>
540 - PCC Thickness Design using MnPAVE-Rigid

MnPAVE-Rigid is a PCC pavement design program which uses transverse cracking as the controlling distress. It is based on the MEPDG version 1.1, a mechanistic-empirical design procedure which accounts for the effects of traffic loading and environment. MnPAVE-Rigid was locally calibrated for Minnesota pavements through: 1) the use of local climate data and weigh-in-motion traffic data; 2) the incorporation of previously conducted calibrations of the MEPDG for Minnesota pavements; 3) the inclusion of advanced analysis features included in MnPAVE-Rigid’s flexible design counterpart, MnPAVE-Flexible.

1. This section provides standards for the design of PCC pavements using the MnPAVE-Rigid program. The MnPAVE-Rigid program may be used for the pavement design of the following:

- New/reconstructed PCC pavements on aggregate base, including full-depth reclamation (FDR). New/reconstructed PCC Pavements on aggregate base that involve working the subgrade must also meet the standards shown in Figure 500.1 and its notes.
- Unbonded PCC overlays of existing PCC.
- PCC overlays on existing HMA, or on a composite pavement of HMA on PCC, with a design life of 35 years. A 20-year design life may be used if the project wasn’t determined to be a candidate for design with BCOA-ME.

Figure 540.1 - View of MnPAVE-Rigid
2. Follow the steps below to perform PCC pavement design using MnPAVE–Rigid. It can be obtained from the Software page of the MnDOT Pavement Design website at http://www.dot.state.mn.us/materials/pvmtdesign/software.html.

**STEP 1.** Open the program. It should open to the “Main” tab which is where design inputs are entered and the thickness calculated.

**STEP 2.** For a new project, begin by entering a short, identifiable name into the “Project name” text box. This will be the name of the data file that saves the user’s inputs. An existing data file can be loaded by clicking on the “Load from *.txt file” button.

**STEP 3.** Enter any notes into the “Project Notes” text box.

**STEP 4.** Enter the design life into the “Design Life, Years” text box. This will be either 20 or 35.

**STEP 5.** Choose the project’s district from the “Climate (by district)” drop-down list.

**STEP 6.** Enter the “Initial, HCADT.” This value is the base year “HCADT: two-way” (Heavy Commercial Average Daily Traffic) that is found on the project’s traffic forecast.

**STEP 7.** Enter the “Linear yearly growth (%).” This value is the “GROWTH/YR” for the “HCADT: two-way” that is found on the project’s traffic forecast.

**STEP 8.** The default “Axle load spectra” is “MnDOT WIM Average” which is appropriate for most situations.

“MnDOT WIM Heavy” may be selected from the “Axle load spectra” drop-down list if a traffic forecast shows that more than 70% of the HCADT is 5 axle + trucks and twin trailers. Use “MnDOT WIM Heavy” if the following formula is true.

\[
\frac{(5AX + TST)\% + (5AX + TST \text{ MAX})\% + (5AX + TST \text{ OTH})\%}{HCADT\%} > .70
\]
STEP 9. For “Widened outer lane,” if any the following conditions are met, select “yes”:

- The outside lane will be paved at least 1 foot past the marked edgeline.
- The outside lane will be paved at the same time as the concrete shoulder and the joint between them will include tie bars (i.e. a concrete shoulder with a tied L1 joint).
- The outside lane will include an integral curb and gutter.

If none of these conditions are met, select “No.”

STEP 10. For “Shoulder type”:

- If the outside lane will be paved separately from a concrete shoulder or a curb and gutter, and the joint between them will include tie bars (i.e. a concrete shoulder with a tied L2 joint) then select “tied PCC.”
- Otherwise, select “HMA, Untied PCC, or Aggregate.”

STEP 11. Set the “Joint spacing” to either 12 or 15 feet. The joint spacing with regard to the calculated thickness must meet the requirements of Section 530. Note: Select 12 feet if 6X6 foot panels are intended to be used.

STEP 12. Left-click on the “Run” button to calculate the pavement thickness. If all inputs haven’t been completed then an error box will appear that requests the completion of all the inputs.

STEP 13. Use the following rounding procedure to determine the Design Thickness.

- Round-down 0.01 to 0.19 to the nearest inch (X.01 to X.19 = X.0)
- Round 0.20 to 0.69 to the nearest ½ inch (X.20 to X.69 = X.5)
- Round-up 0.70 to 0.99 to the next inch (X.70 to X.99 = X+1.0)

STEP 14. Make sure that the joint spacing is appropriate for the design thickness according to Section 530. Run the program again after making any adjustments to the joint spacing.

NOTE: If PCC pavement designs with both 12 and 15-foot joint spacings are both applicable, the design with the 15-foot spacing is generally preferred.
550 - Whitetopping Thickness Design using BCOA-ME

Use this section to design whitetopping with a 20-year design life if the project was determined to be a candidate for BCOA-ME design according to Section 510.1.B. Otherwise, design whitetopping pavement using MnPAVE-Rigid (see Section 540 - PCC Thickness Design Using MnPAVE-Rigid).

A. Use the BCOA-ME program according to the following directions.

**STEP 1.** Load the BCOA-ME. The program is available as a webpage at [http://www.engineering.pitt.edu/Sub-Sites/Faculty-Subsites/J_Vandenbossche/BCOA-ME/BCOA-ME-Design-Guide/](http://www.engineering.pitt.edu/Sub-Sites/Faculty-Subsites/J_Vandenbossche/BCOA-ME/BCOA-ME-Design-Guide/). The program is available only as a webpage and an internet connection is required for its use.

**STEP 2.** Enter the latitude, longitude and elevation of the project.

Left-clicking on the “Geographic Information” button will open the Geographic Information webpage which will provide help with getting this information. The Geographic Information webpage provides two options for getting the latitude, longitude and elevation.

**Option 1** opens an external website that will provide the required information for any city or address. Left-clicking on the “Open Webpage” button opens the veloroutes.org website. Alternatively, Google Earth may also be used. After using the website to determine the latitude, longitude and elevation return to the Geographic Information webpage. Return to BCOA-ME by either left-clicking the “Cancel” button or using your browser's back button. The latitude, longitude and elevation must then be manually entered into the appropriate boxes.

**Option 2** provides a drop-down list of cities with available information. Choose the appropriate city and then Left-click the “submit” button. The “submit” button will return you to BCOA-ME and automatically fill the latitude, longitude and elevation boxes. Only use option 2 if the project is located near one of the available cities.
STEP 3. Enter the Design Lane ESALs. Do not use the “ESALs Calculator” button. If the pavement design will be constructed or is a possible alternate bidding project then use the 20-year Rigid ESALs from the project’s traffic forecast. Otherwise, the average 20-year Rigid ESALs from the ESAL Forecasting Tool are acceptable (see Section 250 – Traffic Data).

STEP 4. Leave the Maximum Allowable Percent Slabs Cracked at “25” and the Desired Reliability against Slab Cracking at “85.”

STEP 5. Set the AMDAT Region ID to “1” using the drop-down box.

STEP 6. Enter the Sunshine Zone using the drop-down box. To determine the correct value, left-click on the blue label that says “Map of Sunshine Zone.” Find the correct value using the map then left-click on the “back” button or anywhere on the map to return to the BCOA-ME. The value is not automatically sent to the BCOA-ME and the value must be manually selected with the drop-down box. For Minnesota the value will always be either “4” or “5.”

STEP 7. Enter the Post-Milling HMA Thickness in inches. This is the Design Existing HMA Thickness minus the proposed milling depth. The Design Existing HMA Thickness is the 85% percentile thickness of the HMA cores (85% with that thickness or greater).

STEP 8. Choose a HMA Fatigue condition, either Adequate or Marginal. Adequate is defined as 0-8% fatigue cracking and Marginal is defined as 8-20% fatigue cracking. Clicking on the “Example of Fatigue Cracking” button opens a webpage with visual examples of both conditions. Return to BCOA-ME by either left-clicking the “Back” button or using your browser’s back button.

STEP 9. Enter the Modulus of Subgrade Reaction, k-value. This value represents the composite support of the subgrade and any in-place base material. Compute this value by using the “k-value Calculator” button. Clicking this button opens your internet browser to the American Concrete Pavement Association’s (ACPA) k-value calculator website at http://apps.acpa.org/applibrary/KValue/. Guidance for its use is shown in Figure 550.2. Calculating the k-value does not automatically place the value in the BCOA-ME and the value must manually be entered.

STEP 10. Select either the “Yes” or “No” button to indicate if transverse cracks are present. The design process includes a check to determine if there is the potential for reflective cracking to occur. This does not affect the design thickness but indicates whether preemptive measures should be taken prior to placing the overlay to prevent reflective cracking into the overlay.
Figure 550.1 – View of BCOA-ME

**GENERAL INFORMATION**
- Latitude (degree): 44.42
- Longitude (degree): -93.14
- Elevation (ft): 874
- Estimated Design Lane ESALs: 1,000,000
- Maximum Allowable Percent Slabs Cracked (%): 25
- Deemed Reliability against Slab Cracking (%): 0

**CLIMATE**
- AMDAT Region ID
- Map of Sunshine Zone

**EXISTING STRUCTURE**
- Post-milling HMA Thickness (in): 6
- HMA Fatigue
- Composite Modulus of Subgrade Reaction, k-value (psi/in):
- Does the existing HMA pavement have transverse cracks?
  - Yes
  - No

**PCC OVERLAY PROPERTIES**
- Average 28-day Flexural Strength (three-point bend)
- Estimated PCC Elastic Modulus (psi):
- Coefficient of Thermal Expansion (10^-6 in/°F/in):
- Fiber Type:

**JOINT DESIGN**
- Joint Spacing (ft): 6 x 6

[Calculate Design]
STEP 11. Enter the “Average 28-day Flexural Strength” as 650.

STEP 12. Enter the “Estimated PCC Elastic Modulus” as 4,000,000. Don’t use the “Epec Calculator” button.

STEP 13. Enter a “Coefficient of Thermal Expansion” of 5.0. Don’t use the “CTE Calculator” button.

STEP 14. Select the “Fiber type” with the drop-down box. The MnDOT Concrete Engineer may be consulted for the use of fibers in whitetopping.

STEP 15. Select a “Joint Spacing” of “6 x 6” with the drop-down box.

STEP 16. Left-click on the “Calculate Design” button to calculate the design. Warning, the program will not automatically recalculate the design when changes are made to the inputs and the “Calculate Design” button must be clicked again.
Figure 550.2 - ACPA k-value Calculator

1. Click on the calculator.

2. Select “Resistance Value (R-Value)” and enter the mean R-value.

3. Click “Calculate Resilient Modulus”

4. Choose Layer Type. Typically the selected material will be “unstabilized (granular) subbase.” (Repeat for each layer.)

5. Use a Resilient Modulus of 27,000 for aggregate base or 15,000 for select granular.

6. Enter the layer thickness.

7. To define another layer repeat 4-6.

8. Click the “Calculate” button to compute the composite k-value.
B. Results

The program displays the calculated PCC overlay thickness, which is the exact, un-rounded value and also displays the design PCC overlay thickness which is the rounded final value. Do not report a design PCC overlay thickness of less than 4.0 inches; report it as 4.0 inches.

C. Printing and saving results

Right-click anywhere on the BCOA-ME and select “Print preview” from the drop-down menu. Make sure that preview looks acceptable. Typically, setting the print size to “shrink to fit” will provide the best appearance for the BCOA-ME; however, superfluous information will be on a second page and only the first page will require printing. Either select a printer to print a physical copy or, if equipped, select “Adobe PDF” to create an Adobe PDF file.
In the MDR, provide the MnDOT Standard Plans and Plates for PCC pavement to include as a reference in the project plans.

1. Access to MnDOT Standard Plans and Plates:

   The MnDOT Standard Plans are available at the following link:
   [http://standardplans.dot.state.mn.us/](http://standardplans.dot.state.mn.us/)

   The MnDOT Standard Plates are available at the following link:
   [http://standardplates.dot.state.mn.us/](http://standardplates.dot.state.mn.us/)

2. These are commonly used or referred to standard plans/plates in PCC paving plans:

   - Any of the Standard Plans in the 200 series (5-297.2xx)
   - Standard Plan 5-296.616 – Rumble Strips for Concrete
   - Standard Plate 1070x - Reinforced Panel over Culverts
   - Standard Plate 1103x - Typical Dowel Bar Assembly
   - Standard Plate 1141x - Pavement Keyway for Keyed Joint Construction
   - Standard Plate 1150x - Construction of Header Joints
   - Standard Plate 1210x – Concrete Pavement Adjacent to Railway Crossing