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TREATMENT GUIDELINES FOR PAVEMENT PRESERVATION

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TREATMENT GUIDELINES FOR PAVEMENT PRESERVATION

INTRODUCTION

Pavement preservation is a proactive approach to maintaining existing pavements and reduces or defers costly, time-consuming rehabilitation and reconstruction projects. However, the Indiana Department of Transportation (INDOT) currently has limited and uncoordinated information on pavement preservation treatment guidelines. Moreover, pavement treatment technologies have changed and their performance has improved as pavement preservation methods have become a more suitable option than pavement rehabilitation. Guidelines for pavement treatment should be developed based on treatment practices in the state of Indiana.

The type and severity of distresses on existing pavement are major factors in selecting a treatment. The use of a distress identification manual is imperative to provide a consistent, uniform basis for applying various treatments. There is also a need to update and improve the current INDOT pavement condition data collection manual to match the current practices of pavement preservation treatments.

State DOTs have made efforts to develop and improve pavement preservation programs, but the most widely used approach for selecting a pavement maintenance treatment is still engineering judgment rather than pavement preservation program implementation. This illustrates that transferring such knowledge is a major challenge to the overall success of a pavement preservation program. Training has been recommended as a tool in technology delivery. Currently, the National Highway Institute (NHI) and the National Center for Pavement Preservation (NCPP) offer training courses related to pavement preservation programs; but these courses are taught using a topic-by-topic approach, based on general conditions that are not typical for Indiana. The primary objectives of the proposed research project are: (1) to provide treatment guidelines for the INDOT pavement preservation program based on literature reviews and a review of current practice in Indiana; (2) to improve/update INDOT's pavement condition data collection manual, revising it into a distress identification manual and adding better descriptions and photos, in order to allow for consistent, precise, uniform decision-making regarding treatment type selection; (3) to develop training materials on the use of the distress identification manual and treatment guidelines to improve the skill level of the personnel involved in the pavement preservation treatments.

FINDINGS

This report presents pavement treatment practice guidelines and a distress identification manual for the purpose of improving INDOT pavement preservation practices. The treatment guidelines consist of ten treatment types for asphalt pavements and composite pavements and eight treatment types for Portland cement concrete pavement (PCCP). The treatment guidelines include treatment descriptions, benefits, applicable pavement conditions, treatment materials, and treatment procedures. The guidelines are based on information obtained mainly from the INDOT Standard Specification, the INDOT Design Manual, and the INDOT Field Operations Handbook for Crew Leaders.

The distress identification manual presents the different types of distresses found on the surfaces of asphalt pavement, composite pavement, and PCCP. Each distress type in this manual is resented along with descriptions, causes, measurements, and pictures of each type of distress. The manual is mainly based on the Distress Identification Manual for the Long Term Pavement Performance Program (LTPP) and the INDOT Design Manual.

IMPLEMENTATION

These guidelines and manual will be introduced to the INDOT Pavement Preservation Subcommittee Section for assisting the district level preservation treatment practices. The details in the manual and guidelines are intended for reference only, not as specifications or design guidance. In the event that any information presented herein conflicts with the Indiana Design Manual, INDOT's Standard Specifications or other INDOT policy, said policy will take precedence and the guidelines and manual will be updated by the Asset Preservation Engineer so that conflicts do not exist.

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16. Abstract

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TREATMENT GUIDELINES FOR PAVEMENT PRESERVATION

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ABSTRACT

This project presents pavement treatment practice guidelines and a distress identification manual for the purpose of improving the INDOT pavement preservation practices. The treatment guidelines consist of ten treatment types for asphalt pavements and composite pavements and eight treatment types for Portland cement concrete pavement (PCCP). The treatment guidelines include treatment descriptions, benefits, applicable pavement conditions, treatment materials, and treatment procedures. The guidelines are based on information obtained mainly from the INDOT Standard Specification, the INDOT Design Manual, and the INDOT Field Operations Handbook for Crew Leaders. The treatments are covered in the guidelines. The distress identification manual presents the different types of distresses found on the surfaces of asphalt pavement, composite pavement, and PCCP. Each distress type in this manual is presented along with descriptions, causes, measurements, and pictures of each type of distress. The manual is mainly based on the Distress Identification Manual for the Long Term Pavement Performance Program (LTPP) and the INDOT Design Manual. To implement the guidelines and the manuals, training slides were developed and are enclosed in this report. The training slides were developed to address all topics of the pavement preservation treatment and combine to make one set of training materials suitable for Indiana. The training slides for pavement preservation implementation can help to enhance the overall construction quality of treatments by illustrating the appropriate use of such treatments in applications, thereby contributing to their improved performance. This improvement will help to ensure that the treatments are used to their maximum benefit and efficiency.

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DISCLAIMER

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1 INTRODUCTION

1.1 RESEARCH BACKGROUND

Pavement preservation is a proactive approach to maintaining existing pavements. It enables state Departments of Transportation (DOTs) to reduce or defer costly, time-consuming rehabilitation and reconstruction projects. In addition, it benefits the traveling public by improving safety and mobility.

Many state DOTs investigate and implement a pavement preservation program in an effort to efficiently use their transportation budget. Cuelho (1) reported that over 90% of North American states/provinces have a preventive maintenance program for pavements. The average annual budget for preventive maintenance was approximately $40 million. Approximately 70% of the jurisdictions have a written manual or decision tree that provides guidelines for preventive maintenance activity. At INDOT, pavement preservation is split between in-house maintenance activities and contract work performed as part of the district's pavement program. These programs must be synchronized, creating a seamless cycle of treatments to provide maximum life for the pavement system.

There is currently limited and uncoordinated information on treatment guidelines available in the INDOT Design Manual (2), the INDOT Maintenance Crew Leaders' Handbook (3), and the INDOT Standard Specifications (4). Moreover, pavement treatment technologies have changed and their performance has improved as pavement preservation methods have become a more suitable option than pavement rehabilitation. Many treatment guidelines in other state DOTs are available, but there are limitations to adopting them as INDOT guidelines due to performance differences, construction techniques, materials, climate, organizational structure, life cycle costs, etc. Guidelines for pavement treatment should be developed based on practices in the state of Indiana. Currently, a study for improving Indiana's pavement management system to evaluate cost-effectiveness, optimal timing for treatment, and a selection of best treatments is being conducted as part of SPR-3092, the Indiana Pavement Preservation Program. In conjunction with that study, this research is needed to establish Indiana treatment guidelines and to provide our decision-makers with training to enable them to select the best treatment option for specific pavement condition.

The type and severity of distresses on existing pavement are major factors in selecting a treatment. The use of a distress identification manual is imperative in order to provide a consistent, uniform basis for applying treatments. INDOT's pavement condition data collection manual (5), developed for the pavement management system, has limitations: currently, it provides (1) no visual materials, (2) no measurement methods for severity and extent, and (3) no information of causes for each distress. Knowing the causes of distresses is also important in order to select a proper treatment. An identified distress often has more than one possible cause. A treatment selection without a precise distress diagnostic can result in improper treatment that may not be effective and ultimately the loss of the proper, most cost-efficient opportunity in which to perform preventative maintenance. There is also a need to update and improve the current INDOT pavement condition data collection manual to match the current practices of pavement preservation treatments.

State DOTs have made efforts to develop and improve pavement preservation programs, but the most widely used approach for selecting a pavement maintenance treatment is still engineering judgment rather than pavement preservation program implementation (1). This illustrates that transferring such knowledge is a major challenge to the overall success of a pavement preservation program. Training has been recommended as a tool for technology delivery. Currently, the National Highway Institute (NHI) and the National Center for Pavement Preservation (NCPP) offer training courses related to pavement preservation programs; however, these courses are taught using a topic-by-topic approach, based on general conditions that are not typical for Indiana. There is a need to have training materials that address all topics of the pavement preservation treatment and that combine to make one set of training materials suitable for Indiana. The availability of training for pavement preservation implementation will help to enhance the overall construction quality of treatments by illustrating the appropriate use of such treatments in applications, thereby contributing to their improved performance. This improvement will help to ensure that the treatments are used to their maximum benefit and efficiency.

1.2 RESEARCH OBJECTIVES

The primary objectives of the proposed research project are:

1. To provide treatment guidelines for the INDOT pavement preservation program based on literature reviews and a review of the current practice in Indiana;
2. To improve/update INDOT's pavement condition data collection manual, revising it into a distress identification manual and adding better descriptions and photos, in order to provide consistent, precise, uniform decision-making regarding treatment type selection; and
3. To develop training materials on the use of the distress identification manual and treatment guidelines in order to improve the skill level of the personnel involved in the pavement preservation treatments.

1.3 REPORT ORGANIZATION

This report is composed of four chapters and five appendices. Chapter 1 presents the research needs and objectives. Chapter 2 describes practice guidelines for treatments for asphalt or composite pavement and Portland Cement Concrete pavement, including descriptions, benefits, proper existing pavement conditions, materials, design, construction procedures, etc. Chapter 3 reports pavement distress identification guidelines. Chapter 4 lists references cited in this report. Appendix 1 summarizes the literature review of the standard specifications of pavement preservation treatments. Treatment selection reviews are presented in Appendix 2, and Appendices 3 and 4 present information on the testing methods for seal coat. Appendix 5 illustrates details about a broom for scrub seal.

2 PRACTICE GUIDELINES FOR PAVEMENT PRESERVATION TREATMENTS

In this chapter, the practice guidelines for pavement preservation treatments are presented along with treatment descriptions, benefits, applicable pavement conditions, treatment materials, and treatment procedures. The guidelines are based on information obtained mainly from the Indiana Department of Transportation Standard Specification, the Indiana Department of Transportation Design Manual, and the Indiana Department of Transportation Field Operations Handbook for Crew Leaders. The treatments covered in the guidelines are shown in TABLE 2-1.

TABLE 2-1 List of pavement preservation treatments

Asphalt or Composite Pavement	**Portland Cement Concrete Pavement (PCCP)**
• Crack Sealing/Routing and Filling • Fog Seal • Scrub Seal (Sand Seal) • Seal Coat (Chip Seal) • Flush Seal • Microsurfacing • Profile Milling • Thin Hot Mix Asphalt Overlay with Profile Milling (HMA Overlay) • Ultra-thin Bonded Wearing Course (UBWC) • Thin Hot Mix Asphalt Mill/Fill (Thin HMA Inlay)	• Crack Sealing/Filling • PCCP Joint Resealing • Retrofit Load Transfer • Cross-stitching • PCCP Profiling (Diamond Grinding) • Partial Depth Patching • Full-depth Patching • Undersealing

2.1 ASPHALT OR COMPOSITE PAVEMENT

2.1.1 CRACK SEALING/ ROUTING AND FILLING

INDOT REFERENCE

INDOT Standard Specification Section 408

TREATMENT DESCRIPTION

Cracking is an inevitable form of damage on asphalt and composite pavement. Cracks should be promptly treated to prevent water penetration, which accelerates pavement deterioration and results in potholes or base failure. Sealing cracks is a common technique used as a preventative maintenance treatment.

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Reduces water infiltration • Decreases further crack deterioration (e.g. spalling at crack) • Milling is not required • Quick opening to traffic	• Over application can cause a reduction in skid resistance • Poor appearance and visibility • No structural improvement

TYPE OF CRACK SEALING

There are two sealing methods, including filling cracks (INDOT Performance Standard Activity 207, Filling Cracks) and routing and sealing cracks (INDOT Performance Standard Activity 209, Sealing Cracks with Crumb Rubber Material [Asphalt Rubber Sealant]). The selection of the sealing or filling method is based on crack movement and crack deterioration. Moving or working crack (e.g. transverse crack and reflective crack) is defined as an annual crack opening that moves greater than 0.1 in. vertically or horizontally due to thermal expansion and contraction or stress concentration at pavement overlaying joints.

TABLE 2-2 Sealing/filling Selection Recommendation [7]

Crack Condition	Routing and Sealing	Filling
Materials	Crumb Rubber (Asphalt Rubber Sealant)	Emulsion
Width (in.)	0.2 to 0.75	0.2 to 1.0
Edge Deterioration (percent of crack length)	<25%	<50%
Annual Horizontal Movement (in.)	>0.1	<0.1
Type of Cracks/Joints	Transverse Thermal Transverse Reflective Longitudinal Reflective Longitudinal Cold-Joint	Longitudinal Reflective Longitudinal Cold-Joint Longitudinal Edge Distantly Spaced Block

ROUTING AND SEALING

The major objective of routing is to provide a uniform and smooth edged rectangular reservoir to let the sealant material adhere better with the asphalt pavement and for allowing the sealant level to remain below the pavement surface, which protects the sealant from traffic and snowplow damage. Typical schematic of a routing reservoir is shown FIGURE 2-1 (a). According to INDOT Spec. Section 408.05, a reservoir should not exceed 0.75 in. width with a minimum depth of 0.75 in. Cracks should be filled with the sealant to within 0.25 in. of the surface.

CRACK FILLING

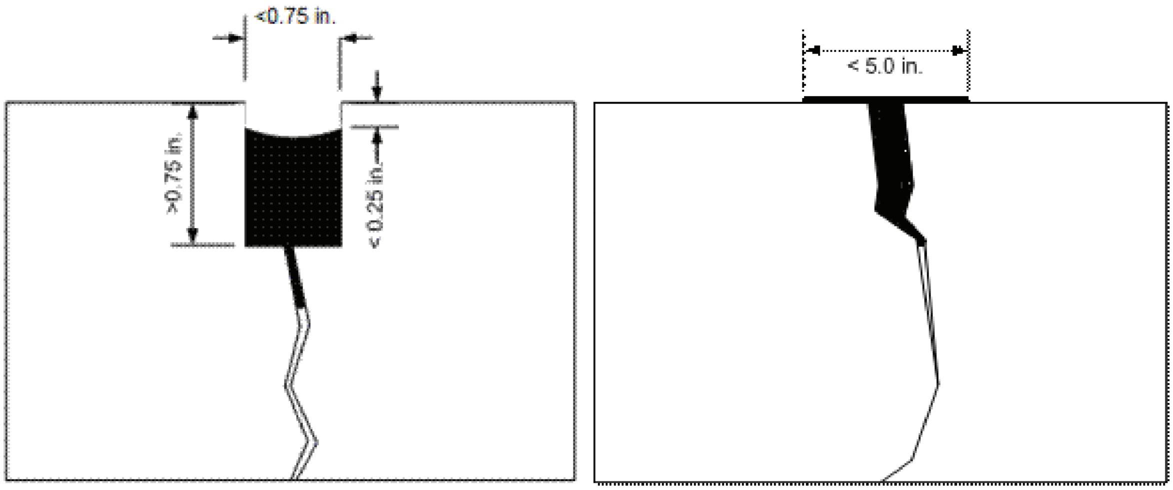
Crack filling should be completely filled or overbanded to a maximum of 5.0 in., or as required. FIGURE 2-1 shows the illustration of a typical crack filling. Once filling materials are applied, the exposed surfaces are flushed or formed with overband shape as shown in FIGURE 2-1 (b). Generally, the strike-off will create a slight overband that provides better adhesion of the sealant to the pavement surface. However, wide overbanded longitudinal crack fillings may cause a reduction in pavement friction. Care should be taken when filling longitudinal cracks.

APPLICATION LIMITATION

Filling and/or routing and sealing crack are not applicable to the pavement having structural problems (e.g., extensive fatigue cracking, high severity rutting) or other extensive pavement deterioration.

TYPE OF SEALING/FILLING MATERIALS

Based on INDOT Spec. Section 408, asphalt emulsion, asphalt rubber sealant, and fine aggregate are used for the crack sealing/filling. In addition, INDOT uses asphalt cement (PG 64-22) as a crack filling material in preparation for microsurfacing application. In general, no traffic can be allowed until sealing/filling material has been cured. If there is an early traffic opening before it is fully cured or low friction is expected due to wide sealing areas, the seal can be blotted. Blotting is the application of fine aggregate (INDOT 23 or 24 aggregate size) on the fresh sealant to protect sealant from tracking or prevent the road from losing friction. List of the materials are summarized in TABLE 2-3.



(a) (b)

FIGURE 2-1 Crack sealing/filling: (a) routing and sealing; (b) crack filling

TABLE 2-3 Materials of Sealing and Filling Cracks

	Materials	References
Crack Filling	AE-90, AE-90S, AE-150	902.01(b)
Fine Aggregates	23 or 24	904
Routing and Sealing	Asphalt rubber sealant	906.02

WEATHER LIMITATIONS

Sealing or filling operations are not desirable on wet surfaces due to problems with adhesion between the crack face and seal or fill material. INDOT specification recommends that the operation temperature be higher than 40°F. Since cool weather makes the pavement contract and opens the crack width, an operation temperature closer to 40°F can result in better crack sealing performance.

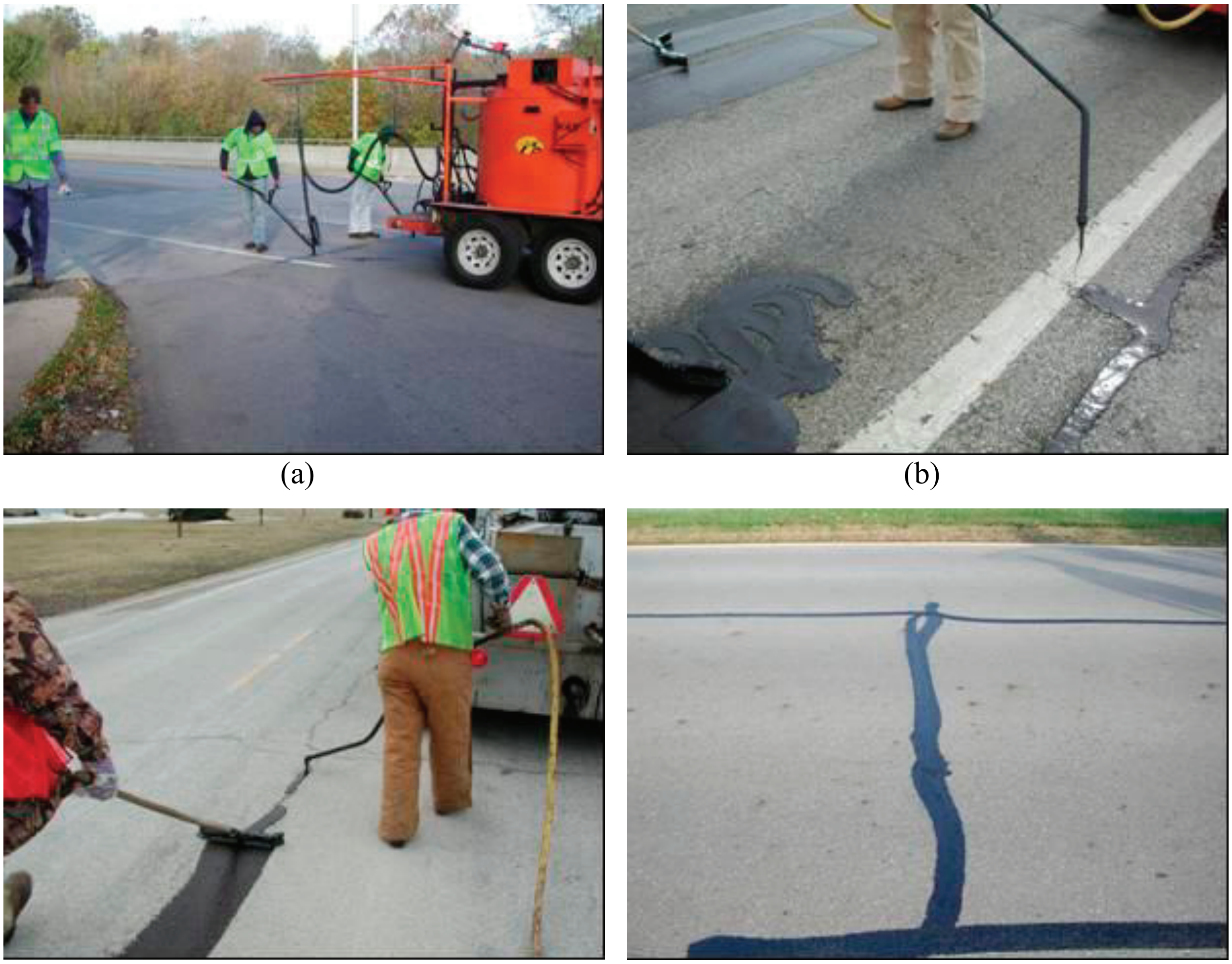
CONSTRUCTION CONSIDERATIONS AND PROCEDURE

Crack Filling Procedure

1. *Cleaning and drying*: Cracks should be cleaned using high pressure air or hot airblasting. The crack should be cleaned to a depth of at least twice the crack width. This procedure is critical to avoid a loss of adhesion between a sealant and crack surfaces.
2. *Emulsion application*: Cracks should be filled with emulsion from the bottom to avoid trapped air bubbles in the emulsion, which can weaken it.
3. *Squeegeeing*: Excess sealant on the pavement surface should be removed with a squeegee.
4. *Blotting*: Fine aggregate should be applied on the surface of the sealant to prevent tacking, in case of an early traffic opening or sealing wide areas.

Crack Routing with Sealing Procedures

1. *Routing*: Reservoirs should be provided along the center of the crack width using a router.
2. *Cleaning and drying*: Reservoirs should be cleaned using high pressure air or hot airblasting.
3. *Sealant application*: Cracks should be filled with sealant from the bottom to avoid air bubbles in the sealant.
4. *Smoothing*: The excess sealant on the pavement surface should be squeegeed to a smooth surface.



(a) (b) (c) (d)

FIGURE 2-2 Crack filling: (a) and (b) applying sealing material; (c) squeegeeing excess and forming overband; (d) sealed cracks


(a)


(b)


(c)


(d)


(e)


(f)

FIGURE 2-3 Routing and sealing procedure for centerline cracking: (a) centerline cracking; (b) routing; (c) sweeping; (d) applying sealing material; (e) smoothing the seal; (f) freshly applied seal

(a)

(b)

(c)

(d)

FIGURE 2-4 Routing procedure for transverse cracking: (a) transverse cracking; (b) routing; (c) cleaning; (d) routed crack

2.1.2 FOG SEAL

INDOT REFERENCE

INDOT Recurring Special Provision 412-R-549

TREATMENT DESCRIPTION

Asphalt ages over time as it is exposed to ultraviolet light and heat, which increase the brittleness of the pavement surface resulting in raveling and hairline cracking. A fog seal coats the aged pavement surface by applying asphalt emulsion. This protects the aged layer from further deterioration and heals minor pavement deteriorations.

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Reduces water infiltration • Decreases further crack deterioration • Milling is not required • Retards raveling/aging • Rejuvenates the viscosity of HMA surface • Recovers the color of pavement that enhances the visibility of pavement markings • Placed in one pass • Quick opening to traffic • No requirement for shutting down adjacent traffic	• Over application can cause a reduction in skid resistance • No structural improvement • Not applicable for stripping

APPROPRIATE PAVEMENT CONDITIONS

Pavements having low to moderate raveling and /or oxidation are good candidates for fog seals.

APPLICATION LIMITATIONS

Fog seals are capable of performing on high-volume roads, but are typically limited to low-volume roads because reduced pavement friction can be a concern after a fresh fog seal has been placed. Fog seals should not be used on pavements having bleeding or flushing. Fog sealed pavement should have a minimum friction number (FN) of 20 (using the smooth tire lock wheel skid test) after treatment. Generally, a fresh fog seal reduces up to 35 % of existing pavement FN (7), and this FN increases as the fog seal is cured. Due to this reason, existing pavement with an FN less than 30 is not recommended for fog seal application. Typically, new seal coats, low volume roads, shoulders, or parking lots are suitable for application of a fog seal. No structural benefit is added by this treatment. Fog seals should not be used on existing pavements that exhibit stripping, as the fog seal will accelerate the stripping process of the underlying pavement layer.

WEATHER LIMITATIONS

Fog seal operations should be conducted on a clean and moisture-free pavement. To avoid prolonged curing time (and hence return to traffic), pavement should be dry and ambient temperatures should be at least 60°F during application. In addition, fog sealing should not be conducted on travel or auxiliary lanes before May 1 or after October 1.

MATERIALS

According to INDOT Spec. Section 412.02, asphalt emulsion (AE-PL and AE-F) and fine aggregate are the recommended materials for fog seals. Fine aggregates are defined as exhibiting 100% passing of the 3/8 in. sieve and a minimum of 80 % passing of the No. 4 sieve. Details about the aggregate are available in INDOT Spec. Section 904.02.

EMULSION APPLICATION RATE

Properly calibrated distribution trucks are critical in fog seal practice. Spray nozzles should be adjusted based on the manufacturer's recommendation to ensure proper application. A test strip 100 ft long is recommended to ensure that the emulsion application rate is adequate. The emulsion application rate typically ranges from 0.10 to 0.15 gal/yd^2. The emulsion should be applied uniformly at a rate within ± 0.02 gal/yd^2 of the target application rate. The overlap application method is recommended on the centerline in both directions.

TRAFFIC CONSIDERATION

If the fog seal covers existing pavement markings, temporary or permanent traffic markings should be installed properly and in a timely manner after the fog seal application.

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Brooming:* Existing pavement should be cleaned by brooming operation.
2. *Strip testing:* Based on the strip test, the fog seal equipments are calibrated and the target application determined. Streaks in the fog seal indicate a clogged nozzle or an improper overlap of spray from adjacent nozzles. The problem needs to be corrected prior to proceeding with the application of the fog seal.
3. *Emulsion application:* Emulsion should be evenly distributed with the target application rate.

4. *Curing:* Applied emulsion should be sufficiently cured before traffic is permitted to avoid tracking. Curing will depend on environmental factors, but traffic can typically be restored in 30 minutes.
5. *Blotting:* Fine aggregate should be applied to pedestrian cross-walks, drive-ways, or other areas as directed by the Construction Engineer.

(a)

(b)

(c)

(d)

FIGURE 2-5 Fog seal: (a) brooming; (b) distributor nozzle; (c) application temperature; (d) fog sealing on shoulder

2.1.3 SCRUB SEAL (SAND SEAL)

INDOT REFERENCE

INDOT Standard Specification Section 404

TREATMENT DESCRIPTION

Scrub seals are thin asphalt surface treatments that consist of spraying a thin layer of asphalt emulsion, dragging a broom across the surface to force the emulsion into the cracks, immediately spreading a thin layer of fine aggregate, and finally dragging another broom over the surface. The final broom-drag scrubs the emulsion and the sand into the cracks and voids. The scrub seal is the same as the sand seal, with the exception of the scrub process, which is not part of the sand seal process.

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Retards raveling/aging • Reduces water infiltration • Decreases further crack deterioration • Improves rideability and surface friction • Does not affect overhead clearance • Quick opening to traffic • No requirement for shutting down adjacent traffic	• No structural improvement • Not applicable for stripping

APPROPRIATE PAVEMENT CONDITIONS

Pavements with low to moderate traffic volumes are the best candidates for scrub seals. Scrub seals are good at filling narrow cracks (up to 0.5 in. wide). The pavement should be in moderate to good condition without any severe ruts or other deterioration.

APPLICATION LIMITATIONS

Scrub seals offer no structural support and should not be used on pavements with structural failure. Scrub seals also should not be placed on pavements with ruts greater than 0.25 in. deep. Scrub seals are not effective on pavements with severe deterioration. Scrub seals should not be used on existing pavements that include stripping in an underlying mixture. Application of a scrub seal on such a pavement will accelerate the stripping process.

MATERIALS

INDOT specification does not include the scrub seal and treats the sand seal as a seal coat, type 1. TABLE 2-4 shows types of sand seal materials and the application rates according to INDOT specifications.

TABLE 2-4 Sand seal (scrub seal) materials

Material	Type	Application Rate	Reference
Emulsions	AE-90, AE-90S, AE-150	0.12-0.16 gal/yd^2	Sections 404, 902.01
Aggregate	23, 24	12-15 lbs/yd^2	Sections 404, 904

WEATHER LIMITATIONS

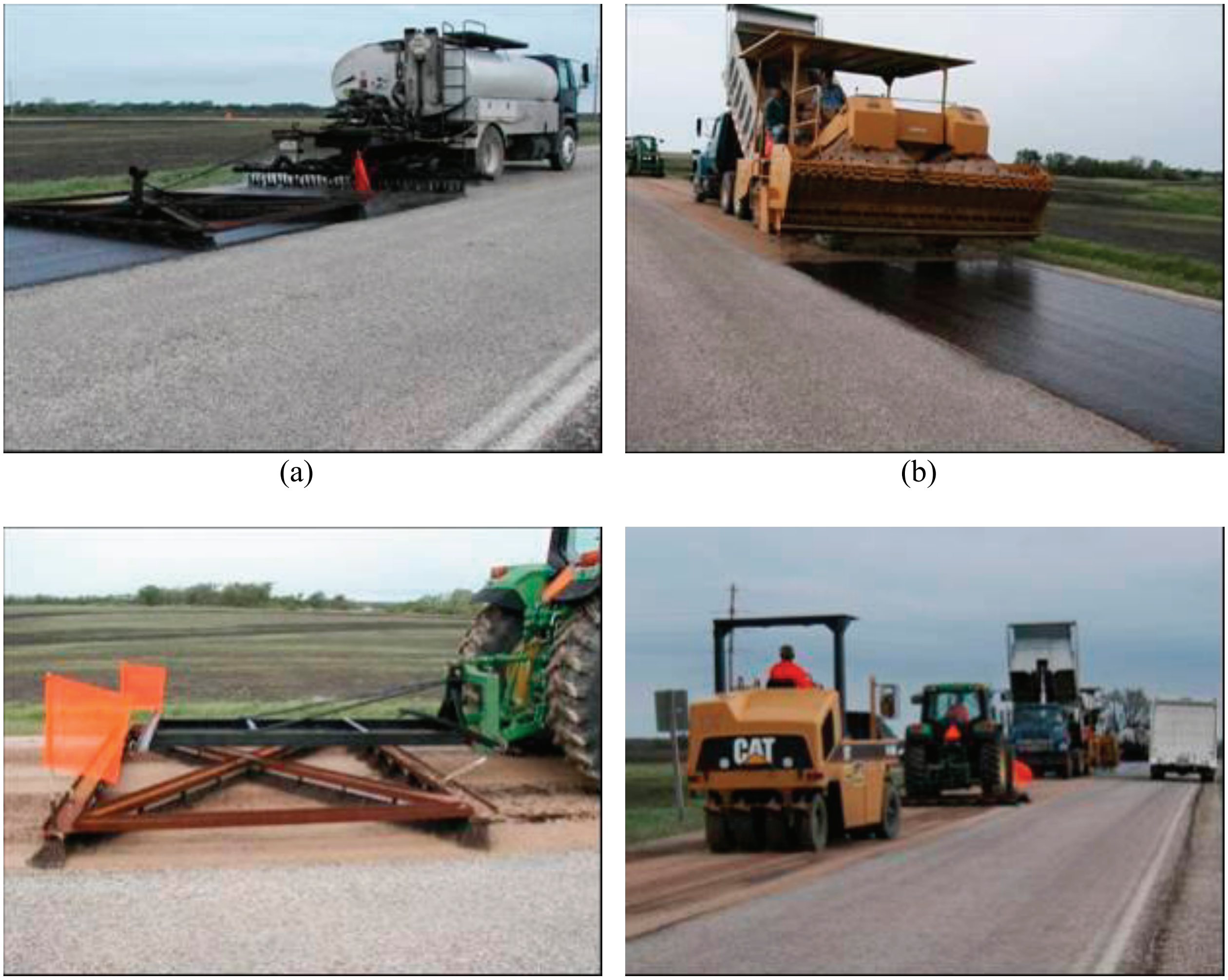
Emulsion should not be applied on a moist surface, or when other weather conditions would adversely affect the scrub seal. The pavement and ambient temperature should be over 60°F. Travel lanes and auxiliary lanes should not be sealed before May 1 or after October 1, but application to shoulders is allowable at any time of the year, as long as the above temperature is maintained.

OTHER CONSIDERATIONS

Scrub seals are susceptible to snow plow damage. Existing raised pavement markers should be protected during the scrub seal operation.

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Brooming:* Existing pavement should be cleaned by brooming operation.
2. *Emulsion application:* Using a pressure distributor, place asphalt emulsion on surface and trail with broom to sweep emulsion into cracks. Details about the broom are available in Appendix 5.
3. *Sand application:* Place sand immediately after emulsion and follow with a second broom.
4. *Rolling*: Tire pneumatic rollers (minimum weight is 10 tons) should roll the area three times within 30 min. after the sand application.



(a) (b)

(c) (d)

FIGURE 2-6 Scrub sealing: (a) applying and scrubbing emulsion; (b) spreading sand; (c) scrubbing sand; (d) rolling

2.1.4 SEAL COAT (CHIP SEAL)

INDOT REFERENCE

INDOT Standard Specification Section 404

TREATMENT DESCRIPTION

The terms "chip seal" and "seal coat" are used interchangeably and have essentially the same meaning. The seal coat activities are defined in Indiana Standard Performance Activity Code 204 (Full Width Shoulder Seal) and 205 (Seal Coat-Chip).

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Retards raveling/aging • Reduces water infiltration • Decreases further crack deterioration • Quick opening to traffic • Experienced and reliable technique • Placed in one pass • Provides a smooth surface with high frictional resistance • No requirement for shutting down adjacent traffic • Does not affect overhead clearance	• No structural improvement • Not applicable for stripping • Potential for windshield damage and excessive noise

APPROPRIATE PAVEMENT CONDITIONS

Seal coats address longitudinal, transverse, and block cracking in low to moderate severity level, as well as raveling, low severity bleeding, and moisture infiltration. Dry, raveled pavements are often good candidates.

APPLICATION LIMITATIONS

A seal coat provides no benefit to pavements with structural problems. In addition, seal coats are not effective against cracks more than 0.25 in. wide, moderate or high severity fatigue cracking, large numbers of potholes, rutting of more than 0.25 in. depth, and extremely rough surfaces. Seal coats are mainly used on low-volume roads because of the potential for broken windshields from loose chips and because of excessive noise. Existing pavements with stripping of underlying mixtures should not be chip sealed. Application of the seal coat will accelerate the stripping process.

TYPES OF CHIP SEALS

There are many types of seal coats in terms of the number of seal coat layers (e.g. single, double, triple seal coats), layer types (e.g. Sandwich seals, Rack-in chip seals, etc.), and materials (e.g. Geotextile seal, Fibermat seal, etc.). INDOT generally uses the single seal coat for a continuous full-width section of roadway.

MATERIALS

The more uniform the gradation and the more cubical the particle shape, the better the seal coat performs. The larger aggregate outperforms the smaller aggregate size in terms of aggregate loss and bleeding, but special care is needed to prevent windshield damage with large size aggregate. According to INDOT Spec. Section 404, asphalt emulsions and course aggregates are used as seal coat materials and are listed in TABLE 2-5. Normal Maximum Aggregate Sizes (NMASs) of 11 and 12 are 3/8" and No. 4, respectively. AE-90S is the most popular emulsion among the four emulsions in Indiana.

TABLE 2-5 Materials for chip seal

	Materials	**Reference**
Emulsions	AE-90, AE-90S, RS-2, HFRS-2	Section 902
Aggregate	11, 12	Section 904

CHIP SEAL PERFORMANCE

Many states still use empirical-based seal coat practices, including the application rate design, material selection, construction procedures, etc. These factors directly affect the seal coat performance. The critical seal coat performance failures are aggregate loss and bleeding. TABLE 2-6 provides a summary of the causes of seal coat failures.

TABLE 2-6 Chip seal failure mode and causes

	Causes
Aggregate Loss	• Presence of a layer of dust or dirt • Existing surface wet or too cold • Improper emulsion property • Insufficient emulsion application rate • Graded aggregate • Elongated aggregate • Delayed aggregate application after emulsion application • Delayed roller application after aggregate application • Failure of traffic control
Bleeding	• Aggregate loss • Excessive emulsion • Rotation of smooth aggregate surface • Graded aggregate

CHIP SEAL APPLICATION RATE DESIGN

Currently, the most popular design methods in North America are the McLeod and the Modified Kearby. The McLeod design method was adopted as a seal coat design method in Minnesota and is available as a software program at http://www.dot.state.mn.us/materials/pvmtdesign/software.html. The designed application rate should be verified through a strip test prior to the main seal coat application. INDOT has a field test method for determining the application rate in ITM No. 579-08P, "Quantity Determination of Asphalt Materials and Aggregates for Seal Coats" (8), and this method can be used for validating other laboratory test-based design methods. Typical seal coat application rates for Indiana are shown in TABLE 2-7.

TABLE 2-7 INDOT chip seal application rate recommendation

Aggregate Size	Aggregate Application Rate lb/yd^2	Emulsion Application Rate gal/yd^2
11	16 - 20	0.36 - 0.4
12	14 - 17	0.29 - 0.33

WEATHER LIMITATIONS

Emulsion should be applied on a moisture-free surface, or when other weather conditions will not adversely affect the seal coat. The pavement surface and ambient temperature should be over 60°F. The travel lane and auxiliary lanes should not be sealed by seal coat before May 1 or after October 1. Shoulder sealing is allowable at any time of the year, as long as the above temperature requirement is met.

EQUIPMENT CALIBRATIONS

Calibration of seal coat equipment is a critical practice that should be conducted prior to seal coat material application in the field. INDOT developed a calibration method of aggregate and emulsion application rates using a square yard carpet. Details about this method are in Appendix 3.

TRAFFIC CONSIDERATIONS

Traffic should not be allowed on a seal coat surface until after rolling and after the bituminous material has set and cured.

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Brooming:* Existing pavement should be cleaned by brooming operation.
2. *Emulsion application:* Emulsion should be evenly distributed with the target application rate at the manufacturer recommended temperature. Streaks in the emulsion usually result from clogged nozzles or inappropriate overlap between individual sprays from adjacent nozzles. It is necessary to make the appropriate corrections prior to continuing the application.
3. *Aggregate application:* Aggregate should be spread within 1 min. after applying emulsion to avoid aggregate debonding due to significant emulsion curing and breaking.
4. *Rolling:* Tire pneumatic rollers should cover the area three times within 30 min. after the aggregate application. The first roller application should be completed within 2 min. after applying the aggregate.
5. *Brooming:* Excess aggregate should be removed from the seal coat surface by light brooming on the morning following application of the seal coat.

(a) (b) (c) (d) (e) (f)

FIGURE 2-7 Seal coating procedure: (a) brooming; (b) applying emulsion; (c) spreading aggregate; (d) rolling; (e) traffic control; (f) brooming seal coat

2.1.5 FLUSH SEAL

INDOT REFERENCE

INDOT Standard Specification Section 404 and Recurring Special Provision 412-R-549

TREATMENT DESCRIPTION

A flush coat or flush seal is an application of a fog seal coat to the surface of a seal coat (chip seal). Flush seals are a variant of seal coat. A major failure mode of seal coat is aggregate loss. This loss of aggregate exposes asphalt at the surface and causes bleeding failure. In addition, loose aggregate can cause windshield damage. A flush seal reduces aggregate loss from the seal coat and restores the color of the pavement, which enhances the visibility of pavement markings.

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Retards raveling/aging • Reduces water infiltration • Decreases further crack deterioration • Provides a smooth surface with frictional resistance • Does not affect overhead clearance • Reduces windshield damage and excessive noise from seal coat • Recovers the color of pavement and enhances the visibility of pavement markings	• No structural improvement • Not applicable for stripping

APPROPRIATE PAVEMENT CONDITIONS

Refer to the appropriate pavement conditions of seal coat.

MATERIALS

Refer to the materials of seal coat and fog seal.

WEATHER LIMITATIONS

Refer to the weather limitations of seal coat and fog seal.

TRAFFIC CONSIDERATIONS

Refer to the traffic conditions of seal coat and fog seal.

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Preparation*: Existing seal coat should be fully cured and have no bleeding or aggregate loss.
2. *Brooming:* The excess seal coat aggregate should be removed by brooming.
3. *Application*: Apply the proper amount of emulsion (typical application rate for AE-PL is 0.11±0.01 gal/yd^2) determined by the strip test.
4. *Blotting:* Fine aggregate should be applied to pedestrian cross-walks, drive-ways, or other areas as directed by the Construction Engineer.

(a) (b) (c) (d)

FIGURE 2-8 Flush seal: (a) brooming of excess or loose seal coat aggregate; (b) applying the emulsion; (c) the applied emulsion on seal coat; (d) blotting

2.1.6 MICROSURFACING

INDOT REFERENCE

INDOT Recurring Special Provision 411-R-432

TREATMENT DESCRIPTION

Microsurfacing consists of a very thin overlay placed on lightly deteriorated asphalt concrete surfaced using a mixture of cationic polymer-modified asphalt emulsions, mineral aggregate, mineral filler, water, and other additives as needed. Microsurfacing can be placed in multiple courses (typically a rutfill, leveling, and surface course).

BENEFITS OF TREATMENT

Microsurfacing is effective at preventing raveling, hardening (oxidation) of the pavement surface, improving surface friction, sealing pavement surface, filling surface irregularities, and filling wheel ruts up to a depth of 1.25 in. Additionally, this treatment is suitable for use on high traffic volume roads. The chemical breaking in microsurfacing allows night-time application. Microsurfacing emulsion sets quickly and usually allows for traffic to be restored within one hour.

Advantages	Disadvantages
• Retards raveling/aging • Reduces water infiltration • Decreases further crack deterioration • Milling is not required • Improves rideability and surface friction • Reduces minor hydroplaning problems • Enhances visibility of pavement markings • Can be constructed at night • Durable surface for high volume roads • Good bonding to existing pavement • Placed in one pass • Quick opening to traffic • No requirement for shutting down adjacent traffic • Re-ground up to 2 or 3 times • Does not affect overhead clearance	• No structural improvement • Need special equipment • Not applicable for stripping

APPROPRIATE PAVEMENT CONDITIONS

Pavements with low severity cracking, raveling, bleeding, and rutting (up to 1.25 in.) are good candidates for microsurfacing. Pavements with severe cracking, structural failure, or extreme pavement deterioration should not be considered for microsurfacing. Progressive rutting due to a structural deficiency should be avoided for the microsurfacing application. Crack sealing can be applied prior to the microsurfacing application. In this case, over application of the crack sealant and early microsurfacing application prior to proper sealant curing should be avoided. Existing pavements that include stripped underlying mixtures should not be microsurfaced. Application of microsurfacing on a stripped existing pavement accelerates the stripping process.

MATERIALS

In INDOT Spec. Section 411, coarse and fine aggregate types for the rut fill course are limestone, dolomite, crushed gravel, sandstone, air-cooled blast furnace slag (ACBF), and steel furnace slag (SF). The aggregate type for the surface course should be selected based on traffic ESALs. The emulsion for microsurfacing is a quickset polymer modified asphalt emulsion conforming to the requirement of ASTM D 2397 (9) for CSS-1h, with the exception that the cement-mixing test is waived. Mix set additives are added as required, providing control of the quickset properties. More details about the materials used in microsurfacing are shown in the references of TABLE 2-8.

TABLE 2-8 Materials for microsurfacing

	Materials	**Reference**
Emulsions	CSS-1h-P	Section 411
Aggregate	• Coarse aggregate: Class B or Higher • Fine aggregate	Sections 401, 904
Portland Cement	Type 1	Section 904, ASTM D 85
Other	Water	Section 913.01

MIX DESIGN

Currently there are several mix designs available. The International Slurry Surfacing Association (ISSA) Technical Bulletin (TB) A143 (10) and ASTM D 6372 (11) are the most widely accepted. INDOT accepts ISSA TB A143 for the mix design, and its mix design criteria are shown in TABLE 2-9.

TABLE 2-9 Microsurfacing mix design requirements

Characteristic	Test Method ISSA*	Requirement
Wet Cohesion 30 minutes, minimum (Set Time) 60 minutes, minimum (Traffic)	TB-139**	12 kg-cm 20 kg-cm
Wet Stripping, minimum.	TB-114	90 %
Wet Track Abrasion Loss 60 minutes. Soak, Maximum.	TB-100	536 g/m^2
Saturated Abrasion Compatibility, Maximum	TB-144	3.0 g loss
Mix Time at 77°F	TB-113**	Controllable to 120 sec.
Mix Time at 104°F	TB-113**	Controllable to 35 sec.

* International Slurry Surfacing Association
** The TB-139 (set time) and TB-113 (mix time) tests shall be checked at the highest temperature expected during construction. For the TB-113 test at 104°F, all ingredients and containers shall be preheated.

EQUIPMENT CALIBRATION

Equipment calibration should be conducted to ensure application of the proper portions of materials with the microsurfacing machine. A trial application of microsurfacing is recommended for microsurfacing consistency and workability.

WEATHER LIMITATIONS

Microsurfacing should not be applied when the temperature of the pavement or air is below 50°F. The application should not be attempted when there is a possibility that the finished product will freeze within 24 hours after application.

TRAFFIC CONSIDERATIONS

Allow time for the materials to cure, and reopen traffic one hour after application (12).

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Preparation:* Severely deteriorated surface should be repaired prior to the microsurfacing application using HMA patching and crack sealing (using PG 64-22 binder); otherwise deterioration may be reflected on the microsurfacing.
2. *Removing:* Lane mark paint and thermoplastic (asphalt rubber sealant) on existing pavement should be removed.
3. *Brooming:* Existing pavement should be cleaned by brooming operation.
4. *Strip testing*: Based on the strip test, the microsurfacing equipment is calibrated and the target application determined.
5. *Application:* A typical application rate is around 30 lb/yd^2. For rut-filling purposes, two passes of the distributor are required—one covering both wheel paths and the other covering the entire width of the lane. For other purposes, make two equivalent passes over the total lane width. The longitudinal construction joints and lane edges should coincide with the proposed painted lane lines. Longitudinal joints should be constructed with less than a 3 in. overlap on adjacent passes and no more than 0.25 in. overlap thickness measured with a 10-ft. straight edge in accordance with INDOT Spec. Section 409.03(f). If applicable, overlapping passes shall be on the uphill side to prevent pooling of water. Construct neat and uniform transverse joints with no more than a 0.125 in. difference in elevation across the joint as measured with a 10-ft. straight edge. The lane edge should be neat and uniform with no more than 2 in. of horizontal variance in any 100 ft.
6. *Rolling:* Rolling is rarely required. When rolling is required, a 10 to 12-ton nine wheel pneumatic tired roller with 50-60 psi tire pressure is adequate for use, and two passes of the roller are generally sufficient. The microsurfacing should be allowed to set enough so that it will support the roller. Steel-wheel rollers are not recommended.

FIGURE 2-9 Microsurfacing: (a) brooming; (b) applying microsurfacing; (c) during curing; (d) fully cured microsurfacing.

2.1.7 ULTRA-THIN BONDED WEARING COURSE (UBWC)

INDOT REFERENCE

INDOT Unique Special Provision

TREATMENT DESCRIPTION

An ultra-thin bonded wearing course (UBWC) is described as a very thin asphalt layer about 0.7 to 1.0 in. thick that is placed while spraying a thick polymer modified emulsion membrane to the existing pavement, all in one pass.

SYNONYMS

NovaChip®, Ultra-thin Friction Course, Bonded Wearing Course, Ultra-thin Wearing Course, Ultra-thin Asphalt Surfacing, Paver Placed Surface Seal.

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Milling is not required • Quick opening to traffic (within an hour) • Placed in one pass • Can be constructed at night • Fewer curb and minimal clearance adjustments • No shoulder overlay is needed • Durable surface for high volume roads • Good bonding to existing pavement • Can be fully recycled • Provides a smooth surface with high frictional resistance • Noise reduction • Vehicle backspray reduction • Recovers the color of the pavement and enhances the visibility of pavement markings • Seals surface	• Need special equipment • Typically proprietary product • Transportation limitation of 1.5 hours from mixing in plant to placement on the road

APPROPRIATE PAVEMENT CONDITIONS

Low severity cracking, raveling, high severity friction loss, low-severity roughness, and low severity bleeding are all addressed by UBWC placement. Cracks greater than 0.25 in. should be sealed prior to UBWC placement. UBWC application to rutted pavement exceeding 0.25 in., overband crack sealing, or new patch is not recommended. This is a preventive treatment, so if the pavement has little life left, it is not recommended. The treatment is capable of withstanding high traffic volumes and truck traffic better than other thin treatments.

LIMITATIONS

Not recommended when structural failures exist, or if there is high severity thermal cracking.

WEATHER LIMITATIONS

UBWC should not be applied when the temperature of the pavement or air is below 60°F, or when other unsuitable conditions exist.

TRAFFIC CONSIDERATIONS

No traffic is allowed until the pavement has cooled sufficiently after completion of the rolling operation.

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Preparation*: Seal all working cracks, all non-working cracks with openings exceeding 0.25 in., and patch potholes.
2. *Cleaning*: Lane mark paint should be removed. Existing surfaces should be cleared of all objectionable and foreign materials by brooming operation prior to the UBWC application.
3. *Strip testing:* Based on the strip test, the emulsion spray is calibrated and the target application rate should be determined.
4. *UBWC application:* Paver should spray emulsion, apply overlay, and level surface all in one pass.
5. *Rolling:* A 10-ton steel double drum roller with two passes is adequate. Rollers should run only in static mode.
6. *Curing:* Applied emulsion should be sufficiently cured before traffic is permitted to avoid tracking.

(a)

(b)

(c)

(d)

FIGURE 2-10 Ultra-thin bonded wearing course (UBWC): (a) existing pavement preparation; (b) and (c) paving UBWC; (d) rolling

2.1.8 PROFILE MILLING

INDOT REFERENCE

INDOT Standard Specification Section 306

TREATMENT DESCRIPTION

Profile milling is the process of removing a portion of pavement surface to correct the pavement profile or roughening the existing surface for a new thin HMA overlay. This surface milling is frequently used in the thin HMA overlay with profile mill, but the milling can be a treatment itself.

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Improves rideability and surface friction • Reduces minor hydroplaning problems • Improves minor cross slop deficiencies	• No structural improvement • Not applicable for major cross slop deficiencies • Limited for maintaining curb height

APPROPRIATE PAVEMENT CONDITIONS

Good candidates for this treatment include pavements without any structural damage and with non-structural distresses in the top levels. In addition, pavements with cross-sloping, grading, and texture problems are also good candidates.

APPLICATION LIMITATIONS

Not recommended for structurally deficient pavements. Not applicable for major cross slope deficiencies. Limited for maintaining vertical clearance or curb height.

TRAFFIC CONSIDERATIONS

Traffic can be opened immediately after pavement is cleaned.

OTHER CONSIDERATIONS

The recovered milled pavement must be disposed of. Often it is hauled away and made part of a reclaimed asphalt pavement (RAP) mixture.

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Preparation:* Prepare surface by cleaning with rotary broom and identify any buried utilities, manholes, and other obstacles.
2. *Milling:* Profile-mill longitudinally with profiling machines capable of one 16-ft. wide and 12-in. deep pass (these values vary by state). Follow milling machine with scraping blade that collects reclaimed material and shaves off high points.
3. *Hauling:* Follow with hauling truck that can receive loading from milling conveyer belt.
4. *Local milling*: Use mini-cold planer to mill around manholes and other obstacles.
5. *Cleaning*: Clean and sweep, but do not allow dust to travel off-site.

2.1.9 THIN HOT MIX ASPHALT MILL AND FILL (THIN HMA INLAY)

INDOT REFERENCE

INDOT Standard Specification Sections 306, 401, 402, and 410

TREATMENT DESCRIPTION

Thin HMA mill/fill is a process that improves surface condition by milling the existing pavement with minor deterioration to a certain depth and then filling it with a new HMA mixture to the original surface elevation or slightly higher. HMA mill/fill and HMA overlay are considered the pinnacles of pavement preservation treatments. Beyond them, treatments are merely structural, and the underlying pavement is beyond preventative maintenance.

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Experienced and reliable technique • Replaceable with a new HMA surface • Improves rideability and surface friction • Reduces hydroplaning problems • Improves cross slop deficiencies • Enhances visibility of pavement markings	• Not suitable for structurally deficient pavements

APPROPRIATE PAVEMENT CONDITIONS

Thin HMA mill/fill is a good candidate for pavement surfaces with raveling, weathering, low severity cracking, low friction, bleeding, or rutting, or when the existing pavement surface is severely deteriorated.

MATERIALS

Refer to the materials of HMA overlay.

APPLICATION LIMITATIONS

Not appropriate for pavement with progressive rutting or other structural damage.

TRAFFIC CONSIDERATIONS

Open traffic in both lanes as soon as curing is complete. Maintain one lane of traffic at all times.

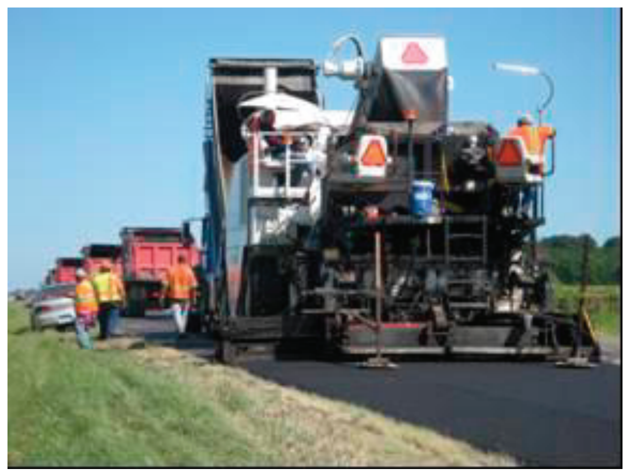
CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Preparation:* Clean existing pavement of all loose materials.
2. *Milling:* Mill the existing surface using the cold milling surface. (The typical milling depth is 1.0 in. and the minimum is scarification.)
3. *Tack coating:* Place light tack coat on vertical faces and base of the milled area (prior to filler).
4. *Filling:* Fill with HMA mixture in uniform lifts. (The typical filling thickness is 1.5 in.)
5. *Rolling:* Compact by rolling with a minimum of three passes.


(a)


(b)


(c)


(d)


(e)

(f)

FIGURE 2-11 Thin HMA mill/fill: (a) surface milling; (b) brooming; (c) milled and scraped surface; (d) paving HMA; (e) correcting surface profile; (f) rolling

2.1.10 THIN HOT MIX ASPHALT OVERLAY WITH PROFILE MILLING

INDOT REFERENCE

INDOT Standard Specification Sections 306, 401, 402, 410, and Unique Special Provision (4.75 MM HMA)

TREATMENT DESCRIPTION

Thin HMA overlays consist of a thin layer of pavement placed over a profile-milled existing pavement. Profile milling removes excessive profile irregularities, roughens the surface and removes excessive crack sealant to prevent slippage of the overlay materials. This milling depth is shallower than the cold milling used for thin HMA mill/fill (thin HMA inlay).

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Experienced and reliable technique • Replaces with a new HMA surface • Improves rideability and surface friction • Reduces minor hydroplaning problem • Improves minor cross slop deficiencies • Enhances visibility of pavement markings	• Not applicable for major cross slop deficiencies • Limited for maintaining vertical clearance or curb height

APPROPRIATE PAVEMENT CONDITIONS

Pavements with low severity cracking, weathering, friction loss, roughness, low severity bleeding, low severity block cracking, and shallow rutting limited to a 0.15 in. average rut depth are appropriate candidates for a thin HMA overlay with profiling milling.

MATERIALS

The mix design for HMA should be in accordance with INDOT Spec. Section 11. The aggregate sizes for HMA are dense grade (DG) 9.5 mm, DG 12.5 mm, and stone mastic aggregate (SMA).

TABLE 2-10 Materials for mill/fill

Material	Type	Reference
Aggregate	DG 4.75mm, DG 9.5 mm, DG 12.5 mm, SMA	401.03, 402.03, 410.03
Binder		401.03, 402.03
Tack Coat	AE-T, AE-PMT,	406.02

LIMITATIONS

Thin HMA overlays are not recommended when structural problems such as fatigue cracking, severe pavement deterioration, or high severity cracking are present. This treatment also is not applicable to correct major cross slope and vertical clearance deficiencies. To maintain curb height, HMA mill/fill is recommended.

TRAFFIC CONSIDERATIONS

Open traffic in both lanes as soon as the overlay has cooled sufficiently and after the rolling operation is completed. Maintain one lane of traffic at all times.

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Milling:* Profile-mill the existing surface.
2. *Tack coating:* Place light tack coat on vertical faces and base of milled area (prior to overlay).
3. *Filling:* Place the HMA mixture in a single, uniform lift.
4. *Rolling:* Compact by rolling to achieve the desired density.

2.2 PORTLAND CEMENT CONCRETE PAVEMENT

2.2.1 CRACK SEALING/FILLING

INDOT REFERENCE

INDOT Standard Specifications Sections 503 and 507

TREATMENT DESCRIPTION

Crack sealing/filling on PCCP pavement is an operation involving significant crack preparation and placement of high-quality sealant into or on top of cracks. INDOT specifies sealing cracks; (Activity 207, Filling Cracks), routing and filling cracks (INDOT Performance Standard Activity 209, Sealing Cracks with Crumb Rubber Material), sealing cracks and joints (INDOT standard specification 503.05), random crack remediation (INDOT Spec. Section 503.06), and routing, cleaning and sealing/cleaning and filling (INDOT Spec. Section 507.03).

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Reduces water infiltration that causes moisture-related distress, including pumping, support reduction, faulting, corner breaks, etc. • Protects cracks from the intrusion of incompressible materials, which can interfere with normal movements (expansion and contraction) and cause blowups and buckling • Experienced and reliable technique	• Poor appearance and visibility • No structural improvement

APPROPRIATE PAVEMENT CONDITIONS

Low to moderate severity transverse or longitudinal cracks with widths smaller than 0.5 in. are ideal candidates for crack sealing. Working cracks are also ideal candidates for sealing. Working cracks with limited spalling or edge deterioration should be sealed rather than filled. Crack filling is recommended for non-working cracks. The working crack criterion is ≥ 0.25 in. of horizontal movement annually. In general, vertical movement is not considered. Working cracks are most often transverse (13).

APPLICATION LIMITATIONS

Crack sealing should not be used on pavements with structural deterioration or where cracks exhibit any other high-severity level of distresses such as spalling, faulting, transverse cracking, and longitudinal cracking. Full-depth working transverse cracks typically have the same range of movement as transverse joints; therefore, it is recommended that these cracks be sealed to reduce the potential of water and incompressible infiltration. An alternative to sealing a full-depth working crack is load transfer restoration (14).

MATERIALS

The typical materials for sealing and filling are hot-applied thermoplastic material (HTP) and cold-applied thermosetting sealant material (CTS). Indiana uses asphalt rubber as HTP for the sealing material and asphalt emulsion as CTS for the filling material. Materials for crack sealing/filling for INDOT PCCP are summarized in TABLE 2-11.

TABLE 2-11 Materials for sealing cracks

	Materials	**References**
Routing, Cleaning, and Sealing	Asphalt rubber sealant	Section 906.02
Cleaning and Filling	AE-90, AE-90S, AE-150	Section 902.01(b)
Fine Aggregates	23, 24	Section 904

TRAFFIC CONSIDERATIONS

No traffic is allowed until curing is complete (15).

OTHER CONSIDERATIONS

Roughness can sometimes be increased as a result of the sealing process itself. This is more likely to happen if the crack sealant is placed in an overband manner.

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

Routing, Cleaning, and Sealing Procedure

1. *Preparing:* The air temperature should be above 40°F and the surface should be dry and clean. Water blasting should not be used under pressure, which can damage the concrete.
2. *Routing:* Route or saw each crack, creating a reservoir. This reservoir should not exceed 0.75 in. width with a minimum depth of 0.75 in.
3. *Cleaning*: Clean each crack with compressed air.
4. *Sealing:* Seal cracks with asphalt rubber material to within 0.25 in. of surface of crack.

5. *Squeegeeing:* Squeegee the filler with “V” shaped wand tip to allow the penetration of the filler into the cracks.

Cleaning and Filling Procedure

1. *Preparing:* The air temperature should be above 40°F, and the surface should be dry and clean. Water blasting should not be used under pressure, which can damage the concrete.
2. *Cleaning*: Clean each crack with compressed air.
3. *Filling:* Fill with asphalt emulsion material. The crack should be completely filled or overbanded (not to exceed 5.0 in.).
4. *Squeegeeing:* Squeegee the filler with “V” shaped wand tip to allow the penetration of the filler into the cracks.
5. *Blotting:* Blot lightly with sand or fine aggregate to prevent asphalt tracking.

2.2.2 PCCP JOINT RESEALING

INDOT REFERENCE

INDOT Standard Specifications Sections 503 and 507

TREATMENT DESCRIPTION

Joint seal distresses commonly include loss of bonding to the sidewall, cohesive failure, spalls, and torn or missing sealant. These seal distresses cause PCCP faulting, surface straining, spalling of the joint wall, blowups, shattering of slab edges, etc. Joint resealing is described as work consisting of routing (sawing to remove old sealant and reshape the joint seal reservoir), cleaning, and sealing joints in PCCP. INDOT specifies the sealing practice in the INDOT Design Manual Chapter 52-11.01. Construction joints and longitudinal joints on PCCP should be inspected periodically and cleaned and resealed as required. INDOT Standard Specifications list two types of joint treatment, including (a) sawing, cleaning and sealing, and (b) cleaning and filling.

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Reduces water infiltration that causes moisture-related distress, including pumping, support reduction, faulting, corner breaks, etc. • Protects joints from the intrusion of incompressible materials in cracks, which can interfere with normal movements (expansion and contraction) and cause blowups and buckling (16) • Experienced and reliable technique	• No structural improvement

APPROPRIATE PAVEMENT CONDITIONS

Joint resealing is effective at any traffic volume and loading. Pavements with joint seal damage are appropriate for joint resealing. For PM, timely sealing of the joints prevents dirt and moisture from entering the joints. PCCP that is eight to ten years old should be inspected. If, on inspection, 10% of the joints have loose, missing, or depressed sealant, sawing and sealing of the joints should be considered (INDOT Design Manual Chapter 52-11.01). FHWA has provided a systematic process of joint seal condition evaluation (13).

APPLICATION LIMITATIONS

Joint resealing is not useful if structural deterioration is present. The major cause of joint seal failure is installation-related. Joint sealing/filling should not be applied when the temperature of the pavement or air is below 40°F.

MATERIALS

Materials for joint sealing for PCCP are summarized in TABLE 2-12.

TABLE 2-12 Materials for joint sealing

Type	Joints	Materials	References
Routing, Cleaning, And Sealing	Transverse Joints	Silicone or preformed elastomeric sealant with or without backer rod	Section 906.02
	Longitudinal Joints	Asphalt rubber or silicone sealant with or without backer rod	Section 906.02
Cleaning and Filling		Asphalt rubber sealant	Section 906.02

TRAFFIC CONSIDERATIONS

Wait until curing has completed until opening to traffic. Traffic may be allowed on the PCCP for up to seven calendar days after the saw cutting and prior to sealing.

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

Sawing, Cleaning and Sealing Procedure

1. *Plowing:* A joint plow applied to remove sealant prior to sawing must remove enough sealant to keep the saw blades from gumming up.
2. *Routing:* Route or saw joints with vertical spindle router if the joint dimensions are not adequate. Refer to INDOT Standard Drawings No. E 503-CCPJ-06 and E 503-CCPJ-03.
3. *Cleaning:* Clean joints with compressed air or power brush (using a minimum air pressure of 100 psi).
4. *Sealing*: Transverse joints should be sealed with silicone sealant or preformed elastomeric joint sealant. Longitudinal joints should be sealed with an asphalt rubber or silicone sealant.

5. *Squeegeeing:* Squeegee the filler with "V" shaped wand tip to allow the penetration of the sealer into the joints.

Cleaning and Filling

1. *Plowing:* A joint plow should be applied to remove sealant.
2. *Cleaning:* Clean joints with compressed air or power brush (using a minimum air pressure of 100 psi).
3. *Filling:* Fill joints with asphalt rubber material to within 0.25 in. of crack surface.
4. *Squeegeeing:* Squeegee the filler with "V" shaped wand tip to allow the penetration of the sealer into the joints.

2.2.3 RETROFIT LOAD TRANSFER

INDOT REFERENCE

INDOT Standard Specification Section 507

TREATMENT DESCRIPTION

Load transfer retrofit is the installation of dowel bars underneath a joint or crack in order to re-establish load transfer across the joint or crack. Load transfer is the mechanism by which the traffic load is conveyed from one slab to the next through shear action. Having poor load transfer efficiency can cause joint deterioration, spalling, pumping, corner breaks, etc.

SYNONYMS

Dowel Bar Retrofit (DBR), Load Transfer Restoration, Load Transfer Retrofit.

BENEFITS OF TREATMENT

Advantage	Disadvantage
• Corrects differential deflections • Alleviates the potential for pumping, faulting, and corner breaks • Improves surface smoothness at joints and cracks	• None

APPROPRIATE PAVEMENT CONDITIONS

Retrofit load transfer is most effective on jointed concrete pavements with poor load transfer caused by poor aggregate interlock, erosion of the base or subbase. Good candidates for retrofit load transfer are summarized as follows (17):

- Load transfer efficiency of 60% or less
- Faulting less than 0.25 in.
- Differential deflection of 10 miles or more

APPLICATION LIMITATIONS

This treatment is not effective when pavement has little remaining structural life due to significant faulting or other signs of structural failure. This application is not cost effective in such cases. A PCCP with D-cracking and reactive aggregate distresses is also not a good candidate since the concrete in the vicinity of the joints and cracks is likely to be weakened.

MATERIALS

The dowel bar should be epoxy-coated and the bond breaker-coated for protection from corrosion and grout adhesion.

TABLE 2-13 Materials for retrofit load transfer

Materials	References
Dowel	Section 910.01
Bond breaker	ASTM A 884, ITM 301
Expansion caps	
Dowel bar support chairs	ASTM A 884
Foam core insert	
Caulking filler	
Non-shrink concrete backfill material	Section 901.07

DESIGN

The performance of the retrofit load transfer is highly dependent on the locations of the dowels (18). Considerations in the design of the slot and dowel bar layout are summarized as follows:

- Slots and dowel bar directions should be parallel to each other and to the longitudinal joint.
- If lane width is 12 ft., a distance between the center of the outermost slot and the outer lane edge should be 3 ft.; if lane width is 14 ft., this distance should be 4 ft.
- Dowel bars should be centered across the joint or crack.
- The depth of a dowel bar should be located at the mid-depth of the slab; too deep a dowel installation can cause corner cracking.
- INDOT specifies three dowels with 12-in. spacing per wheel path.
- INDOT specifies dowel bar sizes in terms of slab thickness as shown in TABLE 2-14.
- Details about layout of slots and dowel location are shown in FIGURE 2-12 and FIGURE 2-13, respectively.

TABLE 2-14 Diameters of dowel bars

Pavement Thickness (in.)	Minimum Dowel Bar Diameter (in.)
Less than 12	1.25
Greater than or equal to 12	1.5

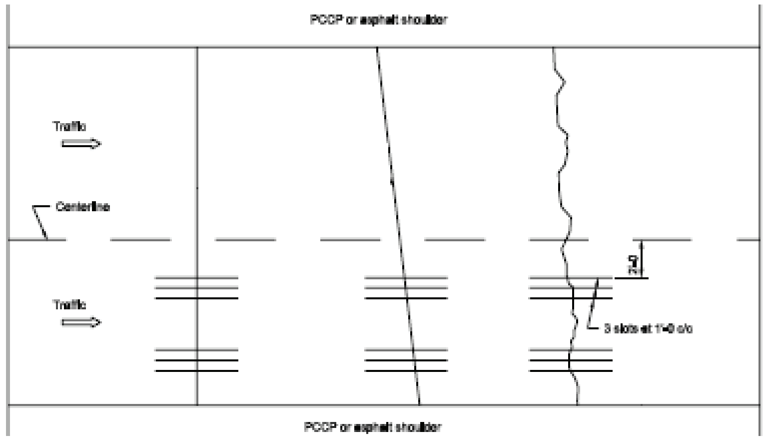


FIGURE 2-12 Retrofit load transfer slot layout (INDOT Standard Drawing E 507-RLTC-02)

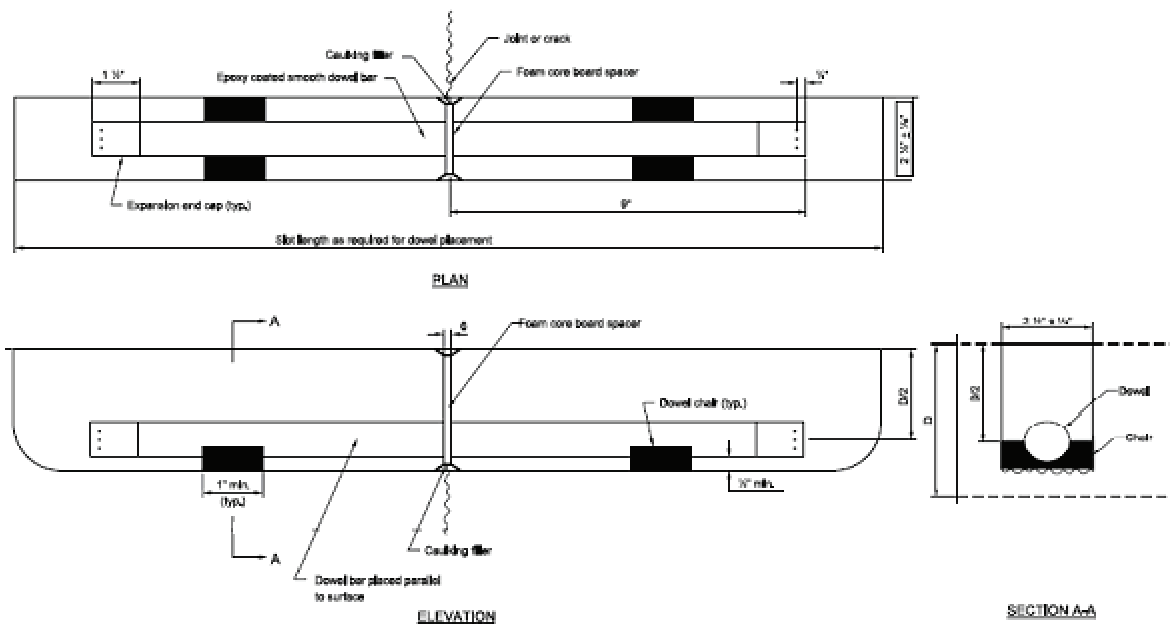


FIGURE 2-13 Design of retrofit load transfer dowel and slot (INDOT Standard Drawing E 507-RLTC-01)

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Survey:* Designed slot location for retrofit dowel bar should be identified and marked on the pavement surface.
2. *Gang saw cutting:* Gang saw cutting is performed to make walls for three slots simultaneously.

3. *Removing concrete fins:* The concrete fin should be removed using lightweight pneumatic hammers not greater than 30 lbs applied at a 45° angle to the plane of the pavement. The bottom of the slots should be smooth, leveled, and clean.
4. *Cleaning slots:* The slots should be cleaned using sand blast, air blast, and vacuum. The slot should be free of dust, slurry, debris, and moisture.
5. *Sealing existing joint:* The existing joints or cracks in slot walls should be sealed using caulking filler to prevent grout from entering the joints or cracks. The sealant should not be over applied (less than 0.5 in. outside of the joint).
6. *Placing the dowel bar:* The dowel bar should be fitted with expansion caps at both ends. These caps allow temperature expansion of the dowel bar as well as slab movement. The dowel bar with caps, dowel chair, and foam core board spacer should be assembled as shown in FIGURE 2-13 prior to placing the dowel bars into the slots. The assembled dowel bars should be centered across the transverse joint or crack in the slots.
7. *Backfilling:* Fill each dowel bar slot with non-shrink concrete backfill material. Special care should be taken to ensure the foam core remains in the center of the existing transverse joint. Slightly overfill the slot and finish the surface of the filled slot to the level of the existing pavement. Slightly overfilled slots can be made flush by diamond grinding.
8. *Profiling*: Profiling (Chapter 2.3.5) may be considered as an additional treatment to improve surface smoothness. Grinding would be performed after the backfill material has cured.

(a)

(b)

FIGURE 2-14 Retrofit load transfer: (a) during installation; (b) after installation

2.2.4 CROSS-STITCHING

TREATMENT DESCRIPTION

Cross-stitching is a load transfer technique used to repair and strengthen longitudinal joints and cracks in PCCP. It uses deformed tie bars epoxied or grouted into holes drilled at an angle through non-working longitudinal cracks or joints. The purpose of cross-stitching is to maintain aggregate interlock and provide added reinforcement and strength to the crack or joints. The tie bars used in cross-stitching prevent the crack from vertical and horizontal movement or widening.

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Corrects poor load transfer at longitudinal cracks or joints • Strengthens longitudinal cracks in slabs to prevent slab migration and to maintain aggregate interlock • Mitigates the issue of tie bars being omitted from longitudinal contraction joints • Ties roadway lanes or shoulders that are separating and causing maintenance problems • Ties centerline longitudinal joints which are starting to fault • Strengthens keyed joints for heavy loads	• None

APPROPRIATE PAVEMENT CONDITIONS

Cross-stitching is not recommended for use on transverse cracks, especially those that are working, because cross-stitching does not allow movement. If used on working transverse cracks, a new crack will likely develop near the stitched crack, or the concrete will spall over the reinforcing bars (19). Also, experience demonstrates that cross-stitching is not a substitute for slab replacement if the degree of cracking is too severe, such as when slabs have multiple cracks or are shattered into more than 4 to 5 pieces (20).

APPLICATION LIMITATIONS

Cross-stitching is recommended for poor load transfer at longitudinal cracks/joints and for roadway lanes/shoulders separating and causing maintenance problems.

TRAFFIC CONSIDERATIONS

Traffic can be allowed on the surface as soon as the epoxy has fully set.

MATERIALS

The following three types of materials have been used on cross-stitching projects:

- Stitch bars
- Anchor bolt epoxy
- Polymer concrete

Specifications of materials used on cross-stitching projects are presented in TABLE 2-15.

TABLE 2-15 Specifications of materials used on cross-stitching projects (21)

Materials	Specifications
Stitch bars	• #6 to #8 Grade 60 deformed bars • A length of bar must be chosen to produce a 1-in. recess between the top of the bar and the pavement surface
Anchor bolt epoxy	• 2-component adhesive consisting of a resin and a hardener or catalyzing agent to be used in horizontal application • Fillers must not abrade or damage the dispensing equipment
Polymer concrete	– Type I (Urethane Base) • Compressive Strength, 24 hours – 750 psi min. • Resilience, 85% min. • Very sensitive to moisture – Type II (Epoxy Base) • Compressive Strength, 24 hours – 2,000 psi min. • Resilience, 70% min.

DESIGN

Cross-stitching generally uses a 0.75 in. diameter deformed tie bar to hold the crack tightly together and enhance aggregate interlock (22). The bars are typically spaced at intervals of 20 to 30 in. along the crack and are alternated to each side of the crack. Heavy truck traffic typically requires 20 in. spacing while 30 in. spacing is adequate for light traffic (19). Recommendations for cross-stitching bar dimensions and angles/locations of holes are presented in FIGURE 2-14 and TABLE 2-16, respectively.

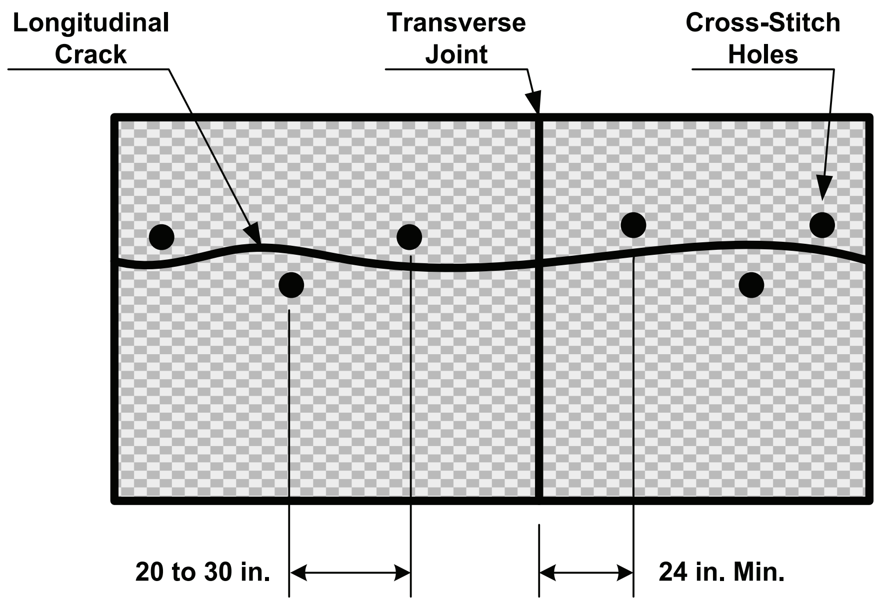


FIGURE 2-15 Schematic of cross-stitch tie bar installation (22)

TABLE 2-16 Cross-stitching bar dimensions and angles/locations or holes (20)

Angle	Slab Thickness (in.)							
	7	8	9	10	11	12	13	14
	Distance from Crack to Hole (in.)							
35°	5.00	5.75	6.50	7.25	7.75	8.50	-	-
40°	-	-	-	-	6.50	7.25	7.75	8.25
45°	-	-	-	-	-	6.00	6.50	7.00
	Length of Bar (in.)							
35°	8.00	9.50	11.00	12.50	14.50	16.00	-	-
40°	-	-	-	-	12.50	14.00	16.00	18.50
45°	-	-	-	-	-	12.00	14.00	16.50
	Diameter of Bar (in.)							
	0.50	0.75	0.75	0.75	0.75	0.75	1.00	1.00

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Drilling holes*: Drill holes an angle (35°-45°) so that they intersect the longitudinal crack or joint at about mid-depth. Drill the hole at a consistent distance from the crack or joint, in order to consistently cross at mid-depth.
2. *Cleaning holes:* Air-blow the holes to removes dust and debris after drilling.
3. *Pouring epoxy:* Pour or inject epoxy into the hole, leaving some volume for the bar to occupy the hole.
4. *Tie installation*: Insert the tie bars into the holes, leaving about 1 in. from top of bar to pavement surface.
5. *Cleaning:* Remove excess epoxy and finish flush with the pavement surface.

2.2.5 PCCP PROFILING (DIAMOND GRINDING)

INDOT REFERENCE

INDOT Standard Specification Section 507

TREATMENT DESCRIPTION

Diamond grinding is one of the cost effective concrete pavement restoration techniques that corrects irregularities such as faulting or roughness on concrete pavements. This treatment creates a texturized pattern on a concrete pavement surface using a diamond grinding machine, which grinds 0.2 in. to 0.25 in. of the concrete surface, as shown in FIGURE 2-16. Similar treatment techniques and equipment are used for diamond grooving. This treatment is mainly used for reducing hydroplaning and accidents by making water channels on the surface of the pavement (23).

FIGURE 2-16 Comparison of ungrounded (left) and grounded (right) textures

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Short lane closures • No requirement for shutting down adjacent traffic • Can be re-ground up to 2 or 3 times • Does not affect overhead clearance • Improves smoothness • Improves friction • Reduces noise • Reduces hydroplaning	• No structural improvement

APPROPRIATE PAVEMENT CONDITIONS

Diamond grinding is best used on pavements exhibiting joint faulting, surface irregularities, and lack of pavement surface friction (e.g. polished surfaces).

APPLICATION LIMITATIONS

Diamond grinding does not address any structural or durability problems in the pavement. Also, pavements with soft aggregate will require more frequent grinding, which will be costly. The presence of material-related distresses will prevent diamond grinding from being effective.

TRAFFIC CONSIDERATIONS

Traffic can be allowed on the surface as soon as grinding residue is cleaned.

DESIGN

Diamond grinding texture should be designed in terms of aggregate hardness. In general, the softer the aggregate, the wider the land areas (i.e. the tighter the blade-spacing) should be to avoid vehicle tracking. The typical designs of diamond grinding texture consisting of height, groove, and land area are shown in FIGURE 2-17 and TABLE 2-17.

FIGURE 2-17 Schematic of diamond grinding texturized pavement

TABLE 2-17 Typical grinding texture for different aggregates (24)

	Hard Aggregate	**Soft Aggregate**
Grooves	0.1 – 0.16 in.	0.1 – 0.16 in.
Land Area	0.08 in.	0.1 in.
Height	0.06 in.	0.06 in.
Grooves per meter	53 – 60	50 – 54

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Preparation*: All structural/material deficiencies of PCCP should be restored before the diamond grinding operation.
2. *Grinding*: Grinding operation should begin and end at lines normal to the pavement centerline. Grinding is always along a traffic lane and is a continuous operation. Spot grinding is not recommended. A diamond saw blade with a cutting head of at least 36 in. in width is used to grind longitudinally. Several machines working together allow a lane to be completed in one pass, thus improving productivity in large projects. One machine and several passes with 2 in. of minimum overlap are used for small projects. The grinding equipment uses water to cool the cutting head.
3. *Cleaning:* The slurry/residue from the grinding operation should be properly removed.
4. *Filling/Resealing*: Joints and cracks should be sealed or filled.

2.2.6 PARTIAL DEPTH PATCHING

INDOT REFERENCE

INDOT Standard Specification Section 507.05

TREATMENT DESCRIPTION

Partial depth patching (PDP) consists of removal and replacement of small, shallow areas of deteriorated PCCP at spalled or distressed joints with rapid-setting patching materials. The INDOT Operation Handbook includes PDP operation in Activity CODE 2010.

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Repairs localized distresses (e.g. joint spalling) within the upper third of the slab thickness • Restores structural integrity • Improves rideability • Defers further deterioration	• None

APPROPRIATE PAVEMENT CONDITIONS

Good candidates for PDPs include joints and cracks with localized low-severity deteriorations, including spalling of joints, scaling of joints, and deterioration adjacent to existing repair. PDPs may be used to temporarily relieve roughness caused by material problems (e.g. D-cracking or reactive aggregate problems). PDPs are effective for localized distresses within the upper third of slab thickness. Cracks through the full thickness of the slab or spalls with exposed load transfer devices should be treated with full-depth repairs.

APPLICATION LIMITATIONS

When spalling is caused by compressive stress buildup, dowel bar misalignment or lockup, improper construction practices, working cracks caused by shrinking or fatigue, D-cracking, or reactive aggregate, PDPs should not be used as a permanent solution. PDPs should be a minimum of 4 in. by 12 in. plan dimensions and 1 to 3 in. in depth.

MATERIALS

The selection of patching materials is based on the curing time, which determines traffic opening conditions. TABLE 2-18 shows the typical Indiana patching materials.

TABLE 2-18 Materials for partial depth patching

Material Type	Materials	References
HMA	Type A	Section 402.4
Concrete	Rapid-setting concrete with a non-vapor barrier bonding agent	Section 506.2, 901.07
Bitumen	HMA with a bonding agent (AE-T)	Section 402. 09, 507.05, 904

TRAFFIC CONSIDERATIONS

PDPs are effective at all traffic volumes and loadings. In case of using concrete for PDP, open to traffic when flexural strength reaches a minimum of 300 psi (Section 506.11).

WEATHER CONSIDERATIONS

PDP should not be placed on frozen, existing PCCP (Section 506.09).

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Survey:* Patch boundaries should be identified and marked on the pavement surface.
2. *Removal:* Make a saw cut to the needed depth (1 in. to 3 in.) and remove all unsound concrete in area.
3. *Joint preparations:* Maintain joints in the area of interest using joint fillers or forms.

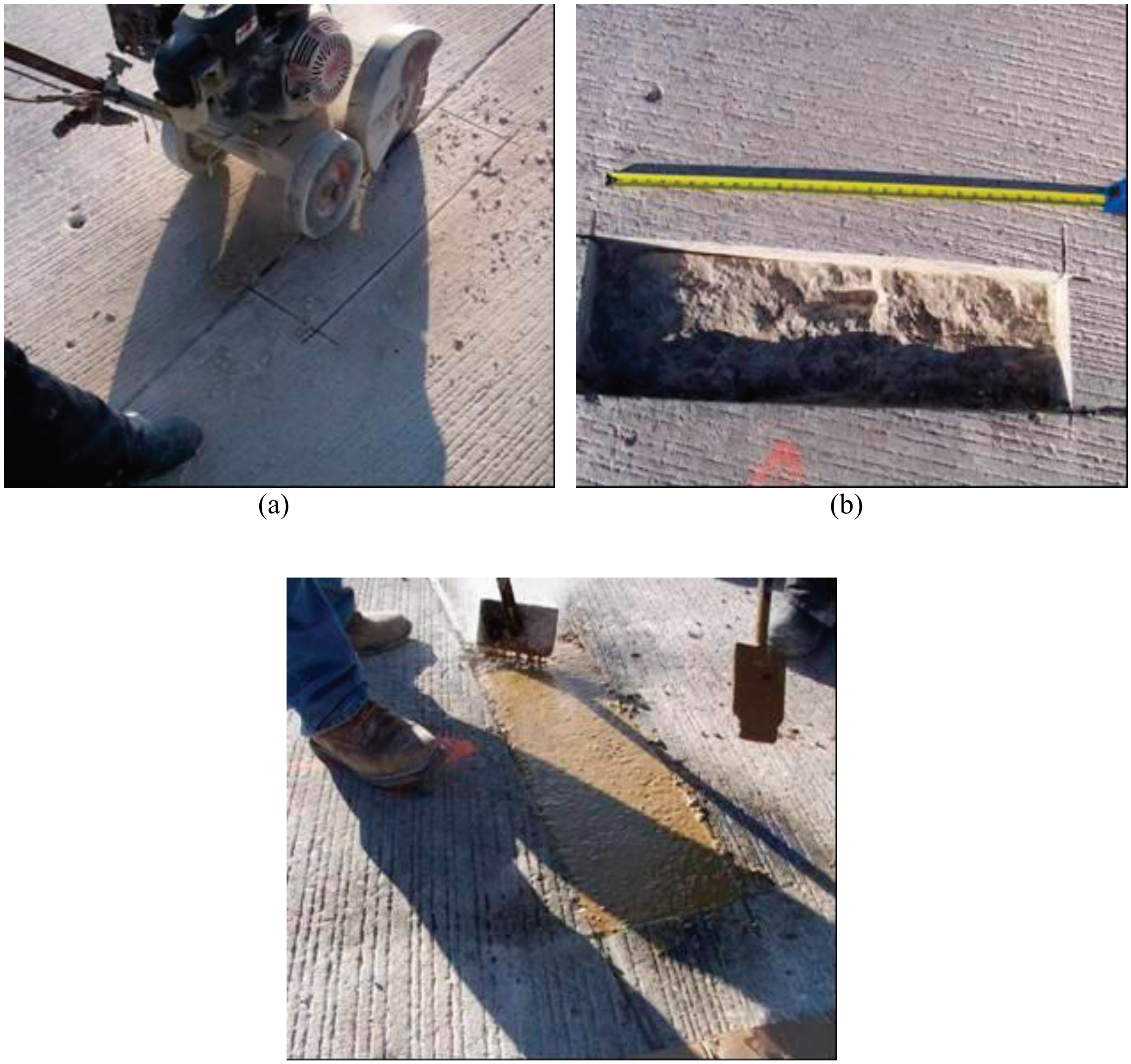
Rapid-setting Concrete Filler

1. *Applying a bond agent*: Apply a non-vapor-barrier type bonding agent to vertical and horizontal surfaces.
2. *Placement:* Slightly overfill to allow counteracting for volume reduction during consolidation.
3. *Consolidation:* Consolidate PCCP filler using vibrators.
4. *Finishing:* Finish the patching area to level with the adjacent pavement and match the texture of the patched surface to that of the existing pavement.
5. *Curing:* Adequate attention to curing is needed to reduce shrinkage cracking. Insulating blankets and traps can reduce curing time.
6. *Joint resealing:* Apply the Joint Resealing Procedure.

HMA Filler

Follow steps 1 through 3 above.

1. *Applying a bond agent:* Apply a bonding agent (AE-T) to vertical and horizontal surfaces.
2. *Placement:* Slightly overfill to allow counteracting for volume reduction during compaction.
3. *Compaction*: Compact using a vibratory roller with a minimum of four passes.
4. *Joint resealing:* See 2.2.2 for Joint Resealing Procedure.



(a) (b) (c)

FIGURE 2-18 Partial depth patching: (a) sawing; (b) removing; (c) placing

2.2.7 FULL-DEPTH PATCHING

INDOT REFERENCE

INDOT Standard Specification Section 506

TREATMENT DESCRIPTION

Full-depth patching (FDP) restores structural integrity and rideability of PCCP. This involves removing the deteriorated concrete down to the base, repairing the disturbed base, installing load transfer devices, and refilling the excavated area with new concrete. It is an effective and permanent treatment to repair pavement distress, particularly which occurs at or near deterioration, and restore the pavement close to its original condition.

SYNONYMS

Full-depth Repair, Full-depth Restoration.

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Corrects transverse cracks, longitudinal cracks, joint spalling, blowup, corner breaks • Restores structural integrity • Improves rideability • Defers further deterioration	• Longer lane closure time than other treatments

APPROPRIATE PAVEMENT CONDITIONS

Spalls with exposed reinforcing steel and cracks through the full thickness of the slab should be treated by FDPs. In detail, pavements with moderate to high-severity levels of distress, including transverse cracking, longitudinal cracking, corner breaks, spalling of joints, blow up, deterioration adjacent to existing repair, and deterioration of existing repairs are good candidates for FDPs.

TABLE 2-19 General distress criteria for full-depth repair (25)

DISTRESS TYPE	MINIMUM SEVERITY LEVEL REQUIRED FOR FULL-DEPTH REPAIR
Blowup	Low
Corner Break	Low
Deterioration Adjacent to Existing Repair	Medium
Joint Deterioration	Medium with faulting 0.25in.
Spalling	Medium
Reactive Aggregate	Medium
Transverse Cracking	Medium with faulting 0.25in.
Longitudinal Cracking	High with faulting 12mm 0.5in.

APPLICATION LIMITATIONS

According to INDOT Specification Section 506 and Standard Drawing E 506-CCPP-01, a minimum FDP length is 6 ft. FDP areas in the same lane that are closer than 10 ft. require that the PCCP between these areas be removed and patched. If a transverse joint is located within the removal area, the limits of the FDP area should be increased to a minimum of 1 ft. beyond the joint. In regard to cost effectiveness, FHWA has suggested the minimum distance between two FDPs in terms of patch width and slab thickness in TABLE 2-20.

TABLE 2-20 Minimum cost-effective distance between two FDPs (25)

Slab Thickness (in.)	PATCH (LANE) WIDTH (ft.)			
	9.0	10	11	12
7.0	17	15	14	13
8.0	16	13	12	11
9.0	13	12	11	10
10	12	11	10	9.0
11	11	10	9.0	8.0
12	10	9.0	8.0	8.0
15	8.0	8.0	7.0	6.0

MATERIALS

INDOT specifies the materials for FDP as summarized in TABLE 2-21.

TABLE 2-21 Materials for full-depth patching (Section 506.02)

Material Type	Materials	References
Admixtures		912.03
Calcium Chloride	Type L	913.02
Chemical Anchor System		901.05
Coarse Aggregate	Class AP, Size No. 8	904
Dowel Bars		910.01(b)10
Fine Aggregate	Size No. 23	904
Portland Cement		901.01(b)
Water		913.01

TRAFFIC CONSIDERATIONS

An FDP may be opened to traffic in accordance with the specifications in TABLE 2-22 when calcium chloride is used. PCCP patches with calcium chloride may be opened to traffic sooner than normally permitted if the test beams indicate a modulus of rupture of 300 psi or greater. ITM 402 "Strength of PCCP Using the Maturity Method" (26) may be used as an alternative method to determine the flexural strength. When other admixtures or admixture systems are used, the PCCP patches may be opened to traffic when flexural strength tests indicate a modulus of rupture of 300 psi or greater.

TABLE 2-22 Opening time to traffic for calcium chloride

T	H	HT	T	H	HT
40-42°F	30	26	61-63°F	14	9.0
43-45°F	27	23	64-66°F	14	9.0
46-48°F	24	21	67-69°F	14	8.0
49-51°F	21	19	70-72°F	14	7.0
52-54°F	19	16	73-75°F	14	6.0
55-57°F	16	14	Above 75°F	14	5.0
58-60°F	16	11			

T = Lowest ambient temperature during placement or the temperature of concrete at the time of delivery, whichever is lower
H = Time in hours until open to traffic
HT = Time in hours until open to traffic when the average daily traffic is less than 10,000

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Survey:* Patch boundaries should be identified and marked on the pavement surface based on engineering judgment using the data from coring, Falling Weight Deflection (FWD) testing, Ground Penetration Radar (GPR) testing, etc.
2. *Removal:* A saw cut should be made to the full lane width and depth over the marked length. The saw cut slab is broken into smaller pieces using a mechanical hammer or rammer and removed by backhoe.
3. *Base/subgrade preparation:* The disturbed base/subgrade should be replaced, treated, or compacted.
4. *Joint preparation:* FDP requires the installation of mechanical load transfer devices, dowels, and tie bars. Details on dowel bar locations and dowel sizes are in INDOT Standard Drawing No. E 506-CCPP-01.
5. *Placement:* Slightly overfill to counteract volume reduction during consolidation.
6. *Consolidation:* Consolidate PCCP filler using vibrators.
7. *Finishing:* Finish patching area to the level of the adjacent pavement and match the texture of patched surface to that of the adjacent pavement.
8. *Curing:* Adequate attention to curing is needed to reduce shrinkage cracking. Insulating blankets and traps can reduce curing time.
9. *Joint sealing:* Transverse and longitudinal joints should be sealed or filled. The details are available in INDOT Standard Drawing No. E 503-CCPJ-06 for the transverse joint seals and E 503-CCPJ-07 for the longitudinal joint seals.

(a)

(b)

(c)

(d)

(e)

FIGURE 2-19 Full-depth patching: (a) removing the existing slab; (b) placing the subbase material; (c) and (d) compacting the subbase; (e) the new slab surface

2.2.8 UNDERSEALING

INDOT REFERENCE

INDOT Standard Specification Sections 507 and 612

TREATMENT DESCRIPTION

Voids under PCCP cause faulting, pumping, corner breaks, and joint failure. Filling the voids with the proper material can extend PCCP life and improve rideability. This technique, called undersealing, consists of furnishing and pumping cement grout or liquid asphalt under PCCP so that the filling material flows into the voids. It is noted that undersealing is not intended to lift the slab but to fill the voids to improve loss of support.

SYNONYMS

Slab Stabilization, Void Filling.

BENEFITS OF TREATMENT

Advantages	Disadvantages
• Reduces slab deflections • Alleviates the potential for pumping, faulting, and corner breaks • Reduces reflective cracking in HMA overlay • Improves rideability	• None

APPROPRIATE PAVEMENT CONDITIONS

Generally, undersealing is done in conjunction with other treatments (e.g. thin HMA overlay for composite pavement). INDOT determines the undersealing location based on deflections obtained through Falling Weight Deflectometer (FWD) tests. The threshold deflection varies in terms of road category, as shown in TABLE 2-23.

TABLE 2-23 INDOT deflection limits for undersealing

Road Type	Deflection (Mil)
National Highway System (Interstate)	8.0
National Highway System (other roads)	10
Non-National highway System	12

APPLICATION LIMITATIONS

Undersealing is not appropriate on pavements with significant faulting, or other signs of structural failure (e.g., pumping, or cracking). Such distresses suggest structural failures that require more extensive rehabilitation. PCCP with open graded subbase should not be undersealed.

INSERTION HOLE PATTERN

Once PCCP slabs are selected for undersealing application, drill hole locations should be determined. These hole locations should be far away from joints or cracks but still within the voids. The drill hole pattern varies depending on the conditions to be corrected and the condition of the pavement. The drill pattern to correct faulted transverse joints normally consists of holes at the centerline of the pavement lane in the settled portion of the slab. Spacing should be approximately 30 to 36 in. from the transverse joints or cracks. The hole diameter should not exceed 1.5 in. Intermediate holes, if necessary, shall be spaced as directed (INDOT Spec. Section 612).

MATERIALS

INDOT specifies asphalt materials as void fillers, as summarized in TABLE 2-24.

TABLE 2-24 Materials for undersealing

Material	Type	Reference
Asphalt	Utility Asphalt (UA-2, and UA-3)	Section 902.01 (d), ASTM D 3141

TRAFFIC CONSIDERATIONS

Traffic must be kept off during hole drilling and material application. Once holes are plugged with hardwood plugs, traffic may be permitted on both lanes.

WEATHER LIMITATIONS

Undersealing should not be applied when pavement surface temperature is below 40°F, or when the subgrade or subbase is frozen.

CONSTRUCTION CONSIDERATIONS AND PROCEDURE

1. *Void detection:* The PCCP slabs needing undersealing application should be identified based on deflections of FWD, and the injection holes should be marked.
2. *Drilling injection holes:* The depth of an injection hole should be beyond the bottom of the slab when a granular subbase is present, and to the bottom of the subbase in the case of a stabilized subbase. Pouring water into the holes and observing the level of water can indicate the presence of voids under the slab.

3. *Preparation:* In advance of pumping operations, the surface of the pavement for an area around each hole should be sprinkled with water to prevent the undersealing material from adhering to the pavement surface.
4. *Material preparation:* The asphalt temperature should be between 350°F and 500°F. Since this temperature is close to or exceeds the flash point of some asphalt, safe operation should be conducted as directed by the material manufacturer's instructions and specifications. If the asphalt is overheated, it should be rejected.
5. *Injection:* A 1-in. tapered asphalt nozzle should be inserted in the hole and driven to a snug fit. Pumping of the asphalt with a pressure between 25 to 90 psi should continue until the underside of the slab is sealed and all voids filled, as indicated by the shoulders showing signs of breaking away from the pavement, or when the pavement begins to rise (27). During the injection operation, the slab lift should be monitored at the pavement edge or any two outside slab corners adjacent to a joint and the adjoining shoulder. The upward movement of the pavement due to undersealing should not exceed 0.1 in. Pavement that has been raised in excess of this amount may be subject to removal and replacement, or diamond grinding to the correct grade, as determined by the engineer (28).
6. *Plugging:* Immediately after pumping, a wood plug should be driven into the hole without an excessive back flow of asphalt material. Once the asphalt is cured, the plug should be removed and a hardwood plug (3.0 in. long and 0.06 in. larger in diameter than the hole) should be driven flush with the surface of the pavement.
7. *Cleaning:* All material extruded during the pumping operations should be immediately removed from the pavement surface.

3 IDENTIFICATION GUIDELINES FOR PAVEMENT SURFACE DISTRESSES

This chapter presents the different types of distresses found in asphalt and concrete pavements. Each subchapter contains descriptions, causes, measurements, and pictures of each type of distress. The guidelines are mainly based on manuals, including the Distress Identification Manual for the Long Term Pavement Performance Program (LTPP) (29) and the Indiana Department of Transportation Design Manual (2). Distresses presented in the guidelines are listed in TABLE 3-1.

TABLE 3-1 List of distresses

Asphalt or Composite Pavement	PCCP
• Fatigue (Alligator) cracking • Reflective Cracking • Longitudinal Cracking • Thermal Cracking (Transverse Cracking) • Block Cracking • Edge Cracking • Pumping and Water Bleeding • Rutting • Flushing (Asphalt Bleeding) • Shoving • Potholes • Raveling • Patch/Patch Deterioration • Polishing • Lane/Shoulder Drop-off or Heave	• Blowup • Corner Break • Transverse Cracks • Longitudinal Cracks • Spalling of Joints and Cracks • PCCP Joint-seal Failure • Faulting • Pumping and Water Bleeding • Punchout • Durability (“D”) Cracking • Lane/Shoulder Drop-off or Heave • Lane/Shoulder Joint Separation • Patch Deterioration • Popouts • Scaling/Map Cracking • Polishing

3.1 ASPHALT OR COMPOSITE PAVEMENT

3.1.1 FATIGUE CRACKING (ALLIGATOR CRACKING)

DESCRIPTION

Fatigue cracking is characterized by a series of interconnected cracks that develop into a multi-sided crack network resembling chicken wire or an alligator skin pattern in the wheel path.

CAUSES

Fatigue cracking is a load-related distress caused by repeated traffic loading, usually after the first few years of pavement life. Fatigue cracking often forms rapidly as the pavement weakens. The cracks originate at the bottom of the asphalt pavement (where the pavement is in tension) and propagate to the surface as parallel cracks. After more traffic loading, the cracks become interconnected and form a recognizable chicken wire or alligator skin pattern. The following are causes of fatigue cracking (30):

- Relatively thin or weak HMA layers for the magnitude and number of repetitions of wheel loads.
- Higher wheel loads and higher tire pressures.
- Soft spots or areas in unbound aggregate base materials or in the subgrade soil.
- Weak aggregate base/subbase layers caused by inadequate compaction or increases in moisture content and/or extremely high ground water table.

SEVERITY LEVELS

- Low: Cracks not spalled or sealed, pumping not evident, cracks not interconnected.
- Moderate: Cracks form interconnected area, slight spalling, cracks may be sealed, pumping not evident.
- High: Area of moderately or severely spalled interconnected cracks forming a pattern, pieces dislodged, cracks may be sealed, and pumping may be evident.

MEASUREMENT

- In square feet, record the surface area affected at each severity level.
- Measure the area by recording the fatigue cracking in lineal feet, assuming the distress exists entirely within the wheel path. The wheel path is defined as 2.5 ft wide.
- If different severity levels existing within an area cannot be distinguished, rate the entire area at the highest severity present.

FIGURE 3-1 Fatigue cracking: (a) and (b) low severity; (c) moderate severity; (d) and (e) high severity

3.1.2 REFLECTIVE CRACKING

DESCRIPTION

Reflection cracks occur in an overlay surface due to stresses at the joints in the underlying concrete pavement. They can be identified by knowledge of slab dimensions (and thus joint location).

CAUSES

Reflection cracking occurs once the movement of the underlying PCCP exceeds the elasticity of the overlay, resulting in the migration of the crack pattern from the underlying pavement to the surface of the pavement. An extremely low temperature or a sudden drop in temperature can create tensile stresses in the pavement beyond the tensile properties of the binder material. Differential movement at the existing crack, as traffic travels across the crack, increases the stress in the overlay. If reflective or transverse cracking is left unchecked, the pavement adjacent to the area of the cracks will further deteriorate by raveling or stripping, and will result in a rough riding surface.

SEVERITY LEVELS

- Low: Unsealed crack with mean width ≤ 0.25 in. Sealed crack with sealant in good condition.
- Moderate: Crack with mean width > 0.25 in. and ≤ 0.75 in. Crack with mean width ≤ 0.75 in. and adjacent random cracking at low severity levels.
- High: Crack with mean width > 0.75 in. Crack with mean width ≤ 0.75 in., adjacent random cracking, and moderate or high severity levels.

MEASUREMENT

- Record total crack length in feet.
- The length recorded is assigned to the highest severity level that is present for at least 10 percent of the crack length.
- Record the number of cracks at each severity level.

(a)

(b)

(c)

(d)

FIGURE 3-2 Reflection cracking: (a) low severity; (b) and (c) moderate severity; (d) high severity

3.1.3 LONGITUDINAL CRACKING

DESCRIPTION

Longitudinal cracks run parallel to the pavement centerline and can be further categorized as either “wheel path” or “non-wheel path” cracks.

CAUSES

These types of cracks are caused by shrinking of the asphalt surface due to temperature fluctuations or asphalt hardening. They are occasionally caused by cracks underneath the asphalt surface, including cracks (but not joints) in underlying concrete slabs. Longitudinal cracks may also be caused by a poorly constructed paving joint.

SEVERITY LEVELS

- Low: Unsealed crack with mean width ≤ 0.25 in. Sealed crack with sealant in good condition.
- Moderate: Crack with mean width > 0.25 in. and ≤ 0.75 in. Crack with mean width ≤ 0.75 in. and adjacent random cracking at low severity levels.
- High: Crack with mean width > 0.75 in. Crack with mean width ≤ 0.75 in., adjacent random cracking, and moderate or high severity levels.

MEASUREMENT

- Record wheel path and non-wheel path cracks separately.
- Record the length in meters of longitudinal cracking.
- Any crack with a quantifiable area is recorded as fatigue cracking.
- Record longitudinal cracks that have been sealed.

FIGURE 3-3 Longitudinal cracking: (a), (b), (c), and (d) low severity; (e) moderate severity; (f) high severity

3.1.4 THERMAL CRACKING (TRANSVERSE CRACKING IN FULL-DEPTH ASPHALT PAVEMENT)

DESCRIPTION

Transverse cracks are cracks that are more or less perpendicular to the pavement centerline.

CAUSES

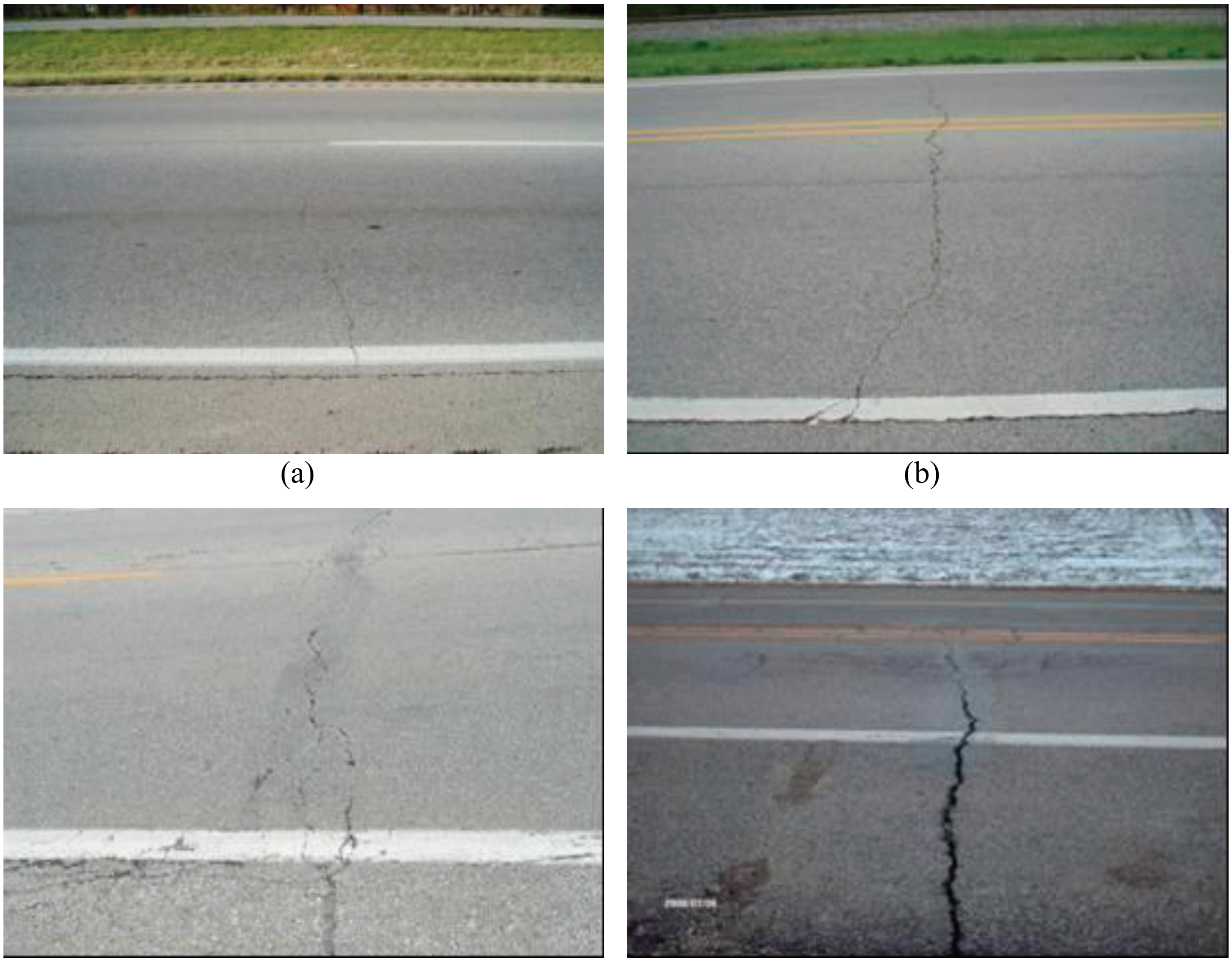
Transverse cracks are often referred to as “thermal cracks” because they may be caused by pavement movement due to cold temperatures and temperature cycling. Another cause of thermal cracking is due to binder material that was originally too hard or has age-hardened. Cracking that results from the cold temperatures is referred to as low temperature cracking. Cracking that results from thermal cycling is generally referred to as thermal fatigue cracking. Low temperature cracking is associated with regions of extreme cold whereas thermal fatigue cracking is associated with regions that experience extremes in daily and seasonal temperatures. There are two types of non-load-related thermal cracks: transverse cracking and block cracking.

SEVERITY LEVELS

- Low: Unsealed crack with mean width ≤ 0.25 in. Sealed crack with sealant in good condition.
- Moderate: Crack with mean width > 0.25 in. and ≤ 0.75 in. Crack with mean width ≤ 0.75 in. and adjacent random cracking at low severity levels.
- High: Crack with mean width > 0.75 in. Crack with mean width ≤ 0.75 in., adjacent random cracking, and moderate or high severity levels.

MEASUREMENT

- In feet, record the length of transverse cracks at each severity level.
- Record the number of transverse cracks at each severity level.
- Assign the highest severity level present for at least 10 percent of the crack length.
- Cracks less than 1.0 ft in length are not recorded.



(a) (b)

(c) (d)

FIGURE 3-4 Transverse cracking: (a) and (b) low severity; (c) moderate severity; (d) high severity

3.1.5 BLOCK CRACKING

DESCRIPTION

Block cracking is characterized by the formation of a rectangular cracking pattern that ranges in size from one square foot to 100 square feet in area.

CAUSES

See the causes of thermal cracking. On a pavement with four or more lanes, block cracking is more typical in the passing lane, as it is a form of non-load-related distress. Traffic loadings in the travel lane tend to relieve the shrinkage stresses.

SEVERITY LEVELS

- Low: Cracks with mean width ≤ 0.06 in. Sealed cracks with sealant in good condition.
- Moderate: Cracks with mean width > 0.06 in. and ≤ 0.25 in. Any crack with a mean width ≤ 0.75 in. and adjacent random cracking of low severity.
- High: Cracks with mean width > 0.25 in. Any crack with a mean width ≤ 0.25 in. and adjacent random cracking of moderate or high severity level.

MEASUREMENT

- Record affected area in terms of square feet for each severity level.
- An occurrence of block cracking should be at least 15 ft in length before it is categorized as such.
- To obtain an estimate of an area, treat each block as a rectangle or square with straight sides, and measure each side with a tape measure.

FIGURE 3-5 Block cracking: (a) low severity; (b), (c), (d), and (e) moderate severity; (f) high severity

3.1.6 EDGE CRACKING

DESCRIPTION

Edge cracking only applies to pavements with unpaved shoulders. The cracks are often crescent-shaped and intersect the pavement edge. Longitudinal cracks located within 2.0 ft of the pavement edge should be classified as edge cracks.

CAUSES

Edge cracks form along a weakened pavement edge that does not have adequate lateral support from a shoulder. The weakened pavement edge can be caused by a number of factors, including a weak base or subgrade layer, poor drainage, or frost heaves. Heavy traffic along the pavement edge or heavy vegetation along the edge of the pavement can accelerate the progression of edge cracking (31).

SEVERITY LEVELS

- Low: Cracks with no breakup, deterioration, or loss of material.
- Moderate: Cracks with some breakup and deterioration for up to 10 percent of the crack length.
- High: Cracks with considerable breakup and material loss for more than 10 percent of the crack length.

MEASUREMENT

Record the length of the crack in feet at each severity level.

(a)

(b)

(c)

FIGURE 3-6 Edge cracking: (a) low severity; (b) moderate severity; (c) high severity

3.1.7 PUMPING AND WATER BLEEDING

DESCRIPTION

Water bleeding is the seepage of water onto the pavement surface. Pumping refers to water being forced out of voids under the pavement. The water carries fine material (sand, fine aggregate) that was eroded or pumped from underlying layers onto the surface, leaving a stained surface layer.

CAUSES

Pumping occurs when water and fine material are ejected from lower pavement layers through cracks in the surface layer. Possible causes include inadequate pavement structure, inadequate compaction (pavement is too porous), poor mix design, a high water table, or poor drainage.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

- Count and record the number of occurrences and the length in feet of the affected pavement.
- Record only minimum lengths of 3.0 ft.
- The length recorded should be a linear measurement of the pavement section that is afflicted by the distress and not the length of the actual distress itself.

(a) (b) (c) (d) (e) (f)

FIGURE 3-7 Pumping/water bleeding

3.1.8 RUTTING

DESCRIPTION

Rutting is a longitudinal surface depression in the wheel path, which may be accompanied by slight transverse displacement.

CAUSES

Rutting is permanent deformation in any of the pavement layers caused by consolidation settlement or lateral movement of asphalt material due to repeated traffic loadings. The plastic movement of the materials can be exacerbated by softening of the asphalt in hot weather or improper compaction during construction. Rutting may also be caused by an improper mix design, soft subgrade, or stripping in the underlying asphalt layers.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

- Record the maximum rut depth to the nearest inch at 50-ft intervals for each wheel path using a 4.0 ft straightedge.
- Alternatively, measure the transverse profile using a dipstick profiler at 50-ft intervals in the wheel path.

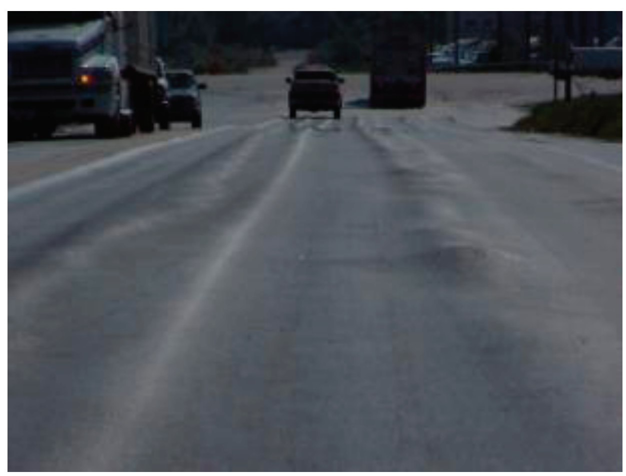
(a)

(b)

(c)

(d)

(e)



(f)

FIGURE 3-8 Rutting

3.1.9 FLUSHING (ASPHALT BLEEDING)

DESCRIPTION

Asphalt bleeding is the collection of bituminous material onto the pavement surface. It is often found in the wheel paths and can manifest itself as a discolored surface, a loss of surface texture due to excess asphalt, or a surface that obscures aggregate because of an excess of shiny, sticky, asphalt binder.

CAUSES

Asphalt bleeding is usually caused by stripping, an excessive moisture at time of placement, and an excessive amount of asphalt binder in the mix design. Hot temperatures enable the asphalt to expand, filling up voids first and then flushing towards the pavement surface. Increased traffic loads will reduce the amount of voids and will amplify the amount of bleeding.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

- Record the square feet of the surface area affected by bleeding.
- Record the area of the actual distress itself and not the entire area of the pavement section that is afflicted by bleeding.
- Alternatively, using standard wheel path widths (2.5 ft) and the length of the pavement affected by bleeding, one can record percentages of rutting (by area or length).

FIGURE 3-9 Flushing (asphalt bleeding)

3.1.10 SHOVING

DESCRIPTION

Shoving, also known as corrugation, is typified by ripples or bumps in the asphalt surface caused by plastic movement of material. It is a longitudinal displacement of the pavement in a localized area.

CAUSES

The plastic movement associated with shoving is caused by shear action in the pavement surface from vehicles. Shoving is often found at stop bars or bus stops where vehicles are most often turning, stopping, or starting.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

Count the number of occurrences and measure the area in square feet of the affected surface area.

(a) (b) (c) (d)

FIGURE 3-10 Shoving

3.1.11 POTHOLES

DESCRIPTION

Potholes are localized bowl-shaped holes with a minimum diameter of 6 in.

CAUSES

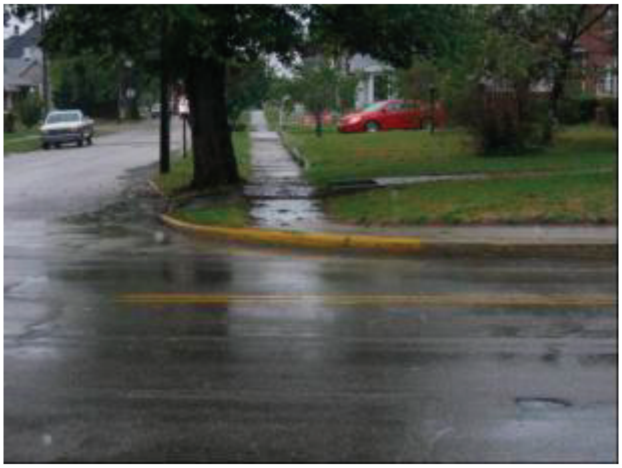
Potholes are caused by severe alligator cracking, stripping, pavement disintegration, or freeze-thaw cycles. They are considered to be structural and functional types of distresses.

SEVERITY LEVELS

- Low: Less than 1.0 in. deep.
- Moderate: 1.0 to 2.0 in. deep
- High: More than 2.0 in. deep

MEASUREMENT

- Count and record the number of potholes as well as the area, in square feet, of each pothole.
- Record the depth as the maximum depth below the pavement surface.
- The minimum plan dimension of the pothole is 6 in.
- Reduce the pothole area within an area of fatigue cracking by the area of the fatigue cracking.



(a)

(b)

(c)

FIGURE 3-11 Potholes: (a) and (b) moderate severity; (c) high severity

3.1.12 RAVELING

DESCRIPTION

Raveling, or weathering, is characterized by the wearing away of pavement surface caused by dislodged aggregate or loss of asphalt binder.

CAUSES

Raveling is caused by insufficient binder material, insufficient compaction, or segregation of the mixture during construction of the pavement.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

Record the affected surface area in square feet.

(a) (b) (c) (d) (e) (f)

FIGURE 3-12 Raveling

3.1.13 PATCH/PATCH DETERIORATION

DESCRIPTION

A patch is a portion of the pavement surface at least one square foot in area that has been removed and replaced with additional material after original construction.

CAUSES

Traffic loading, materials, and poor construction practices can all cause patches to become distressed and to deteriorate. Any distress occurring within a patch can be considered patch deterioration.

SEVERITY LEVELS

- Low: Patch has only low severity distresses, including rutting ≤ 0.25 in. and no pumping.
- Moderate: Path has moderate severity distress, including rutting > 0.25 in. but ≤ 0.50 in. and no pumping.
- High: Patch has high severity distress, including rutting > 0.50 in., and pumping may be evident. Patch may also have additional different patch material within it.

MEASUREMENT

Count and record the number of patches as well as the area affected in square feet.

3.1.14 POLISHING

DESCRIPTION

Polishing occurs when aggregate becomes smooth and loses roughness and angularity. It is characterized by a lack of aggregates extending above the surface, reducing friction.

CAUSES

Polished aggregate is most often caused by soft aggregate in HMA surface course. Polishing of the surface aggregate is traffic dependent. The INDOT Spec. Section 904 allows only certain types of aggregates for surface courses, dependent on the number of ESALs specified.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

Record the affected surface area in square feet

3.1.15 LANE/SHOULDER DROP-OFF OR HEAVE

DESCRIPTION

This distress is characterized simply by a difference in elevation between the roadway surface and the outside shoulder.

CAUSES

A difference in elevation between lane and shoulder is caused by eroding away of shoulder material (especially gravel) by trucks or settlement of the soil underneath the shoulder. Heaving of the shoulder is usually caused by environmental conditions in the soil (freezing, thawing, swelling, etc.).

SEVERITY LEVELS

Not applicable.

MEASUREMENT

- Measure elevations to the nearest sixteenth of an inch at the longitudinal construction joint between lane edge and shoulder.
- If the traveled surface is lower than the shoulder, record the measurement as a negative elevation value.

(a) (b) (c) (d)

FIGURE 3-13 Shoulder drop-off

3.2 CONCRETE PAVEMENT

3.2.1 BLOWUP

DESCRIPTION

A blowup is an isolated and sudden elevation change along the profile of the roadway. It is often seen with shattering of the concrete in the area.

CAUSES

A severe blowup is defined as adjacent panels rising off the ground in a tent-like manner. A blowup is caused by the buildup of compressive stresses in the pavement due to the infiltration of incompressible materials into the joints, growth of the concrete pavement due to expansive coarse aggregate, and thermal expansion A blowup occurs at a transverse crack or joint that is not wide enough to accommodate the expansion of the concrete slab. Some coarse aggregates exposed to freeze-thaw conditions in the presence of free moisture will influence the growth of the concrete pavement. In addition, a buildup of water within the pavement structure acts as a lubricant and catalyst for a blowup to occur.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

Record the number of blowups in the sample area.

FIGURE 3-14 Blowup

3.2.2 CORNER BREAKS

DESCRIPTION

Corner breaks are cracks that intersect both sides of a slab and extend through the entire slab's thickness. The length of the sides ranges from 1.0 ft to half of the width of the slab on each side of the corner.

CAUSES

Corner breaks are caused by load repetition and support loss, poor load transfer across joints, thermal curling stresses, and moisture warping stresses. Corner breaks extend vertically throughout the entire concrete slab thickness.

SEVERITY LEVELS

- Low: Spalling not present for more than 10 percent of the crack length, no faulting, corner piece is not broken with any material loss.
- Moderate: Low severity spalling may be present for more than 10 percent of the length, faulting of crack is ≤ 0.50 in., corner piece is not broken.
- High: Moderate to high severity spalling evident for more than 10 percent of the length, faulting may be > 0.50 in., corner piece is broken into two or more pieces or contains patch material.

MEASUREMENT

- Record number of corner breaks at each of the severity levels.
- If breaks have been repaired completely and all broken pieces removed and replaced with patch material, rate as a patch.
- If corner break boundaries are visible even with patching, then also rate as a high severity corner break.

(a)

(b)

(c)

FIGURE 3-15 Corner breaks: (a) low severity; (b) and (c) moderate severity

3.2.3 TRANSVERSE CRACKING

DESCRIPTION

A transverse crack is a random crack oriented predominantly across the pavement away from the planned joint locations.

CAUSES

Transverse cracking is caused by poor construction techniques or improper joint design. Poor support, a poor mix design, improper mixture, improper subbase placement, or untimely sawing of the pavement can also cause random transverse cracking.

SEVERITY LEVELS

- Low: Crack widths < 0.12 in., no spalling, no faulting, crack may be well sealed.
- Moderate: Widths ≥ 0.12 in. and < 0.25 in., spalling < 3.0 in., or faulting < 0.25 in.
- High: Widths ≥ 0.25 in., spalling ≥ 3.0 in., or faulting ≥ 0.25 in.

MEASUREMENT

- In meters, record the length of each crack as well as the number at each severity level.
- Rate each crack based on the highest severity level present for at least 10 percent of the total crack length.
- Record the length that is still the total length of the crack assigned to the highest severity level present at least 10 percent of length.
- Include well-sealed cracks in this distress.

FIGURE 3-16 Transverse cracking: (a) and (b) low severity; (c) and (d) moderate severity; (e) and (f) high severity

3.2.4 LONGITUDINAL CRACKING

DESCRIPTION

A longitudinal crack is a random crack oriented predominantly parallel to the centerline of the pavement.

CAUSES

A longitudinal crack may occur due to a loss of support or improper sawing of the joints. Longitudinal cracking is detrimental because it allows water flowing across the pavement to enter the pavement structure.

SEVERITY LEVELS

- Low: Crack widths < 0.12 in., no spalling, no faulting, crack may be well sealed.
- Moderate: Widths ≥ 0.12 in. and < 0.25 in., or spalling < 3.0 in., or faulting < 0.25 in.
- High: Widths ≥ 0.25 in., or spalling ≥ 3.0 in., or faulting ≥ 0.25 in.

MEASUREMENT

- Record the length of the crack in feet for each severity level.
- Record the length of the crack with sealant in good condition at each severity level.


(a)

(b)


(c)

FIGURE 3-17 Longitudinal cracking: (a) low severity; (b) moderate severity; (c) high severity

3.2.5 SPALLING OF JOINTS AND CRACKS

DESCRIPTION

Spalling of cracks and joints is the breaking and deterioration of the edges of a joint or crack. When deterioration occurs within 1.0 ft from the face of the joint or crack, it is considered spalling.

CAUSES

Spalling usually occurs because of an excess of stress near the joint or crack, caused by an infiltration of loose materials, joint expansion, or repeated traffic loading. Additionally, it can be caused by poor construction or design practices, disintegration of concrete, and weak concrete at the joints caused by overworking.

SEVERITY LEVELS

- Low: Spalls < 3.0 in. wide with no loss of material and no patching.
- Moderate: Spalls 3.0 to 6.0 in. wide with loss of material.
- High: Spalls > 6.0 in. wide with lost and broken material or patching materials.

MEASUREMENT

- Record the number of affected joints and cracks at each severity level.
- Record if the total spall length is at least 10 percent of the total crack or joint length.
- Rate the entire joint or crack at the highest severity level present for at least 10 percent of the crack.
- In feet, record the length of the spalled portion of the joint or crack at the assigned severity level.
- If patching is visible and the spall is completely patched, then rate as a patch.
- If the boundaries of the spall are visible after patching, also rate as a high severity spall.

(a) (b) (c) (d) (e) (f)

FIGURE 3-18 Spalling of joints: (a) and (b) low severity; (c) moderate severity; (d), (e), and (f) high severity

3.2.6 PCCP JOINT-SEAL FAILURE

DESCRIPTION

Joint-seal failure is evidenced by extrusion of sealant, weed growth, hardening of filler, bonding failure between slabs, or lack of sealant in the joint.

CAUSES

This is caused by external environmental or weather conditions, inadequate joint installation, and/or inadequate sealant material selection.

SEVERITY LEVELS

- Low: Seal damage exists over < 10 percent of the joint.
- Moderate: Seal damage exists over 10 to 50 percent of the joint.
- High: Seal damage exists over > 50 percent of the joint.

MEASUREMENT

- Count the number of sealed transverse joints at each severity level.
- If there is no joint seal damage, mark as low severity.

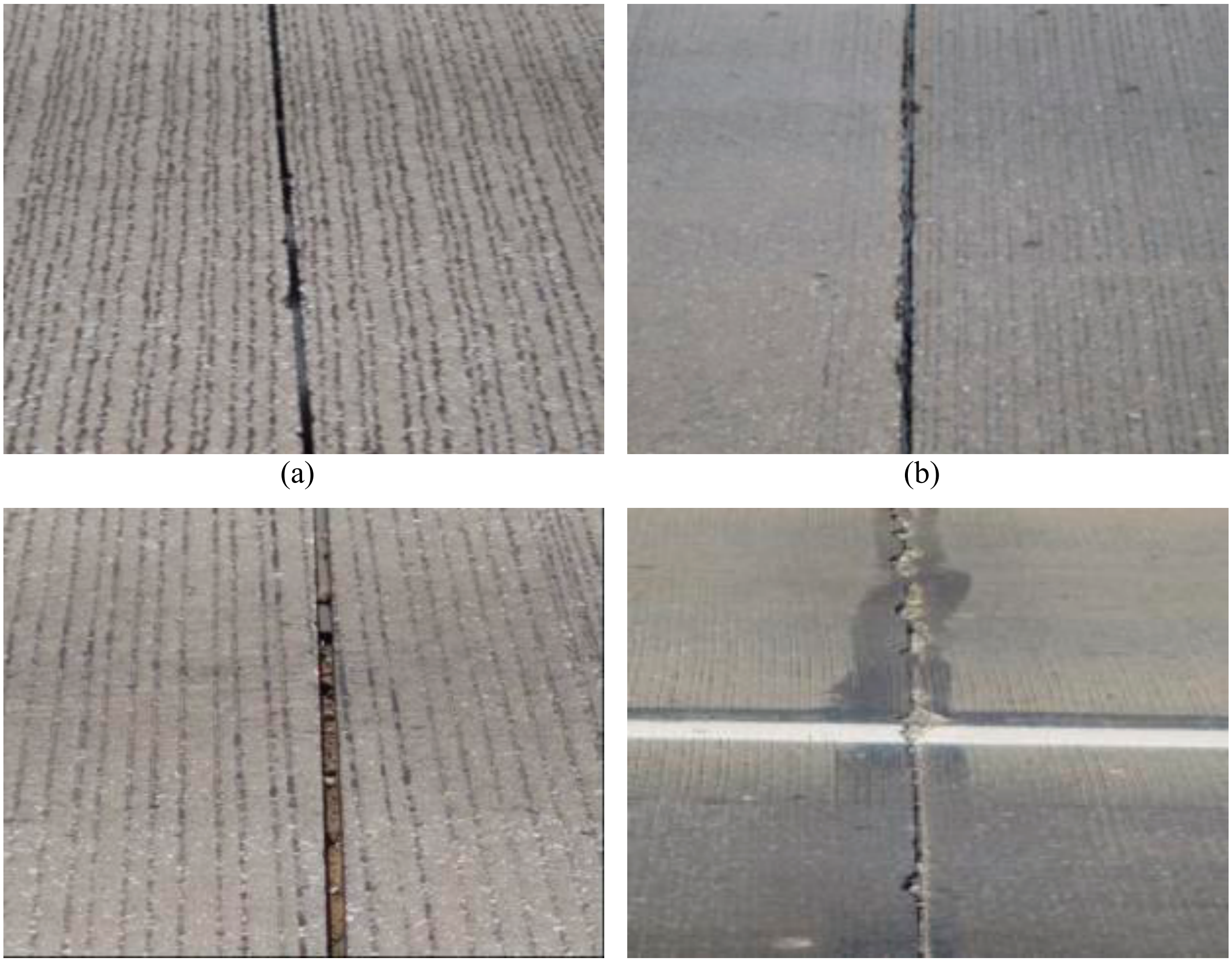


FIGURE 3-19 Joint seal damage: (a) low severity; (b) and (c) moderate severity; (d) high severity

3.2.7 FAULTING

DESCRIPTION

Faulting is a change in elevation across a joint or crack.

CAUSES

Faulting can occur at a joint or at a random transverse crack in PCCP. Faulting is caused either by a depression in a departure slab or an aggregation of loose materials in an approach slab. Pumping of loose materials into areas near the crack is caused by heavy traffic loadings. The tendency of the slab to warp or curl near the joint or crack contributes to the pumping problem. Lack of load transfer between slabs also exacerbates faulting. An animation demonstrating the faulting and pumping is available at http://pavementinteractive.org/images/f/fa/Faulting.swf.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

- Record the elevation of the "approach" and "departure" slabs to the nearest sixteenth of an inch at the outer wheel path locations (1.0 ft and 2.5 ft from outside slab edge).
- If the approach slab is higher than the departure slab, the value is positive; otherwise, the value is negative.
- It is allowable to offset the measurements by as much as 1.0 ft if anomalies such as patching occur in the place of elevation measurement.
- A null value ("N") can be recorded if it is not possible to obtain an elevation due to anomalies.

(a)

(b)

FIGURE 3-20 Faulting

3.2.8 PUMPING AND WATER BLEEDING

DESCRIPTION

Pumping is the ejection of water carrying fine material through joints and cracks. In many cases it is detectable by deposits of fine material that were pumped from underlying layers on the pavement surface.

CAUSES

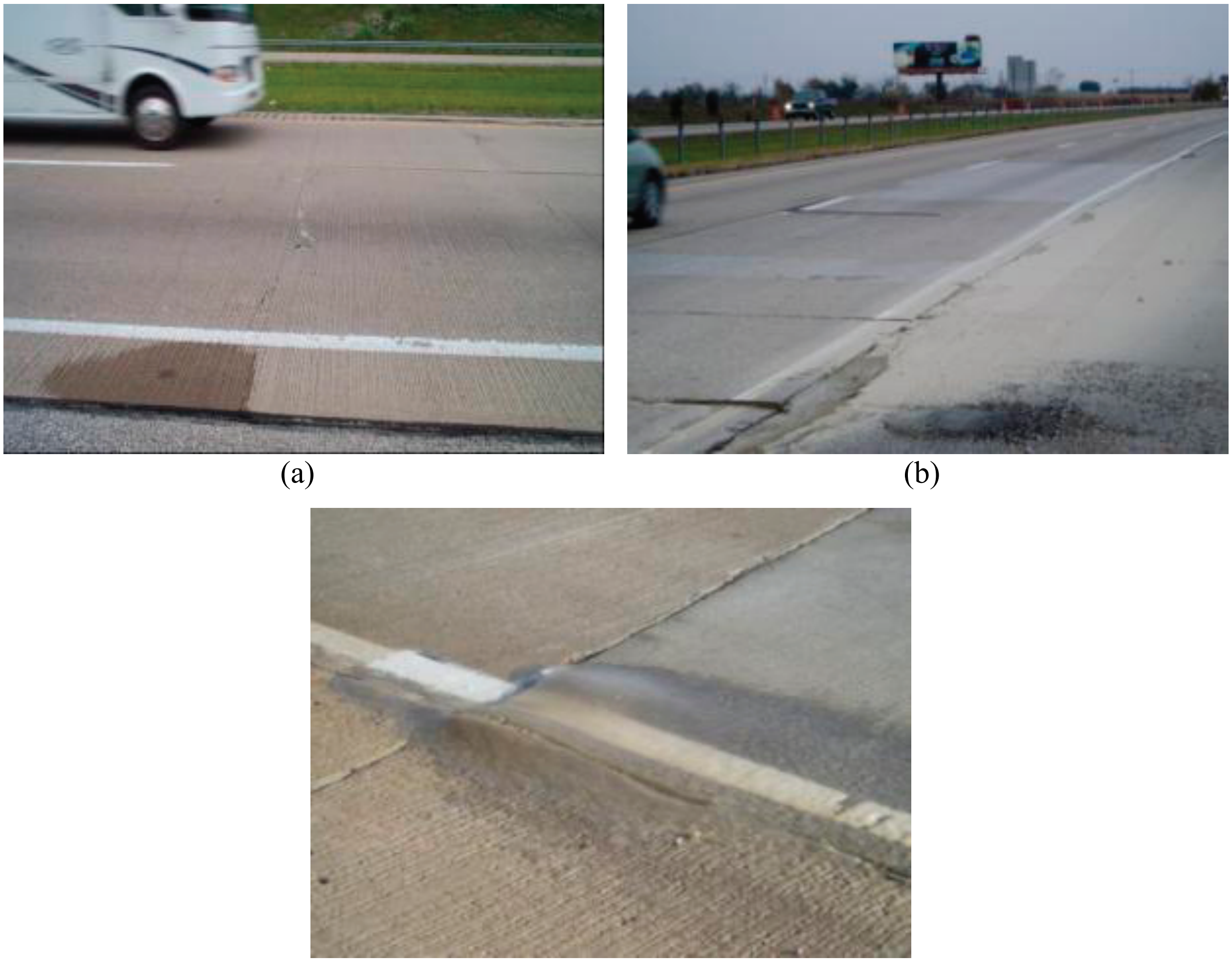
See the causes of faulting.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

Count and record the number of occurrences of pumping and water bleeding as well as the length in feet of the affected pavement (minimum 3.0 ft).



(a) (b) (c)

FIGURE 3-21 Pumping and water bleeding

3.2.9 PUNCHOUT

DESCRIPTION

A punchout is a major structural distress of continuous reinforced concrete (CRC) pavement typified by two closely spaced (< 2.0 ft) transverse cracks, a short longitudinal crack, and the edge of the pavement or longitudinal joint. They also can take the form of “Y” cracks.

CAUSES

Punchouts are typically caused by repeated heavy traffic loadings. They begin with a loss of aggregate at some closely spaced transverse cracks and develop as the cracks begin to fault and spall. As heavy truck loadings continue, a short longitudinal crack can form between the parallel transverse cracks near the pavement edge. The transverse cracks continue to deteriorate, causing steel dowels to rupture and pieces of concrete to punch downward into the underlying pavement layers. Punchouts can also be caused by inadequate consolidation, steel corrosion (dowels), or an inadequate amount of steel.

SEVERITY LEVELS

- Low: Cracks are tight and may have spalling < 3.0 in. or faulting < 0.25 in. with no loss of material or patching present.
- Moderate: Spalling ≥ 3.0 in. and < 6.0 in., faulting ≥ 0.25 in. and < 0.50 in.
- High: Spalling ≥ 6.0 in., or concrete within punchout is punched down ≥ 0.50 in., is loose and moves under traffic, is broken, or contains patch material.

MEASUREMENT

- Count and record the number of punchouts at each severity level.
- Rate as a patch if punchouts are completely repaired and patching is evident.
- If boundaries of the punchout are present within a patch, rate as a high severity punchout.
- If the transverse cracks are spaced > 2.0 ft but < 3.0 ft, only rate as a punchout if the cracks are spalling.

3.2.10 DURABILITY ("D") CRACKING

DESCRIPTION

"D" cracking is a network of closely-spaced, hairline cracks that appear near corners of joints along the slab edge in crescent shapes, along the entire joint.

CAUSES

"D" cracking is caused by an expansive coarse aggregate in the PCCP under freeze-thaw conditions in the presence of water; such cracking starts near the bottom of the slab and progresses up through the concrete. Symptoms of "D" cracking in jointed PCCP are spider web cracks at the transverse joints. "D" cracking detected at a surface location indicates that other locations are also "D" cracking.

SEVERITY LEVELS

- Low: "D" cracks are tight with no loose or missing pieces, and no patching.
- Moderate: Cracks are well-defined, some small missing pieces or displacement
- High: Cracks have developed a pattern, with a significant amount of displacement, loose material, and patching.

MEASUREMENT

- Count and record the number of slabs with "D" cracking present.
- Record the square feet of the area affected at each defined severity level.
- The severity level is based on the highest present level for at least 10 percent of the affected area.
- Measure the area using rectangles as the assumed shape.

(a)

(b)

(c)

(d)

(e)

FIGURE 3-22 “D” Cracking: (a) and (b) low severity; (c) moderate severity; (d) and (e) high severity

3.2.11 LANE/SHOULDER DROPOFF OR HEAVE

DESCRIPTION

This distress is characterized by a difference in elevation between the slab edge and the outside shoulder.

CAUSES

This distress is caused by settlement of the soil or eroding away of shoulder material. The cause and description are identical to the distress for asphalt pavement.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

- Measure elevations to the nearest sixteenth of an inch at the longitudinal construction joint between the lane edge and the shoulder.
- If the traveled surface is lower than the shoulder, record the measurement as a negative elevation value.


(a)


(b)


(c)


(d)


(e)

FIGURE 3-23 Lane/shoulder drop-off

3.2.12 PCCP LANE-ASPHALT SHOULDER JOINT SEPARATION

DESCRIPTION

This distress is characterized by the opening of the joint between the traffic lane and the roadway shoulder.

CAUSES

The distress is caused either by shear action in the shoulder, movement at the embankment edge due to slope instability, shrinking of shoulder material, thermal displacements, or a combination of the above. It is not considered a distress if the joint is well sealed and impermeable to water.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

- Record to the nearest sixteenth of an inch the width of separation at 50-ft intervals along the lane-shoulder joint.
- A null value may be recorded when anomalies such as patching are present.

3.2.13 PATCH DETERIORATION

DESCRIPTION

Patch deterioration can occur when a portion greater than one square foot of the concrete slab has been removed and replaced with filler material.

CAUSES

This distress is often caused by poor construction placement of the patch, loss of support, repeated heavy loadings, lack of load transfer devices (dowel bars), improper or absent joints, and moisture or thermal gradients.

SEVERITY LEVELS

- Low: Patch has low severity distress of any type, no faulting, settlement, or pumping.
- Moderate: Patch has moderate severity distress of any type, faulting and settlement may be present up to 0.25 in., pumping not evident.
- High: Patch has high severity distress of any type, faulting or settlement ≥ 0.25 in., pumping evident.

MEASUREMENT

- Record the number of patches as well as the area (in square feet) of the affected surface at each severity level.
- Record separately by patch material type.
- All patches meeting size criteria (one square foot) shall be rated.
- Treat each patch as either a rectangle or a circle.

(a)

(b)

(c)

(d)

(e)

(f)

FIGURE 3-24 Patch/patch deterioration: (a) and (b) moderate severity; (c), (d), (e), and (f) high severity

3.2.14 POPOUTS

DESCRIPTION

Popouts are small pieces of aggregate that break off or erode from the surface, normally ranging in diameter from 1.0 to 4.0 in. and in depth from 0.5 to 2.0 in.

CAUSES

Popouts are caused by expansive, nondurable, or unsound aggregates. They can also be caused by freeze/thaw action.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

Count the number of popouts in a representative area (e.g. 2 popouts/sq. ft).

(a)

FIGURE 3-25 Popouts

3.2.15 SCALING/MAP CRACKING

DESCRIPTION

Map cracking is characterized by a network of hairline cracks that only exist in the upper concrete layers. Scaling is the breakdown of the slab surface to a depth of no more than 0.50 in.

CAUSES

Map cracking is usually caused by over-finishing of the concrete. Scaling is caused by improper curing, de-icing salts, traffic, improper construction, freeze-thaw cycles, or by steel reinforcements placed too close to the surface.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

- Record the number of occurrences as well as the area (in square feet) of the affected area.
- Treat each area as a rectangle.

FIGURE 3-26 Scaling

3.2.16 ALKALI-SILICA REACTIVITY (ASR)

DESCRIPTION

Alkali-silica reactivity (ASR) is a form of material-related distress that occurs in PCCP. This distress presents random cracks on the surface of PCCP in a map-like pattern after it has been in service for a few years. During later stages of ASR distress, the surface will begin to spall.

CAUSES

ASR occurs if silica in the aggregates and alkali in the cement react in the presence of water to form a gel-like substance. The substance absorbs moisture and deleteriously expands. This expansion manifests itself as spider webbed cracking on the PCCP. The necessary conditions for ASR are as follows:

- Reactive forms of silica minerals that are present in some aggregate sources.
- A sufficiently high concentration of soluble alkalis, sodium, and potassium.
- Exposure of the PCCP to moisture.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

- Record the number of occurrences as well as the area (in square feet) of the affected area.
- Treat each area as a rectangle.

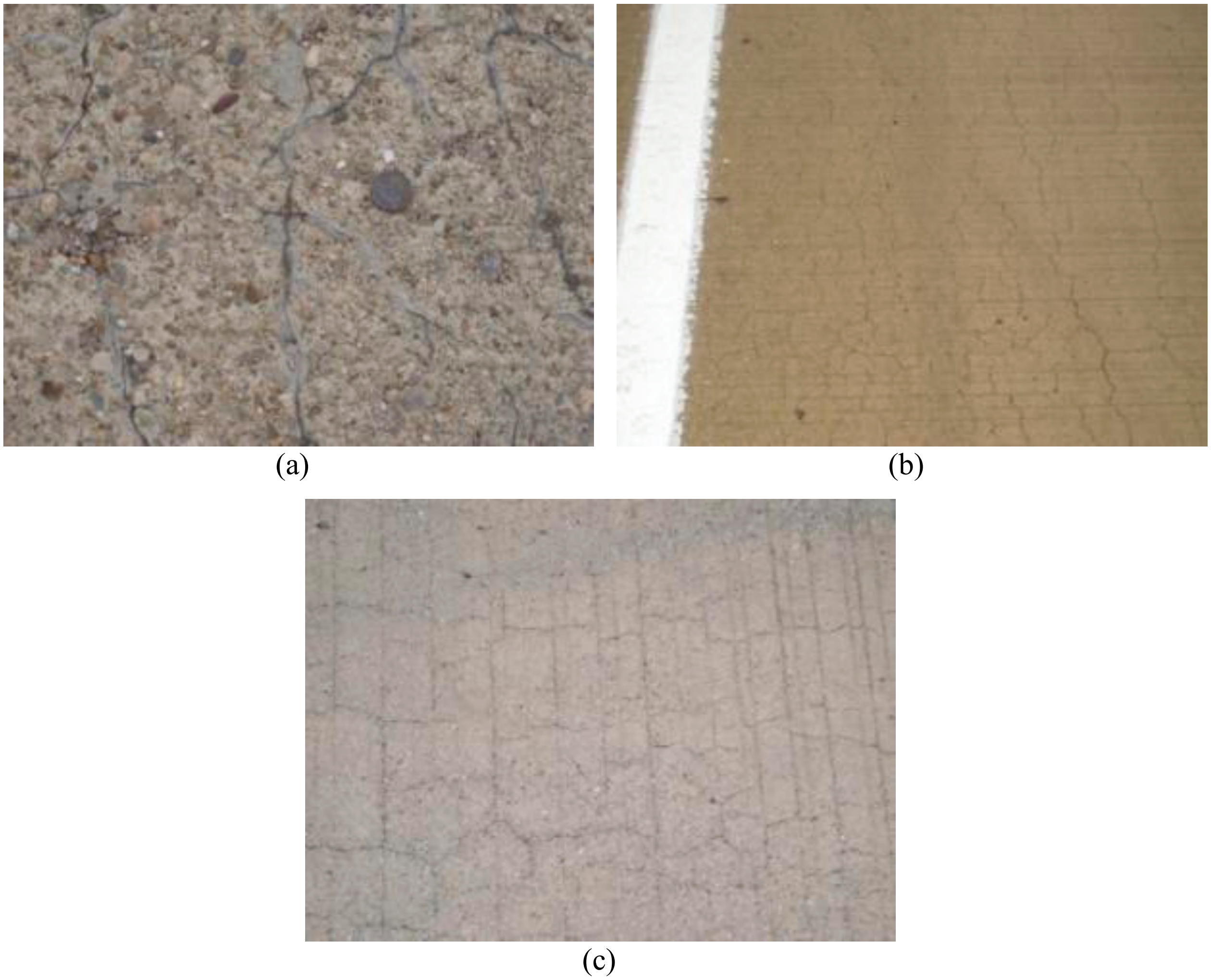


FIGURE 3-27 Alkali-silica Reactivity

3.2.17 POLISHING

DESCRIPTION

Polishing occurs when traffic abrades the surface removing the tining.

CAUSES

Polishing is caused by the abrasion of the surface to the extent that the surface becomes slick. Polishing is traffic-dependent.

SEVERITY LEVELS

Not applicable.

MEASUREMENT

- Record the square feet of the affected area.
- Treat each area as a rectangle.

(a)

(b)

FIGURE 3-28 Polishing

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APPENDIX

1 STANDARD SPECIFICATIONS FOR PAVEMENT PRESERVATION TREATMENTS

This chapter is a summary of different standard specifications for pavement preservation treatment techniques commonly used in the Midwestern United States. The focus is on the state of Indiana. The following states were used for comparison:

- Minnesota
- Iowa
- Wisconsin
- Missouri
- Illinois
- Michigan
- Ohio
- Kentucky

For some of the more obscure treatment methods, additional states were surveyed:

- South Carolina
- North Carolina
- Oklahoma
- New Jersey
- South Dakota

The following treatments were reviewed:

<u>Asphalt or Composite Pavement Treatments</u>

- Crack Filling/Sealing
- Scrub Seal
- Sand Seal
- Seal Coat
- Fog Seal
- Flush Seal
- Slurry Seal
- Microsurfacing
- Cape Seal
- Ultra-thin Bonded Wearing Course (UBWC)
- Thin HMA Mill/Fill (Thin HMA Inlay)
- Surface Milling (Profiling)
- Cold In-Place Recycling
- Hot In-Place Recycling

<u>PCCP Pavement Treatments</u>

- PCCP Crack Sealing
- PCCP Joint Sealing
- Diamond Grinding (PCCP profiling)

- Partial Depth Patching
- Full-Depth Patching
- Retrofit Load transfer
- Undersealing

1.1 TREATMENTS FOR ASPHALT OR COMPOSITE PAVEMENT

1.1.1 FLEXIBLE CRACK FILLING AND SEALING

Indiana's specifications for crack filling and sealing are similar to those of its neighboring states, except for several small differences. Also, the level of detail regarding certain procedures is less than that of some of the other states. All of the states in the region (Illinois, Indiana, Michigan, Missouri, and Ohio) have similar requirements for the condition of the pavement and environment during the application of the filler or sealant. The air temperature must be at least 40°F (45°F for Ohio), and the pavement surface must be clean and dry. Indiana also has fewer requirements for the cleaning equipment, and no specifications are provided regarding the use of a heat lance. Indiana, along with all of the states besides Missouri, does not contain separate specifications for crack filling and crack sealing. Indiana allows the use of asphalt rubber and asphalt emulsion in filling the cracks. It is the only state that does not specify the level of the fill material with respect to the surface of the pavement. All of the states except Missouri require that the material cure before opening to traffic, and all states have similar methods for dealing with tracking. Finally, Indiana and Ohio are the only states that require payment based on the weight of the material. Illinois, Michigan, and Missouri require payment based on the length of the cracks filled or sealed (TABLE 1-1).

1.1.2 SCRUB SEAL

The scrub seal is the same as the sand seal, with the exception of the scrub process, which the sand seal does not require. Only one state, Missouri, includes specifications for scrub seal in the standard specification documents (TABLE 1-2). Indiana includes scrub seal in the sand seal specification.

1.1.3 SAND SEAL

The sand seal is a type of seal coat that involves immediately covering the asphalt emulsion with fine aggregate or sand. After the sand is spread, compaction and rolling is performed with a pneumatic tired roller. Very few states have specifications for sand seals, although they are very similar to seal coats and scrub seals. Indiana specifies the sand seal as a Type 1 seal coat.

1.1.4 SEAL COAT (CHIP SEAL)

The term seal coat is generally used as technical terminology in most states, except for Illinois, Michigan, and Kentucky. Another term for seal coat is chip seal. For seal coat aggregates, Ohio and Minnesota specify that the allowable fines content is 2.0%. Indiana uses a Nominal Maximum Aggregate Size (NMAS) of 3/8 in. and No. 4, and their allowable fines contents are

2.0% and 2.5%, respectively. Generally, free water on the surface of aggregate is not allowed or is limited. Some state DOTs, including Iowa and Wisconsin, recommend using dampened aggregates with no free water on the surface.

Indiana requires cover aggregate to be spread within one minute of the application of asphalt material. The state does not specify a minimum distance between the distributor and the spreader, unlike the other states of Iowa, Michigan and Ohio. Some states specify initial rolling time or distance between the spreader and the roller (e.g. a minimum of two or five minutes, or 200 ft). A pneumatic-tired roller is the typical type of roll used for seal coat compaction, except in Wisconsin, where they use a combined steel-wheel roller and pneumatic-tired roller). Indiana requires the final roller application to be completed within 30 minutes after the cover aggregate is applied. The technical terminologies of rolling pass and coverage can cause confusion. In a recent update, Indiana clarified their requirement by stating that aggregate shall be seated with at least three roller applications, defining “roller applications” as one pass of the roller over the entire width of the seal.

Some states specify a maximum roller speed and rolling patterns, though Indiana does not. The standard specifications of Missouri and Ohio include a strip test to evaluate short-term seal coat performances prior to actual seal coating. Indiana has a similar test method specified in ITM No. 579-08P (APPENDEX 4) to the strip test, but it is not included in Indiana’s seal coat standard specification (TABLE 1-3).

1.1.5 FOG SEAL

Indiana's fog seal specifications contain several minor differences from those of its neighboring states (Iowa, Minnesota, and Missouri). Indiana and Iowa are the only states that restrict the placement of a fog seal based on the time of year. Indiana is also unique in its restriction of the application rate; Iowa, Minnesota, and Missouri set a specific rate or provide a range of rates, while Indiana only requires that the application rate fall within a certain tolerance of the rate shown on the plans. This is because the minimum allowable rate within the specified application rate range could be used by contractors regardless of pavement surface conditions, which should be reflected in determining the fog seal application rate. Finally, Indiana and Minnesota are the only states that require blotting materials to be placed on certain surfaces, such as pedestrian crossings (TABLE 1-4).

1.1.6 FLUSH SEAL

A flush coat or flush seal is an application of a fog seal coat to the surface of a seal coat. Flush seals are a variant of seal coats; therefore, the specifications of seal coat and fog seal can be used for flush seals in Indiana.

1.1.7 MICROSURFACING

Indiana has a three-year warranty specification for microsurfacing. Indiana's microsurfacing specification contains far fewer details than its neighboring states in certain aspects of the construction process. However, Indiana has similar specifications to Illinois, Michigan, Missouri, and Ohio regarding the gradation of the mixtures and the mixture design criteria. Illinois, Michigan, and Ohio explain in detail the necessary application rates for rut filling and standard courses. Indiana mentions rut filling and other distresses in regard to taking remedial action on pavement, but does not provide any specific application rates because of the warranty specification (TABLE 1-6).

1.1.8 ULTRA-THIN BONDED WEARING COURSE (UBWC)

Ohio, Michigan, Missouri, New Jersey, and Indiana have a specification specifically for a UBWC. Illinois, Kentucky, South Carolina, Oklahoma, and North Carolina specifications call for an "open graded friction course," which is included in this document due to similarity. For both Illinois and Kentucky, placement of the thin course cannot occur if the temperature is below 60ºF, whereas in Missouri and Indiana the temperature cannot be below 50ºF. Each state has similar traffic requirements during curing. One main difference among the states' specifications is in regard to surface preparation and pre-treatment. Missouri requires that all working cracks and some non-working cracks be sealed prior to placement of the course. Illinois, New Jersey, and Kentucky only require a level and clean, debris-free surface prior to placement.

1.1.9 THIN HMA MILL/FILL (THIN HMA INLAY)

Only Iowa has information on thin HMA mill/fill in its Standard Specifications document. Indiana has a separate specification for surface milling and HMA overlay. Taken together, these two specifications could be used for performing an HMA Mill/Fill. The Iowa specifications call for milling equipment to remove the existing layer and compaction equipment to compact the new lifts of asphalt pavement. The milling should occur in one pass. Lifts are to be placed with a maximum depth of 3 in. are to be compacted with at least three passes. The filler asphalt mixture has to have a structural capacity of at least 300,000 ESALs. After milling and before filling, the specifications call for the application of a tack coat. Payment is figured by the ton (TABLE 1-9).

1.1.10 SURFACE MILLING (PROFILING)

All states in the region have specifications for surface milling existing pavements. Indiana's specification is quite detailed and slightly different from some of the other states' specifications. For example, Indiana is the only state to require that macrotexture testing be performed a minimum of once per day. Indiana is also one of only two states (Kentucky is the other) that have specifications for approach milling. All states use square yards as a pay unit, although Michigan and Wisconsin also allow tons. Illinois and Kentucky break down the pay items into separate groups, such as pavement milling/removal, median removal, drainage device removal, and mobilization for milling. None of the states have any restrictions on temperature or seasonal requirements. Indiana requires a longitudinal smoothness that does not vary more than ¼ in. within 16 ft, which is different than some other states. Kentucky and Ohio use 1/8 in. within 10 ft, and Illinois uses 3/16 in. within 16 ft. Indiana also has a cross-slope requirement of 1/8 in. within 10 ft, whereas Kentucky and Ohio both use 3/8 in. within 10 ft. as a maximum deviation. Iowa uses a maximum misalignment of ¼ in. within 12 ft. (TABLE 1-10).

1.1.11 COLD IN-PLACE RECYCLING

Only the state of Iowa has a specification regarding cold in-place recycling techniques. Indiana has a draft specification from 1994 that outlines some construction methods for cold in-place recycling. That document does not provide a temperature at which construction can be allowed to proceed. During construction, compaction should commence 25 minutes after replacing the recycled mat, and compaction should be done with five passes of a large vibratory roller, four passes of a 25-ton pneumatic roller, and three passes of a static roller finish. The milling machine should be self-propelled and have a drum cutting head of 12 ft in width. It should be able to cut 6 in. in one pass. Iowa's specification calls for operation to occur only if the temperature is above 60ºF during the time period of May 1 to October 1. The milling machine mills pavement that is then placed in a mixing truck with emulsified asphalt. The mixture is then placed on the milled surface (TABLE 1-11).

1.1.12 HOT IN-PLACE RECYCLING

Indiana does not have a current specification for Hot In-Place Recycling (HIPR). There is a draft specification from 1997 that was used for this literature review. The specification contained fewer details than other states such as Iowa and Illinois. The draft document states that the process should only occur if the temperature is above 45°F and is rising, which is the same temperature specified by Illinois. Among the Midwestern states, Iowa, Illinois, and Ohio have specifications for this treatment. In Illinois and Iowa, the process involves heating equipment (10 million BTUs per hour or more in Iowa) followed by a scarifier to dig up the loosened material. A leveler spreads the heated/scarified material, and then a thin HMA overlay is placed on top. Iowa has a minimum scarification depth of ¾ in. at high points and ½ in. at low points, whereas Illinois only specifies an average scarification depth of ¾ in. Iowa has a maximum old-pavement temperature of 475ºF while Illinois specifies a temperature of 375ºF. The heated mixture should have a minimum temperature of 175ºF in Illinois and should fall in the range of 220ºF to 260ºF in Iowa. Iowa specifies a temperature below 170ºF for the new HMA overlay to be placed, and Illinois only specifies that the layer be placed 48 hours after scarified/heated material has been placed. In the Ohio specification, it is unclear what type of machine works through the heated, loosened top layer of asphalt concrete. Ohio mandates a depth of 2 in. for the recycle-in depth procedure. There is no HMA overlay in Ohio, and the temperature of the recycled mix should not exceed 325ºF. All three states use a pay unit of square yards for the heating-scarifying operation (TABLE 1-12).

1.2 TREATMENT FOR PCCP PAVEMENT

1.2.1 PCCP CRACK SEALING

Indiana's specifications for sealing cracks in PCCP pavements are very similar in most areas to the specifications of Illinois, Michigan, and Missouri. Indiana, Illinois, and Missouri all require the air temperature to be at least 40°F before performing the crack sealing. Also, Indiana's requirements for routing or sawing are very close to those of other states in the region. Each state has different standards for the process of sealing the cracks. Indiana and Illinois are the only states that explicitly prohibit traffic until the sealant has completely cured, and Indiana is unique in that it requires fine aggregate to be spread in order to prevent tracking (TABLE 1-13).

1.2.2 PCCP JOINT SEALING

Indiana's specifications for joint sealing in PCCP pavements are comparable to those of other states in the region (Illinois, Iowa, Kentucky, Michigan, Minnesota, Missouri, and Ohio), but many of the states emphasize different areas of the joint sealing procedure. For example, Illinois and Ohio are the only states that set limits for the sawing of joints, and Illinois and Iowa are the only states that discuss the use of backer rods. Most of the states require the temperature to be at least 40°F, and the states have similar specifications for cleaning the joints prior to sealing (TABLE 1-14).

1.2.3 PCCP PROFILING (DIAMOND GRINDING)

Indiana's specifications for diamond grinding are less detailed than those of other states in the region (Kentucky, Michigan, Ohio, and Wisconsin). Indiana, Kentucky, Ohio, and Michigan all have similar requirements for the equipment used to complete the grinding. All states in the region deal with the residue generated from grinding using similar methods. However, Indiana provides very little information regarding the actual process of diamond grinding concrete pavement. Specifically, Kentucky, Ohio, Michigan, and Wisconsin all give details explaining required widths and heights of grooves formed by grinding, while Indiana only states that the surface must have a uniform texture that is not smooth or polished (TABLE 1-15 and TABLE 1-16).

1.2.4 PARTIAL DEPTH PATCHING

Indiana's specifications for partial-depth repairs are similar to those of Iowa, Missouri, and Ohio with a few distinct differences. Specifically, Indiana's temperature requirements contain more detail than other states. Missouri and Ohio do not list any specifications regarding temperature. Also, Indiana treats the depth of pavement removal differently than Iowa and Missouri. The maximum depths of pavement removal are based on the slab thickness in both Iowa and Missouri, while in Indiana the maximum depth is set at 3 in., regardless of slab thickness. In other areas, such as joint and crack preparation and placement of material, Indiana's specifications do not differ significantly from those of other states in the region (TABLE 1-17).

1.2.5 FULL-DEPTH PATCHING

Indiana's specifications for full-depth repairs are very similar to those of Iowa, Missouri, and Ohio. All four states handle pavement removal and placement of the new material in the same general ways. However, there are a few distinctions that differentiate Indiana from other states in the region. Indiana and Illinois are the only states that provide detailed specifications regarding temperature requirements before performing full-depth repairs. Also, Indiana is the only state that provides details regarding the treatment of joints and cracks that will remain in the patched pavement (TABLE 1-18).

1.2.6 UNDERSEALING

Indiana is the only state to use asphalt as a void filler material in undersealing. A draft specification for using grout filler is currently available in Indiana, which is similar to those of surrounding states (TABLE 1-19).

1.2.7 RETROFIT LOAD TRANSFER

Load transfer retrofit refers to a PCCP restoration method that increases load transfer efficiency at transverse joints by linking slabs together via dowel rods. Indiana has standard drawings detailing dowel bar placement. Ohio specifies a diameter of 1 1/2 in. and a length of 18 in. Michigan specifies hole sizes of 1 3/8 in. but does not give a dowel diameter. All states require dowels to be coated with bond-breaking materials. Indiana and Ohio both give specifications for backfill or patch material; this is to be placed over the dowel bars to the same level as the previously existing pavement. In addition, Indiana and Ohio both require all cracks to be sealed using silicone sealer prior to placing dowel bars. Finally, Indiana, Ohio, and Michigan all require a pay unit of each dowel rod that is placed (TABLE 1-20).

TABLE 1-1 Standard specification comparison of crack filling and sealing

State	Missouri	Illinois	Michigan	Ohio	Indiana
Name	o Bituminous Pavement Crack Sealing/Filling	o Crack Sealing Bituminous Pavement	o Overband Crack Fill	o Crack Sealing, Hot Applied	o Sealing Cracks and Joints
Temperature and Pavement Surface Requirements	o Air temp above 40 ºF	o Air temp above 40ºF	o Air temp above 40 ºF	o Air temp above 45 ºF	o Air temp above 40° F
	o Dry and clean surface	o Dry and clean surface	o Dry and clean surface	o Dry and clean surface	o Dry and clean surface
Routing	o Minimum width of 1/2 in. o Minimum depth of 1/2 in.	o 3/4 in. wide o 3/4 in. deep		o Maximum width of 3/4 in. o Maximum depth of 1 in.	o Maximum width of 1/2 in. o Minimum depth of 3/4 in.
Cleaning Equipment		o Power brush/blower o or o Compressed air minimum pressure of 90 psi	o Compressed air o Minimum of 100 psi o Continuous 150 CFM air flow o Heat lance may also be used	o Compressed air with a minimum of 100 psi o Water cleaning equipment capable of delivering water under 2000 psi of pressure o Propane lance operating at 1000°F and gas velocity of 2000 ft per second	o Compressed air with a minimum of 100 psi
Distributor Requirements			o Full-sweep agitator for continuous blending	o Mechanical agitation	o Mechanical agitation
Filling	o Filler shall be applied to the reservoir from the bottom up o Reservoir shall be slightly overfilled o Excess material squeegeed with a V or U-shaped squeegee, level to the surface pavement forming a wipe zone 3 to 4 in. wide	o Crack shall be slightly overfilled and immediately squeegeed for band-aid effect o 2 in. wide flush with pavement surface with edges feathered out	o Apply material by either a wand followed by a V or U-shaped squeegee or a round application head having a concave underside o Apply 4 in. wide and at a thickness of 1/8 to 3/16 in.		
Sealing	o Sealant shall be applied to the reservoir from the bottom up o Reservoir shall be slightly overfilled and excess material squeegeed with a V or U-shaped squeegee, level to the surface pavement forming a wipe zone 3 to 4 in. wide			o Fill entire crack reservoir with sealant from bottom up to 1/16 in. above the pavement surface, o Scrape with a V or U-shaped squeegee, or similar hand tool	o Cracks and joints shall be filled with rubber asphalt to within 1/4 in. of the surface o asphalt shall be placed using a V-shaped wand tip o cracks and joints shall be completely filled or overbanded not to exceed 5 in.
Requirements During Curing		o No traffic allowed until completed curing	o No traffic allowed until completed curing	o No traffic allowed until completed curing	o No traffic allowed until completed curing
Blotting	o Light coating of sand or other blotting material if tracking occurs	o Dust with fine sand, portland cement or mineral filler, or cover with tissue paper to prevent tracking when necessary	o Cover materials approved by engineer - no paper products	o Dust with portland cement or other approved material to eliminate tracking when necessary	o Fine aggregate to prevent tracking
Payment	o Crack Sealing: foot o Crack Filling: foot	o Crack Routing (Pavement): foot o Crack Filling: pound	o Overband Crack Fill: foot	o Crack Sealing: pound	o Crack Sealing: ton o Route and Seal: ton

TABLE 1-2 Standard specification comparison of scrub seal

State	Missouri
Name	○ Scrub seal
Temperature and Pavement Surface Requirements	○ air temp at least 60 ºF ○ Clean of all debris, dry
Emulsion placement	○ Distributor places asphalt emulsion and pulls broom to sweep and spread emulsion into cracks
Aggregate Placement	○ Fines placed immediately after emulsion along with second broom assembly to combine aggregate and emulsion
Application rate (emulsion and aggregate)	○ 0.18 to 0.22 gal/sy ○ 16 to 22 lb/sy
Rolling	○ Pneumatic tire roller immediately follows second broom ○ Minimum of 2 passes ○ Minimum weight of 10 tons
Requirements During Curing	○ All traffic closed until 2 hours after placement
Payment	○ square yard

TABLE 1-3 Standard specification comparison of seal coat

State	Minnesota	Iowa	Missouri	Wisconsin	Illinois	Michigan	Ohio	Kentucky	Indiana
Name	o Bituminous o seal coat	o Bituminous o seal coat	o Seal coat	o Seal Coat	o Bituminous o Surface Treatment	o Chip seal	o Chip seal with polymer binder	o Asphalt o seal coat	o Seal coat
Aggregate Condition	o <2% fines (by mass) o <4% free surface moisture	o Crushed gravel or stone o Use damp aggregate, but with no free water.	o Crushed stone or lightweight aggregate	o Dry or moisten the aggregate to ensure that it is damp to surface dry.	o No free moisture.	o Natural aggregate or blast furnace slag and Blast furnace slag for shoulder chip seals	o Washed limestone or dolomite, o A max of 2.0% fines	o Dry surface	
Temp. or Time Restrictions	o May 15 - August 31. o Base and air temp above 70ºF. o Relative humidity: < 75 %. o Dry and clean surface.	o Not after September 15	o Base and air temp above 60ºF. o Dry and clean surface.	o Base and air temp above 60ºF. o Dry and clean surface.	o May 1 - October 1. o Base and air temp above 60ºF. o Dry and clean surface.	o Base and air temp above 60ºF. o June 1-August 15 for the Upper Peninsula o May 15-September 1 for the Lower Peninsula north of M-46 o May 15-September 15 for the Lower Peninsula south of M-46	o Base and air temp above 60ºF o May 1 - September 1	o Base temp above 45ºF.	o Base and air temp above 60ºF (40-60 ºF if agg is heated).
Distance between Distributor and Spreader	Immediately	150 ft	Before emulsion chills, sets up, or dries		Immediately	150 ft	150 ft		Within 1 minute
Rolling	o Self-propelled, smooth-tread pneumatic-tired rollers. o Initial rolling within 5 min. o Five coverages within 30 min. o A minimum of two rollers o Max speed: 5 mph o Begin at the edges and continue to the center	o Self-propelled pneumatic-tired rollers. o A minimum of two rollers o Rolling within 30 min. o The initial roller coverage shall be as close to the aggregate spreader as possible, not to exceed 200 ft. o Initial rolling within 2 min.	o Self-propelled, pneumatic-tired rollers. o Max speed: 5 mph	o Self-propelled steel-wheel roller weighing between 6 and 9 tons o Self-propelled, pneumatic-tire roller o Roll the surface immediately after spreading the aggregate with a steel-wheel roller. o Begin at the edges and	o Roll immediately with a pneumatic-tired roller. o Begin at the edges and continue to the center, overlapping on successive trips by at least 1/2 the width of the roller.	o Self-propelled, pneumatic-tired rollers. o Max speed: 5 mph o Make a minimum of two complete passes over the coarse aggregate. A complete pass is one trip, forward and backward, over the same path. Overlap each pass by	o Make a minimum of two complete passes over the coarse aggregate. A complete pass is one trip, forward and backward, over the same path. Overlap each pass by one-half the width of the roller. o A minimum of three rollers o Max speed: 5	o pneumatic-tired rollers o At least 3 passes of the rollers	o At least three roller applications (one pass over entire seal width) o Rolling completed within 30 min

		○ five coverages ○ Max speed: 5 mph		continue to the center, lapping 1/2 the roller width on each successive pass. After this initial rolling, perform subsequent rolling using both steel-wheel rollers and pneumatic-tire rollers.		one-half the width of the roller. ○ A minimum of two rollers ○ Max speed: 5 mph	mph		
Curing	○ Place traffic cones at intervals of not more than 200 ft on the inner longitudinal edge of the freshly applied seal coat. Placement of these cones shall be maintained until the road is opened to unrestricted use by traffic.	○ Traffic control not to exceed 25 mph for a minimum of 2 hours	○ No traffic until all rolling has been completed.	○	○ The surface may be opened to traffic as soon as it has cured sufficiently to prevent the material from being picked up by the wheels of vehicles passing over it.	○ Allow the new surface sufficient cure time to prevent damage by vehicle tires before opening to traffic. ○ The speed of vehicles in the open lane at a maximum speed of 35 miles per hour.	○ Traffic control not to exceed 35 mph	○ The seal coat shall be protected by the restriction of traffic or by controlling ○ Traffic speed until the asphalt material has cured or set sufficiently to hold the cover aggregate without displacement.	○
Brooming after rolling	○ On the morning following each day of seal coat operations	○ early the next morning	○ Before the roadway, paved shoulders, intersections, etc., are opened to unrestricted traffic flow ○ A second brooming may be required within 24 hours	○ Lightly broom the surface to remove excess loose material.	○ The surface shall be swept clean, removing all dirt, debris, and loose material.	○ Before the end of each day's work or within 24 hours	○ Within 4 hours ○ Additional sweeping in subsequent days	○ After the asphalt material has cured sufficiently	○ The day following placement of the seal coat
Test			○ Test Strip: 500 ft long and the width of one lane. Evaluation for 24 hours after placement				○ Test Strip: 1000 ft long and the width of one lane. Review the test strip the next workday.		○
Payment	○ Binder: gallon ○ Aggregate: ton	○ Binder: gallon ○ Aggregate: ton		○ Cubic yard or ton	○ Binder: gallon or ton ○ Aggregate: ton	○ Square yard of seal coat in place	○ Square yard of seal coat in place	○ Binder: ton ○ Aggregate: ton	○ Binder: ton ○ Aggregate: ton ○ Square yard of seal coat in place

TABLE 1-4 Standard specification comparison of fog seal

State	Minnesota	Iowa	Missouri	Indiana
Name	○ Bituminous Fog Seal	○ Bituminous Fog Seal (Shoulders)	○ Bituminous Fog Sealing	○ Fog Seal
Temperature, Time, and Pavement Surface Requirements	○ Air temp above 40ºF ○ Dry and clean surface	○ Air temp above 60ºF ○ No placement after August 31 ○ Dry and clean surface	○ Dry and clean surface	○ Air temp above 60ºF ○ No placement on travel or auxiliary lanes before May 1 or after October 1 ○ Dry and clean surface
Application Rate	○ 0.10 to 0.15 gallon per square yard	○ 0.20 gallon per square yard	○ 0.20 gallon per square yard	○ within +/- 0.02 gallon per square yard of the rate shown on plans
Temperature of Material	○ **Liquid Asphalt:** 120 to 175°F ○ **Emulsified Asphalt:** 120 to 175°F			
Additional Specifications	○ Sand shall be spread on the newly fogged surface at pedestrian crossings.	○ May use sand dams if necessary	○ May use sand dams if necessary	○ Fine aggregate or other approved blotting material shall be applied to pedestrian crosswalks, driveways, or other areas.
Payment	**Bituminous Material for Fog Seal:** gallon	**Asphalt Emulsion:** gallon	**Asphalt Emulsion:** gallon	**Fog Seal:** square yard

TABLE 1-5 Standard specification comparison of slurry seal

State	Iowa	Michigan
Name	o Slurry Leveling, slurry wedge, and strip slurry treatment	o Slurry seal
Materials	o Asphalt Emulsion (CSS-1H or SS-1H); Aggregate (No. 22 and 23), Mineral filler (Portland cement), water	
Temperature and Pavement Surface Requirements	o Air temp at least 50 ºF. No placement after October 1st. o Surface and cracks cleaned	o Air temp at least 45°F and rising, placement only from June 1 to Sept 15 for Upper Peninsula, May 1 to Oct 1 for Lower Peninsula o Surface washed clean of debris, all visible cracks treated
Application rate	o As approved by engineer	
Equipment	o Slurry mixer with 5 tons minimum storage, emulsion pump, mechanical type squeegee distributor, power brooms, blowers, air compressors (for cleaning)	o Continuous flow mixing tank attached to a mechanical squeegee distributor, maximum operating speed of 180 ft per min, minimum operating speed of 60 ft per min
Tack coat	o Apply tack coat at a rate of 0.05 to 0.1 gal/sy	
Requirements during curing	o Traffic not allowed until curing complete	o No traffic during curing
Payment	Miles	Square yard (seal and slurry)

TABLE 1-6 Standard specification comparison of microsurfacing

State	Missouri	Illinois	Michigan	Ohio	Indiana
Name	o Microsurfacing	o Microsurfacing	o Microsurfacing	o Microsurfacing	o Warranted Microsurfacing
Temperature, Time, and Pavement Surface Requirements	o Air temp above 50°F and the forecast above 32°F for next 24 hours o Pavement surface temp above 50°F o Clean and misted surface	o Air temp above 40ºF and rising and the forecast for next 24 hours above 32°F o Air temp above 50ºF after October 31 and before March 31 o Clean and misted surface	o Air temp above 45°F and the forecast above 32°F for next 24 hours o Pavement surface temp above 45°F o Place between June 15 and September 15 for Upper Peninsula and May 1 and October 1 for Lower Peninsula o Clean surface with bond coat applied	o The forecast for air temp above 32°F for next 24 hours o Pavement surface temp above 40°F o Pavement surface temp above 50°F between September 30 and May 1 o Clean surface with tack seal applied	o Clean surface o Contractor responsible for pre-condition
Mix Design Criteria	o **Mineral Aggregate, dry mass:** 10 to 20 lb/yd^2 for leveling and surface courses and 15 to 30 lb/yd^2 for rut fill courses o **Polymer Modified Emulsion (residual), % by wt. of Aggregate:** 5.5 to 10.5 o **Mineral Filler, % by wt. of Aggregate:** 0.0 to 3.0	o **Mineral Aggregate, dry mass:** 15 to 50 lb/yd^2 o **Latex Emulsified Asphalt Residue, % by wt. of Aggregate:** 6 to 8 o **Latex Base Modifier:** As required with % by mass of binder min. of 2.5 o **Mineral Filler, % by wt. of Aggregate:** 0.5 to 2.5, depending on weather conditions	o **ISSA TB-114:** 90% min o **ISSA TB-100 One Hour Soak:** 1.0 lb/yd^2 max o **ISSA TB-100 Six Day Soak:** 1.5 lb/yd^2 max o **ISSA TB-144:** 3 g loss, max o **ISSA TB-113 Mix Time at 77°F:** Controllable to 120 sec, min o **ISSA TB-113 Mix Time at 100°F:** Controllable to 35 sec, min	o **Residual Asphalt, % by wt. of Aggregate:** 7.0 to 8.5 for leveling and surface courses and 6.5 to 8.0 for rut fill courses o **Mineral Filler, % by wt. of Aggregate:** 0.25 to 3.5 o **ISSA TB-114:** 90% min o **ISSA TB-100 One Hour Soak:** 1.0 lb/yd^2 max o **ISSA TB-144:** 3 g loss, max o **ISSA TB-113 Mix Time at 25°C:** Controllable to 120 sec, min o **ISSA TB-113 Mix Time at 40°C:** Controllable to 35 sec, min o **ISSA TB-139 30 min Set Time:** 12 kg-cm, min o **ISSA TB-139 60 min Traffic Time:** 20 kg-cm, min	o **ISSA TB-114:** 90% min o **ISSA TB-100 One Hour Soak:** 1.0 lb/yd^2 max o **ISSA TB-144:** 3 g loss, max o **ISSA TB-113 Mix Time at 77°F:** Controllable to 120 sec, min o **ISSA TB-113 Mix Time at 104°F:** Controllable to 35 sec, min o **ISSA TB-139 30 min Set Time:** 12 kg-cm, min o **ISSA TB-139 60 min Traffic Time:** 20 kg-cm, min
Application	o For rut filling, a crown of 1/8 to1/4 in. per in. of depth shall be formed.	o For rut filling, a first pass shall be used to fill the two wheel paths, and a second pass shall cover the entire width of the lane at a minimum of 15 lb/yd^2. o For other than rut filling, the surface mix shall be applied over the total width of each lane in two passes to provide a total rate of at least 30lb/yd^2.	For rutfilling, limit each pass to a maximum depth of 1 in. Provide an additional 1/8 in. crown for traffic consolidation. Apply a second course to the full lane width at 20 +/-2 pounds per square yard. For standard microsurfacing, apply a first course at 14 +/-2 pounds per square yard and a second course at 16 +/-2 pounds per square yard. For single course microsurfacing, apply a single course at 20 +/-2 pounds per square yard.	o Apply rut fill courses in widths from 5 to 6 ft for each wheel path with maximum crown of 1/8 in. after 24 hours of traffic compaction. o Apply leveling courses at 14 +/-2 pounds per square yard. o Apply surface courses at 16 +/-1 pounds per square yard if placing on another microsurfacing course, or at a minimum of 18 pounds per square yard otherwise.	
Traffic Specifications	o Reopen to traffic on 1/2 in. thick surface within one hour after placement at 75°F and 50 percent humidity	o Reopen to traffic one hour after application	o Reopen to traffic one hour after application	o Reopen to traffic one hour after application	o Reopen to traffic one hour after application
Payment	**Microsurfacing:** square yard	**Microsurfacing 1 Pass:** square yard **Microsurfacing 2 Passes:** square yard **Microsurfacing Rut Filling:** foot	**Microsurfacing, Std:** square yard **Microsurfacing, Single Cse:** square yard **Micro-Surface, RutFilling:** Ton	**Microsurfacing, Surface Course:** square yard **Microsurfacing, Leveling Course:** square yard **Microsurfacing, Rut Fill Course:** ton	**Microsurfacing, Warranted:** square yard

TABLE 1-7: Standard specification comparison for cape seal

State	Illinois
Name	Cape Seal
Materials	○ Coarse aggregate ○ Fine aggregate ○ Polymer modified emulsified asphalt ○ Mineral filler ○ Latex modified emulsified asphalt ○ Additives
Temperature and Pavement Surface Requirements	○ Temperature above 55 ºF ○ Placement from May 1 to August 31
	○ Surface clean, all cracks cleaned, surface smooth
Application rate	○ Aggregate: ~20 lb/sy ○ Bitumen: 0.3 gal/sy
Equipment	○ Pneumatic-tired roller ○ Mechanical sweeper ○ Spreader (aggregate and bitumen) ○ Heating equipment ○ Pressure distributor ○ Mixing machine ○ Proportioning device ○ Air compressor ○ Oil kettle
Construction sequence	○ Repair and prepare surface, ○ Apply chip seal ○ Apply microsurfacing
Payment	**Square yards**

TABLE 1-8 Standard specification comparison of ultra-thin bonded wearing course (UBWC)

State	Indiana	Oklahoma	Missouri	North Carolina	Illinois	New Jersey	Kentucky
Name	o Ultra-thin Bonded Wearing Course, Warranted	o Open-graded friction surface course	o Ultra-thin bonded asphalt wearing surface	o Open-graded asphalt friction course	o Open-graded asphalt friction course	o Ultra-thin friction course	o Open-graded friction course
Temperature and Pavement Surface Requirements	o Air temp at least 50º F o Clean, dry o Properly tacked	o Air temp at least 50º F o Dry, clean	o Air temp at least 50 ºF o Clean, dry surface (damp surface OK)	o Air temp at least 50ºF o Placement between Apr. 1 and Oct. 31 only o Clean of debris o Properly tacked	o Air temp must be at least 60 ºF two days prior to and during construction	o Air temp at least 50 ºF, no rain o Dry surface	o Air temp at least 60 ºF o No placement between Sept. 15 and May 1 o Clean and dry
Surface preparation	o Free of objectionable material o Protect Utility Structures	o Swept clean of all debris o Fix any minor defective areas	o All non-working surface cracks with an opening size exceed 1/4 in. o Any working size crack shall be sealed prior to placement		o Level surface	o Swept clean of all debris with power broom equipped with vacuum collection	o Perform necessary leveling, wedging, and patching prior to placement
Paver	o Capable of spraying emulsion, applying asphalt mix, and leveling in one pass o 30 to 90 ft/min. speed	o Paver should move continuously (no stopping)	o Capable of spraying polymer modified asphalt emulsion membrane, applying HMA overlay, and leveling surface of mat in one pass.	o Self propelled o Capable of operating at uniform rate	o Paving speed limited to 35 ft/min.		
Application rate	o ½ in. thickness: 0.2 gal/sy o 3/8 in: 0.17 gal/sy o #4: 0.14 gal/sy o Tolerance is ±.02		o As shown on plans			o 65 to 95 lb. per sq. yd. (aggregate)	o 65 pounds per sq. yd. (aggregate)
Rolling	o 3 passes of rollers o Capable of exerting at least 150 lb/in.	o 2-3 passes on a steel-wheeled roller (weight approved by engineer)	o 3 passes o roller weight of 10 tons	o One coverage with tandem steel-wheel roller o Max weight of 10 tons	o Max of three coverages by two tandem rollers	o Two 10-ton steel-wheel rollers	o Steel-wheel, tandem roller weighing 5 to 8 tons
Wearing course thickness	o ½ in. o 3/8 in. o ¼ in.		o Type A: 1/2 in. o Type B: 5/8 in. o Type C: 3/4 in.		o 5/8 in. nominal		o Approx. 3/4 in.
Distributor Requirements	o Must be capable of uniform distribution				o Pressure distributor truck capable of operating at speeds as low as 0.8 mph		o Spread mixture with paver o Prevent segregation of fines and coarse aggregate
Requirements During Curing		o No traffic permitted until pavement temperature is with 10ºF of ambient air temperature or until 2 hours have elapsed	o No traffic allowed		o Two-way traffic not allowed until mixture has adequately cooled	o No traffic permitted until pavement temperature is below 140ºF	o No traffic in lane of placement
Payment	Ton	Ton	Sq. yd. (m2)	Ton	Sq. yd. (m2)	Ton	Ton

TABLE 1-9 Standard specification comparison of thin HMA mill/fill (Thin HMA Inlay)

State	**Iowa**
Name	Transverse joint repair
Temperature, Time, and Pavement Surface Requirements	○ Remove all loose materials
Equipment	○ Milling equipment capable of removing material to minimum 12 in. width in one pass (to specified depth). ○ Mechanical tampers, trench rollers, vibratory compactors, or weighted vehicle wheels for compacting lower lifts.
Construction	○ Mill transverse surface for entire pavement width at joint repair areas. ○ Prior to filling the milled area, lightly tack vertical faces and base of area. ○ Place filler material in uniform lifts not to exceed 3 in. depth. ○ Compact with minimum 3 passes. ○ Finished elevation not more than 1/4 in. above surrounding pavement
Surface preparation	○ Clean and dry milled surface prior to tack coat application.
Materials	○ Filler HMA mixture of 300,000 ESAL or better. ○ Mixture size 3/4, 1/2, or 3/8 in. ○ Tack coat bitumen.
Roadway wearing surface	○ If necessary, seal edges of joint repair with CRS-2 Bitumen. ○ Use 3 in. wide V-Shaped squeegee tool, blot with sand
Joints	○ Cleaned prior to repair
Traffic and safety requirements	○ One lane at a time, finish everything in 1 day if road is not closed to traffic.
Payment	○ **Ton**

TABLE 1-10 Standard specification comparison of surface milling (surface profiling)

State	Minnesota	Iowa	Missouri	Wisconsin	Illinois	Michigan	Ohio	Kentucky	Indiana
Name	○ Mill Pavement Surface	○ Pavement surface repair (milling)	○ Cold milling existing pavement	○ Salvaged asphaltic pavement milling	○ Bituminous surface removal for subsequent resurfacing	○ Cold-Milling HMA Surfaces	○ Pavement planning	○ Asphalt Pavement Milling and Texturing	○ Milling
Temperature, Pavement Requirements		○ No work at night, Sundays, or holidays ○ Clean by rotary broom	○ Clean						
Equipment	○ Power operated self propelled machine. ○ Should automatically establish profile grades within 1/8 in. by referencing from existing pavement or independent grade control.	○ Cold planning equipment capable of milling in 2 or less passes. ○ 60 cutting teeth per foot. ○ Spacing 1/4 in. ○ Cutting teeth angled at not more than 75 degrees. ○ Also use a rotary broom to clean surface. ○ Water for dust nuisance.	○ Capable of removing thickness to specified depth and provide uniform slopes and profiles. ○ Should have automatic grade leveling and slope control.	○ Self-propelled milling machine with depth, grade, and slope controls. ○ Should drum to prevent discharge of loose matter.	○ Self-propelled planning or milling machine. ○ Wheel base no less than 10 ft. ○ Capable of removing layer at least 6 ft wide and 1 1/2 in depth in one pass.	○ Machines must be equipped with the following: ○ Automatic cutting drums, grade and slope (transverse and long.) controls, grade reference attachment	○ Use cutters with a suitable carrier wheelbase or an automatic control system with an external reference. ○ Cutters should be adjustable for depth and cross-slope.	○ Power operated ○ Self-propelled machine that can remove pavement to required depth, profile, cross-slope, and surface texture. ○ Mechanical sweeper and water to control dust.	○ Power operated cold milling machine with automatic control devices. ○ Should be able to control cross slope and grading. ○ Should prevent airborne dust from escaping. ○ Should produce cuttings such that 90% of conglomerate particles pass 2 in sieve
Construction	○ Milled to depth, width, grade, and cross-slope shown in plans, or by engineer's judgment. ○ Taper edges (transverse and/or longitudinal) such that they pose no threat to traffic.	○ Mill longitudinally, against traffic. ○ At least 95% of area in each 100 ft section shall have newly textured surface. ○ The first pass at the center line may overlap the joint line by 2 in. ○ The joint match between two passes shall be within 1 foot of center of lane	○ Roadway shall be milled longitudinally, around and over manholes, drainage devices, and utilities. ○ Place temporary wedge around such appurtenances.	○ Do not allow abrupt longitudinal differences of more than 2 in. ○ Taper edges so as not to endanger traffic	○ Remove to the depth specified in the plans. ○ Temperature and other conditions also specified in plans.	○ Remove entire HMA surface in one or more passes, providing required grade and uniformly textured surface.	○ Mill longitudinally in one or more passes.	○ Remove pavement in successive cuts of 1 to 1 1/2 in. over entire length and width of area. ○ Provide average depth of 2/10 in. between high and low points of milled pavement. ○ Taper longitudinal faces, limit them to 1 1/2 in. in height	○ Existing pavement shall be milled to the cross-slope as shown on the plans
Pavement finishing		○ Transverse slope such that no depression or misalignment great than 1/4 in. in 12 ft. exists.					○ Cross slope within 3/8 in. in 10 ft. of specified cross-slope	○ Cross slope not to deviate more than 3/8 in. in 10 ft.	○ Cross slope shall not vary more than 1/8 in. in 10 ft.

Pavement profiling	○ Operations referenced from independent grade control, where necessary. ○ Entire pavement width should be milled to flush surface at end of work period.	○ Partly profiled on initial trace by engineer. ○ Control trace used to identify required smoothness. ○ Each segment should have profile index of 35% of control profilograph trace or 10 in. per mile, whichever is greater. ○ No bumps exceed .5 in. in 25 ft.	○ Automatically establish profile grades within 1/8 in. of each edge of machine. ○ Smoothness shall no vary more than 1/4 in. in 10 ft.		○ Establish profile grades by reference or from independent grade control. ○ Smoothness of at least 3/16 in. in 16 ft.		○ Plane surface free from grooves, ridges, or other irregularities. ○ Smoothness of 1/8 in in 10 ft if no resurfacing. ○ Smoothness of 1/4 in. in 10 ft. if resurfacing. ○ Match surface at edges of adjacent passes within 1/8 in	○ Establish profile grades by referencing from existing pavement or independent grade control. ○ Longitudinal edges of adjacent cuts are not to differ by more than 1/8 in. ○ Longitudinal smoothness not to deviate more than 1/8 in. in 10 ft.	○ Longitudinal smoothness that does not vary more than 1/4 in. in 16 ft.
Pavement testing		○ Test pavement for smoothness using same procedure as control trace.							○ Macrotexture testing minimum once per day; value of 2.2 for single course, 1.8 for multiple course overlays.
Approaches and tapers			○ Depth transitions as approved by engineer.					○ Mill approaches and tapers aligned to finished cut. ○ Transition them to existing surface with 1/8 in.	○ Approach milling should provide smooth transitions.
Traffic requirements	○ Open pavement to traffic after working period.	○ Allow one open lane for traffic. ○ Entire road opened at end of working period.	○ Provide appropriate signage.	○ Maintain one lane of roadway traffic at all hours.					
Additional Specifications	○ Clean and sweep after milling. ○ Debris resulting from milling shall be disposed outside of Right of Way.	○ Milling residue should not be allowed off site into drainage structures.	○ Loose material should be swept to shoulders if approved by engineer. ○ Otherwise should be hauled and disposed of.		○ Clean and dispose of residue. ○ Drainage devices may need to be removed, as well as roadway medians.	○ Clean surface immediately after cold-milling, disposing of residue.	○ Clean surface of loose material before opening to traffic.	○ Sweep and clean loose materials. ○ Haul away and dispose. ○ Don't let materials into drainage structures. ○ Drainage structures and manholes may be adjusted to match finished pavement.	○ Sweep and clean loose materials before opening to traffic.
Payment	○ Square yards	○ Square yards	○ Square yards	○ Ton or square yard	○ **Pavement removal:** Square yard. ○ **Median Removal:** foot ○ **Drainage device removal:** foot	○ Ton or square yard	○ Square yards	○ **Asphalt Pavement Milling**: Ton. ○ **Mobilization for Milling:** Lump sum. ○ **Adjusting manhole:** Each. ○ **Adjusting drainage structures:** Each	○ Square yards

TABLE 1-11 Standard specification comparison of cold in-place recycling

State	Iowa	Indiana
Name	o Cold In-Place Asphalt Pavement Recycling	o Cold In-Place Recycling
Temperature and Pavement Surface Requirements	o Air temp at least 60ºF placement between May 1 and Oct. 1 o Clean of all debris	
Materials	o Emulsified asphalt pulverized bituminous material with at least 90% passing 1-in. sieve	o Cationic recycling agent o Aggregate o Asphalt emulsion
Equipment Requirements	o Self-propelled milling machine capable of working to full-depth in one pass; o Mixing equipment that can mix material and place into spreader in continuous operation; paver or spreader; o Vibratory steel roller or 25-ton pneumatic tire roller	o Self propelled miller o 12 ft. wide cutting drum, capable of 6 in. depth in one pass o Spray bar to full width of cutter head o Paver stiff-leg attached to milling machine
Application rate	o Paver or spreader should apply emulsion asphalt to pulverized material at 0.3 gallon per square yard per in. of compacted thickness	o
Compaction and Density	o Min. field density of 92% for non-Primary roads, 94 % for primary roads; roll first with pneumatic-tire, then with steel-wheel.	o 5 passes large vibratory roller o 4 Passes 25-ton pneumatic tire roller o 3 Passes Static roller
Other requirements	o Discontinue rolling if pavement distress occurs. o Check density with test strips if mix proportions are altered, if resurfacing is included. o Cover with one full lift of HMA prior to winter shutdown.	o QC control with nuclear density gage
Requirements During Curing	o No traffic until curing complete and moisture content of recycling mixture is less than 1.5%.	o Allow recycled base to cure for one week.
Payment	o **Recycling Asphalt Pavement**: sq. yd. o **Asphalt Rejuvenating Agent (Emulsion):** gallon	o **Asphalt Emulsion**: per ton o **Milling**: per square yard

TABLE 1-12 Standard specification comparison of hot in-place recycling

State	Iowa	Illinois	Ohio	Indiana
Name	○ Surface recycling by heater scarification	○ Pavement rehabilitation by the heat-scarify-overlay method	○ Hot In-place Recycling with warranty	○ **Hot in-place recycling**
Temperature, Time, and Pavement Surface Requirements	○ Air temp at least 50ºF ○ clean trash and debris	○ Air temp at least 45ºF and rising ○ Surface free of water, earth, and foreign material	○ Remove cold patch areas to depth of 3 in. and fill with asphalt concrete, ○ Remove thermoplastic pavement markings	○ **Surface clean** ○ **Remove patches** ○ **Temperature 45ºF and rising**
Equipment	○ Heater scarifier capable of producing 10 million BTUs per hour or more ○ Pressure loaded rakes or scarifiers ○ Leveling unit capable of distributing heated and scarified material over the width	○ Heater, scarifier, and distributor for asphalt overlay. ○ Heating scarifying operation shall not exceed 30 ft per minute. ○ Heating unit shall move continuously.	○ Self-contained, self-propelled units capable of continuous operation. ○ Heating units shall not damage asphalt binder.	○ **Heater softens pavement** ○ **Scarifier cuts pavement to depth of one in.** ○ **Rejuvenator added after scarify**
Construction	○ Heater scarifier to operate the full width as a continuous operation. ○ Minimum depth of scarification of 3/4 in. at high points (edges, between wheel paths). ○ Minimum depth of 1/2 in. at lowest points (wheel paths).	○ Pavement will be scarified to average depth of 3/4 in. ○ Apply asphalt modifier immediately after scarifying at a rate of 0.1 gal/sy.	○ Heat existing pavement to loosen material. ○ Recycle in-place to a depth of 2 in. measured behind the screed (min. depth is 1 1/2 in.).	
Operation rate	○ 1500 sy per hr over a minimum of one lane width (12 ft.)			
Temperature of material	○ Old pavement shall be below 475ºF during heating. ○ Heated material shall have temperature range of 220ºF to 260ºF ○ Heating operation shall extend at least 4 in. beyond scarification width.	○ Old pavement temperature not to exceed 375ºF ○ New material shall have a minimum temperature of 175ºF.	○ The temperature of the recycled mix (behind screed) shall not exceed 325ºF.	○ **Temperature of recycled mix should be 200ºF to 250ºF**
Leveling	○ Leveled to uniform cross slope using system of augers and screed		○ Transverse slope not to vary from specified slope more than 3/8 in. in 10 ft.	
HMA overlay	○ When mix drops below 170ºF, new surface course shall be placed.	○ 48 hours after scarified/treated material placed, play a uniform HMA layer at 70 lb/sy		○ **Paving and rolling are standard practice after virgin mixture is combined into hopper with recycled mixture**
Additional Specifications	○ Compacted thoroughly after new surface course placed.	○ Compaction should occur before temperature of mix drops below 150ºF.	○ Modified binder should have a penetration value between 40 and 90. ○ Surface should have consistent texture, no segregation or excessive asphalt cement.	
Traffic and safety requirements	○ Route opens to traffic (one lane closed). Owners of utilities and city should check for gas leaks and buildups. ○ Business owners should be advised to temporarily refrain from dispensing flammable fuels (i.e. gasoline).			
Payment	○ Square yards	○ **Heat-scarifying:** square yard ○ **Bituminous mixture:** ton ○ **Asphalt modifier:** liter	○ Square yards	○ **Square yards**

TABLE 1-13 Standard specification comparison of PCCP crack sealing

State	Missouri	Illinois	Michigan	Indiana
Name	o Portland Cement Concrete Pavement Joint/Crack Sealing	o Crack and Joint Sealing Portland Cement Concrete Pavement	o Sawing and Sealing Cracks	o Routing, Cleaning, and Sealing Cracks
Temperature and Pavement Surface Requirements	o Air temp above 40ºF o Dry and clean surface	o Air temp above 40°F o Dry and clean surface	o Dry and clean surface`	o Air temp above 40°F o Dry and clean surface
Routing or Sawing	o Minimum width of 3/8 in. o Minimum depth of d/4, where *d* is the thickness of the pavement	o 3/4 in. wide o 3/4 in. deep	o 3/8 to 1/2 in. wide o 1/2 to 5/8 in. deep	o Maximum width of 1/2 in. o Minimum depth of 3/4in.
Cleaning Equipment		o Power brush/blower or o Compressed air with minimum pressure of 90 psi	o Compressed air with a minimum pressure of 90 psi	o Compressed air with a minimum of 100 psi
Backer Rod		o Use if a void exists that exceeds 3/4 in. depth.	o Use if crack below reservoir is greater 3/8 of an in. wide	
Sealing	o Sealant shall be applied to the reservoir from the bottom to 1/2 in. from the top	o Transverse cracks shall be slightly overfilled and immediately squeegeed for band-aid effect 2 in. wide flush with pavement surface with edges feathered out o Longitudinal cracks shall be sealed flush	o Bring surface of the sealant flush to in. below surface of pavement. o If required by crown of roadway and slope of shoulder, fill reservoir in two or more passes and/or place temporary dikes in sealed reservoir	o Cracks and joints shall be filled with rubber asphalt to within 1/4 in. of the surface. o Asphalt shall be placed using a V-shaped wand tip.
Requirements During Curing		o No traffic allowed until completed curing		o No traffic allowed until completed curing
Blotting		o Dust with sand or cover with tissue paper to prevent tracking when necessary		o Fine aggregate to prevent tracking
Payment	**Crack Sealing:** foot	**Crack Routing or Sawing:** foot **Crack Filling:** pound	**Crack Sealing:** foot	**Cracks in PCCP, Rout and Seal:** foot

TABLE 1-14 Standard specification comparison of PCCP joint sealing

State	Iowa	Missouri	Illinois	Michigan	Ohio	Indiana
Name	o Sealing Joints	o Portland Cement Concrete Pavement Joint/Crack Sealing	o Crack and Joint Sealing Portland Cement Concrete Pavement	o Sealing Joints	o Sealing Joints	o Sawing, Cleaning, and Sealing Joints
Temperature and Pavement Surface Requirements	o Air temp above 40°F o Dry and clean surface	o Air temp above 40ºF o Dry and clean surface	o Air temp above 40°F o Dry and clean surface		o Dry and clean surface	o Air temp above 40°F o Dry and clean surface
Sawing			o 3/4 in. wide o 3/4 in. deep		o For pavement less than or equal to 10 in., saw the joint to a minimum depth of one-fourth the specified pavement thickness. o For pavements greater than 10 in., saw to a minimum depth of one-third the pavement thickness. o Saw joints 1/4 +/-1/16 in. wide.	
Cleaning	o For joints narrower than 3/8 in., use high pressure water blast operating at minimum pressure of 1000 psi. o For joints 3/8 in. and wider, use sand cleaning.		o Power brush/blower o Compressed air with minimum pressure of 90 psi	o Blast clean with an oil-free dry abrasive. Give all joints a final cleaning with a jet of compressed air with a minimum pressure of 90 psi.		o Compressed air with a minimum pressure of 100 psi
Backer Rod	o May be necessary when not using a shallower depth early, green-concrete saw.		o Use if a void exists that exceeds 3/4 in. depth.			
Sealing	o Joint sealer shall be prepared and installed in the joint and to the proper level as shown in the contract documents and as recommended by the manufacturer.	o Sealant shall be applied to the joint from the bottom to 1/2 in. from the top	o Joints shall be slightly overfilled and immediately squeegeed for band-aid effect 2 in. wide flush with pavement surface with edges feathered out			o Transverse joints shall be sealed with silicone sealant or preformed electrometric joint sealant. o Longitudinal joints shall be sealed with an asphalt rubber or silicone sealants.
Traffic Requirements			o No traffic allowed until completed curing	o No traffic allowed until completed curing		o Traffic may be allowed on the PCCP for up to 7 calendar days after the saw cutting prior to sealing.
Blotting			o Dust with sand or cover with tissue paper to prevent tracking when necessary.			
Payment		**Joint Sealing:** foot	**Joint Routing:** foot **Joint Filling:** pound	**Joint:** foot		**Joints in PCCP, Saw and Seal:** foot

TABLE 1-15 Standard specification comparison of diamond grinding (PCCP profiling)

State	Wisconsin	Michigan	Ohio	Kentucky	Indiana
Name	○ Continuous Diamond Grinding	○ Diamond Grinding Concrete Pavement	○ Diamond Grinding Portland Cement Concrete Pavement	○ Diamond Grinding JPC Pavement	○ Grinding
Equipment Requirements		○ Diamond blades mounted on a self-propelled machine	○ Power driven, self-propelled machine with diamond blades or impregnated cylinder rings with grinding head at least 3 ft wide, and effective wheel base of at least 12.0 ft.	○ Self-propelled machine with diamond blades capable of cutting or planning at least 3 ft wide on each pass.	○ Diamond tipped saw blades mounted on a power driven, self-propelled machine containing transverse and longitudinal grade controls and cutting head no less than 36 in.
Grinding	○ Grind in longitudinal direction so that 95 percent of any 3 foot by 100 foot section of pavement area within a single lane has a grooved or corduroy-type appearance ○ Make grooves approximately 1/16 in. from peak to bottom, and uniformly space them a minimum of 50 per linear foot.	○ Grind in longitudinal direction beginning and ending at lines perpendicular to the pavement centerline. ○ Texture a minimum of 95 percent of the pavement surface. ○ Grind to a parallel corduroy type texture consisting of grooves 1/16 to 1/8 in. wide, 1/16 in. deep and 1/16 to 1/8 in. on center.	○ Produce a pavement surface that is true to grade with the ground area consisting of a longitudinal corduroy-type texture. ○ Ensure peaks of ridges are approximately 1/16 in. higher than the grooves with 53 to 57 evenly spaced grooves per foot.	○ Grind in longitudinal direction and parallel to the pavement centerline. Begin and end at lines normal to the pavement centerline. Create texture with the width of grooves between 0.09 and 0.130 in., width between grooves between 0.08 and 0.125 in., and height of groove between 0.031 and 0.063 in.	○ The pavement surface shall have a uniform texture but shall not be smooth or polished.
Grinding Residue Restrictions	○ Remove residue by vacuuming. ○ Do not allow residue and water to flow or blow across lanes used by public traffic or to enter any storm sewer, stream, lake, reservoir, or marsh. ○ Dispose of residue and water at an acceptable material disposal site.	○ Spread residue a minimum of 5 ft from edge of curb. ○ Do not spread within 100 ft of a natural stream or lake. Do not spread within 5 ft of a water-filled ditch.	○ Remove residue before it is blown by traffic action or wind. ○ Do not allow residue to flow across lanes used by the traveling public or into gutters or drainage facilities.	○ Remove residue from the pavement surface before traffic or wind blows it. ○ Ensure that waste water and residue do not flow across the pavement, into gutters, or into drainage structures.	○ Remove residue or slurry continuously from pavement. ○ Slurry shall not encroach into adjacent pavement lanes carrying traffic, or flow into gutters or other drainage facilities and shall be immediately and directly deposited into a tanker truck and removed from the jobsite.
Payment	**Concrete Pavement Continuous Diamond Grinding:** square yard	**Diamond Grinding Concrete Pavement:** square yard	**Diamond Grinding Portland Cement Concrete Pavement:** square yard	**JPC Pavement Diamond Grinding:** square yard	**Profiling PCCP:** square yard

TABLE 1-16 Standard specification comparison of diamond grooving

State	Iowa
Name	○ Longitudinal grooving
Equipment	○ Mechanical wire broom or comb with single row of tines 1/8 in. width. ○ Equipment should have horizontal and vertical alignment controls. ○ Slabs smaller than 20 ft wide and 600 ft long can be hand-grooved.
Grooving	○ The groove depth shall be 1/8 in. with a tolerance of 1/16 in. ○ Grooves shall be uniformly spaced at 3/4 in. intervals.
Joints	○ 2 to 3 in. wide strip of pavement centered around the joint should be protected from grooving
Other specifications	○ If abutting pavement is to be placed, groove up to 6 in. from edge or 1 foot from curb. ○ Do not groove where rumble strips to be placed.
Payment	

TABLE 1-17 Standard specification comparison of partial-depth patching

State	Iowa	Missouri	Ohio	Indiana
Name	o Partial Depth Finish Patches	o Class A Partial Depth Pavement Repairs	o Partial Depth Pavement Repair	o PCCP Patching
Temperature Requirements	o Air and pavement temp above 45ºF			o Placement of PCCP patches in continuous reinforced concrete pavement shall be after 1:00 P.M. when the next day's forecasted ambient temp is 70°F or greater. o PCCP patches shall not be placed on frozen subgrade, subbase, or PCCP.
Pavement Removal	o Remove concrete to a minimum depth of 3 in. o Maximum depth is 75% of the pavement thickness but not more than 9 in. o Patch area is to be cleaned by sandblasting followed by cleaning with compressed air.	o Repair limits shall extend beyond the delaminated or spalled area by 3 to 4 in. o The channel shall not exceed half the slab depth. o Concrete shall be removed by a milling process.	o Remove pavement to the specified depth within the designated limits without loosening or otherwise damaging adjacent pavement.	o The saw cut shall be a minimum of 1 in. to a maximum of 3 in. o Removal of all unsound concrete to a minimum depth of 1 in. shall be by hand chipping tools hand held mechanically driven equipment. o The partial depth cavities shall be thoroughly sandblasted and cleaned of all dust, chips, and water.
Joint and Crack Preparation	o A joint or crack in the patch area shall be recreated with a joint board of the proper size and shape.	o A compressible insert shall be placed against the joint or crack to form a bond breaker between the patch material and joint or crack.		o Existing joint openings within the patch shall be maintained for the full-depth of the patch by preformed joint fillers or forms.
Placement of Material	o A cement-sand-water grout shall be scrubbed onto the patch surfaces. o Patch material shall be placed before the grout dries.	o Bonding material shall be applied in a thin even coat over the entire area. Concrete material shall be placed into the channel and consolidated with a small spud vibrator. o The repair and slab interface shall be sealed by painting the repair perimeter with a 1:1 cement-water grout.	o Place and compact asphalt concrete in one or more lifts as necessary to finish flush with the adjacent pavement surface.	o A non-vapor barrier type bonding agent shall be applied to the vertical and horizontal surfaces. o Concrete shall be placed level to the adjacent PCCP and consolidated by internal vibration.
Payment	**Partial Depth PCC Finish Patches:** square feet	**Class A Partial Depth Pavement Repair:** 1/10 square yard	**Partial Depth Pavement Repair:** square yard	**PCCP Patching:** square yard

TABLE 1-18 Standard specification comparison of full-depth patching

State	Iowa	Missouri	Ohio	Indiana
Name	○ Full-depth Finish Patches	○ Full-depth Pavement Repairs	○ Full-depth Pavement Removal and PCCP Replacement	○ PCCP Patching
Temperature Requirements		○ When the ambient temp may drop below 60°F, the temperature of the concrete at the time of placement shall be no lower than 80°F.		○ Placement of PCCP patches in continuous reinforced concrete pavement shall be after 1:00 P.M. when the next day's forecasted ambient temp is 70°F or greater. ○ PCCP patches shall not be placed on frozen subgrade, subbase, or PCCP.
Pavement Removal	○ Remove concrete for the full pavement depth. All patches will be full lane width unless otherwise shown in the contract documents.	○ The full-depth of the pavement shall be removed without mechanically breaking in place, and with a minimum disturbance of sound base.	○ Saw cut the existing PCCP pavement to the full-depth at the limits of the area designated by the engineer using a diamond saw blade.	○ The saw cut shall be full lane width and thickness of the PCCP. ○ Full-depth removal shall be extended until sound PCCP is encountered to allow dowel bars to be firmly anchored.
Joint and Crack Preparation				○ Patches constructed adjacent to transverse contraction joints or random cracks that are to remain in place shall be constructed with type D-1 contraction joints.
Placement of Material	○ Concrete shall be dumped or conveyed into the patch areas to avoid segregation of the aggregates and cement, spread into place, vibrated with a mechanical vibrator, smoothed, and finished to the elevation of the adjacent PCC surface.	○ All full-depth pavement repairs exceeding 30 ft in length shall be constructed with tie bars along the longitudinal centerline joint.	○ Cast each patch in one continuous operation and consolidate the concrete around the perimeter of the patch and within the limits of the patch area using an internal type vibrator.	○ Patches shall be anchored with dowel bars to the adjacent PCCP. ○ Dowel bars shall be installed using a chemical anchoring system.
Payment	**Full-depth Finish Patches:** square yards	**Full-depth Pavement Repair:** 1/10 square yard	**Full-depth Pavement Removal and PCCP Replacement:** square yard	**PCCP Patching:** square yard

TABLE 1-19 Standard specification comparison of undersealing

State	Iowa	Missouri	Indiana
Name	Concrete Pavement Undersealing by Pressure Grouting	Undersealing Pavement	Undersealing
Temperature Requirements	○ Temp at bottom of pavement slab above 40°F	○ Air temp above 40°F ○ No application on a frozen subgrade	○ Air temp above 40°F ○ No application on a frozen subgrade ○ Material heated to at least 350°F at time of application and never heated above 500°F
Drilled Holes	○ Holes shall be 1 1/4 in. to 1 1/2 in. diameter. ○ Drilled at locations designated by the Engineer.	○ Holes shall be a maximum of 1 1/2 in. in diameter. ○ The hole pattern shall be as shown on the plans or as directed by the engineer. ○ In no case shall there be less than two holes at any location.	○ Holes shall not exceed 1 1/2in. in diameter. ○ Where existing pavement has transverse joints, holes shall be drilled on centerlines between transverse joints or cracks at approximately 30 to 36 in. from the joints or cracks.
Pumping Asphalt	○ Grout shall be pumped under the pavement panel until movement of the slab is detectable.	○ Pumping shall be stopped when the pumping pressure increases, grout appears at any adjacent hole or longitudinal or transverse joint or crack, or the pavement is raised 1/8 in. or more.	○ Use a metallic hose with a 1 in. nozzle. ○ Hose shall be inserted in the hole, driven to a snug fit. ○ Temporary wood plug shall be driven into the hole after pumping.
Plug	○ Drill holes shall be plugged by tamping the hole full of very dry concrete (1 part cement, 2 parts sand) ○ The plug shall be finished flush with the pavement surface.	○ Drill holes shall be filled flush with the surface of the pavement using a fast setting mortar or concrete.	○ After material has hardened, a hardwood plug at least 3 in. long and a minimum of 1/16 in. larger than the diameter of the drilled hole shall be driven flush with the surface of the pavement.
Traffic Requirements	○ Traffic shall be permitted to use the pavement during construction operations. ○ Traffic will be permitted on the undersealed pavement slab when the grout has obtained satisfactory set.	○ At least one-way traffic shall be maintained at all times. ○ No construction traffic shall be permitted on the undersealed pavement until three hours after the end of pumping operations and after all drill holes have been plugged.	○ Maintain one lane traffic in immediate vicinity of pumping operations. ○ Traffic may be permitted to use area after hardwood plugs are driven.
Payment	**Portland Cement (for Pressure Grouting):** ton **Holes (for Pressure Grouting):** Each	**Portland Cement:** 1/10 ton **Fly Ash:** 1/10 ton **Holes:** Each	**Asphalt Material for Underseal:** ton **Drilled Hole for Underseal:** Each

TABLE 1-20 Standard specification comparison of retrofit load transfer

State	Wisconsin	Michigan	Ohio	Indiana
Name	Pavement dowel bars for load transfer	Installing dowels in transverse joints	Dowel bar retrofit	Retrofit Load Transfer for PCCP
Temperature, Time, and Pavement Surface Requirements			o Clean edge of slots by approved blast methods.	o Surfaces thoroughly cleaned by sand blasting
Equipment		o Grout dispenser, drilling machine	o Diamond blade saws (capable of sawing 3 slots at one time). o Jack hammers weighing less than 30 lbs. o Abrasive blast equipment. Pressure applicator	o Diamond saw blades o Mechanical chipping hammers (weighing less than 15 lbs)
Drilling	o Drill holes into edge of existing PCCP as shown on plans. o Clean drilling dust, debris, moisture from drill holes before inserting dowel bar and epoxy	o Drill faces of existing pavement. o Clean holes with compressed air minimum 90 psi. o Drill or punch through fiber filler in joints. o Holes should be drilled mid pavement. o Holes for dowels should be 1 3/8 in. diameter and 9 in. deep.	o Cut 2 1/2 in. wide slots into pavement so that center of dowel is mid-depth in slab. o Cut 3 slots on 1 ft centers in each wheel path.	o Diamond saw slot cutting
Dowel bars	o Anchor dowel bars to existing concrete pavement with epoxy grout. o Insert dowel bars in drill holes and rotate 1/2 turn. o Coat free end of each dowel with a thin layer of bond breaking lubricant	o Insert dowel bars into holes with twisting motion (hand pressure). o Coat with grout. o Coat portion of dowels that extend beyond pavement or fiber filler face with bond-breaking coating. o Install extension cap.	o Use 1 1/2 in. diameter and 18 in. long dowels. o Coat dowels with oil or other bond breaking material. o Place expansion cap on end that will allow 1/4 in. movement at each end. o Dowels should be centered across crack.	o Dowel bar assemblies as shown on plans. o Coat with bond breaking materials. o Place parallel to pavement surface.
Patching material			o Use two chairs (2 1/2 in. wide) to hold dowel in slot during placement of patching material. o Mix, place, and cure patching material using vibrator.	o Rapid setting patch material placed in slots and troweled to patch existing adjoining PCCP
Epoxy/Sealant	o Inject epoxy grout into back of drill hole. o After dowel insertion, fill annular space entirely with epoxy. o Use positive fixed displacement dispensing system to deposit epoxy at back of drilled hole.	o Fill holes with grout after cleaning. o Deposit grout in back of holes.	o Caulk cracks at bottom with silicone sealant.	o Seal all cracks with a silicone sealer
Material requirements	o Furnish a 2-component, color epoxy grout conforming to AASHTO M235, grade 3 non-sagging consistency, type IV epoxy. o Epoxy grout should have workable viscosity, pumpable but thick enough to remain in hole. o Dowel bars should conform to AASHTO M 31 M grade 300 or 400.		o One part silicone sealant with max. tensile stress of 45 psi, flow of 0.3 in. maximum. o Aggregate, o Curing material, o Dowel bars, o Dowel bar chairs, o Preformed filler, o Patching material	o Silicone sealers, o Dowel bars o Patching material
Traffic and safety requirements		o Open to traffic when new concrete has a flexural strength of 300 psi	o Do not allow traffic until all retrofit dowel bars in place and have cured.	
Payment		o Each	o **Retrofit dowel bar:** Each	o **Retrofit load transfer:** Each

2 TREATMENT SELECTION METHODOLOGY REVIEW

2.1 OPTIMAL TIME AND PAVEMENT DISTRESS CONDITION

Preventative maintenance treatments such as chip seals, fog seals, and UBWC have the potential to save state highway agencies (SHAs) a significant amount of money if implemented appropriately as a part of a pavement preservation program. For these savings to be realized, however, state agencies must take care to "place the right treatment on the right road at the right time" (**Error! Reference source not found.**). Specifically, state agencies should consider the optimal time for applying treatments as well as the treatment best suited for the existing pavement distresses. Several state agencies have begun this analysis. What follows in this report is an overview of some research findings regarding treatment timing as well as current methods already in practice among state highway agencies.

In a survey of 35 SHAs conducted by Peshkin and Hoerner (2), the most common approach for selecting a preventative maintenance treatment was "engineering judgment" with 28 responses, followed by a selection matrix or decision tree based on pavement distresses, which had 21 responses. This suggests that although many SHAs have a mature system established for decision making, many are relying on past experience and judgment. In the same survey, 23 SHAs responded that treatment selection is integrated into the pavement management system (PMS). The survey also found that the most common technique for selecting appropriate timing for treatments is based on appearance of minimal distress. Although no firm conclusions should be drawn from these surveys, it appears that many SHAs have a fairly good understanding of optimization of timing and pavement distress when considering preventative maintenance treatments.

Many agencies already have an approach to determine the most appropriate treatment for a given pavement. These approaches range from qualitative guidelines based on engineering judgment to complex computer algorithms based on data analysis and modeling procedures. The Iowa DOT began a process in 1997 to develop qualitative guidelines for seal coats, slurry seals, and microsurfaces. The guidelines, which provided guidance on which roads were good candidates for a particular treatment, were developed to supplement engineering judgment and to Iowa road conditions (2).

2.2 USE OF MATRICES AND DECISION TREES

A report by Peshkin and Horner contained a summary of the benefits and limitations of using decision trees or matrices for selecting pavement treatments. Their findings are shown in TABLE 2-1. Decision trees have been commonly used in Ontario and Canada, as well as in New Mexico (2). FIGURE 2-1 shows an example of a pavement treatment decision tree made by the National Center for Pavement Preservation (3).

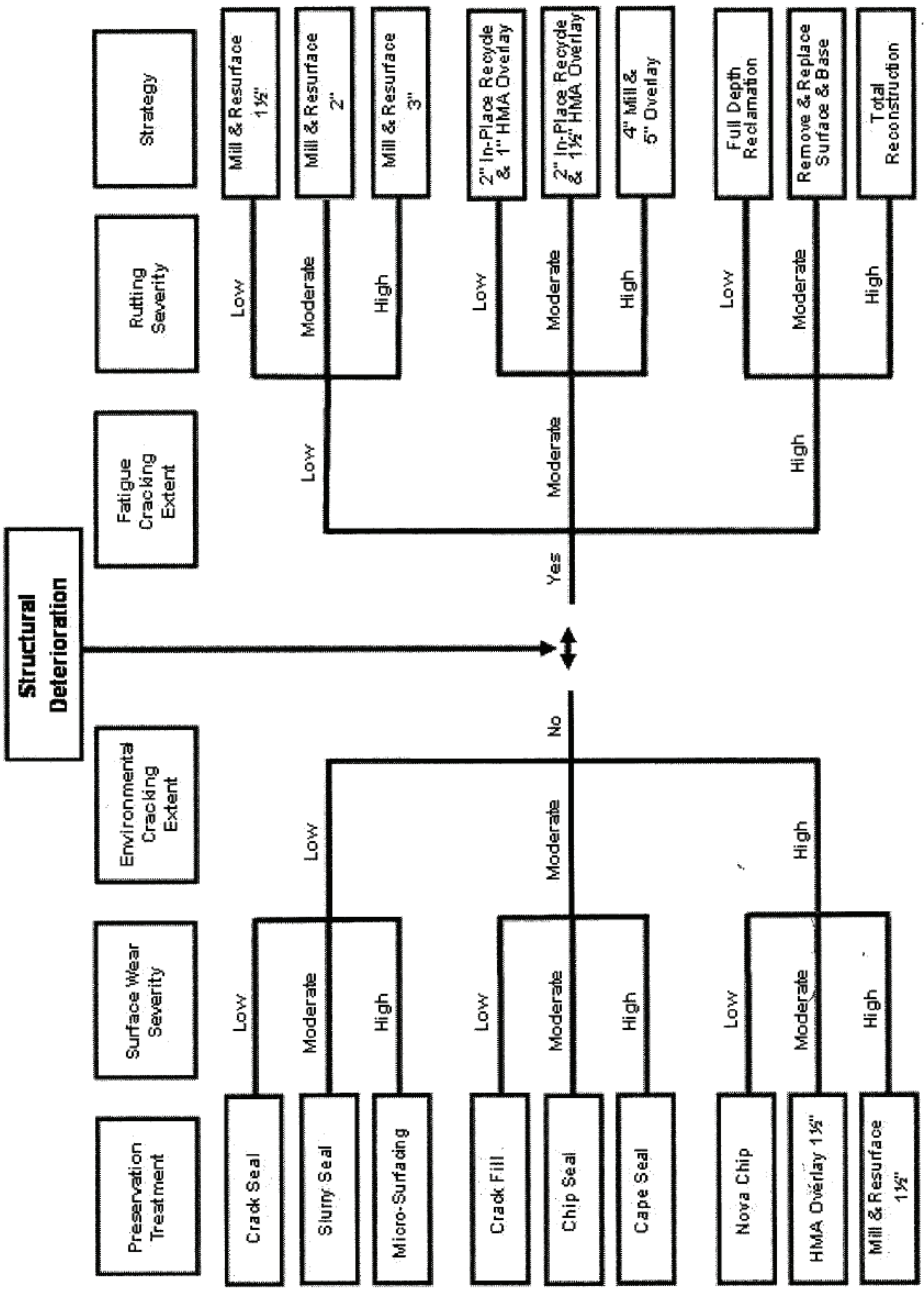

FIGURE 2-1 Decision tree example

TABLE 2-1 Benefits and limitations of decision tree

Benefits
• Makes use of existing experience
• Works well for local conditions
• Good as a project-level tool

Limitations
• Not always transferable between agencies
• Limits innovation or use of new treatments
• Hard to incorporate all factors
• Difficult to incorporate multiple pavement distress types
• Does not include life cycle costs and feasible alternatives analysis

2.3 TREATMENT TIMING AND SELECTION

2.3.1 COLORADO DEPARTMENT OF TRANSPORTATION (CDOT)

In addition to the work of Peshkin et. al. on optimal timing, other SHAs and individuals have begun exploring similar options. In Colorado, CDOT has developed a Best Practices Manual of Preventive Maintenance, which outlines optimal timing and distress scenarios for the placement of six treatment types, with half being for asphalt pavement and half for concrete pavement (4). The results are briefly discussed below.

CRACK FILLING

CDOT recommends that crack filling should take place as soon as cracks first appear, if possible. When cracks of lesser width are filled before they propagate, the effectiveness is much greater. TABLE 2-2 shows pavement candidates for crack filling, based on crack density. As the table illustrates, high density cracks (25 to 50 ft transverse length) are not recommended for crack filling at widths greater than 1/4 in.

TABLE 2-2 Pavement candidates for crack filling

		Density		
		Low, Transverse @ 75-100 ft (23 – 30 m) Longitudinal @ CL	Mod, Transverse @ 50 – 75 ft (15 – 23 m) Longitudinal @ Lane CLs	High, Transverse @ 25 – 50 ft (8 – 15 m) Longitudinal @ Lane CLs+
Description/ Width, inch	Slight, <1/4	1	2	3
	Intermediate, ¼ - ½	4	5	6
	Severe, > 1/2	7	8	9

1, 2, 3, 4, 5	Crack filling is appropriate
7 ,8	Crack filling is appropriate or Crack filling after routing
6,9	Crack filling is not recommended

Also important to crack filling is the timing before overlays or other treatments are be placed. CDOT recommends that cracks less than 1/8 in. width should be filled three months before placing an overlay. TABLE 2-3 shows the remaining conditions.

TABLE 2-3 Timing of crack fill prior to overlay

Crack Width, in (mm)	Time before overlay (months)
< 1/8 (3)	3
1/8 to1/4 (3 to 6)	6
¼ to 1/2 (6 to 12)	9
1/2 to 3/4 (12 to 19)	12

CHIP SEAL

CDOT reports that many of their districts use the chip seal as a preventive maintenance tool on a five-year cycle. However, they also report from interviews with maintenance personnel that some districts are still applying chip seals to pavements in conditions that are far beyond preventive maintenance repairs. It is stressed here that preventive maintenance techniques are intended for pavements already in good, acceptable condition and not pavements that may be severely deteriorated and contain structural damage.

THIN OVERLAYS

Pavement candidates for thin overlays should be in fair to good condition. Cracking and raveling should be of low to moderate severity. Ideally there should be no potholes, although they can be cut and patched with HMA overlays and still be effective.

JOINT RESEALING

CDOT bases the timing of PCC joint resealing operations on pavement conditions, environmental/climate conditions, and traffic conditions. Of interest in this report is pavement condition: CDOT considers average faulting, corner breaks, pumping, and spalling. They have benchmarks set up for these criteria to help determine an overall "pavement rating," and, coupled with the environmental condition rating and traffic rating, they use a decision table to determine which pavements should be resealed. See TABLE 2-4 and TABLE 2-5 for the decision-making process.

TABLE 2-4 Concrete pavement survey form

Seal Condition

	Low	Med	High
Water entering, % length	< 10	10-30	> 30
Stone intrusion	L	M	H
Seal Rating	Good	Fair	Poor

Environmental Conditions

Avg annual precip., mm	
Days ≤ 0°C	
Avg low / high temp, °C	
Climatic Region [a]	WF WNF DF DNF

Traffic Conditions

ADT (vpd); % Trucks			
Traffic Level [b]	Low	Med	High

Pavement Condition

	Low	Med	High
Expected Pavement Life, yrs.	> 10	5-10	< 5
Average faulting, mm	<1.5	1.5-3.0	>3.0
Corner breaks, % slabs	< 1	1-5	> 5
Pumping, % joints	< 1	1-5	> 5
Spalls >25 mm, % slabs	< 5	5-10	>10
Pavement Rating	Good	Fair	Poor

Current Joint Design

Sealant age, yrs	
Avg. sealant depth, mm	
Avg. joint width, mm	
Avg. joint depth, mm	
Max. joint spacing, m	

TABLE 2-5 Decision Tree for joint resealing

Sealant Rating[a]	Pvmt. Rating	Traffic Rating	Climatic Region			
			Freeze		Nonfreeze	
			Wet	Dry	Wet	Dry
Fair	Good	Low	Possibly	Possibly	Possibly	Possibly
Fair	Good	Med	Yes	Possibly	Possibly	Possibly
Fair	Good	High	Yes	Yes	Yes	Possibly
Fair	Fair	Low	Yes	Possibly	Possibly	Possibly
Fair	Fair	Med	Yes	Yes	Yes	Possibly
Fair	Fair	High	Yes	Yes	Yes	Possibly
Fair	Poor	Low	Possibly	Possibly	Possibly	Possibly
Fair	Poor	Med	Yes	Yes	Yes	Possibly
Fair	Poor	High	Yes	Yes	Yes	Yes
Poor	Good	Low	Yes	Possibly	Possibly	Possibly
Poor	Good	Med	Yes	Yes	Yes	Possibly
Poor	Good	High	Yes	Yes	Yes	Yes
Poor	Fair	Low	Yes	Yes	Yes	Possibly
Poor	Fair	Med	Yes	Yes	Yes	Yes
Poor	Fair	High	Yes	Yes	Yes	Yes
Poor	Poor	Low	Yes	Yes	Yes	Possibly
Poor	Poor	Med	Yes	Yes	Yes	Yes
Poor	Poor	High	Yes	Yes	Yes	Yes

DIAMOND GRINDING

Pavement candidates for diamond grinding should not have corner breaks, spalling, popouts, D-cracking, or alkali-silica reactions. Allowable distresses include low severity cracking, faults not exceeding ¼ in., and moderate to severe aggregate polishing. TABLE 2-6 and TABLE 2-7 show some important values that determine whether or not diamond grinding can occur on a given pavement.

TABLE 2-6 Trigger values for diamond grinding

	JPCP			JRCP			CRCP		
Traffic Volumes*	High	Med	Low	High	Med	Low	High	Med	Low
Faulting avg inches (mm)	0.08 (2)	0.08 (2)	0.08 (2)	0.16 (4)	0.16 (4)	0.16 (4)		N.A.	
IRI in/mi	63	76	90	63	76	90	63	76	90

*Volumes: High ADT>10,000; Med 3000<ADT<10,000; Low ADT <3,000

TABLE 2-7 Limit values for diamond grinding

	JPCP			JRCP			CRCP		
Traffic Volumes*	High	Med	Low	High	Med	Low	High	Med	Low
Faulting avg, inches (mm)	0.35 (9)	0.5 (13)	0.6 (15)	0.35 (9)	0.5 (13)	0.6 (15)		N.A.	
IRI in/mi	160	190	222	160	190	222	160	190	222

*Volumes: High ADT>10,000; Med 3000<ADT<10,000; Low ADT <3,000

2.3.2 MINNESOTA DEPARTMENT OF TRANSPORTATION (MNDOT)

Minnesota utilizes a decision table method for determining appropriate crack treatments and surface treatments (4). TABLE 2-8 shows surface treatments, and TABLE 2-9 shows crack treatments. These treatments are meant only for structurally sound pavements. As can be seen in the tables, some distresses, such as alligator (fatigue) cracking, have very limited options for treatment. Others, including polished aggregate, can be alleviated with a variety of different surface treatments.

TABLE 2-8 Minnesota treatments for surface defects

Type of Distress	Treatment						
	Patching	Fog seal	Seal coat	Double chip seal	Slurry seal	Micro-surfacing	Thin hot-mix overlay
Potholes							
Low severity	X						
Medium severity	X						
High severity	X						
Patch deterioration							
Low severity							
Medium severity	X						
High severity	X						
Surface Defects							
Rutting							
Low severity	X				X	X	
Medium severity	X				X	X	X
High severity	X					X	X
Shoving							
Low severity							
Medium severity	X						
High severity	X						
Bleeding							
Low severity			X	X	X	X	
Medium severity			X	X	X	X	
High severity			X	X	X	X	X
Polished aggregate							
Low severity			X	X	X	X	
Medium severity			X	X	X	X	X
High severity			X	X	X	X	X
Raveling							
Low severity		X					
Medium severity		X	X				
High severity	X		X	X	X	X	X

TABLE 2-9 Minnesota treatments for crack defects

Type of Crack	Treatment							
	Full-depth crack repair	Crack Repair w/sealing			Crack filling	Patching	Chip seal or seal coat	Thin hot-mix overlay
		Clean and Seal	Saw and seal	Rout and seal				
Alligator								
Low severity							X	
Medium severity						X		
High severity						X		
Transverse								
Low severity		X		X			X	
Medium severity		X		X	X		X	
High severity	X				X	X	X	
Longitudinal								
Low severity		X		X	X			
Medium severity	X	X		X	X			
High severity	X				X	X		
Block								
Low severity		X		X			X	
Medium severity							X	X
High severity					X	X		X
Reflection								
Low severity		X		X				
Medium severity		X		X	X			
High severity		X			X	X		X

2.3.3 CONNECTICUT DEPARTMENT OF TRANSPORTATION (CONNDOT)

Connecticut offers some guidance on appropriate pavement conditions for applying crack treatments. They use crack sealing for working cracks, which are defined as having a movement in excess of 3 millimeters. Transverse cracks are almost always categorized as working cracks. Crack filling is used for non-working cracks, or those for which there is little observed movement. Most longitudinal cracks are viewed as non-working (5).

When evaluating a roadway for crack treatment, Connecticut considers a pavement rating based on several performance and distress criteria. The criteria and associated weights are as follows:

- Cracking: 25 %
- Distortion: 15%
- Disintegration: 30%
- Drainage: 20 %
- Ride: 10 %

The rating is based on visual judgment and is therefore somewhat subjective (5).

2.3.4 SOUTH DAKOTA DEPARTMENT OF TRANSPORTATION (SDDOT)

The South Dakota Department of Transportation has developed a set of guidelines for selecting pavement treatments, making use of a selection matrix (6). The first step for South Dakota is to see if a treatment is applicable, considering factors such as extensive fatigue cracking, extensive patching requirements, high-severity potholes, and other indicators of structural damage. If any of these types of indicators are present, surface treatments are most likely not applicable. Once it has been decided that a treatment would apply, the next set of factors is considered through a decision matrix:

- Pavement condition
- Traffic volumes
- Project location
- Aggregate availability
- Equipment availability
- Cost effectiveness (benefit/cost ratio)

The most important factor for deciding an appropriate surface treatment is pavement condition. The decision matrix, shown in TABLE 2-10, identifies seven distresses that are addressed by various surface treatments.

TABLE 2-10 Decision matrix for surface treatments

Significant Distresses	Rural Roadway			Urban Roadway		
	Low Volume	**Med. Volume**	**High Volume**	**Low Volume**	**Med. Volume**	**High Volume**
Rutting 12-25 mm (0.5-1.0 in)	Microsurfacing Mill/Inlay and Thin Overlay	Microsurfacing Mill/Inlay and Thin Overlay	Microsurfacing Mill/Inlay and Thin Overlay	Microsurfacing Mill/Inlay and Thin Overlay	Microsurfacing Mill/Inlay and Thin Overlay	Microsurfacing Mill/Inlay and Thin Overlay
Bleeding > 10%	Microsurfacing Thin Overlay Sand Seal Chip Seal	Microsurfacing Thin Overlay Sand Seal Chip Seal	Microsurfacing Thin Overlay Chip Seal*	Microsurfacing Thin Overlay Sand Seal Chip Seal	Microsurfacing Thin Overlay Chip Seal*	Microsurfacing Thin Overlay Chip Seal*
Roughness (IRI) 100-160 in/mi	Sand Seal Chip Seal	Sand Seal Chip Seal	Chip Seal* Friction Course Thin Overlay	Sand Seal Chip Seal	Sand Seal Chip Seal Chip Seal*	Chip Seal* Friction Course Thin Overlay
Alligator Cracking 0-2% high 2-10% med 4-25% low	Scrub Seal Sand Seal Chip Seal	Sand Seal Chip Seal	Chip Seal* Friction Course Thin Overlay	Sand Seal Chip Seal	Sand Seal Chip Seal Chip Seal*	Chip Seal* Friction Course Thin Overlay
Long./Trans. Cracking 0-2% high > 2% med > 4% low	Scrub Seal Sand Seal Chip Seal	Sand Seal Chip Seal	Chip Seal* Friction Course Thin Overlay	Sand Seal Chip Seal	Sand Seal Chip Seal Chip Seal*	Chip Seal* Friction Course Thin Overlay
Poor Surface Friction SN < 40	Flush Seal Scrub Seal Sand Seal Chip Seal	Sand Seal Chip Seal	Chip Seal* Friction Course Thin Overlay	Sand Seal Chip Seal	Sand Seal Chip Seal Chip Seal*	Chip Seal* Friction Course Thin Overlay
Raveling 0-2% high 5-25% med 10-50% low	Flush Seal Scrub Seal Sand Seal Chip Seal	Sand Seal Chip Seal	Chip Seal* Friction Course Thin Overlay	Sand Seal Chip Seal	Sand Seal Chip Seal Chip Seal*	Chip Seal* Friction Course Thin Overlay
Oxidation (Asphalt Hardening)	Fog Seal Flush Seal Scrub Seal Sand Seal Chip Seal	Flush Seal Sand Seal Chip Seal	Chip Seal* Friction Course Thin Overlay	Sand Seal Chip Seal	Sand Seal Chip Seal Chip Seal*	Chip Seal* Friction Course Thin Overlay

Traffic levels are defined as follows:

- Low Volume: < 1,000 ADT
- Medium Volume: 1,000 to 2,500 ADT
- High Volume: > 2,500 ADT

* Indicates that one or more of the following additional modifications should be considered:

- Use of high-quality aggregate that may not be locally available
- Use of polymer-modified asphalt emulsion
- Application of a fog seal or flush seal over the chip seal
- Use of precoated chips
- Sweeping of chips before opening to traffic

In the decision matrix, the percentage associated with a severity level (high, medium, or low) indicates the degree that each is considered to be the significant, dominant distress in the pavement. As an example, if raveling is the controlling distress, the treatment options for a low-volume urban roadway are sand seal or chip seal. To then decide between these treatments, consider other factors such as aggregate and equipment availability, as previously mentioned (7).

The decision matrix also allows consideration of more than one distress type. The distresses are ordered in such a way that the feasible surface treatments provided for the controlling distress can also address all lower-level distresses. For example, the treatments listed in the roughness row are also capable of treating distresses in all the rows below, namely cracking, friction, oxidation, etc. (7).

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3 FIELD TEST METHOD FOR MEASURING SEAL COAT AGGREGATE AND EMULSION APPLICATION RATES

Equipment:

Field Balance
32 Gallon Trash Bin
5-gallon Bucket
1 SYD carpet, burlap, or canvas, cut into square
Long-handled Tongs/Hooks/Pliers
Garbage Bags
Marker
Rubber Gloves
Rolled Paper (for walk path)

Emulsion Measurement Method:

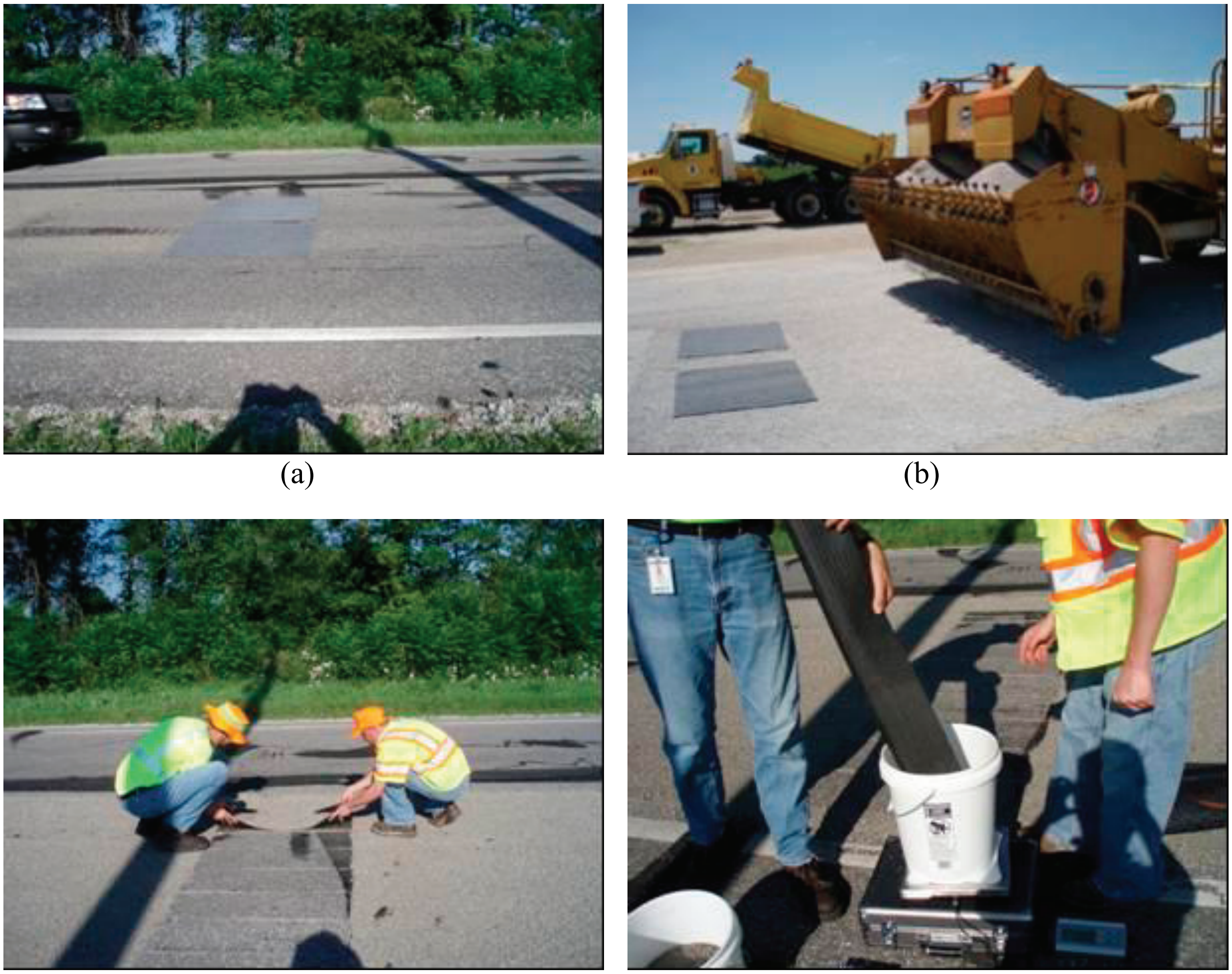
1. Label each carpet square.
2. Place a clean trash bag in the garbage container.
3. Weigh and record weights of each carpet square and the garbage container/bag.
4. Record location of test.
5. Lay 1 SYD carpet squares in line with distributor – 2 squares, roughly in the wheel paths.
6. Run distributor at application speed and emulsion rate over squares.
7. Place the ground paper on sprayed emulsion to approach the carpets.
8. Immediately pick up carpet square, garbage container, and weigh.
9. Record total weight.
10. Calculate and report application rate.
11. Reseal the area covered the carpets.

Aggregate Measurement Method:

1. Weigh and record weight of 5-gallon bucket.
2. Record location of test.
3. Lay 1 SYD burlap or canvas in line with aggregate spreader.
4. Run aggregate spreader at application speed and application rate over burlap.
5. Pick up burlap square, and deposit aggregate into 5-gallon bucket.
6. Weigh 5-gallon bucket and aggregate.
7. Record total weight.
8. Calculate and report application rate.
9. Sweep/reseal the area covered by the burlap square.

(a) (b) (c) (d)

FIGURE 3-1 Emulsion measurement procedure



(a) (b) (c) (d)

FIGURE 3-2 Aggregate measurement procedure

Worksheet for Field Determination of Emulsion Application Rate

Date: ______________ Location: ______________ Emulsion Type: ______________

Emulsion Density = 235 Gal/ton
Emulsion Density = 8.51 lb/gal

		A	B	C	D=C-(A+B)	D/8.51
Location	**Carpet Label**	**Carpet Weight (lbs)**	**Garage Bin + Bag (lbs)**	**Total Weight with Emulsion (lbs)**	**Weight of Emulsion (lbs)**	**Application Rate (gal/SYD)**

Revised 1/1/08

Worksheet for
Field Determination of Aggregate Application Rate

Date: ______________ Location: ____________

Aggregate Type: ____________

	A	B	C=B-A	C
Location	**5 Gallon Bucket Weight (lbs)**	**Total Weight with Aggregate (lbs)**	**Weight of Aggregate (lbs)**	**Application Rate (lb/SYD)**

4 INDIANA DEPARTMENT OF TRANSPORTATION OFFICE OF MATERIALS MANAGEMENT QUANTITY DETERMINATION OF ASPHALT MATERIALS AND AGGREGATES FOR SEAL COATS, ITM NO. 579-08P

1.0 SCOPE.
1.1 This method covers the procedure for determination of the quantity of asphalt materials and aggregates in seal coat applications.
1.2 The values stated in either acceptable English or SI metric units are to be regarded separately as standard, as appropriate for a specification with which this ITM is used. Within the text, SI metric units are shown in parentheses. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other, without combining values in any way.
1.3 This ITM may involve hazardous materials, operations, and equipment and may not address all of the safety problems associated with the use of the test method. The user of the ITM is responsible for establishing appropriate safety and health practices and determining the applicability of regulatory limitations prior to use.

2.0 TERMINOLOGY. Definitions for terms and abbreviations shall be in accordance with the Department's Standard Specifications, Section 101.

3.0 SIGNIFICANCE AND USE. This ITM shall be used to determine the quantity of asphalt materials and aggregates required for a seal coat application.

4.0 APPARATUS.
4.1 Traffic control equipment and personnel to be furnished by the District
4.2 Pneumatic tire roller or vehicle
4.3 Yield test scales
4.4 Buckets as needed
4.5 5-gallon can with pour spout
4.6 Stove
4.7 0.5 yd_2 template consisting of a 30 x 48 in. metal plate with an 18 x 36 in. opening, ITM 579-08P, Revised 1/1/08
4.8 Aggregate shaker box approximately 18 in. square and 3 in. deep with a 1-in. open slot in the bottom along one side. A piece of 1/2-in. opening screen cloth shall extend under this open slot.
4.9 Squeegee and brushes as needed
4.10 Thermometer, range 50 to 300°F

5.0 MATERIALS.
5.1 A minimum of 5 gallon of the asphalt material that is to be used on the project.
5.2 A minimum of 75 lb. of the aggregate that is to be used on the project.

6.0 PROCEDURE.
6.1 Select a location typical of the project. Sites shall be selected to prevent tracking of asphalt from one test area to another. On the mainline, select a wheel path.

6.2 Set up traffic control.
6.3 Heat the asphalt material according to the following:

Asphalt	Temperature
AE-90, AE-150	140 – 160°F
RS-2	120 – 140°F
RC-800	230 – 250°F
RC-3000	250 – 275°F

6.4 Clean and prepare surface as necessary.
6.5 Place the template on the selected site.
6.6 Weigh the aggregate. The quantity shall be within the values listed in TABLE 1.
6.7 Weigh the heated bituminous material. The quantity shall be within the values listed in TABLE 1.
6.8 Apply the liquid asphalt uniformly on the test area by pouring and using the squeegee, and brush to distribute.
6.9 Place the aggregate uniformly on the test area with the shaker box.
6.10 Remove the template.
6.11 Roll the test area with the pneumatic tire roller or the vehicle tire.
6.12 Repeat the above procedure by varying the quantities of asphalt material and aggregates until the desired result is obtained.

Rate of Application per Square Yard		
Aggregate Size No.	**Cover Aggregate, lb**	**Asphalt Material gal at 60°F**
23, 24	12 – 15	0.12 – 0.16
12	14 – 17	0.29 – 0.33
11	16 – 20	0.36 – 0.40
9	28 – 32	0.63 – 0.68

6.13 Remove traffic control. If test areas are on the mainline, removal of traffic control shall be delayed until the asphalt material has cured sufficiently to hold the aggregate without displacement.
6.14 Return to location the next day, broom off and weigh the excess aggregate for shoulder locations. This procedure is not required for mainline locations.
6.15 Make a visual inspection of the test areas for asphalt content and aggregate retention. Further visual inspection shall be made until the seal coat operation starts. The test area shall appear to be one aggregate particle in depth, and the particle shall be embedded in the asphalt material 50-70%.

7.0 REPORT.
7.1 The quantity of asphalt material and aggregate for the seal coat shall be reported on the appropriate form for use on the proposed project. If there are different pavement sections on the project, several test sections may be necessary.

5 SCRUB SEAL BROOM (MISSOURI)