FDM 14-25-10 Pavement Rehabilitation Guidelines

May 15, 2019

10.1 General

These guidelines are intended to help determine the best method for rehabilitating pavements. Pavement rehabilitation is a structural or functional enhancement that extends the pavement life, by significantly improving the pavement condition and ride quality.

The recommendations presented are intended as general guidance for the pavement evaluation process and are not intended as absolute criteria applicable to all circumstances. Therefore, each project must be evaluated on its own merits.

An important preliminary activity is an assessment of the existing condition of the pavement. This assessment examines the International Roughness Index (IRI) and Pavement Condition Index (PCI) history and draws conclusions from that data. The assessment should also include a field survey of the project for evaluating pavement condition and estimating repair quantities.

A visual survey, involving a field review of the pavement in person, does have limitations. The level of distress at a joint or crack may not be fully determined simply by visual inspection of the surface. However, it is not in the scope of any one design project to core or perform nondestructive testing on every joint or crack to determine if there is underlying distress. Therefore, the designer must rely on resources such as PMDSS, the Concrete Pavement Rehabilitation Manual, and the limited coring performed on each project.

The base and subgrade conditions also play a significant role in performance. If serious base and/or subgrade problems exist, then a more extensive rehabilitation may be needed. Designers should request their Regional Soils engineer to drill soil borings and help determine the cause of the base or subgrade problems. If a more extensive rehabilitation level cannot be attained, a lower level of performance can be expected of the rehabilitation. It is important to determine the cause of the distress so that the correct rehabilitation strategy can be identified.

One of the key criterion governing the choice of a pavement rehabilitation strategy is the amount of existing pavement in need of repair. When the amount of repair necessary exceeds an amount economically feasible for the project, the pavement should be reconstructed. Each project should be evaluated individually utilizing Life Cycle Cost Analysis to determine if rehabilitation or reconstruction is most cost effective.

Typically, the term repair refers to a full depth procedure, except in the case of Partial Depth Repair. Just as typically, the term “patch” refers to a partial depth procedure.

10.2 Concrete Pavement

There are several distresses in concrete pavements that justify a pavement rehabilitation. Some common distresses are transverse or longitudinal cracking, joint deterioration, and faulting. Concrete pavement rehabilitation methods used by WisDOT consist of full/partial depth repair, slab replacement, diamond grinding, and rubblization. More guidance on concrete pavement rubblization can be found in FDM 14-25-15.

The May 1992 version of the Concrete Pavement Rehabilitation Manual (Exhibit 10.1) should be used as a resource for estimating repair quantities. This manual provides the methodology, based upon type and rehabilitation strategy, for the assessment of distresses in concrete pavements.

If *Concrete Pavement Repair* or *Concrete Pavement Repair SHES* are part of a project, designers should also consider including *Concrete Pavement Replacement* and *Concrete Pavement* bid items since unforeseen pavement patching/repairs may extend beyond 15 feet in length.

10.3 Hot Mix Asphalt (HMA) Pavement

There are several distresses in HMA pavements that justify a pavement rehabilitation. Some common distresses are alligator/fatigue cracking, centerline joint deterioration, reflective cracking, and rutting. Common methods of HMA pavement rehabilitation used by WisDOT are mill and overlay, Cold In-Place Recycling(CIR), and pulverization. More guidance on HMA pavement pulverization can be found in FDM 14-25-20 and CIR in FDM 14-25-25.

LIST OF EXHIBITS

FDM 14-25-15 Concrete Pavement Rubblization

November 15, 2022

15.1 General

The purpose of this procedure is to provide guidance on rubblization of concrete pavement. Further guidance can be found in CMM 3-50. The use of crack/break and seat is not recommended on the state trunk highway system.

The objective of rubblizing concrete pavement is to produce a structurally sound base and to prevent reflective cracking in an overlay by destroying the integrity of the existing slab. This objective is achieved by fracturing the distressed concrete pavement in place, thereby reducing the concrete to rubble. The rubblized material acts as an interlocked unbound layer comparable to a high-quality aggregate base.

The rubblization process is applicable to Jointed Plain Concrete (JPC), Jointed Reinforced Concrete (JRC), and Continuously Reinforced Concrete (CRC) pavement. Reinforcing steel in JRC and CRC pavement must become debonded from the concrete to be successful and meet the performance expectations.

Rubblization, along with an HMA or concrete overlay, is considered pavement replacement. Conform with FDM 14-15-10, Table 10.2 for standard rehabilitation scenarios.

15.2 Why Rubblize

Reflective cracking is a major problem in HMA overlays placed over intact concrete pavement, even when used in combination with other repair techniques (such as slab-jacking, partial and full-depth slab replacement, etc.). Reflective cracks can start to appear in the overlay within a few years after overlay placement. These reflective cracks then should be sealed and maintained to prevent further deterioration of the overlay. Rubblization addresses the reflective cracking problem by thoroughly fracturing the concrete pavement to produce a uniform, high quality base, thus eliminating slab action. Some benefits to rubblization include:

- Prevents reflective distresses in the overlay
- Recycles concrete into a high-quality base material
- Reduces or eliminates the need to haul the existing concrete
- Can be accomplished next to live traffic lanes
- Can be accomplished over existing utilities
- Can be accomplished in urban and rural situations
- Reduces time of construction

15.3 Selecting Rubblization Projects

Rubblization is an effective pavement replacement technique in many situations, but inadequate project scoping can lead to constructability problems. Proper project scoping should follow these steps:

1. Check the condition of the existing concrete pavement
2. Check for roadway features
3. Verify subgrade conditions

15.3.1 Condition of Existing Concrete Pavement

Determine the condition and distresses of the existing concrete pavement. Rubblization is considered a viable option when the concrete pavement has no remaining life – i.e., exhibits extensive structural distress along the project. Remedial action may need to be performed on joints prior to rubblization. However, there may be cases where the pavement is far too deteriorated for rubblization to be used as a valid treatment, i.e, wide open joints, severe faulting.

To maximize the initial construction investment of the concrete pavement, rubblization should be considered when one or more of the following structural deficiencies exist(s):

- Greater than 20% of the concrete pavement joints need repair
- Greater than 20% of the concrete surface has been patched
- Greater than 20% of the concrete slabs exhibit the “slab breakup” pavement distress
- Greater than 20% of the project length exhibits “longitudinal joint distress” greater than 4 inches wide

If delamination is present in the existing concrete pavement, additional breakage and/or equipment may be needed.

15.3.2 Roadway Features

Many conditions need to be addressed before rubblizing. The following is a non-inclusive list of roadway features that need to be addressed in the design phase:

- Matching into existing curb and gutter that will remain in place (milling is required)
- Cross-slope correction (milling or additional material may be required)
- Location of any utility structures, e.g., manholes, catch basins (positive identification for construction)
- Profile changes (check overhead clearances)
- Existing shoulder pavement structure (if required for handling traffic)
- Underlying rigid layer, e.g., bedrock, an old intact concrete pavement (additional breakage may be needed)
- Old/brittle underground utilities (gas lines, water lines, etc.) that are within 4 feet of the rubblized layer (requires detailed evaluation)

FDM Chapter 11 contains additional feature constraints.

15.3.3 Subgrade Conditions & Drainage

Past construction practices of paving concrete pavement directly on subgrade or "weak" subgrade make rubblization susceptible to subgrade yielding problems during construction operations. Consult the Regional Soil engineer for guidance on classifying the soil and the assignment of a Design Group Index (DGI) value. Based on WisDOT research and experience, the rubblization construction process experiences difficulties with soil classified with a DGI greater than 12 (AASHTO A-6 & A-7 classification) or when the water table is less than 4 feet from the top of the existing subgrade. If the water table is less than 4 feet from the top of the existing subgrade, a more detailed investigation may be needed. Consult the Regional Soil engineer for guidance.

It is not statewide standard practice to use edge drains on rubblization projects. However, rubblizing the concrete slabs significantly increases the permeability of the concrete layer, and any surface water entering the rubblized layer can be removed through the use of edge drains, especially for pavements supported by fine-grained soils with low permeability. In areas with coarse-grained soils that have high permeability, edge drains are not typically needed. If a drainage system is desired, the edge drains and outfalls can be designed similar to typical drainage systems when open graded base course is used on a project. The use of drains in spot locations is an acceptable practice.

15.3.3.1 Edge Drains

When used, edge drains should be installed before rubblizing to ensure that there is sufficient time to allow the subbase and subgrade to drain and dry out. If edge drains are installed before rubblizing, attention must be paid to ensure that the trench is well compacted and protected. An HMA layer may be paved over the trench before allowing traffic next to the trench. If staging requires a high volume of traffic over the trench for an extended period, an HMA layer should be placed over the trench. Consult the Regional Soil engineer to determine any drainage needs of rubblization projects.

15.3.3.2 Subgrade Investigation

To help determine the foundation support conditions and strength before construction, a supplementary subgrade investigation can be performed. Falling Weight Deflectometer (FWD), Ground Penetrating Radar (GPR) and Dynamic Cone Penetrometer (DCP) testing are methods used to evaluate the current subgrade condition. FWD and GPR testing will provide information on subgrade uniformity, and the computed Resilient Modulus (M_R) values. DCP testing, which requires coring of the existing concrete pavement, will provide information on the subgrade bearing capacity. Contact the Geotechnical Unit supervisor at (608) 246-7952 to request subgrade testing for a project. For the DCP testing method, the Department recommends the following procedure:

Determine the base course thickness from as-built plans. Penetrate the rod of the DCP to the bottom of the base course, i.e. to the top of the subgrade. From that point, record the Penetration Rate (PR), in inches per blow, until a rock or other obstruction is hit or until the rod cannot go any deeper. The PR for that location can be an average or a common value of the individual recordings. Using Figure 15.1, convert the PR to the California Bearing Ratio (CBR). Then, use Figure 15.2 to determine whether the subgrade, rubblized concrete, and base aggregate layer provide enough support to accommodate the construction process, or whether any remedial action is required. Use the CBR value determined from Figure 15.1 as the x-axis value for Figure 15.2. The y-axis value can be calculated by adding the thickness of any existing base aggregate to the thickness of the rubblized concrete pavement. The intersection of these values identifies a support relationship that is to be compared to the curve shown in Figure 15.2. If the support relationship falls above the curve, then adequate support for construction is present. If the support relationship falls below the curve, then remedial improvements to the base structure are required. An intermediate base layer can be used to provide the required support.

Note that the figures could also be used in reverse order by first determining the minimum CBR needed, then determining the maximum penetration rate permissible to provide adequate support.

Each DCP test location along a project should be analyzed individually. The individual tests should also be compiled and the information looked at in unison to arrive at generalized project conditions for pavement design. Additional testing in soft/weak areas may be needed to determine the exact limits requiring remedial improvements.

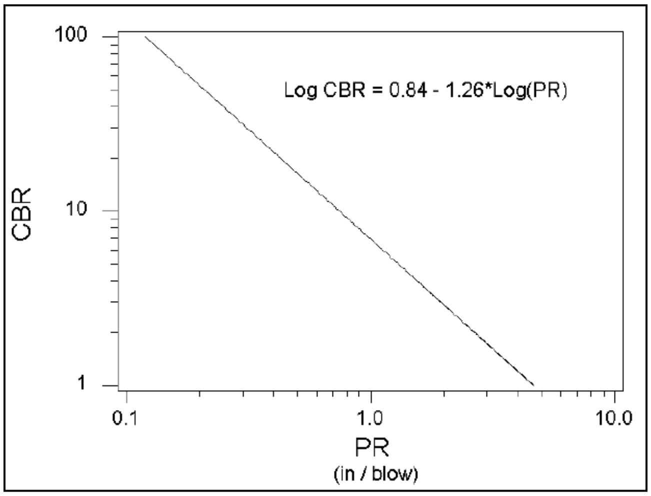

Figure 15.1. DCP Data Conversion to CBR

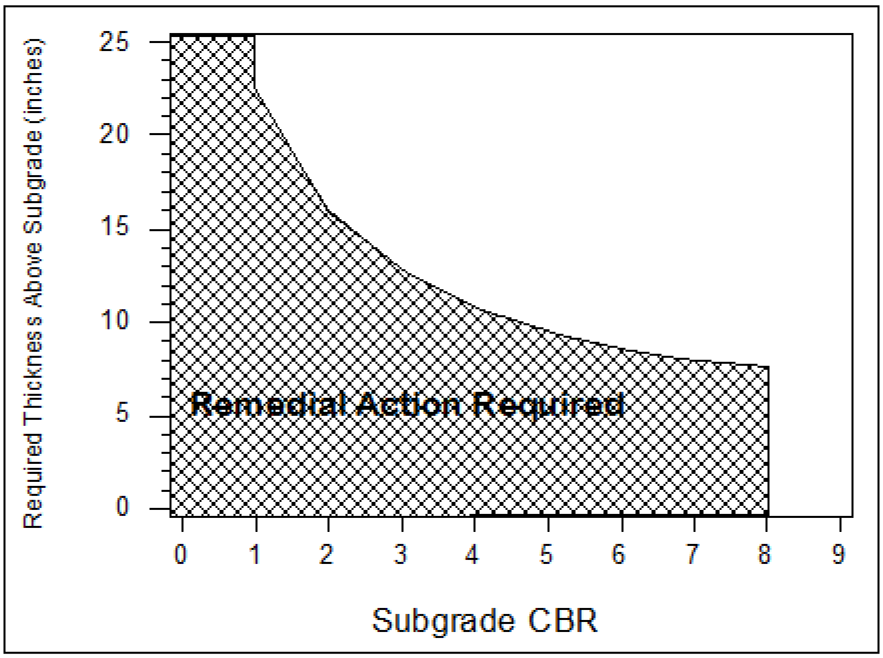

Figure 15.2. Subgrade/Base Layer Adequacy

For localized areas of poor stability, the specification allows for some modification to the broken particle sizes during construction. Excavation Below Subgrade (EBS) or increasing the overlay thickness are other possible solutions for these poor areas. It is important to remember that the rubblized layer must still provide a good working platform for paving operations and a stable foundation for the new pavement.

It should be noted that judgment is involved in determining existing and corrective subgrade needs. DCP and

FWD test results are dependent on the subsurface conditions at the time of testing and may differ from the conditions at the time of construction. The time of year construction occurs and the amount of rainfall during construction may have a large effect on subgrade stability.

15.4 Structural Design

WisPave is WisDOT's official software for pavement structural design.

15.4.1 HMA Pavement

When determining the HMA overlay thickness, both constructability and structural requirements of the rubblized pavement must be satisfied. The specific design input is the structural layer coefficient for each structural layer within the flexible pavement. The structural capacity of the entire pavement structure is represented using the Structural Number (SN) index, which is a sum of the product of the layer coefficient and layer thickness of all layers. The nationwide typical structural layer coefficient assigned to the rubblized layer is in the range of 0.14 to 0.30. Wisconsin policy is to use a range of 0.20 to 0.24.

The minimum HMA overlay thickness placed over rubblized concrete is 4 inches from a constructability standpoint. The first layer of HMA must be thick enough to adequately cover the rubblized concrete pavement and carry the expected construction traffic temporarily until the additional layers are placed. When making cross-slope corrections with the first layer of HMA pavement, maintain an adequate thickness at both the centerline and the edge of the pavement. Minimum HMA pavement layer thicknesses are found in Standard Spec 460.3.

Estimated quantities for the first layer of HMA are to be calculated by using the following formula:

Width (ft) x Length (ft) x [{112 lb/SY/inch x Depth (inch)} + 20 lb/SY] x 1 SY/9 ft^2 x 1 ton/2000 lbs = _____ tons

This method adds 20 lb/SY to account for possible irregularities in the rubblized surface.

15.4.2 Concrete Pavement

Give credit to the rubblized material in the thickness design by increasing the k value, provided in the soils report, by an amount directly related to the thickness of the rubblized concrete pavement. Table 15.1 indicates the increase in the k value for different thicknesses of rubblized material. These values should be interpolated for intermediate thicknesses. The modified k value should be used in WisPave to determine thickness design.

***Table 15.1* Modified k Values for WisPave**

Thickness of Rubblized Material	Increase in k Value
Less than 6"	0
6"	45
8"	90
10"	120
12"	150
16" and up	175

When placing concrete pavement over rubblized concrete, a bond breaker layer must be used. This should be a thin layer (about 1 1/2 inches) of asphalt treated permeable base, standard HMA pavement, open graded base, dense graded base. The purpose of the bond breaker is to allow for curling and warping of the concrete pavement. A bond breaker does not affect the structural coefficient of the rubblized material.

15.4.3 Intermediate Base Layer

The surface of the rubblized concrete layer cannot be bladed with a motor grader but is generally suitable for paving over.

If an intermediate base layer is proposed to restore the grade, make cross-slope corrections, and/or to improve base support, the following materials (and associated bid items) can be specified:

ITEM NUMBER	DESCRIPTION	UNIT
305.0110	Base Aggregate Dense 3/4-Inch	TON
305.0115	Base Aggregate Dense 3/4-Inch	CY
305.0120	Base Aggregate Dense 1 1/4-Inch	TON
305.0125	Base Aggregate Dense 1 1/4-Inch	CY
306.0110	Salvaged Asphaltic Pavement Base	TON
306.0115	Salvaged Asphaltic Pavement Base	CY

An intermediate base layer should be a minimum of 4 inches thick for constructability purposes. Therefore, it should be accounted for in the structural design. The structural coefficient of the rubblized layer should not exceed the structural coefficient of the intermediate base layer material. The layers of a HMA pavement structure are usually arranged such that the quality of materials decreases with increasing depth. Rubblized concrete pavement is allowed a structural coefficient ranging from 0.20 to 0.24, and an intermediate base layer can consist of several materials ranging in coefficients from 0.10 to 0.25. Therefore, depending on material used, an intermediate base layer can decrease the structural coefficient of the rubblized material. (FDM 14-10, Attachment 10.1)

When estimating quantities add 20 lb/SY to account for possible irregularities in the rubblized surface.

15.5 Structure Clearance

Often, special circumstances are required to accommodate overhead structure clearances. Each situation must be evaluated to determine which design will best provide long-term pavement performance while meeting project requirements.

Options available in these areas include reconstruction, partial-depth concrete milling and pavement inlay, or simply an overlay.

Some factors to consider are:

- Reconstruction: Existing elevations can be maintained or even lowered. Reflective cracking is eliminated.
- Partial-depth concrete milling and pavement inlay: This process can be completed quickly and under traffic. Existing elevations can be maintained. Reflective cracking of the overlay should be expected.
- Overlay: This process can be completed quickly and under traffic. The pavement elevation will increase but not as much as with the rubblize and overlay alternative. Reflective cracking of the overlay should be expected.

15.6 Other Considerations

Any existing asphaltic overlay must be removed before rubblizing the underlying concrete. This will require a separate bid item. Full-depth concrete pavement repair is not necessary. Full-depth asphalt patches, in good condition, may remain in place. Refer to Standard Spec 335.3.3 for the removal requirements of other materials. For severely deteriorated concrete joints not previously repaired, replace the joint with concrete base patching prior to rubblization or remove the joint and replace with base aggregate dense 1 1/4-inch or 3/4-inch.

15.7 Staging

If staging is required for a rubblization project, special consideration must be given in certain areas.

15.7.1 Shoulders and Edge Drains

It is vital to protect the shoulders and edge drains. Following are three common staging scenarios along with a suggestion for protecting the shoulder and edge drains:

1. Roadway closed to traffic: edge drain system is installed, concrete is rubblized, and asphalt overlay is paved on travel lanes and shoulders before opening to traffic.
2. Construction with single lane closures and edge drains installed in advance of rubblizing and paving operation: the edge drain trench is capped either with HMA, crushed aggregate, or asphalt millings to provide an adequate shoulder before opening the adjacent lane to traffic.
3. Construction with single lane closures and edge drain installed just ahead of rubblizing: edge drain system is installed, concrete is rubblized, asphalt overlay is paved on the closed lane and adjacent shoulder before opening to traffic.
4. Edge drains should be maintained to provide proper performance for the life of the pavement.

15.7.2 Traffic Over Rubblized Concrete

The rubblized pavement should not carry traffic. It is best to provide traffic control that will not allow traffic to travel on rubblized pavement or on a thin layer of HMA over the rubblized pavement. If traffic must travel on one layer of HMA over the rubblized pavement, a sufficient HMA thickness must be in place.

If staging requires that traffic travel on an intermediate layer of HMA pavement before the full pavement is placed, consider providing an undistributed quantity of patching in the contract. Patching can be specified under one or more of the following bid items:

ITEM NUMBER	DESCRIPTION	UNIT
390.0103	Base Patching	SY
390.0201	Base Patching Asphaltic	TON
390.0203	Base Patching Asphaltic	SY
465.0110	Asphaltic Surface Patching	TON

15.7.3 Ramps and Intersections

Stage the rubblization and paving at ramps and intersections to maintain traffic flow. Require the contractor to provide proper traffic control.

FDM 14-25-20 HMA Pavement Pulverization

May 15, 2019

20.1 General

Pulverization is a pavement replacement technique that involves the in-place, full-depth pulverizing and mixing of an HMA pavement and a predetermined amount of the underlying base material. The objective of pulverization is to produce a structurally sound, homogeneous base and to prevent reflective cracking by reducing the distressed HMA pavement into a base material.

Pulverize and relay differs from mill and relay in that pulverize and relay cannot be performed on HMA pavements over concrete, whereas mill and relay can. The other major difference between the two techniques is the size of the reprocessed material. See Standard Spec 325 and Standard Spec 330.

Pulverization is considered a pavement replacement option. Conform with FDM 14-15-10, Table 10.2 for standard rehabilitation scenarios.

20.2 Why Pulverize

Overlaying an HMA pavement may result in reflective cracking, premature pavement distress, and reduced overlay performance. Pulverization addresses these problems by reprocessing the entire HMA pavement in-place to produce a uniform, high quality base material.

Pulverization benefits include:

- Can be accomplished next to live traffic lanes
- Can be accomplished over existing utilities
- Can be accomplished in urban and rural situations
- Reduces or eliminates the need to haul material
- Provides a window of opportunity to fix localized subgrade problems
- Recycles HMA into a base material
- Provides a high-quality base material
- Prevents reflective distresses

20.3 Selecting Pulverization Projects

Pulverizing is an effective pavement replacement technique in many situations, but inadequate project scoping can lead to constructability problems. Proper project scoping should follow these steps:

- Check the condition of the existing HMA pavement
- Check for roadway features
- Verify subgrade conditions

20.3.1 Existing HMA Pavement

Any HMA pavement, except those directly on concrete, can be pulverized. To maximize the initial construction investment of the HMA pavement, pulverization should be considered after at least one rehabilitation cycle, or when one or more of the following structural deficiencies exist(s):

- Alligator cracking
- Block cracking
- Extensive potholing or patching
- Structural rutting
- Longitudinal or transverse distortion (e.g. shoving or tenting)
- Extensive transverse cracking (banded or spacings (10 feet)

20.3.2 Roadway Features

Many conditions need to be addressed prior to pulverizing. The following is a non-inclusive list of roadway features that need to be addressed in the design phase:

- Matching into existing curb and gutter that will remain in place
- Cross-section
- Location of any utility features
- Profile changes

FDM Chapter 11 contains additional feature constraints.

20.3.3 Verify Roadway and Subgrade Conditions

The pavement must be cored to determine the HMA thickness. The base thickness and the condition of the subgrade should be determined by roadway borings. Coring and boring logs or a summary table showing pavement thickness, base thickness, and subgrade information should be included in the plans.

HMA pavements that were placed on very thin base materials may be problematic during pulverization in that the pulverizer may get into the subgrade material. The pulverized material may also be susceptible to subgrade yielding problems if the thickness of the pavement or base materials is inadequate. If poor subgrades exist, improvements to the subgrade are required. It is important to remember that the pulverized layer must still provide a good working platform for paving operations and a stable foundation for the new pavement. Susceptible soils can also be problematic if the pulverized material is inadequately compacted or unpaved and exposed to rain. Each project must be individually analyzed during the design phase for potential problems.

If the pulverized material will not provide adequate base thickness or desired gradation, additional base material may be added. Additional base material should be spread on the existing pavement and pulverized with the pavement if possible. If not, consider limiting exposure to rain.

If the pulverized material will not have the structural strength or necessary mechanical properties to support the traffic loads, additional base material and/or a stabilizing additive (such as liquid asphalt, foamed asphalt, asphalt emulsion, or fly ash) may be required.

Additional required materials will be paid for separately.

20.4 Structural Design of Pavements Over Pulverized Material

WisPave is Wisconsin DOT’s official software for pavement structural design.

20.4.1 HMA Pavements

Use WisPave to design HMA pavements over pulverized material using the structural layer coefficients guidance given below.

20.4.2 Structural Layer Coefficients

Pulverized material can vary in both strength and stability; therefore, its structural layer coefficient ranges from 0.10 to 0.25. Despite the thickness of the existing HMA, one to two inches of the existing base material is typically incorporated with the pavement thereby producing a blend of pavement and base material. If a thin HMA pavement (e.g., 3 inches) is pulverized, and another 1-2 inches of base material is mixed with it, the net effect is essentially an aggregate base layer with a layer coefficient typical of crushed stone or crushed gravel (0.14 or 0.10). On the other hand, if a thick HMA pavement (6 inches or greater) is subject to the same operation, producing a blend of predominantly pavement material, the net effect is a layer coefficient greater than that of aggregate base material. When pulverizing these thick pavements, a structural layer coefficient as high as 0.25 can be used if the base consists of crushed stone. An important factor in the range for this material is whether the existing base material is crushed gravel or crushed stone. In the absence of this knowledge, it is recommended that a crushed gravel be assumed. The type of aggregate within the HMA pavement to be pulverized is irrelevant.

Table 20.1 provides guidelines to determine the appropriate structural layer coefficients of the material:

Table 20.1 Structural Layer Coefficients

Percentage of Base Material in Pulverized Mix (%)	Structural Layer Coefficient	
	Crushed Gravel or Unknown Base	Crushed Stone Base
> 25	0.10	0.14
> 20 and ≤ 25	0.14	0.18
> 14 and ≤ 20	0.18	0.22
≤ 14	0.21	0.25

Note: Use 0.25 as a structural layer coefficient if a stabilizing additive is used.

20.4.3 Minimum HMA Thickness

Consider the thickness of the first layer of HMA. It must be thick enough to adequately cover the pulverized material and carry traffic temporarily until the additional layer or layers is/are placed. Minimum HMA pavement layer thicknesses are specified in Standard Spec 460.3. Cross-slope corrections should typically be done while re-shaping and compacting the pulverized material. However, when making cross-slope corrections with the first layer of HMA pavement, maintain an adequate thickness not only at the centerline but also at the edge of the pavement.

20.4.4 Concrete Pavements

Credit should be given to the pulverized material in the thickness design. This should be done by increasing the k value by an amount directly related to the thickness of the pulverized material. Table 20.2 indicates the increase in the k value for different thicknesses of pulverized material. These values should be interpolated for intermediate thicknesses. The modified k value should be used in WisPave to determine thickness design.

Table 20.2 Modified Values for WisPave

Thickness of Pulverized Material	Increase in k Value
Less than 6”	0
6”	30
8”	50
10”	80
12”	120
16” and up	150

20.5 How to Pulverize

Any HMA patches may remain in place. Loose asphaltic joint fillers visible on the pulverized surface must be removed before the new pavement is placed.

The maximum pulverizing depth of most pulverizers in one pass is 16 inches. The pulverization process must include a minimum of one inch of base material to provide cooling for the pulverizer. HMA pavements greater than 15 inches must be milled prior to pulverizing. The standard width that can be pulverized in one pass is 8 feet. To achieve proper compaction, it is important that a sufficient amount of water be added. Therefore, it is recommended that water be paid for as a separate bid item at a rate of 10 gallons/ton of pulverized material. The volume increase of the pulverized material, after compaction, is approximately 10-15 percent. The pulverization specifications are located in Standard Spec 325.

Selecting an appropriate pulverization depth depends on the uniformity of pavement thickness, as determined from the cores. Avoid getting into the subgrade.

HMA shoulders will be pulverized with and at the same depth as driving lanes. Base shoulder material, extending beyond or in lieu of HMA shoulders, can be left in place if the structure is not to be widened.

The characteristics of the compacted pulverized base will vary depending on the grade of the existing asphalt, temperature, amount of aggregate in the mix, and any stabilizing additives used.

20.6 Pavement Design Report

Specify in the Pavement Design Report, the depth of base material to be pulverized and the width to which the material should be spread.

20.7 Pavement Widening

The existing shoulder material and the finished cross-section should both be considered if the pavement is to be widened. HMA shoulders will be pulverized with and at the same depth as driving lanes. Treatment options of base shoulder material, extending beyond or in lieu of HMA shoulders, include:

- Excavating and spreading the existing base shoulder material onto the existing pavement before pulverizing
- Moving existing base shoulder material so it is not pulverized.

The pulverized material shall be spread across the desired widened width to provide a homogeneous mixture. Quantity is to be paid for per Standard Spec 325.4 or Standard Spec 325.5.

20.8 Curb and Gutter

Pre-milling along the edge of the gutter is required. Excess material may be hauled or stockpiled for other uses. These items will be paid for according to Standard Spec 330.

20.9 Structure Clearance

Special considerations are often required to accommodate structure clearances. Each situation must be evaluated to determine which design will best provide long-term pavement performance while meeting project requirements. Options available in these localized areas include:

- Reconstruction
- Partial-depth milling and pavement overlay
- Partial-depth milling, pulverizing, and applying a new pavement
- Pulverizing, removing some of the material and applying a new pavement, or
- Simply an overlay

Some factors to consider are:

- Reconstruction – Existing elevations can be maintained or even lowered. Reflective cracking is eliminated.
- Partial-depth HMA milling and pavement overlay – This process can be completed quickly and under traffic. Existing elevations can be maintained. Reflective cracking of the overlay may occur.
- Partial-depth milling, pulverizing, and applying a new pavement - This process can be completed quickly and under traffic. Existing elevations can be maintained. Reflective cracking is eliminated.
- Pulverizing, removing some of the material and applying a new pavement - This process can be completed quickly and under traffic. Existing elevations can be maintained. Reflective cracking is eliminated.
- Overlay - This process can be completed quickly and under traffic. The elevation will be increased, but not as much as in the pulverize and overlay sections. Reflective cracking of the overlay may occur.

20.10 Traffic Over Pulverized HMA

Traffic may be allowed to travel on pulverized material according to Standard Spec 325. Evaluate the quality of old road mixes that are pulverized because they may take longer to set prior to handling traffic loads.

20.11 Tack Coat

When placing an HMA pavement on pulverized HMA, if the pulverized mix contains less than 25 percent of original base material, a tack coat should be applied to the pulverized surface. Tack coat shall be applied according to Standard Spec 455 and FDM 14-10-10.10.

FDM 14-25-25 HMA Pavement Cold In-Place Recycling (CIR)

November 17, 2020

25.1 General

Cold In-Place Recycling (CIR) is an asphalt pavement rehabilitation or reconstruction technique where existing asphaltic pavement is recycled in-place without application of heat. The process is sometimes referred to as partial depth recycling because only the upper asphalt pavement materials are recycled. Typically, the underlying materials and some of the asphalt pavement is left intact. CIR treatment depth is generally from 3 to 4 inches. In the CIR process, milled material from the existing pavement is crushed and sized to the required gradation and mixed with a stabilizing agent. Nationally, foam asphalt and emulsified asphalt are commonly used as stabilizing agents, however WisDOT only uses foam asphalt. The milled Recycled Asphalt Pavement (RAP) is mixed with the stabilizing agent then placed and compacted using conventional paving equipment. A final surfacing layer is placed over the CIR layer. This is to protect the CIR layer from moisture ingression and to provide additional structural support for the design traffic load.

Designers should consider CIR, along with HMA overlay, as pavement resurfacing or pavement replacement type of work during the scoping/design stage, depending on CIR treatment depth.

The CIR process is considered as resurfacing when only a portion of the HMA layer is recycled, leaving a 1" minimum of the existing HMA layer. If the CIR process recycles the entire HMA pavement thickness, then CIR is considered pavement replacement. Conform to FDM 14-15-10, Table 10.2 for standard rehabilitation scenarios and FDM 3-5-1 for Highway Improvement Type definitions.

25.2 Reasons for CIR

When pavement distresses exist deep in the asphalt layer, traditional rehabilitation methods such as mill and overlay do not provide a long-term solution. In such situations, the CIR process can be a viable rehabilitation alternative. In most cases, within a short period of time after rehabilitation of the pavement with mill and overlay technique, pavement distresses, primarily cracking, reflect through the new HMA overlay. Reflected cracks affect ride quality and allow water to penetrate the underlying base and subgrade. This causes the asphalt mix to deteriorate and the base and subgrade to soften. Consequently, the service life of the pavement is reduced. The CIR process disrupts existing crack patterns and produces a crack free layer for the new surface, such as an asphalt overlay or an asphalt surface treatment. For maximizing the effectiveness of CIR in mitigating cracking, as much as possible of the existing asphaltic pavement layer should be treated.

The following are some of the benefits of CIR process:

- Potential cost savings compared to mill and overlay rehabilitation technique with equivalent depth of treatment
- Reflective cracking eliminated/mitigated
- Pavement structural improvements may be achieved without significantly changing geometry
- Conservation of non-renewable resources
- Reduced traffic disruptions and road user inconvenience
- Can be used in urban and rural roadways
- No need to haul material from project, therefore minimize hauling costs and trucking

25.3 Selecting CIR Projects

Project selection is among the most important factors in assuring the success of a CIR project. The selection process should include the following steps:

- Distress identification
- Traffic assessment
- Historic Information assessment
- Geometric assessment
- Roadway, subgrade, and drainage conditions

25.3.1 Distress Identification

CIR can be used to address several distresses, both load and non-load related. CIR should be considered when one or more of the following deficiencies exist(s):

- Non-Load Associated Cracking
    - Block
    - Longitudinal
    - Transverse

    - Reflective
- Surface Defects
    - Weathering and Raveling
    - Pot holes
    - Flushing/bleeding
    - Skid resistance
- Deformations
    - Surface rutting <1/2”
    - Rut depth >1/2” (should be investigated to determine the cause. Rutting caused by instability of base and/or subgrade layers are not candidates for CIR).
- Load Associated Cracking
    - Fatigue - bottom up and top down should be investigated to determine the cause (Low and medium severity level fatigue cracking can be treated with CIR if the distress is not caused by poor drainage or a soften base or subgrade).
- Poor ride quality. Pavement roughness caused by an unstable base and subgrade cannot be adequately treated by CIR.

If the distresses present are caused by poor base, soft subgrades or lack of proper drainage, CIR would not be an appropriate rehabilitation strategy without prior corrective action. When small areas of failure are encountered, generally less than 10 percent of the project area, it may be feasible to perform full depth repair for those areas, then proceed with a complete CIR rehabilitation of the remaining roadway.

Depending on the available HMA overlay thickness and the condition of the underlying concrete pavement, CIR may be applied to composite pavements (i.e. HMA overlays of concrete pavements). CIR on composite pavement may be an option to removing and replacing the HMA overlay. However, this option is only feasible if the underlying concrete is in fair to good condition. If there is underlying slab movement or differential settlement, this may indicate unstable or non-uniform subgrade support. In such situations, CIR on composite pavement cannot be considered as a viable alternative.

25.3.2 Historic Information Assessment

When assessing the required CIR treatment depth and surface requirements, a review of available historic information can be helpful. The review of historic or existing information includes:

- Pavement age
- Previous distress survey results
- Thickness of as-built layers
- Maintenance history

Pavement age and past distress surveys can be used to assess the rate of pavement deterioration. Maintenance records such as patching material types would affect the number of mix design required or the requirement of surface milling.

25.3.3 Geometric Assessment

Roadway geometry will influence the types of areas which can be treated with a CIR in a project segment, especially in urban settings. CIR equipment can handle moderate radius turns such as acceleration/deceleration lanes, turn lane, etc. depending on the type of CIR train to be used in the project. Single-unit trains measure about 70 feet in length, while multi-unit trains can stretch up to 150 feet long. Some conditions may need to be addressed prior to CIR. The following is a non- inclusive list of roadway features that must be considered in the design phase:

- Matching into existing curb and gutter that will remain in place
- CIR equipment access and maneuverability
- Roadway profile
- Location of utility manhole covers
- Vertical overhead clearances
- Roadway intersections

FDM Chapter 11 contains Department policy and other guidance on roadway geometrics.

25.3.4 Verify Roadway, Subgrade, and Drainage Conditions

The existing pavement thickness must be determined and included in the contract documents. The pavement thickness may be determined for the entire project length using Ground Penetrating Radar (GPR). GPR is an effective device to determine thickness and variability of the pavement structure. Boring and/or coring shall be taken periodically along the project length to verify the GPR data. Contact Bureau of Technical Services, Geotechnical Unit, to request GPR testing.

The condition of the subgrade, if questionable, should be determined by roadway borings. Coring and boring logs or a summary table showing pavement thickness, base thickness, and subgrade information should be included in the plans. Falling Weight Deflectometer (FWD) can be used to assess the load-carrying capacity and uniformity of the existing base, subbase and subgrade by back-calculating subgrade resilient modulus. Contact Bureau of Technical Services, Geotechnical Unit, to request FWD testing.

It is important to remember that the CIR technique is only able to correct distresses within the layer being recycled. Beneath this layer must exist a stable foundation and a good working platform for CIR and paving operations for the new pavement. In general, if there is a minimum of one inch of asphalt pavement or six inches of granular base remaining below the CIR treatment depth, the risk of equipment break-through is low. If poor subgrades exist, improvements to the subgrade are required. Likewise, pavement damage due to poor drainage conditions cannot be corrected using CIR treatment. CIR candidate projects should have an adequate drainage system in terms of surface and subsurface drainage.

HMA pavements that were placed in varying thicknesses may also be problematic during CIR. If the treatment depth is equal to the total HMA layer thickness, caution needs to be exercised to minimize the incorporation of underlying material into the CIR mixture. Locations of any thin HMA sections must be identified in the plan to allow for an adjustment of machine depth or for a separate CIR mix design to be prepared for incorporating some of the base materials. Locations incorporating base material may require additional quantities of stabilizing agent.

25.4 Structural Design of Pavements Over CIR Material

WisPave is Wisconsin DOT's official software for pavement structural design. Consult the Regional Soils engineer for guidance on classifying the soil and the assignment of a Design Group Index (DGI) value to be used by WisPave.

25.4.1 HMA Pavements

Use WisPave to design HMA overlays over CIR material. When determining the HMA overlay thickness, both constructability and structural requirements of the pavement must be satisfied.

25.4.2 Structural Layer Coefficients

The structural layer coefficient of CIR mixtures typically ranges from 0.30 to 0.35. A layer coefficient value of 0.32 shall be used for design purpose.

25.4.3 Minimum HMA Thickness

Thickness design is based on the structural number concept. Minimum HMA pavement layer thicknesses are specified in Standard Spec 460.3.2 based on nominal size mixtures.

25.5 How to Construct CIR

Some CIR projects may require surface milling prior to CIR operation in order to maintain existing roadway profile, minimum overhead clearance and to match existing curb and gutter profile. In addition to maintaining roadway geometry, surface milling will remove excess deteriorated HMA layer to allow the CIR process to penetrate deeper into the HMA pavement layer. The surface mill will also remove any deleterious materials, such as vegetation or loose asphaltic joint/crack filler material, from the pavement surface. Surface mill items will be paid for according to Standard Spec 330. After any required surface milling, the pavement surface should be inspected for areas of yielding subgrade. Areas of yielding subgrade should be corrected and paid for in accordance with Base Repair for CIR Pavement special provision. To minimize contamination by the shoulder material, the existing base aggregate shoulders should be bladed away from the asphaltic surface edge.

The first step in the CIR process itself is to mill the existing asphaltic surface to the specified depth and then size this material to the proper gradation. Some systems will be able to mill and size the material in a single operation; others will mill the material and transfer the millings into a sizing/crushing component to achieve the required gradation as per CIR special provision.

If utility covers (manholes and valves) are encountered in the project segment, manholes and valves should be lowered to at least 2 inches below the CIR treatment depth and their locations accurately recorded. Manholes should be covered with a strong steel plate and the excavation can then be backfilled with cold or hot mix asphalt. CIR treatment of the roadway can then take place in an uninterrupted manner. Prior to the placement of the overlay, the manholes and valves should be raised. Any upgrading of existing underground utilities should be undertaken prior to the CIR treatment. In areas where utility covers cannot be lowered in the CIR process, the pavement is milled around the utility and the materials placed in front of the CIR train and the area paved back. The utilities are later raised up through final overlay.

The processed RAP material will be blended with the mix design, specified proportions of stabilizing agent, and water. It is recommended that stabilizing agent application be estimated for plan production at a rate of 2.0 percent. There are two different systems, employing different methods, to complete this step. One system will inject the stabilizing agent into the RAP material and mix it as it lays on the grade. The second type of system will transfer the processed material into a separate mixing unit or pug mill where it will be injected and mixed before being re-laid.

The stabilized RAP material is then re-laid or spread to the specified grade, elevations, and slopes. This is accomplished by transferring the stabilized material, either directly from the mixing unit or by picking up the material from a windrow on the grade, into a standard asphalt paving machine. This asphalt paving machine then places the stabilized material much like it would hot mix asphalt. Depending on the RAP gradation and environmental conditions, CIR material can be expected to increase in thickness approximately 10 to 15 percent once processed, stabilized, and compacted.

If the pavement is to be widened, HMA shoulders will be processed with and at the same depth as driving lanes. The CIR material shall be spread across the desired widened width to provide a homogeneous mixture. Additional asphalt binder will need to be added when incorporating aggregate base shoulder material (base aggregate dense material under paved shoulder). Crushed aggregate shoulders (surface) generally will not be incorporated in the CIR process. In rare cases where crushed aggregate shoulders (surface) are needed to be incorporated into CIR process, the design and work plan needs to be approved by, or in conjunction with, WisDOT Central Office (refer to Originator, FDM 14-1-1).

The final step of the CIR process is to compact the material. Compaction of CIR mixture is an important part of the construction process. Poor compaction can lead to premature failure or poor performance in terms of smoothness, load capacity, resistance to rutting and shoving, and disintegration. Typically, CIR mixes are stiffer than HMA mixes and require additional compaction efforts. This is due to the high internal friction developed between mixture particles, the higher viscosity of the aged binder, and colder compaction temperature. A combination of vibratory smooth double drum roller and pneumatic rollers are used to get to the final target density per CIR special provision. Additional breakdown and intermediate rolling is accomplished with both pneumatic-tired rollers and double drum vibratory steel rollers. Smooth double drum rollers in static mode can be used as the finishing roller to remove roller marks.

25.6 Pavement Design Report

Specify in the Pavement Design Report, the depth and corresponding locations (stationing) of the CIR treatment.

25.7 Curb and Gutter

CIR equipment can generally process to the edge of a curb and gutter section. If the area is not accessible by CIR equipment, pre-milling can be done with a small milling machine(s) ahead of the main CIR equipment. The area will be replaced with CIR mix by use of an extendable screed on the paver.

25.8 Structural Clearance

Special considerations are often required to accommodate structure clearances. CIR trains may require as much as 14 feet of vertical clearance with some of the smaller single unit trains. Clear span heights for bridges, underpasses, and utilities must be checked.

25.9 Traffic Over CIR Rehabilitated Surface

Traffic may be allowed to travel on CIR material. It is the contractor’s responsibility to determine when the CIR is stable enough to be subjected to traffic loading. Subjecting the CIR material to loading too early or for too long may result in deformation (rutting or shoving) or surface raveling, respectively.

Traffic control for CIR projects is similar to mill and overlay projects except mill and overlay generally requires more trucks. However, the CIR train is longer and maintaining traffic through and around the construction zone needs to be considered. Use of pilot cars should be considered for CIR projects with longer closures.

25.10 Surfacing

Due to the high voids in total mix content, CIR mixes need a wearing surface to protect the mixture from intrusion of surface moisture.

Roadways requiring additional structural support for the design traffic loadings will require additional structural contribution from HMA overlays. For these type of roadways, structural design to determine overlay thickness shall follow FDM 14-10-15.

25.11 Tack Coat

When placing an HMA pavement on CIR a tack coat should be applied to the CIR surface. Tack coat shall be applied according to Standard Spec 455 and FDM 14-10-10.10.