JOINT TRANSPORTATION RESEARCH PROGRAM

INDIANA DEPARTMENT OF TRANSPORTATION
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Field Handbook for Maintenance and Preservation Treatments of Concrete Pavements

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SPR-4601 • Report Number: FHWA/IN/JTRP-2024/07 • DOI: 10.5703/1288284317725

RECOMMENDED CITATION

Mirzahosseini, M., Olek, J., Abraham, D. M., Ram, P., & Smith, K. (2024). *Field handbook for maintenance and preservation treatments of concrete pavements* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2024/07). West Lafayette, IN: Purdue University. https://doi.org/10.5703/1288284317725

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NOTICE

ACKNOWLEDGEMENTS

The research team acknowledges the support and guidance provided by the project's Study Advisory Committee (SAC) members during the course of the study, for providing access to photographs depicting pavement distresses and maintenance and preservation (M&P) strategies used to address pavement distresses, and for their reviews of several drafts of the Guidebook. The SAC members included Rusty Fowler, INDOT; Tommy Nantung, INDOT; Mike Byers (ACPA), Terry Burris (Milestone Contractors); Rick Baumer (Primco, Inc.) and John Leckie (ACPA). Thanks to John Roberts, IGGA; Kumar Dave, INDOT; Dan King, CPTech Center; and Jeff Uhlmeyer, QES for providing photographs related to M&P strategies used to address distresses in concrete pavements.

The research team extends its gratitude and appreciation to representatives from the following State Departments of Transportation (DOT)Alabama DOT, Arizona DOT, Arkansas DOT, Connecticut DOT, Delaware DOT, Florida DOT, Idaho DOT, Indiana DOT, Kansas DOT, Kentucky Transportation Cabinet, Louisiana DOT, Michigan DOT, Minnesota DOT, Missouri DOT, Montana DOT, Nebraska DOT, North Carolina DOT, Pennsylvania DOT, Rhode Island DOT, Texas DOT, North Dakota DOT, Ohio DOT, South Dakota DOT, Utah DOT, Virginia DOT, Washington DOT, and Wyoming DOT. These representatives participated in the survey and/or interviews that were used to gain insight about maintenance and preservation (M&P) strategies used by State Transportation Agencies across the US.

Technical Report Documentation Page

1. Report No. FHWA/IN/JTRP-2024/07	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Field Handbook for Maintenance and Preservation Treatments of Concrete Pavements		5. Report Date July 2024 6. Performing Organization Code
7. Author(s) Mohammadreza Mirzahosseini, Jan Olek, Dulcy M. Abraham, Prashant Ram, and Kurt Smith		8. Performing Organization Report No. FHWA/IN/JTRP-2024/07
9. Performing Organization Name and Address Joint Transportation Research Program Hall for Discovery and Learning Research (DLR), Suite 204 207 S. Martin Jischke Drive West Lafayette, IN 47907		10. Work Unit No. 11. Contract or Grant No. SPR-4601
12. Sponsoring Agency Name and Address Indiana Department of Transportation (SPR) State Office Building 100 North Senate Avenue Indianapolis, IN 46204		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.		

16. Abstract

Information related to maintenance and preservation (M&P) treatments of Portland cement concrete pavement (PCCP) has not been uniformly presented across various Indiana Department of Transportation (INDOT) maintenance-related documents, including INDOT Standard Specifications and the INDOT Design Manual. Since this data is scattered across different documents and frequently incomplete, it is often challenging for field personnel to obtain consistent information which can assist in making decisions related to selection of treatments that can benefit the service life of concrete pavements. To address this gap, the SPR-4601 guidebook was developed to provide succinct descriptions of common distresses and failures observed in concrete pavements, and guidance related to routine maintenance and preservation (M&P) practices. Having consistent and comprehensive information should aid in implementing more uniform M&P practices and help to ensure the quality of the concrete pavement assets over their service life.

17. Key Words	18. Distribution Statement
maintenance and preservation (M&P) treatments, concrete pavements, distresses, distress severity levels, continuously reinforced concrete pavements (CRCP), jointed plain concrete pavements (JPCP), jointed reinforced concrete pavements (JRCP), crack sealing, joint resealing, full-depth patching, partial-depth patching, cross-stitching, retrofit load transfer (RLT), diamond grinding, diamond grooving, undersealing, post-construction evaluation	No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	107	

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EXECUTIVE SUMMARY

Pavement preservation treatments cover the early years of a pavement's service life (i.e., the period of time when it is still in fair to good condition) and include both maintenance and minor rehabilitation activities. When properly implemented, pavement preservation treatments provide several benefits, including improvement of pavement condition, cost savings due to decreased user costs and lower vehicle operating costs, higher customer satisfaction, and increased safety. They may also enhance sustainability, especially when performed using low-cost, low-environmental-impact treatments that maintain or extend the life of the pavement.

At present, information related to maintenance and preservation (M&P) treatments of Portland cement concrete pavement (PCCP) is not coordinated, nor is it uniform across various Indiana Department of Transportation (INDOT) maintenance-related documents, including INDOT Standard Specifications, and the INDOT Design Manual. Since the data is scattered across different documents and frequently not complete, it is often challenging for field personnel to obtain consistent information that can assist in making treatment decisions that can benefit the service life of concrete pavements. To address this gap, this guidebook first provides succinct descriptions of common distresses, each at different severity levels, that are observed in concrete pavements. Then, for each severity level, the guidebook describes recommended M&P treatment option(s), along with pictorial examples of acceptable and poorly completed repair jobs. Furthermore, the guidebook also discusses common issues that a contractor or inspector may encounter in the field during and after the implementation of specific M&P strategies and the corresponding recommended solutions. Finally, the guidebook presents a brief overview of emergency repair (stopgap) measures and possible approaches for evaluating the performance of the repaired concrete pavements. There are two versions of the guidebook: the print version and the electronic version. In the electronic version of the guidebook, all photographs, specifications, and standard drawings are linked to the citation of the source from which they have been collected.

List of Recommended Maintenance and Preservation (M&P) Strategies

	Concrete Pavement Preservation Treatments								
Distress	**Undersealing (Slab Stabilization)**	**PDP**	**FDP**	**RLT (DBR)**	**Cross Stitching**	**Diamond Grinding**	**Diamond Grooving**	**Joint Resealing/ Repair**	**Crack Sealing**
Corner Breaks	–	–	✓	–	–	–	–	–	✓[a]
"D" Cracking	–	–	✓	–	–	–	–	✓	–
Longitudinal Cracking	–	–	✓	–	✓	–	–	–	✓
Transverse Cracking	–	–	✓	✓	–	–	–	–	✓
Joint Seal Damage	–	–		–	✓[b]	–	–	✓	–
Joint Spalling	–	✓	✓	–	–	–	–	–	–
Map Cracking, Crazing, Scaling	–	–	✓[c]	–	–	–	–	–	–
Polishing/Low Friction	–	–	–	–	–	✓	✓	–	–
Popouts	–	–	–	–	–	✓[d]	–	–	–
Blowup	–	–	✓	–	–	–	–	–	–
Faulting	–	–	–	✓	–	✓	–	–	–
Lane-to-Shoulder Dropoff	It can be addressed by rehabilitation/reconstruction strategies.								
Lane-to-Shoulder Separation	–	–	–	–	✓	–	–	✓	–
Patch/Patch Deterioration	–	–	✓	–	–	–	–	–	–
Water Bleeding and Pumping	✓	–	–	✓	–	–	–	✓	✓
Transverse Construction Joint Deterioration	–	✓	✓	–	–	–	–	–	✓
Punchouts	–	–	✓	–	–	–	–	–	–

Note: Many of these treatments are commonly done in combination, in order to fully address the existing pavement deficiencies.

[a] Crack with limited vertical movements.

[b] For longitudinal joint seal damage only.

[c] When map cracking/scaling, due to ASR, extends over the entire area of the PCC pavement of high-priority highways with high-traffic volume.

[d] If popouts density is ≥ 3 popouts/yd^2.

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GUIDEBOOK ORGANIZATION

This guidebook consists of the following six main sections.

- *Chapter 1: Introduction.* This chapter contains a brief background on the motivation for the development of the *INDOT Concrete Pavement Maintenance and Preservation Guide*, presents the Pavement Maintenance and Preservation (M&P) concepts and reviews the organization of the guidebook.
- *Chapter 2: Concrete Pavement Distresses.* This chapter contains descriptions of types of distress encountered in concrete pavements and their causes. This material has been adopted from the *Long-Term Pavement Performance (LTPP) Manual* (FHWA, 2014). The provided information includes the following: a representative picture (or a schematic drawing) of the distress, instruction for measurements of the distresses, descriptions of distress severity level (accompanied by representative picture), criteria for identifying the severity levels, and recommended M&P option(s) for different severity levels along with the pictorial examples of acceptable and poorly completed repair jobs. These are additionally identified with either "thumbs-up" (for good repair) or "thumbs-down" (for poor repair) icons. Please note that due to the limited availability of road distresses photographs, some of the images used in this guidebook show similar distresses encountered on airfield pavements.
- *Chapter 3: Concrete Pavement M&P Strategies*. This chapter covers various aspects of M&P strategies as applied to concrete pavements, including materials and design considerations, construction considerations (such as traffic and weather conditions), detailed construction steps, and related INDOT standards specification(s) and standard drawing(s).
- *Chapter 4: Troubleshooting and Stopgap Measures*. This chapter covers the lists of common issues that a contractor or inspector may encounter in the field during and after the implementation of specific M&P strategies, and corresponding recommended solutions. A brief overview of emergency repair (stopgap) measures is also presented in this chapter.
- *Chapter 5: Post-Construction Activities.* This chapter presents possible approaches for evaluating the performance of the repaired concrete pavements.
- *Chapter 6: Summary.* This chapter contains a table summarizing M&P approaches recommended for different types of distresses.

CHAPTER 1: DOCUMENT OVERVIEW

1.1 Introduction

At present, information related to maintenance and preservation (M&P) treatments of Portland cement concrete pavement (PCCP) is not coordinated, nor is it uniform across various Indiana Department of Transportation (INDOT) maintenance-related documents, including INDOT Standard Specifications, and the INDOT Design Manual. Since the data is scattered across different documents and frequently not complete, it is often challenging for field personnel to obtain consistent information which can assist in making decisions related to selection of treatments that can benefit the service life of concrete pavements. To address this gap, this guidebook provides succinct descriptions of common distresses and failures observed in concrete pavements, and provides guidance related to routine maintenance and preservation activities such as performance monitoring and functional concrete pavement repair. Having consistent and comprehensive information will lead to more uniform M&P practices that will help to ensure the quality of the concrete pavement asset over its service life.

1.2 Pavement Maintenance and Preservation (M&P) Concepts

As defined by the Federal Highway Administration (FHWA) Pavement Preservation Expert Task Group (ETG) (and reiterated in the Moving Ahead for Progress in the 21st Century Act, MAP-21), pavement preservation is "*a program employing a network level, long-term strategy that enhances pavement performance by using an integrated, cost-effective set of practices that extends pavement life, improves safety and meets motorist expectations.*" A general schematic illustrating the relative timing of pavement maintenance, preservation, and rehabilitation activities is shown in Figure 1.1. The preservation component is represented by the area of the graph that covers the early years of the service life when the pavement is in fair to good condition and includes both maintenance and minor rehabilitation activities.

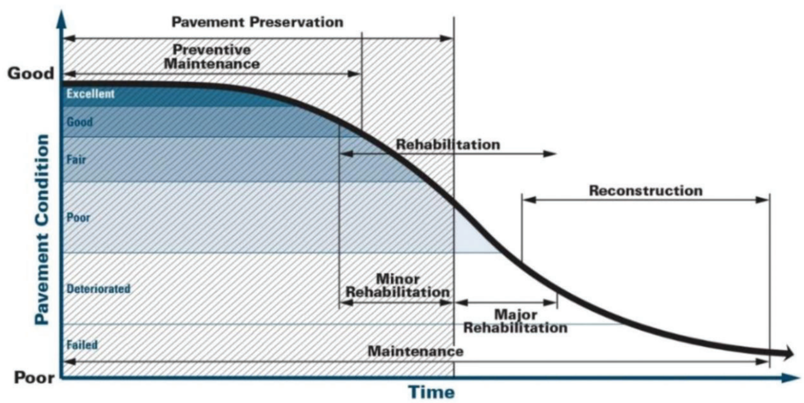


Figure 1.1 Representation of pavement preservation, rehabilitation, and reconstruction definitions (as cited in Smith et al., 2014; original image from Peshkin et al., 2011).

1.2.1 Benefits of Pavement Preservation Treatments

When properly implemented, pavement preservation treatments provide several benefits, including the following (Smith et al., 2022).

- *Higher customer satisfaction:* A well-implemented preservation treatment program provides safer roads, reduces traffic delays, and results in a higher level of functional performance in terms of improved smoothness and reduced noise.
- *Improved pavement condition:* Pavements subjected to effective preservation treatments stay in a state of good condition for longer periods, thereby delaying the need for major rehabilitation and reconstruction activities.
- *Cost savings:* Several agencies have reported cost savings from using preservation strategies. Savings are realized in the form of (a) extending service lives using less expensive treatments, (b) decreased user costs resulting from reduced traffic delays, (c) lower vehicle operating costs (due to smoother roads), and lower crash-related costs.
- *Increased safety:* Safety is one of the fundamental expectations of road users. Pavements in conditional condition are generally smoother and contribute to safer operating environments.
- *Enhanced sustainability:* Pavement preservation activities are inherently sustainable in that they often employ low-cost, low-environmental-impact treatments to maintain or extend the life of pavement structures, thereby conserving energy and virgin materials while reducing greenhouse gas emissions. In addition to reducing environmental impacts, preservation activities also offer societal benefits such as reduced cost, increased safety, and reduced noise.

1.2.2 Selection of Preservation Treatments

For concrete pavement structures, the selection of appropriate preservation treatments is largely driven by the existing level of distress and by prevailing pavement conditions. Each of the PCCP treatments is directed at one or two primary deficiencies, and while they can be used as stand-alone treatments in many cases, a pavement preservation project often will employ several of the treatments to fully restore the serviceability of the pavement and to minimize the potential for the deficiencies to redevelop. When multiple concrete pavement preservation treatments are used concurrently, it is important that they be performed in a logical progression to ensure the effectiveness of each treatment while not diminishing or compromising the effectiveness of any previously placed treatment. A typical sequence of M&P treatments is shown in Figure 1.2. Note that the specifics regarding M&P strategies can be found in Chapter 3 of the guidebook.

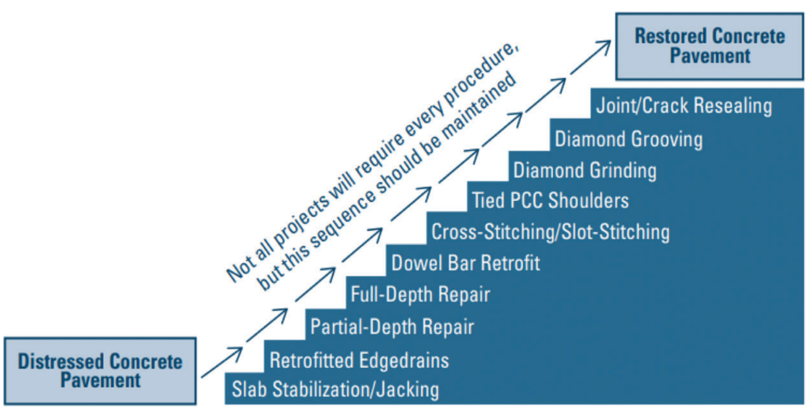


Figure 1.2 A typical sequence of maintenance and preservation treatments as part of concrete pavement restoration (ACPA, 2008).

CHAPTER 2: CONCRETE PAVEMENT DISTRESSES

2.1 Introduction

This chapter provides information about concrete pavement distresses. INDOT's concrete pavement network consists of three main pavement types: Jointed Plain Concrete Pavement (JPCP), Jointed Reinforced Concrete Pavement (JRCP), and Continuously Reinforced Concrete Pavement (CRCP). Although distress types are fairly similar across different pavement types, there are certain distresses that are observed only on a specific type of concrete pavement. Table 2.1 shows the list of distresses for JPCP/JRCP and CRCP based on the LTPP Distress Identification Manual (FHWA, 2014).

TABLE 2.1
Distresses of JPCP/JRCP and CRCP (FHWA, 2014)

Distress Type	Pavement Type	
	JPCP/JRCP	CRCP
Corner Breaks	✓	–
Durability Cracking ("D" Cracking)	✓	✓
Longitudinal Cracking	✓	✓
Transverse Cracking	✓	✓
Transverse Joint Seal Damage	✓	–
Longitudinal Joint Seal Damage	✓	✓
Spalling of Longitudinal Joints	✓	✓
Spalling of Transverse Joints	✓	–
Map Cracking	✓	✓
Scaling	✓	✓
Polished Aggregate	✓	✓
Popouts	✓	✓
Blowups	✓	✓
Faulting of Transverse Joints and Cracks	✓	–
Lane-to-Shoulder Dropoff	✓	✓
Lane-to-Shoulder Separation	✓	✓
Patch/Patch Deterioration	✓	✓
Water Bleeding and Pumping	✓	✓
Transverse Construction Joint Deterioration	–	✓
Punchouts	–	✓

In this chapter, each type of concrete pavement distress is introduced by presenting a representative picture (or a schematic drawing) of that distress. This is followed by the description of the distress and common causes for the distress (adopted from the LTPP manual). Additionally, the severity levels of distresses, accompanied by representative pictures and criteria for identifying the severity levels, are presented. Finally, appropriate M&R option(s) for each severity level are proposed.

2.1.1 Distresses Encountered in Jointed Plain Concrete Pavements (JPCP) and Jointed Reinforced Concrete Pavements (JRCP)

- Corner Breaks
- Durability Cracking ("D" Cracking)
- Longitudinal Cracking
- Transverse Cracking
- Joint Seal Damage
- Spalling of Joints
- Map Crack and Sealing
- Polished Aggregate
- Popouts
- Blowups
- Faulting of Transverse Joints and Cracks
- Lane-to-Shoulder Dropoff
- Lane-to-Shoulder Separation
- Patch/Patch Deterioration
- Water Bleeding and Pumping

2.2 Corner Breaks

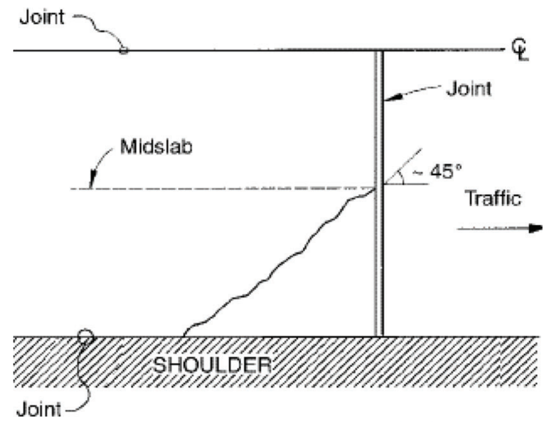
2.2.1 Description and Causes

A corner break is a full depth crack that intersects the joints of the Portland cement concrete (PCC) slab near the corners, at approximately 45-degree angle with respect to the direction of traffic. The length of the sides of the broken piece can range from between 1 ft. to one-half the width of the slab at each side of the corners.

The primary causes of corner breaks include load repetitions in conjunction with a loss of support, poor load transfer across the joint, and curling and warping stresses.

Measurement

Record the number of corner breaks at each severity level.



Corner break on JPCP/JRCP (FHWA, 2014).

2.2.2 Severity Levels and Maintenance and Preservation Options

Low Severity: Distress Criteria

- A crack is not spalled for more than 10% of its length.
- There is no measurable faulting.
- The broken-off corner remains in one piece.

Low Severity: Maintenance & Preservation Options

- Do nothing if the crack is less than 0.125 in. wide.
- Consider sealing the cracks with the widths greater than 0.125 in. providing they are not spalled or otherwise deteriorated.

Moderate Severity: Distress Criteria

- Some spalling along more than 10% of the total length of the crack and the crack width is equal to or greater than 0.125 in.
- Faulting of crack or joint < 0.5 in.
- The broken-off corner remains in one piece.

Moderate Severity: Maintenance & Preservation Options

- Crack sealing.
- Full depth patch (FDP).[a]

High Severity: Distress Criteria

- Extensive spalling along more than 10% of the total length of the crack.
- Faulting of the crack or joint ≥ 0.5 in.
- The broken-off corner is separated into two or more pieces.

High Severity: Maintenance & Preservation Options

- Full depth patch (FDP).[a]

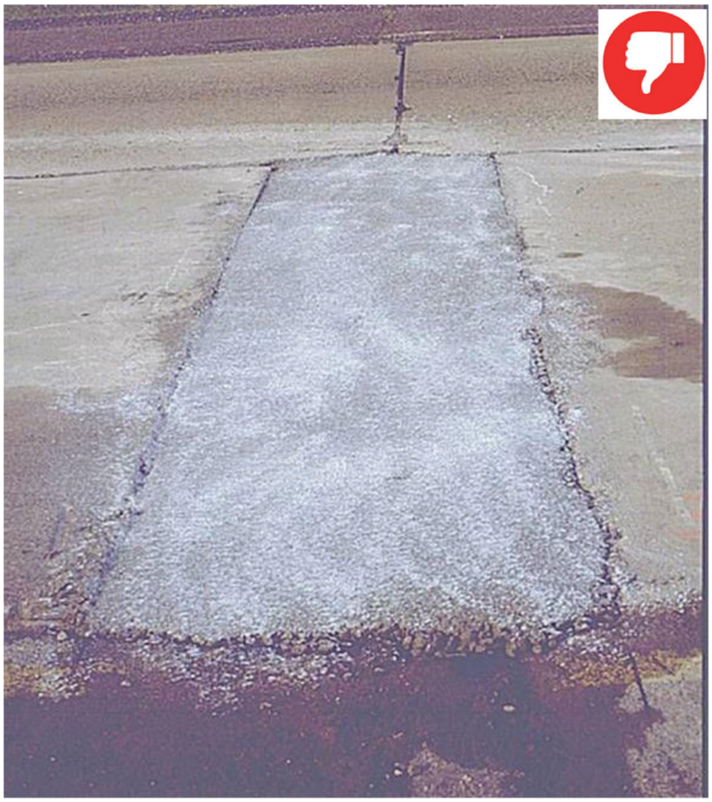
[a] If multiple corner breaks occur on a slab or there are corner breaks on multiple slabs, it may be more cost-effective to do slab replacements instead of several FDP jobs.

© Photos by Applied Pavement Technology (APTech)

Sealed low-severity corner break (© Photo by Applied Pavement Technology (APTech)).

Improper use of asphalt mix patch to repair corner break (© Photo by Applied Pavement Technology (APTech)).

Properly installed full depth patch and associated joints (© Photo by Applied Pavement Technology (APTech)).



Poorly installed full depth patch (not flush with the surface, jagged joints, and nonuniform application of curing compound) (© Photo by Applied Pavement Technology (APTech)).

2.3 Durability Cracking ("D" Cracking)

2.3.1 Description and Causes

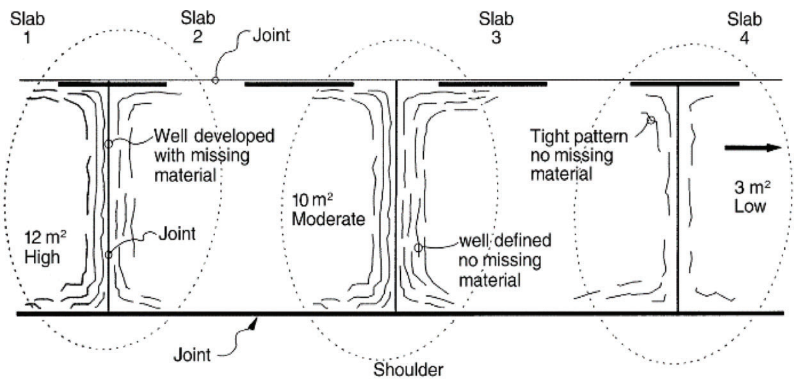
Durability cracking (or "D" cracking) manifests itself as a network of closely spaced, crescent-shaped hairline cracks parallel to joints. Cracks originate near the joints and spread outward toward the center of the slab.

"D" cracking is caused by freeze-thaw deterioration of critically saturated aggregate, often as a result of pavement being in contact with wet (water-bearing) base and subbase layers.

Dark coloring can usually be seen around the fine cracks. This type of cracking may eventually lead to the disintegration of the concrete within 1 to 2 ft. of the affected joint or crack.

Measurement

- For each severity level, record the number of slabs with "D" cracking and the square footage of the affected area.
- The slab and affected area severity rating are based on the highest severity level present for at least 10% of the affected area.



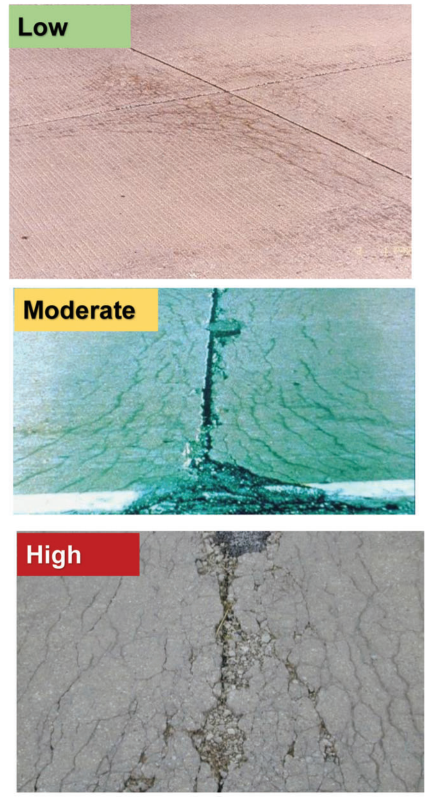
"D" cracking on JPCP/JRCP (FHWA, 2014).

2.3.2 Severity Levels and Maintenance and Preservation Options

Low Severity: Distress Criteria
• "D" cracks are tight. • No loose or missing pieces, no evidence of previous patching.
Low Severity: Maintenance & Preservation Options
• Do nothing but monitor for future repairs. • Joint resealing.

Moderate Severity: Distress Criteria
• "D" cracks are well-defined. • Some small pieces are loose or have been displaced.
Moderate Severity: Maintenance & Preservation Options
• Full depth patch (FDP).

High Severity: Distress Criteria
• "D" cracking has a well-developed pattern. • A significant amount of loose or missing material. • Displaced pieces up to 1 $ft.^2$ may have been patched.
High Severity: Maintenance & Preservation Options
• Full depth patch (FDP).



(© Photos by Applied Pavement Technology (APTech))

A well-sealed joint that helps reduce the ingress of moisture which may exacerbate “D” cracking (Zhang, 2013).

Progression of “D” cracking especially near the slab corner (Zhang, 2013).

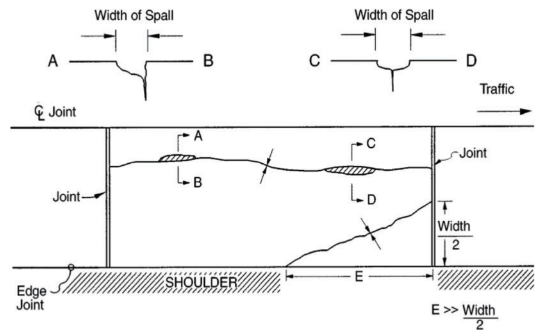
2.4 Longitudinal Cracking

2.4.1 Description and Causes

Longitudinal cracking is characterized by the presence of one or more cracks that are predominantly parallel to the pavement centerline. This kind of cracking is usually caused by a combination of accumulation of load-related stresses, curling stresses, and shrinkage stresses.

Measurement

- Record the length (in feet) of longitudinal cracking at each severity level.
- Record the length (in feet) of longitudinal cracking with sealant in good condition (i.e., greater than 3 ft. of continuous sealant is in good condition) at each severity level.
- When a crack, with a length of at least 1 ft., is within 1 ft. of a joint, and runs for only a portion of the joint's length, it should be recorded as a spall.
- If a crack is farther than 1 ft. from the joint, it should be recorded as a longitudinal crack.



Longitudinal cracking on JPCP/JRCP (FHWA, 2014).

2.4.2 Severity Levels and Maintenance and Preservation Options

Low Severity: Distress Criteria

- Cracks widths < 0.125 in.
- Cracks have no spalling and there is no measurable faulting.
- Cracks are well-sealed; the width cannot be determined.

Low Severity: Maintenance & Preservation Options

- Do nothing but monitor for future repairs.

Moderate Severity: Distress Criteria

- Crack widths ≥ 0.125 in. and < 0.25 in.
- Length of spall along the crack < 3 in. or faulting < 0.25 in.

Moderate Severity: Maintenance & Preservation Options

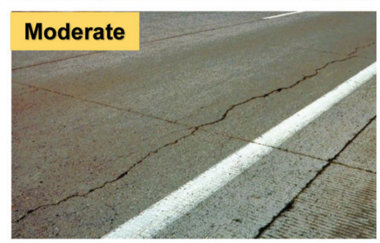
- Crack sealing.
- Retrofit load transfer (RLT) if there is limited spalling.

High Severity: Distress Criteria

- Crack widths ≥ 0.25 in.
- Length of spall along the crack ≥ 3 in. or faulting ≥ 0.25 in.

High Severity: Maintenance & Preservation Options

- Crack sealing if there is limited spalling.
- Full depth patch (FDP).



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Poorly sealed longitudinal crack (© Photo by Applied Pavement Technology (APTech)).

Well-sealed longitudinal crack repaired by cross-stitching (ACPA, n.d.).

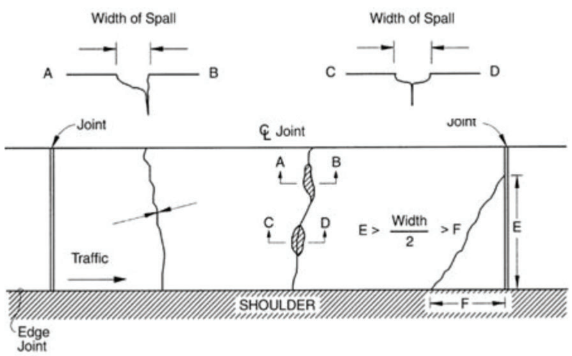
2.5 Transverse Cracking

2.5.1 Description and Causes

Transverse cracking is characterized by the presence of one or more cracks that are predominantly perpendicular to the pavement centerline. This kind of cracking is usually caused by a combination of load-related stresses, curling stresses, and shrinkage stresses.

Measurement

- Record the number and the length of transverse cracks at each severity level.
- Record the total length (in feet) of the transverse crack at the highest severity level present for at least 10% of the crack length.
- Also record the length (in feet) of transverse cracking at each severity level where the sealant is in good condition for at least 90% of the crack length.
- When a crack, with a length of at least 1 ft., is within 1 ft. of a transverse joint and runs for only a portion of the joint's length, it should be recorded as a spall.
- If a crack is farther than 1 ft. from the transverse joint, it should be recorded as a transverse crack.



Transverse cracking on JPCP/JRCP (FHWA, 2014).

2.5.2 Severity Levels and Maintenance and Preservation Options

Low Severity: Distress Criteria
• Cracks widths < 0.125 in. • Cracks have no spalling and there is no measurable faulting. • Cracks are well-sealed; the width cannot be determined.
Low Severity: Maintenance & Preservation Options
• Do nothing but monitor for future repairs.

Moderate Severity: Distress Criteria
• Crack widths ≥ 0.125 in. and < 0.25 in. • Length of spall along the crack < 3 in. or faulting < 0.25 in.
Moderate Severity: Maintenance & Preservation Options
• Crack sealing. • Retrofit load transfer (RLT) if there is limited spalling.

© Photos by Applied Pavement Technology (APTech)

High Severity: Distress Criteria
• Crack widths ≥ 0.25 in. • Length of spall along the crack ≥ 3 in. or faulting ≥ 0.25 in.
High Severity: Maintenance & Preservation Options
• Crack sealing if there is limited spalling. • Full depth patch (FDP).

(Marko, 2018)

Crack sealing and retrofit load transfer across a moderate-severity transverse crack (Smith et al., 2022).

2.6 Joint Seal Damage

2.6.1 Description and Causes

Joint seal damage is any sealant condition that enables incompressible materials or a significant amount of water to infiltrate the joint from the surface. Joint seal damage is typically caused by extrusion, hardening, adhesive failure (bonding), cohesive failure (splitting) or complete loss of sealant leading to intrusion of foreign material into the joint or grass or weed growth in the joint.

2.6.2 Transverse Joint Seal Damage

Measurement

- Indicate whether the transverse joints have been sealed (yes or no). If yes, record the number of sealed transverse joints at each severity level.
- *Note:* The portion of a joint with spot patching in good condition (i.e., no defects) is considered to be well-sealed, and patches are rated separately.

2.6.3 Severity Levels and Maintenance and Preservation Options

Low Severity: Distress Criteria
• Seal damage visible along less than 10% of the length of the joint.
Low Severity: Maintenance & Preservation Options
• Do nothing but monitor for future repairs.

Moderate Severity: Distress Criteria
• Seal damage visible along 10 to 50% of the length of the joint.
Moderate Severity: Maintenance & Preservation Options
• Joint resealing.

High Severity: Distress Criteria
• Seal damage exists along more than 50% of the length of the joint.
High Severity: Maintenance & Preservation Options
• Joint resealing.

© Photos by Applied Pavement Technology (APTech)

2.6.4 Longitudinal Joint Seal Damage

Measurement

- Record the number of longitudinal joints that are sealed.
- Record the total length (in feet) of sealed longitudinal joints with joint seal damage.
- Individual occurrences are recorded only when they are at least 3 ft. long.
- *Note:* The portion of a joint with spot patching in good condition (i.e., no defects) is considered to be well sealed, and patches are rated separately.

2.6.5 Severity Levels and Maintenance and Preservation Options

Severity Level
The LTTP manual does not define severity levels for longitudinal joint seal damage.
Maintenance & Preservation Options
Joint resealing. Cross-stitching in case of separation and/or poor load transfer.

Improperly installed joint sealant (voids and discontinuities in the sealant material)
(© Photos by Applied Pavement Technology (APTech)).

Joint seal damage (INDOT Office of Aviation, 2022c).

Temporary patching approaches to repair high-severity damage may not be an appropriate long-term solution (Burger, 2017).

2.7 Spalling of Joints

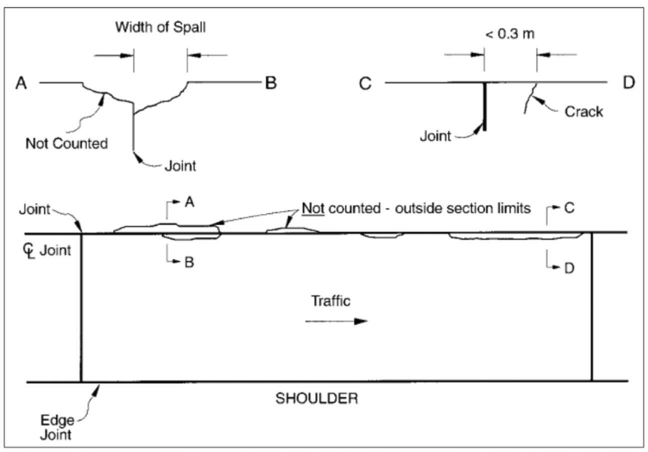
2.7.1 Description and Causes

Spalling of joints is defined as cracking, breaking, chipping, or fraying of slab edge within 1 ft. from the face of the joint. Spalling of the joint is caused by the following.

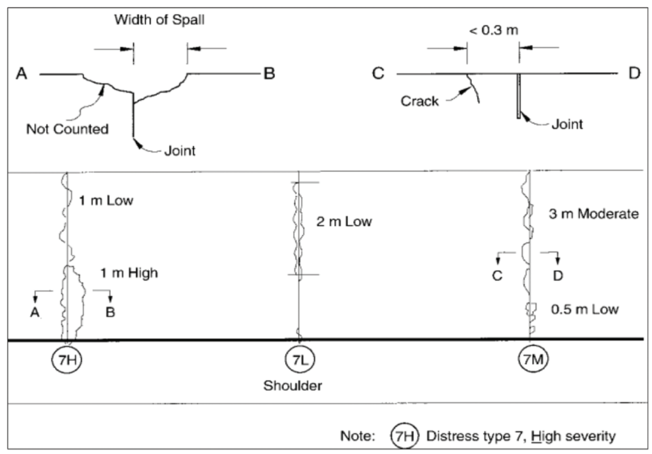
1. Excessive stresses at a joint due to the following.
   a. Infiltration of incompressible materials.
   b. Moving dowels.
   c. Locked joints.
   d. Curling–warping.
   e. Traffic loads, freeze-thaw cycles, and temperature gradients.

2. Improper construction practices due to the following.
   a. Inadequate consolidation of concrete at joints.
   b. Poor joint sawing practices.

3. Materials-related distress such as alkali silica reaction (ASR) and Durability Cracking (“D” Cracking).



Spalling of longitudinal joints in JPCP/JRCP (FHWA, 2014).



Spalling of transverse joints in JPCP/JRCP (FHWA, 2014).

Measurement

- Record the length (in feet) of the affected longitudinal and transverse joints at each severity level.
  – A transverse joint is considered to be affected only if the total length of spalling is 10% or more of the length of the joint.
- For longitudinal joints, only record spalls that have a length of 4 in. or more.
- Rate the entire transverse joint at the highest severity level present for at least 10% of the total length of the spalling. Record the length (in feet) of the spalled portion of the joint at the assigned severity level for the joint.
- Spalls that have been repaired by completely removing all broken pieces and replacing them with patching material (rigid or flexible) should be rated as a “patch.”
- When a crack, with a length of at least 1 ft., is within 1 ft. of a joint and extends only for a portion of the joint’s length, it should be recorded as a spall. If the crack is farther than 1 ft. from the joint, it should be recorded as a transverse crack.

2.7.2 Severity Levels and Maintenance and Preservation Options

Low Severity: Distress Criteria

- Spalls < 3 in. wide (as measured from the face of the joint) with loss of material.
- Spalls with no loss of material and no patching.

Low Severity: Maintenance & Preservation Options

- Do nothing but monitor for future repairs.

Moderate Severity: Distress Criteria

- Spalls 3 to 6 in. wide (as measured from the face of the joint) with loss of material.

Moderate Severity: Maintenance & Preservation Options

- Partial depth patch (PDP).

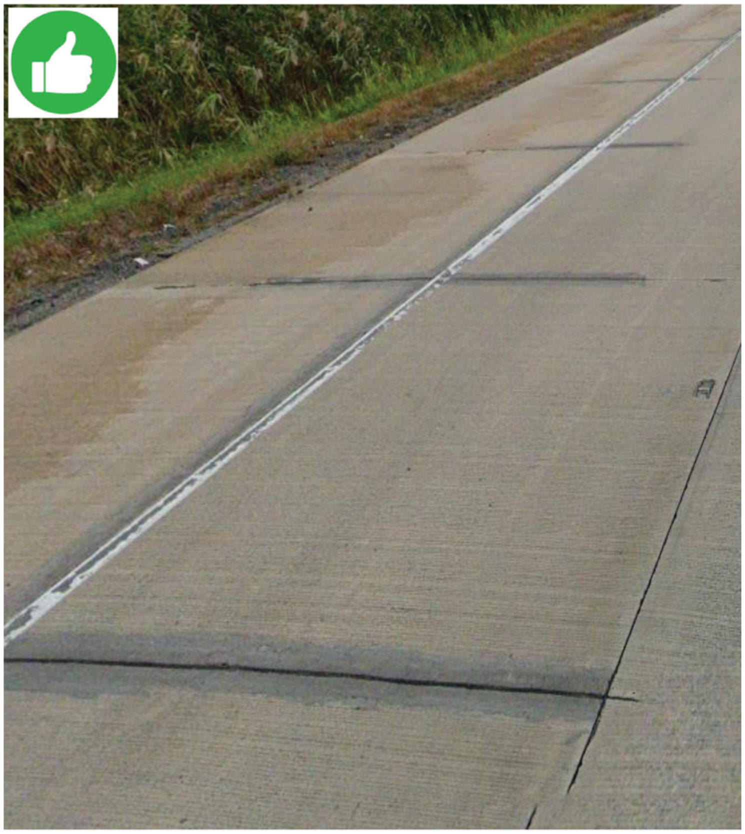
High Severity: Distress Criteria

- Spalls > 6 in. wide (as measured from the face of the joint) with loss of material.
- Spalls broken into two or more pieces.
- Spalls containing patch material.

High Severity: Maintenance & Preservation Options

- Partial depth patch (PDP).
- Full depth patch (FDP), if the depth of deterioration exceeds half of the slab thickness.

© Photos by Applied Pavement Technology (APTech)



Properly installed PDP to repair spalling of the transverse joint (© Photo by Applied Pavement Technology (APTech)).

Deteriorated PDP (© Photo by Applied Pavement Technology (APTech)).

Properly installed PDP to repair spalling of the transverse joint (Rodeco Group, n.d.).

PDP installed without proper joint preparation (© Photo by Applied Pavement Technology (APTech)).

2.8 Map Cracking and Scaling

2.8.1 Description and Causes

Map cracking is a network of shallow, hairline cracks that extends only into the upper surface of the slab. Larger cracks are frequently oriented in the longitudinal direction of the pavement and are interconnected by finer transverse or random cracks.

Scaling is the deterioration of the upper concrete slab surface, normally 0.12 to 0.5 in., and may occur anywhere over the pavement.

Over-finishing of the PCC surface during construction or finishing of the surface in the presence of bleed water, exposure to deicing salts and freeze-thaw cycles, or poor-quality aggregate-related distresses (e.g., alkali silica reactivity (ASR)) are common causes of map cracking and scaling.

Measurement

- Record the number of affected slabs and the square feet of the affected area.

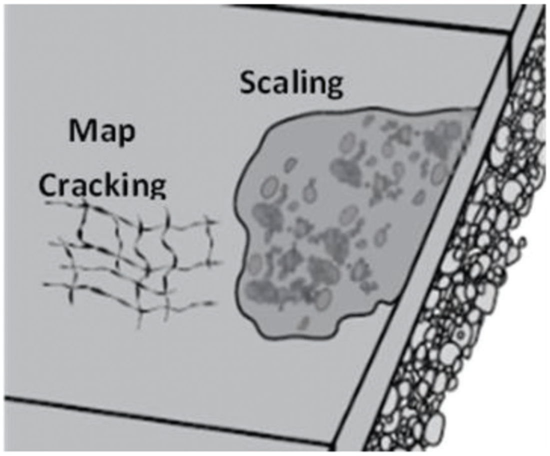


Illustration of map cracking and scaling on JPCP/JRCP (Modified from Harrington & Fick, 2014).

2.8.2 Severity Levels and Maintenance and Preservation Options

Severity Level
The *Long-Term Pavement Performance (LTPP) Manual* (FHWA, 2014) does not define severity levels for map cracking and scaling.
Maintenance & Preservation Options
Do nothing, especially when map cracking/scaling is caused due to construction-related practices but monitor the progression of the distress for future repairs.
Full depth patch (FDP) when map cracking due to ASR poses safety concerns on high-priority highways with high-traffic volume. However, the section may require complete reconstruction.


Map cracking on PCC pavement (© Photo by Applied Pavement Technology (APTech)).


Scaling of concrete pavement (© Photo by Applied Pavement Technology (APTech)).

JPCP/JRCP

Map Cracking and Scaling

2.9 Polished Aggregate

2.9.1 Description and Causes

Polished aggregate occurs when surface layer of mortar and texturing are worn away resulting in exposed coarse aggregate. Polished aggregate is a safety issue, as the polished surface has reduced skid resistance. Polished surfaces of aggregates are the result of abrasion caused by repeated traffic applications (not necessarily heavy loads).

Measurement

- Record the square feet of affected surface area.

2.9.2 Severity Levels and Maintenance and Preservation Options

Severity Level
The *Long-Term Pavement Performance (LTPP) Manual* (FHWA, 2014) does not define severity levels for polished aggregate type of distress. The degree of polishing may be reflected in a reduction of surface friction.
Maintenance & Preservation Options
Diamond grinding Diamond grooving

Examples of polished aggregate on the PCC pavement (© Photos by Applied Pavement Technology (APTech)).

JPCP/JRCP

Polished Aggregate

A close-up view of a diamond ground concrete pavement surface (© Photo by Applied Pavement Technology (APTech)).

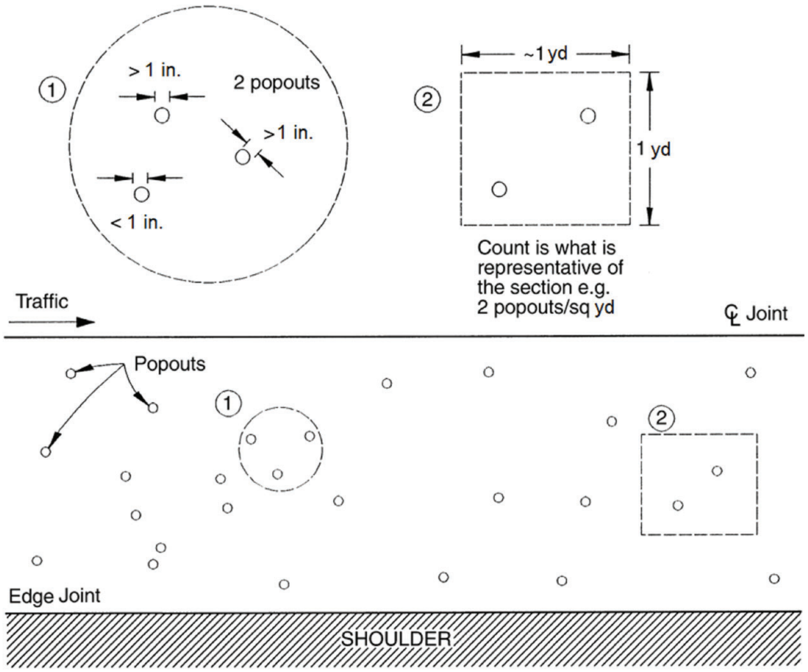
2.10 Popouts

2.10.1 Description and Causes

Popouts are small pieces of pavement broken loose from the surface, normally ranging from 1 to 4 in. in diameter and from 0.5 to 2 in. in depth. Popouts develop as a result of expansion and cracking of highly absorptive aggregates during freeze-thaw cycles.

Measurement

- Popouts are not recorded in LTPP surveys. However, according to ASTM protocols, if the density of popouts (i.e., number of popouts/area) is greater than or equal to three popouts per square yard over the entire slab, popouts will be counted as distress (ASTM, 2020b). To ensure that this density limit is not exceeded, at least three random 1-square-yard areas should be checked.



Illustrations of popouts dimensions, distribution, and counting method (FHWA, 2014).

2.10.2 Severity Levels and Maintenance and Preservation Options

Severity Level
The *Long-Term Pavement Performance (LTPP) Manual* (FHWA, 2014) does not define severity levels for popouts. However, the density of popouts in slabs should be recorded.
Maintenance & Preservation Options
Do nothing. However, preventive actions (such as using air-entraining admixtures, selecting less absorptive aggregate, good stockpile management practices, good quality control measures, extra care in placement, consolidation, finishing, curing, and sealing) should be considered. If popouts density is $\geq$ 3 popouts/yd^2, diamond grinding can help improve aesthetics.

Extensive popouts (i.e., density $\geq$ 3 popouts/yd^2) on a PCC pavement (© Photo by Applied Pavement Technology (APTech)).

JPCP/JRCP

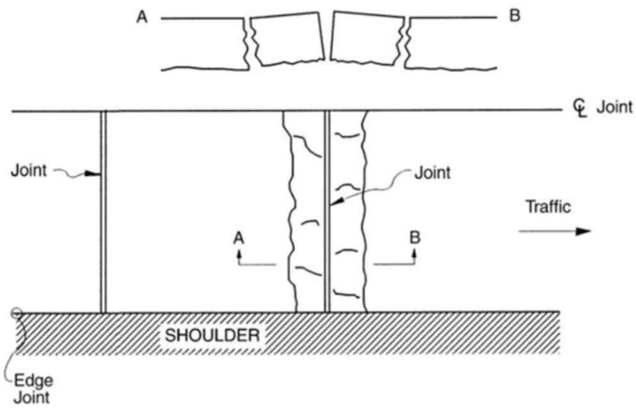
Popouts

2.11 Blowups

2.11.1 Description and Causes

Blowups involve localized upward movement of the pavement surface at transverse joints or cracks; often accompanied by shattering of concrete in that area.

Blowups occur in PCC pavement, typically during exceptionally hot weather. When PCC pavements do not have room to expand sufficiently, internal forces can become great enough to cause a localized upward movement of the slab edges resulting in buckling or shattering of the joint or crack.



Blowups on JPCP/JRCP (FHWA, 2014).

Measurement

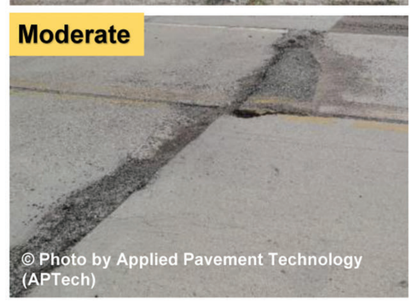
- Record the number of slabs in which blowup occurs.
- At a crack, a blowup is counted as being in one slab. However, if the blowup occurs at a joint and affects two slabs, the distress should be recorded as occurring in two slabs.

2.11.2 Severity Levels and Maintenance and Preservation Options

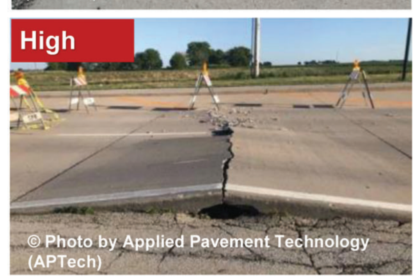
LTPP does not define the severity for blowups, therefore definitions provided by (ASTM, 2020b) are used here.

Low Severity: Distress Criteria
• Buckling or shattering has not rendered the pavement inoperable. • Only a slight amount of roughness exists.
Low Severity: Maintenance & Preservation Options
• Full depth patch (FDP).

Moderate Severity: Distress Criteria
• Buckling or shattering has not rendered the pavement inoperable. • A significant amount of roughness exists.
Moderate Severity: Maintenance & Preservation Options
• Full depth patch (FDP) with required narrow pressure-relief cuts (2 to 3 in.).[a]



High Severity: Distress Criteria
• Buckling or shattering has rendered the pavement inoperable.
High Severity: Maintenance & Preservation Options
• Full depth patch (FDP) with required pressure-relief cuts.[a]



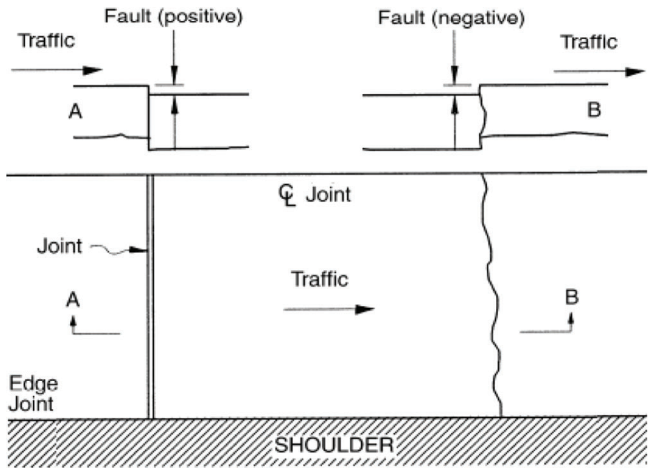
[a] See Step 12 of the FDP Construction Steps on page 59.

2.12 Faulting of Transverse Joints and Cracks

2.12.1 Description and Causes

Faulting is the difference in elevation across a joint or crack. It is typically caused by the following.

1. Pumping of water and fines from under slab corners.
2. Loss of support under the corner of leave slab.
3. A buildup of fines under the corner of the approach slab.
4. Uneven settlement of adjacent slabs.
5. Frost heave.
6. Repeated traffic loads which result in the failure of the load transfer capacity across joint (either due to aggregate interlock or presence of mechanical devices).



Faulting of transverse joints and cracks in JPCP/JRCP (FHWA, 2014).

Measurement

- Faulting across a joint is counted as occurring in one slab. Only affected slabs are counted.
- Faults across a crack are not counted as distress but are considered when defining crack severity.

2.12.2 Severity Levels and Maintenance and Preservation Options

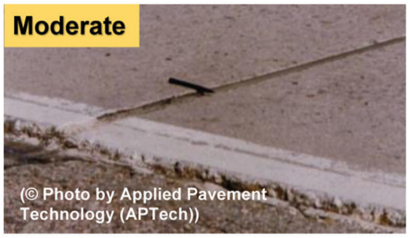
LTPP does not define severity for Faulting, therefore definitions provided by (ASTM, 2020b) are used here.

Low Severity: Distress Criteria
• The elevation difference is 0.125 to 0.375 in.
Low Severity: Maintenance & Preservation Options
• Do nothing if the elevation difference is at around 0.125 in. • Diamond grinding.[a] • Retrofit load transfer (RLT).[a]

Moderate Severity: Distress Criteria
• The elevation difference is 0.375 to 0.75 in.
Moderate Severity: Maintenance & Preservation Options
• Diamond grinding.[a] • Retrofit load transfer (RLT).[a]

High Severity: Distress Criteria
• The elevation difference is greater than 0.75 in.
High Severity: Maintenance & Preservation Options
• Diamond grinding.[a] • Retrofit load transfer (RLT).[a]

[a] Selection of Diamond Grinding and RLT for low-severity faulting depends on the slab thickness, class of roadway, traffic levels, traffic speeds, and the joint spacing.



Example of proper diamond grinding to address faulting on JPC pavements (J. Roberts, personal communication, August 7, 2023).

An RTL (Retrofit Load Transfer) device installed on a faulted joint of a PCCP (© Photo by Applied Pavement Technology (APTech)).

Cracks in the pavement leading to deterioration of grout in the RTL (© Photo by Applied Pavement Technology (APTech)).

2.13 Lane-to-Shoulder Dropoff

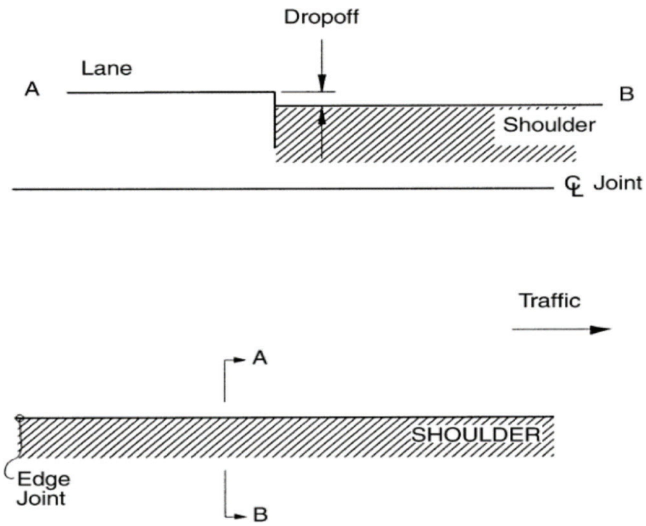
2.13.1 Description and Causes

The lane-to-shoulder dropoff represents the difference in elevation between the edge of the slab and the outside shoulder; typically occurs when the outside shoulder settles. This distress is caused by the following.

1. Loss of support in response to moisture and/or freezing damage (e.g., frost heave).
2. Differences in response to the applied load or eroding of shoulder material.
3. Improper compaction of subgrade/subbase materials in the shoulder.

Measurement

- Record elevation difference between lane and shoulder (to the nearest 0.125 in.) at 50-ft intervals along the lane-to-shoulder joint.
- If the traveled surface is lower than the shoulder, record it as a negative value.



Lane-to-shoulder dropoff (FHWA, 2014).

2.13.2 Severity Levels and Maintenance and Preservation Options

The LTPP does not define severity for Lane-to-Shoulder Dropoff, therefore definitions provided by (ASTM, 2020b) are used here.

Low Severity: Distress Criteria

- The height difference between the pavement edge and shoulder is 1 to 2 in.

Moderate Severity: Distress Criteria

- The height difference between the pavement edge and shoulder is 2 to 4 in.

High Severity: Distress Criteria

- The difference between the pavement edge and shoulder is greater than 4 in.

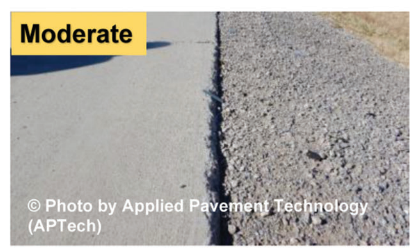
Maintenance & Preservation Options

Lane-to-Shoulder Dropoff is a distress that can only be addressed by **major rehabilitation strategies** for the following.

- Aggregate shoulder → Regrade the shoulder and add new materials to the shoulder.
- Asphalt shoulder → Perform mill and overlay or place a thin bonded wearing course.
- Concrete shoulder → Place thin asphalt overlay or, if the dropoff is the result of failed tie bars and foundation subsidence, perform complete reconstruction.

The following is a **temporary measure** when the height difference between the pavement edge and shoulder is less than 6 in.

- Cement Slurry/Foam Slab Jacking.



Appropriately completed undersealing using polyurethane foam (T. Nantung, personal communication, August 14, 2023).

JPCP/JRCP

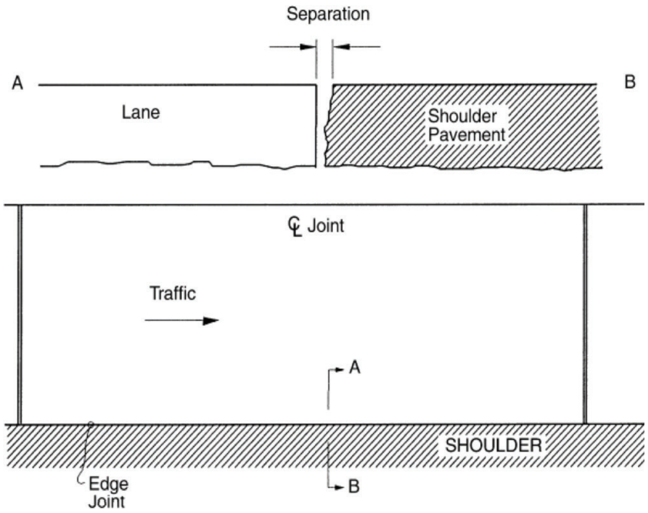
Lane-to-Shoulder Dropoff

2.14 Lane-to-Shoulder Separation

2.14.1 Description and Causes

Lane-to-shoulder separation is the widening of the joint between the edge of the slab and the shoulder. This distress is caused by lateral slippage of the concrete slab due to the following.

1. An insufficient number of tie bars, or loss of support in response to moisture and/or freezing damage (e.g., frost heave).
2. Fracture/corrosion of tie bars at the longitudinal joints.



Lane-to-shoulder separation in JPCP/JRCP (FHWA, 2014).

Measurement

- Record the width of separation to the nearest millimeter at intervals of 50 ft. along the lane-to-shoulder joint.
- Indicate whether the joint is well-sealed (yes or no) at each location.
- *Note:* A null value should be recorded and entered into the database when the surveyor is unable to measure the width of separation, due to the presence of sealant or patch material.

2.14.2 Severity Levels and Maintenance and Preservation Options

Severity Level
No severity levels are defined in the LTTP manual for lane-to-shoulder separation. Instead, separation measurements should be categorized. A complete record of the measurements taken is more desirable compared to the severity level because that record is more accurate and repeatable.
Maintenance & Preservation Options
1. Joint resealing for the following. Asphalt shoulder with a separation up to 1 in. Concrete shoulder with a separation up to 0.5 in. 2. Cross-stitching.

Example of lane-to-shoulder separation (Texas Transportation Institute, 2008).

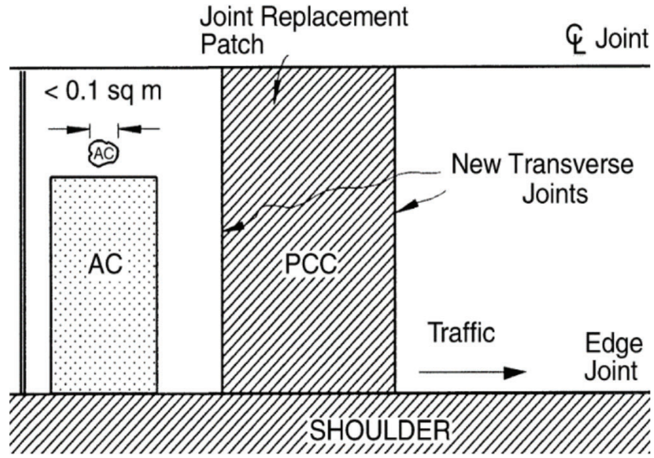
Effective sealing of the shoulder-lane joint (FHWA, 2014).

2.15 Patch/Patch Deterioration

2.15.1 Description and Causes

A patch is a portion (small patch if $\leq$ 5 ft.^{2} and large patch if $>$ 5 ft.^{2}) or all of the original concrete slab that has been removed and replaced, or additional HMA or PCC material applied to the pavement after the original construction. This distress is often caused by the following.

1. Poor construction placement of the patch.
2. Loss of support.
3. Repeated heavy loadings.
4. Lack of load transfer devices (dowel bars).
5. Improper or absent joints.
6. Moisture or thermal gradients across the patch.



Patch/patch deterioration on JPCP/JRCP (FHWA, 2014).

Measurement

- Record the number of patches and square feet of affected surface area at each severity level by type of material used in the patch—rigid versus flexible.
- *Note:* If temporary skin/surface patches have worn away revealing underlying distress, then rate the distress. Similarly, if the underlying distress reflects through the surface patch, then also rate the distress.
- Any new distress in the original pavement layer in the patched area should also be rated.
- Distresses in the patched area affect the severity level of the patch. Patches with no distress are rated as low severity.
- Applications of sealant without aggregate are not to be recorded as patches.

2.15.2 Severity Levels and Maintenance and Preservation Options

Low Severity: Distress Criteria
• Patch has predominantly low-severity distresses. • No measurable faulting or settlement is observed. • Pumping is not evident.
Low Severity: Maintenance & Preservation Options
• Do nothing but monitor for future repairs.

Moderate Severity: Distress Criteria
• Patch has predominantly moderate-severity distresses. • Faulting or settlement up to 0.25 in. is observed between the patch and the existing pavement. • Pumping is not evident.
Moderate Severity: Maintenance & Preservation Options
• Partial depth patch (PDP). • Full depth patch (FDP).

High Severity: Distress Criteria
• Patch has high-severity distress of any type. • Faulting or settlement ≥ 0.25 in. is observed. • Pumping may be evident.
High Severity: Maintenance & Preservation Options
• Partial depth patch (PDP). • Full depth patch (FDP).

Well-applied PDP (INDOT Office of Aviation, 2022d).

Poor quality of installed full depth patch (not flush with the surface, jagged joints, and nonuniform application of curing compound (© Photo by Applied Pavement Technology (APTech)).

2.16 Water Bleeding and Pumping

2.16.1 Description and Causes

Water bleeding and pumping is the seeping or ejection of water from beneath the pavement through cracks or joints. In some cases, pumping is detectable by deposits of fine material that have been left on the pavement surface, which were eroded (pumped) from the support layers and have stained the surface. The common causes of pumping are as follows.

1. Excess moisture in the pavement structure.
2. Erodible base or subgrade materials.
3. High volumes of high-speed, heavy-wheel loads.

Measurement

- Record the number of occurrences of water bleeding and pumping and the length of affected pavement if that length is greater than 3 ft.
- *Note:* Water bleeding and pumping are measured longitudinally along the length of the pavement where these distresses are observed.

2.16.2 Severity Levels and Maintenance and Preservation Options

Severity Level
No severity levels are defined in the LTTP manual for water bleeding and pumping because the amount and degree of water bleeding and pumping change with varying moisture conditions. It is sufficient to indicate that pumping exists.
Maintenance & Preservation Options
Full depth patch (FDP), if FWD test results confirm that the pavement has drainage layer. Undersealing, if FWD test results confirm that the pavement has no drainage layer. Joint and crack resealing. Retrofit load transfer (RLT).

Example of water bleeding and pumping on CRCP (left) and JPCP (right) (© Photos by Applied Pavement Technology (APTech)).

2.16.3 Distresses in Continuously Reinforced Concrete (CRCP) Pavements

- Durability Cracking ("D" Cracking)
- Longitudinal Cracking
- Transverse Cracking
- Blowups
- Lane-to-Shoulder Separation
- Patch/Patch Deterioration
- Spalling of Longitudinal Joints
- Transverse Construction Joint Deterioration
- Punchouts

2.17 Durability Cracking ("D" Cracking)

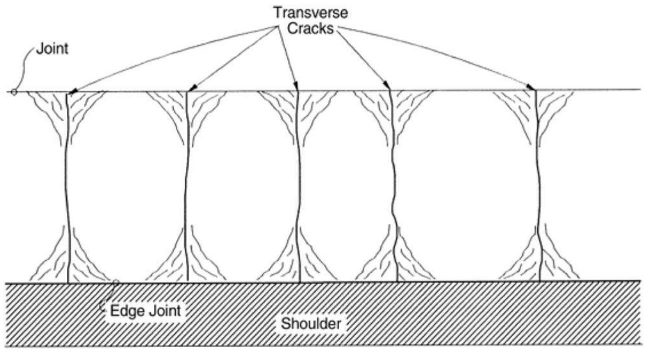
2.17.1 Description and Causes

Pattern of closely spaced crescent-shaped hairline cracks adjacent to, and running parallel to longitudinal joints, linear cracks, or free edges. Often found near slab corners.

"D" cracking is caused by concrete's inability to withstand environmental factors such as freeze-thaw cycles. Dark coloring can usually be seen around the these fine cracks. This type of cracking may eventually lead to the disintegration of the concrete within 1 to 2 ft. of the affected joint or crack.

Measurement

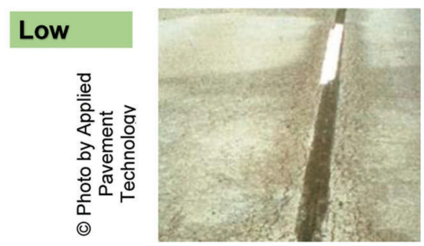
Record the number of slabs with "D" cracking and number of square feet of the area affected at each severity level. The slab and affected area severity rating should be based on the highest severity level present in least 10% of the affected area.



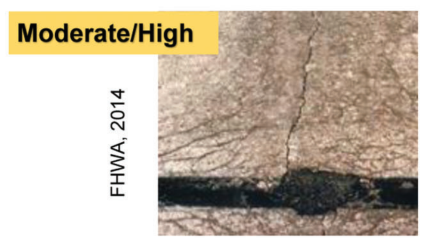
"D" cracking on CRCP (FHWA, 2014).

2.17.2 Severity Levels and Maintenance and Preservation Options

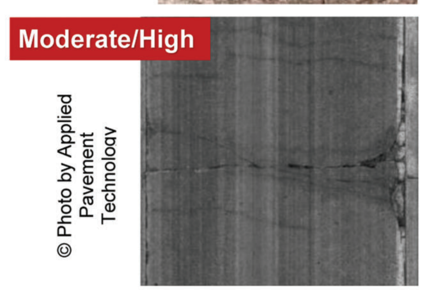
Low Severity: Distress Criteria
• "D" cracks are tight. • No loose or missing pieces and no patching applied.
Low Severity: Maintenance & Preservation Options
• Do nothing but monitor for future repairs. • Joint resealing.



Moderate Severity: Distress Criteria
• "D" cracks are well-defined (outlines of the cracks are visible). • Some small pieces are loose or have been displaced.
Moderate Severity: Maintenance & Preservation Options
• Drum grinding 3 to 4 in. and Partial depth patch (PDP).[a]



High Severity: Distress Criteria
• Clearly visible pattern of cracks. • A significant amount of material is missing from the slab. • Displaced pieces up to 1 ft.^{2} may have been patched.
High Severity: Maintenance & Preservation Options
• Full depth patch (FDP).[a] • Localized reconstruction if deterioration is present >30% of area.

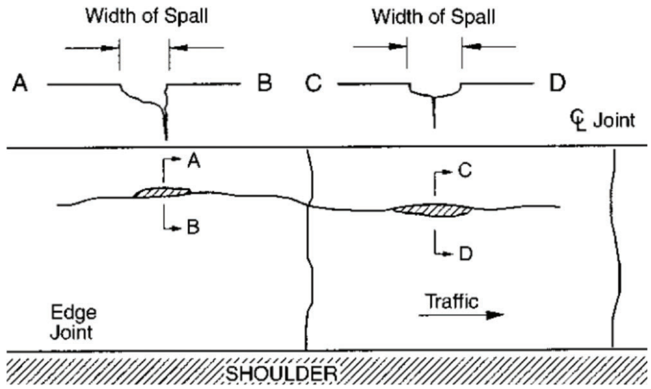


[a] If the project has a rehabilitation contract.

2.18 Longitudinal Cracking

2.18.1 Description and Causes

Longitudinal cracks, that are predominantly parallel to the pavement centerline, are usually caused by a combination of load repetition, insufficient depth of cover over the longitudinal reinforcement, poor consolidation (particularly around the embedded steel), foundation movement, and shrinkage stresses.



Longitudinal cracking on CRCP (FHWA, 2014).

Measurement

- Record the length (in feet) and width (in inches) of longitudinal cracking at each severity level.
- Record the length in feet of longitudinal cracking with sealant in good condition (i.e., greater than 3 ft. of continuous sealant is in good condition) at each severity level.
- When a crack, with a length of at least 1 ft., is within 1 ft. of a joint and runs for only a portion of the joint's length, it should be recorded as a spall.
- If a crack is farther than 1 ft. from the joint, it should be recorded as a longitudinal crack.

2.18.2 Severity Levels and Maintenance and Preservation Options

Low Severity: Distress Criteria
• Crack widths < 0.125 in. • Crack with no spalling and no measurable faulting. • A well-sealed crack whose width cannot be determined.
Low Severity: Maintenance & Preservation Options
• Do nothing but monitor for future repairs.

Moderate Severity: Distress Criteria
• Crack widths ≥ 0.125 in. and < 0.5 in. • Crack with spalling < 3 in. or faulting up to 0.5 in.
Moderate Severity: Maintenance & Preservation Options
• Crack sealing.

High Severity: Distress Criteria
• Crack widths ≥ 0.5 in. • Crack with spalling ≥ 3 in. or faulting ≥ 0.5 in.
High Severity: Maintenance & Preservation Options
• Full depth patch (FDP).

Properly sealed longitudinal crack with moderate severity (© Photo by Applied Pavement Technology (APTech)).

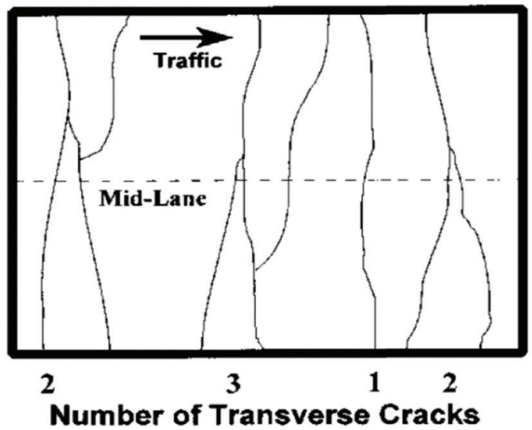
2.19 Transverse Cracking

2.19.1 Description and Causes

Transverse cracks are predominantly perpendicular to the pavement centerline. Transverse cracks are a typical occurrence in CRCP, and they are not deemed problematic until they exhibit signs of deterioration.

Measurement

- Record the number and length (in feet) and width (in inches) of transverse cracking, especially at moderate and high severity levels.
  - Low-severity transverse cracks are expected to develop on CRCP and are not an issue.
- The sum of all the individual crack lengths shall be recorded.
- *Note:* All transverse cracks that intersect an imaginary longitudinal line at mid-lane and propagate from the pavement edges (centerline joint or the edge joint) shall be counted as individual cracks.



Transverse cracking on CRCP (FHWA, 2014).

2.19.2 Severity Levels and Maintenance and Preservation Options

Low Severity: Distress Criteria
• Crack with no spalling. • Crack with spalling along ≤ 10% of the crack length.
Low Severity: Maintenance & Preservation Options
• Do nothing.

Moderate Severity: Distress Criteria
• Crack with spalling along > 10% and ≤ 50% of the crack length.
Moderate Severity: Maintenance & Preservation Options
• Crack sealing. • Full depth patch (FDP), if FWD test results confirm that the aggregate interlock at crack location is insufficient.

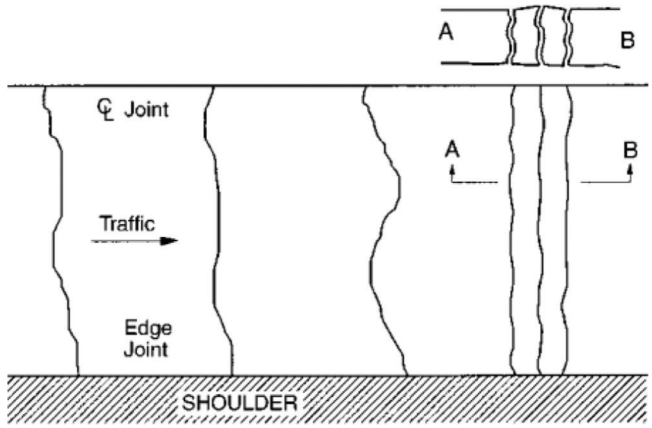
High Severity: Distress Criteria
• Crack with spalling along > 50% of the crack length.
High Severity: Maintenance & Preservation Options
• Full depth patch (FDP).

FHWA, 2014

2.20 Blowups

2.20.1 Description and Causes

Blowups appear as a localized upward buckling of the pavement surface at transverse cracks. Blowups occur if there is spalling (shear delamination) that results in formation of wide transverse cracks. These cracks can subsequently fill with incompressible material, thus causing blowups.



Blowups in CRCP (FHWA, 2014).

Measurement

- Record the number of slabs in which blowups have occurred.
- At a crack, a blowup is counted as being in one slab. However, if the blowup occurs at a joint and affects two slabs, the distress should be recorded as occurring in two slabs.

2.20.2 Severity Levels and Maintenance and Preservation Options

LTPP does not define the severity for blowups, therefore definitions provided by (ASTM, 2020b) are used here.

Low Severity: Distress Criteria
• Buckling or shattering has not rendered the pavement inoperable. • Only a slight amount of roughness exists.
Low Severity: Maintenance & Preservation Options
• Full depth patch (FDP).

Moderate Severity: Distress Criteria
• Buckling or shattering has not rendered the pavement inoperable. • A significant amount of roughness exists.
Moderate Severity: Maintenance & Preservation Options
• Full depth patch (FDP).

High Severity: Distress Criteria
• Buckling or shattering has rendered the pavement inoperable.
High Severity: Maintenance & Preservation Options
• Full depth patch (FDP).

Low

No photograph available

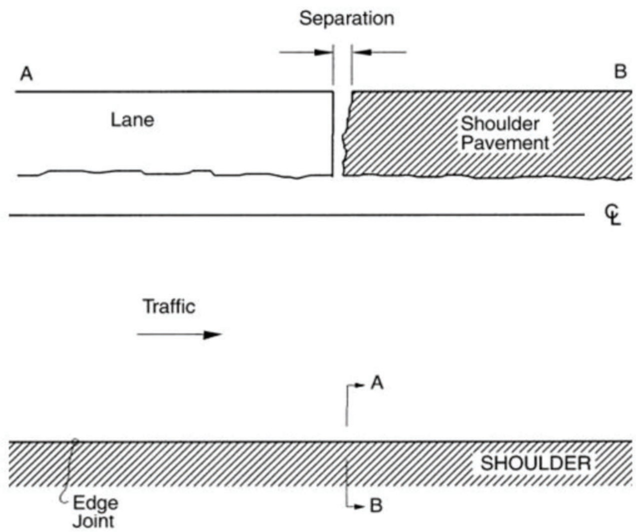
D. King, personal communication, August 7, 2023

2.21 Lane-to-Shoulder Separation

2.21.1 Description and Causes

Lane-to-shoulder separation is the widening of the joint between the edge of the slab and the shoulder. This distress is caused by lateral slippage of the concrete slab due to the following.

1. An insufficient number of tie bars.
2. Fracture/corrosion of tie bars at the longitudinal joints.



Lane-to-shoulder separation in CRCP (FHWA, 2014).

Measurement

- Record the width of separation (to the nearest 1/8th in.) at intervals of 50 ft. along the lane-to-shoulder joint.
- Indicate whether the joint is well-sealed (yes or no) at each location.
- *Note:* A null value should be recorded and entered into the database when the surveyor is unable to measure the width of separation, due to the presence of sealant or patch material.

2.21.2 Severity Levels and Maintenance and Preservation Options

Severity Level
No severity levels are defined in the LTTP manual for lane-to-shoulder separation. Instead, separation measurements should be categorized on the basis of the width of separation.
Maintenance & Preservation Options
Joint resealing for the following. Asphalt shoulder with a separation up to 1 in. Concrete shoulder with a separation up to 0.5 in.

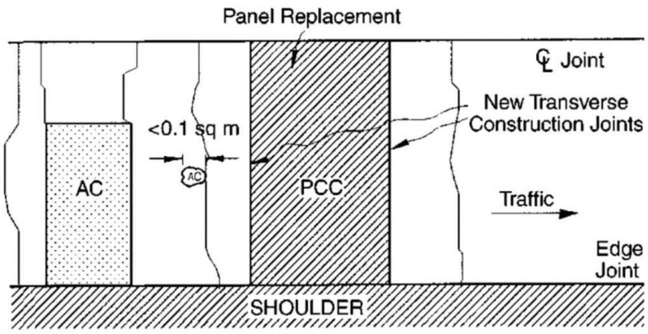

Example of lane-to-shoulder separation (VEA Group, 2019).

2.22 Patch/Patch Deterioration

2.22.1 Description and Causes

A patch is a portion (small patch if ≤ 5 ft.^{2} and large patch if > 5 ft.^{2}) or all of the original concrete slab that has been removed and replaced, or additional HMA or PCC material applied to the pavement after the original construction. This distress is often caused by the following.

1. Poor construction placement of the patch.
2. Loss of support.
3. Repeated heavy loadings.
4. Lack of sufficient reinforcing steel.
5. Improper or lack of transverse construction joints.
6. Moisture or thermal gradients across the patch.



Patch/patch deterioration on CRCP (FHWA, 2014).

Measurement

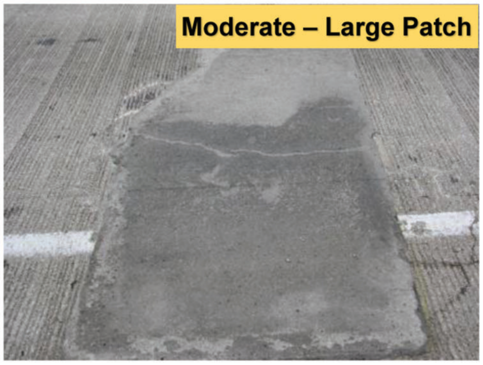
- Record the number of patches and square feet of affected surface area at each severity level by material type—rigid versus flexible.
- *Note:* If a surface patch has worn away revealing underlying distress or if the underlying distress has reflected through the surface patch (already verified on prior surveys), then also rate the distress.
- Distresses in the patched area affect the severity level of the patch. Patches with no distress should be rated as low severity.

2.22.2 Severity Levels and Maintenance and Preservation Options

Low Severity: Distress Criteria
• Patch has, at most, low-severity distress of any type. • No measurable faulting or settlement is observed. • Pumping is not evident.
Low Severity: Maintenance & Preservation Options
• Do nothing but monitor for future repairs.

Moderate Severity: Distress Criteria
• Patch has moderate-severity distress of any type. • Faulting or settlement of up to 0.25 in. is observed. • Pumping is not evident.
Moderate Severity: Maintenance & Preservation Options
• Full depth patch (FDP).

(Ram et al., 2013)



(Ram et al., 2013)

High Severity: Distress Criteria
• Patch has high-severity distress of any type. • Faulting or settlement ≥ 0.25 in. is observed. • Pumping may be evident.
High Severity: Maintenance & Preservation Options
• Full depth patch (FDP).

Ram et al., 2013

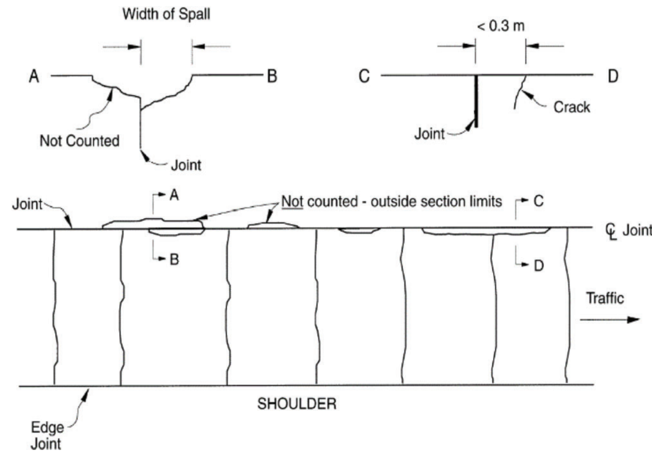
K. Dave, personal communication, June 22, 2023

2.23 Spalling of Longitudinal Joints

2.23.1 Description and Causes

Spalling of joint can manifest itself as cracking, breaking, chipping, or fraying of slab edge within 1 ft. from the face of the longitudinal joint. Spalling of the longitudinal joint is caused by the following.

1. Excessive stresses at a joint due to the following.
   a. Infiltration of incompressible materials.
   b. In-service stress levels due to factors such as traffic load, freeze-thaw cycling, and thermal expansion.
2. Improper construction practices include the following.
   a. Inadequate consolidation of concrete at longitudinal joints.
   b. Poor longitudinal joint sawing practices.
3. Materials-related distress such as alkali silica reaction (ASR) and Durability Cracking ("D" Cracking).



Spalling of longitudinal joints in CRCP (FHWA, 2014).

Measurement

- Record the length of the longitudinal joint affected at each severity level.
- Only record spalls that are greater than 4 in.
- Spalls that have been repaired by completely removing all broken pieces and replacing them with patching material (rigid or flexible) should be rated as a "patch."

2.23.2 Severity Levels and Maintenance and Preservation Options

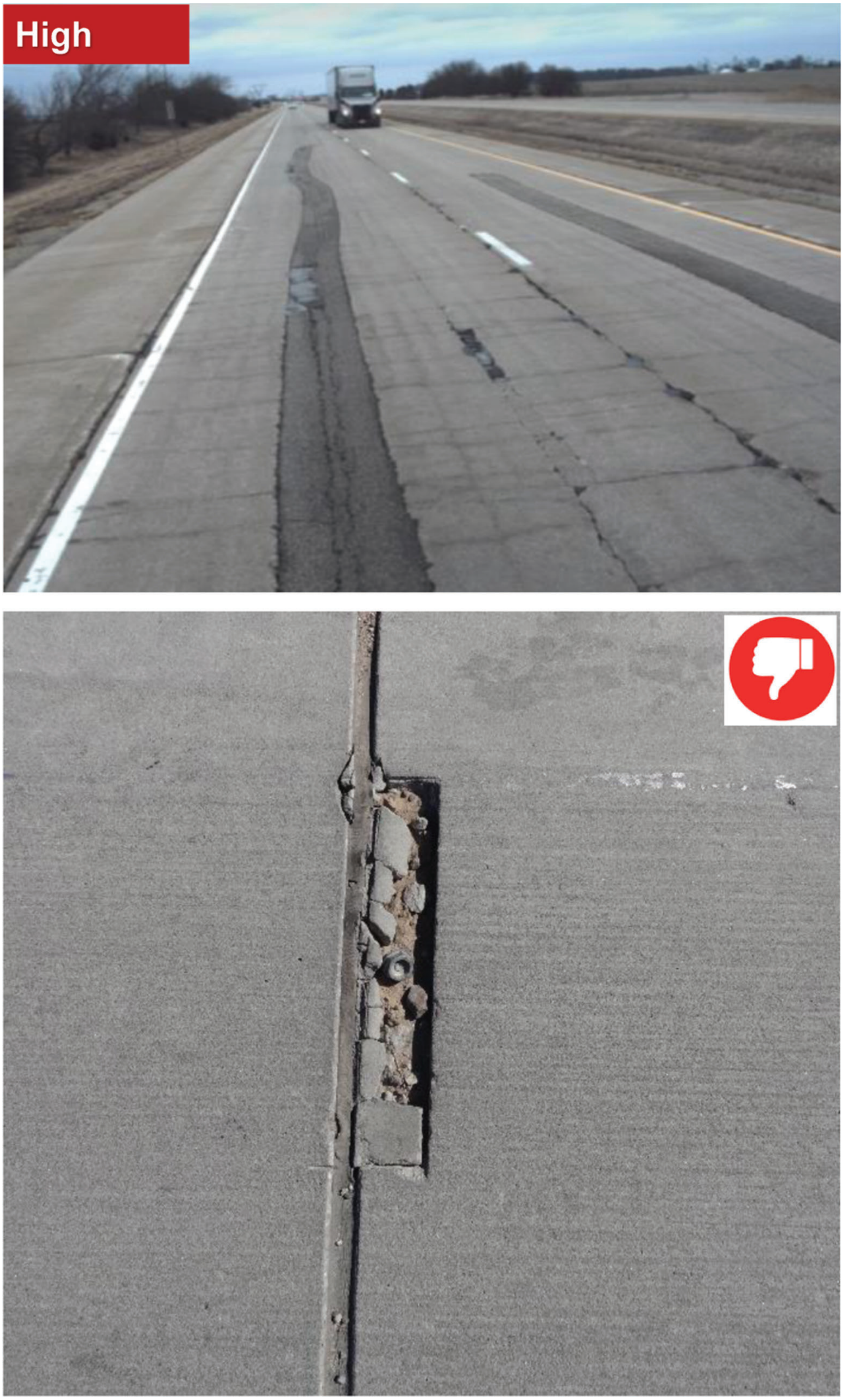
Low Severity: Distress Criteria
• Spalls < 3 in. wide measured from the face of the joint with loss of material. • Spalls with no loss of material and no patching.
Low Severity: Maintenance & Preservation Options
• Do nothing but monitor for future repairs.

FHWA, 2014

Moderate Severity: Distress Criteria
• Spalls 3 to 6 in. wide measured from the face of the joint with loss of material.
Moderate Severity: Maintenance & Preservation Options
• Partial depth patch (PDP).

FHWA, 2014

High Severity: Distress Criteria
• Spalls > 6 in. wide measured from the face of the joint with loss of material. • Spalls are broken into two or more pieces. • Spalls containing patch material.
High Severity: Maintenance & Preservation Options
• Partial depth patch (PDP). • Full depth patch (FDP), if the depth of deterioration exceeds half of the slab thickness.



Failed PDP that was used to address joint spalling (© Photos by Applied Pavement Technology (APTech)).

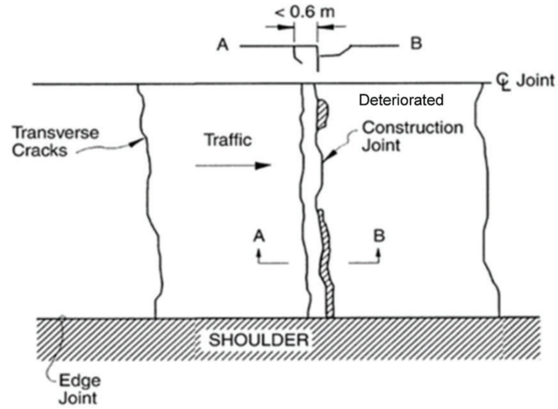
2.24 Transverse Construction Joint Deterioration

2.24.1 Description and Causes

Transverse construction joint deterioration is a series of closely spaced transverse cracks or a large number of interconnecting cracks occurring near the transverse construction joint.

Measurement

- Record the number of construction joints that have deteriorated and are showing signs of spalling along joints or parallel cracks to the joint.



Deterioration of transverse construction joints in CRCP (FHWA, 2014).

2.24.2 Severity Levels and Maintenance and Preservation Options

Low Severity: Distress Criteria
• No spalling or faulting within 2 ft. of the construction joint.
Low Severity: Maintenance & Preservation Options
• Do nothing if there is a single crack. • Seal cracks if there is a cluster of cracks close to the joints.

Moderate Severity: Distress Criteria
• Spalling < 3 in. exists within 2 ft. of the construction joint.
Moderate Severity: Maintenance & Preservation Options
• Seal cracks. • Full depth patch (FDP).

High Severity: Distress Criteria
• Spalling ≥ 3 in. and breakup exists within 2 ft. of the construction joint.
High Severity: Maintenance & Preservation Options
• Full depth patch (FDP).

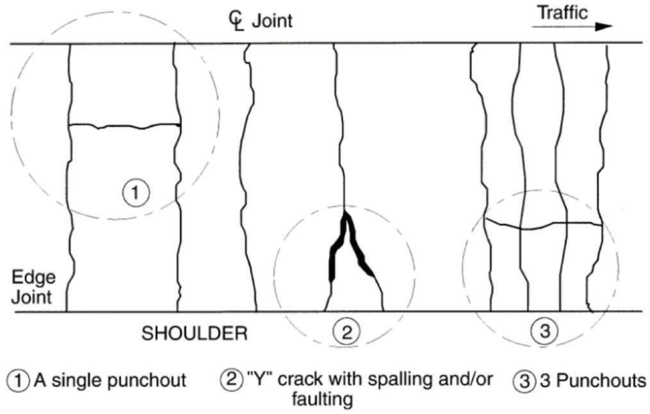
2.25 Punchouts

2.25.1 Description and Causes

A punchout is defined as the area enclosed by two closely spaced (usually < 3 ft.) transverse cracks, a short longitudinal crack, and the edge of the pavement or a longitudinal joint.

Punchouts also includes "Y" cracks that exhibit spalling, breakup, or faulting. Punchouts are caused by the following.

1. Repeated heavy traffic loadings.
2. Pumping.
3. Poor support.
4. Erodible base.
5. Inadequate concrete consolidation.
6. Inadequate concrete slab thickness.
7. Inadequate amount of reinforcement.
8. Ruptured or corroded reinforcing steel.



Punchouts on CRCP (FHWA, 2014).

Measurement

- Record the number of punchouts at each severity level.
- The cracks which outline the punchout are also recorded under "longitudinal cracking" and "transverse cracking."
- Punchouts that have been repaired by completely removing all broken pieces and replacing them with patching material (rigid or flexible) should be rated as a "patch."
- If the boundaries of the punchout are visible, rate it as a high-severity punchout.
- *Note:* Areas between two transverse cracks spaced greater than 2 ft. but less than or equal to 3 ft. apart and bounded by the edge of pavement (or longitudinal joint) and a longitudinal crack, are rated as moderate or high severity punchouts if the cracks exhibit spalling or if the area is breaking up or is faulting.

2.25.2 Severity Levels and Maintenance and Preservation Options

Low Severity: Distress Criteria

- Longitudinal and transverse cracks that:
  - Are tight and may have spalling < 3 in. or faulting < 0.25 in.
  - Have no loss of material.
- There is no patching.
- Does not include "Y" cracks.

Low Severity: Maintenance & Preservation Options

- Do nothing but monitor for future repairs.

Moderate Severity: Distress Criteria

- Longitudinal and transverse cracks that:
  - Have spalling ≥ 3 in. and < 6 in., or faulting > 0.25 in. and < 0.5 in. exists.

Moderate Severity: Maintenance & Preservation Options

- Full depth patch (FDP).

High Severity: Distress Criteria

- Longitudinal and transverse cracks that have spalling ≥ 6 in.
- Concrete within the punchout is:
  - Punched down by ≥ 0.5 mm, or
  - Loose and moves under traffic, or
  - Contains patch material.

High Severity: Maintenance & Preservation Options

- Full depth patch (FDP).

CHAPTER 3: CONCRETE PAVEMENT M&P STRATEGIES

3.1 Introduction

This chapter presents different aspects of M&P strategies for concrete pavements. It starts with the introduction to M&P strategies and continues with the discussion of materials and design considerations, construction considerations and detailed description of construction steps associated with each M&P strategy. The chapter also includes references to the following relevant INDOT Standard Specification(s) and Standard Drawing(s).

- Crack Sealing
- Joint Resealing
- Full Depth Patching (FDP)
- Cross-Stitching
- Retrofit Load Transfer (RLT) (also known as Dowel Bar Retrofit (DBR))
- Partial Depth Patching (PDP)
- Diamond Grinding
- Diamond Grooving
- Undersealing (also known as Slab Stabilization)

3.2 Crack Sealing

Crack sealing is a concrete pavement preservation activity that serves two primary purposes. One purpose is to reduce the amount of moisture and deicing chemicals that can infiltrate a pavement structure, while the second is to prevent the intrusion of incompressible materials (sand, pebbles, and other solid debris) into the joint.

Sealed transverse crack on concrete pavement (Texas Transportation Institute, 2008).

3.2.1 Material and Design Considerations

TABLE 3.1
Materials for crack sealing

Type	Materials	References
Routing, Cleaning, and Sealing	Hot pour asphalt sealant	INDOT Standard Spec. 906.02 (INDOT, 2022c)
Cleaning and Filling	AE-90, AE-90S, AE-150	INDOT Standard Spec. 902.01(b) (INDOT, 2022c)
Fine Aggregates	23, 24	INDOT Standard Spec. 904.02 (INDOT, 2022c)

3.2.2 Construction Considerations

Construction Steps (Adapted from Lee & Shields, 2010; FHWA, 2019a; & Smith et al., 2022)

1. *Preparation:* Ensure that the surface is clean and dry, and any existing vegetation has been removed from cracks. Water blasting should not be used under pressure, since doing so can damage the concrete pavement.
2. *Routing:* Route or saw each crack, creating a reservoir. This reservoir should not exceed 0.75 in. in width and should have 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 the surface of the crack.
5. *Squeegeeing:* Squeegee the filler with a "V" shaped wand tip to allow the penetration of the filler into the cracks.

Sealing (Step 4) of a crack in concrete pavement using polymer binder (Maxwell Products, n.d.).

Relevant Specifications and Standard Drawings

- INDOT Standard Specifications 503 and 507 (INDOT, 2022a)

Traffic

Operations shall cease if rain commences during installation. No traffic is allowed until curing is complete (Lee & Shields, 2010). For more detailed information about temporary traffic control for all pavement repair jobs, please review the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD), Part 6C (FHWA, 2009).

Weather

Air and/or surface temperature shall meet manufacturer requirements and all agency requirements (typically 40°F and rising) for sawing and sealing. Sealants should not be installed when temperatures are at or below the dew point. Sealing shall not proceed if rain is imminent. The pavement surface and the joint should be free of moisture before the crack-sealing operation can commence (FHWA, 2019a).

3.3 Joint Resealing

Joint resealing is a concrete pavement preservation activity that serves two primary purposes. The first purpose is to reduce the amount of moisture and deicing chemicals that can infiltrate a pavement structure, while the second is to prevent the intrusion of incompressible materials (sand, pebbles, and other solid debris) into the joint.

Sealed contraction joint on concrete pavement (© Photo by Applied Pavement Technology (APTech)).

3.3.1 Material and Design Considerations

TABLE 3.2
Materials for joint resealing

Type	Joints	Materials	References
Routing, Cleaning, and Sealing	Transverse Joints	Silicone, hot pour asphalt, or preformed elastomeric sealant with or without backer rod	INDOT Standard Spec. 906.02 (INDOT, 2022c)
	Longitudinal Joints	Hot pour asphalt or silicone sealant with or without backer rod[a]	
Cleaning and Filling	–	Hot pour asphalt	

[a] The preferred method is the use of asphalt rubber without a backer rod.

3.3.2 Construction Considerations

Construction Steps (Adapted from Lee & Shields, 2010; FHWA, 2019a; & Smith et al., 2022)

A. Sawing, Cleaning, and Sealing Procedure

1. *Plowing:* A joint plow should be applied to remove existing sealant prior to sawing. The plow must remove enough sealant to keep the saw blades from gumming up.
2. *Routing/Sawing:* Route or saw joints with a vertical spindle router if the joint dimensions are not adequate. Refer to INDOT Standard Drawings No. E 503-CCPJ-05 and E 503-CCPJ-03 (INDOT, 2020a) for Longitudinal Joint Details and D-1 Contraction Joint Details, respectively.
3. *Cleaning:* Clean joints with compressed air or a powder brush (using a minimum air pressure of 100 psi).

4. *Sealing:* Transverse joints should be sealed with hot pour asphalt, silicone sealant, or preformed elastomeric joint sealant. Longitudinal joints should be sealed with hot pour asphalt or silicone sealant.
5. *Squeegeeing:* Squeegee the filler with a "V" shaped wand tip to allow the penetration of the sealer into the joints.

B. Cleaning and Filling

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

Sealing of a transverse joint in concrete pavement (Part A Step 4 Construction Steps) (© Photo by Applied Pavement Technology (APTech)).

Relevant Specifications and Standard Drawings

- INDOT Standard Specifications 503, 506, 507 and 509 (INDOT, 2022a)
- Standard Drawing E 503-CCPJ (INDOT, 2020a)
- Standard Drawing E 506-CCPP (INDOT, 2020b)
- Standard Drawing E 509-CCJR (INDOT, 2021)

Traffic

Traffic may be allowed on the PCCP for up to seven calendar days after the saw cutting and prior to sealing. No traffic is allowed until curing of sealant is complete (Lee & Shields, 2010). For more detailed information about temporary traffic control for all pavement repair jobs, please review the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD), Part 6C (FHWA, 2009).

Weather

Air and/or surface temperature shall meet the manufacturer and the agency requirements for sawing and sealing (typically 40°F and rising). Sealants should not be installed when temperatures are at or below the dew point. Sealing shall not proceed if rain is imminent. The pavement surface and the joint should be free of moisture before the joint sealing operation can commence (FHWA, 2019a).

3.4 Full Depth Patching (FDP)

Full depth patching (FDP) entails removing and replacing at least a portion of a slab to the bottom of the concrete, in order to restore the rideability and structural integrity of concrete pavements and to extend pavement service life.

Completed concrete full depth patch on a concrete pavement (© Photo by Applied Pavement Technology (APTech)).

3.4.1 Material and Design Considerations

TABLE 3.3
Materials for concrete full depth patching (FDP)[a]

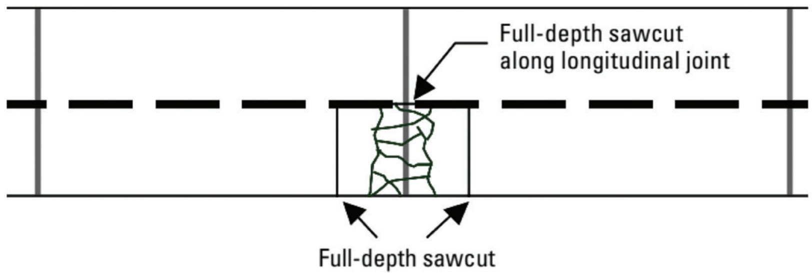
Type	Materials	References
Curing Materials and Admixtures	–	INDOT Standard Spec. 912.01 & 03 (INDOT, 2022c)
Calcium Chloride	Type L	INDOT Standard Spec. 913.02 (INDOT, 2022c)
Chemical Anchor System	–	INDOT Standard Spec. 901.05 (INDOT, 2022c)
Coarse Aggregate	Class AP, Size No. 8	INDOT Standard Spec. 904.03 (INDOT, 2022c)
Fine Aggregate	Size No. 23	INDOT Standard Spec. 904.02 (INDOT, 2022c)
Portland Cement (including CSA)	–	INDOT Standard Spec. 901.01 (b) & (b) (INDOT, 2022c)
Water	–	INDOT Standard Spec. 913.01 (INDOT, 2022c)
Reinforcing Steel and Dowel Bar[b]	–	INDOT Standard Spec. 910.01 (INDOT, 2022c)
Bond Breaker	–	ASTM, 2020a, INDOT, 2019
Expansion Caps	–	–
Dowel Bar Support Chairs	–	ASTM, 2020a, INDOT, 2019
Foam Core Insert	–	–
Caulking Filler	–	–
Non-Shrink Rapid Setting Concrete	–	INDOT Standard Spec. 901.07 (b) & (b) (INDOT, 2022c)

[a] INDOT Design Manual (INDOT, 2024) allows HMA to be used for PCCP patching in special circumstances.
[b] Minimum Dowel Bar Diameter (INDOT, 2020b): For slab thickness $\leq$ 10 in., 1 in., and for slab thickness $>$ 10 in., 1.5 in.

3.4.2 Construction Considerations

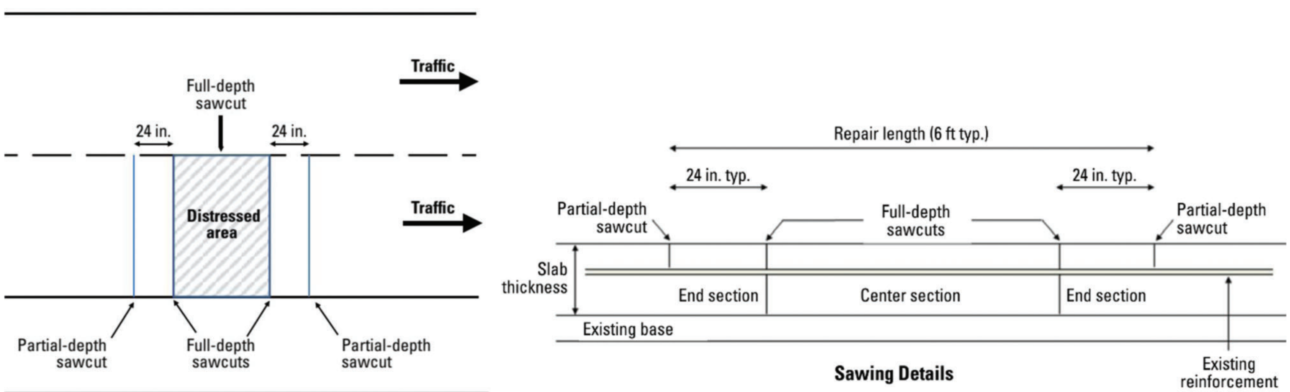
Construction Steps (Adapted from Lee & Shields, 2010; FHWA, 2019e; & Smith et al., 2022)

1. *Survey:* Patch boundaries should be identified and marked on the pavement surface based on engineering judgment using data from coring, Falling Weight Deflection (FWD) testing, Ground Penetration Radar (GPR) testing, etc.
2. *Saw-cutting:*
   a. ***JPCP and JRCP:*** A saw cut should be made to the full lane width and depth over the marked length.



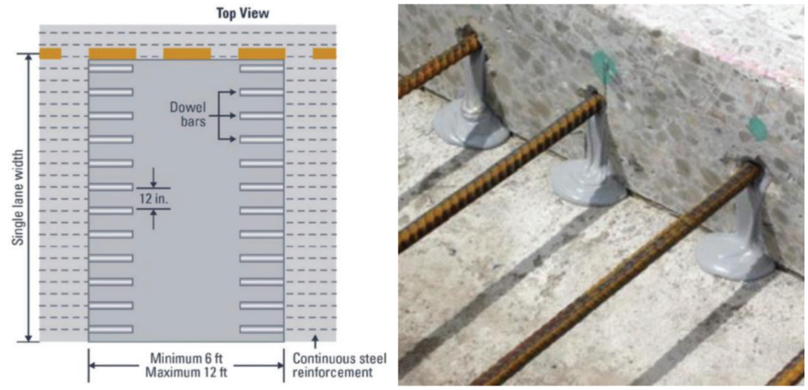
Saw-cut locations for FDP of JPCP/JRCP (Smith et al., 2022).

   b. ***CRCP:*** The saw-cutting procedures for CRCP will depend upon the repair methodology employed.
      - In the traditional method, two sets of saw-cuts are required to provide a rough joint face at the repair boundaries and to maintain the continuity of reinforcement throughout the repair. This is accomplished by first making a partial depth cut at each side of the repair area, and then making two full depth saw-cuts within the repair area at a distance of 24 in. from the partial-depth cuts.



Saw-cut locations (left) and sawing details for traditional CRCP FDP (right) (Smith et al., 2022).

      - In modified procedures, a single full depth saw-cut in CRCP is employed and no efforts are made to tie-in the new reinforcing steel directly with the existing reinforcing steel. Instead, holes are drilled in the faces of the existing concrete slabs (typically 12 in. apart) and new reinforcing steel (either dowel bars [South Carolina method] or tie bars [Texas method]) is anchored into the existing slab.



Details of the modified procedure of CRCP FDP; anchored dowel bars, referred to as the South Carolina method (left), and anchored tie bars, referred to as the Texas method (right) (Smith et al., 2022).

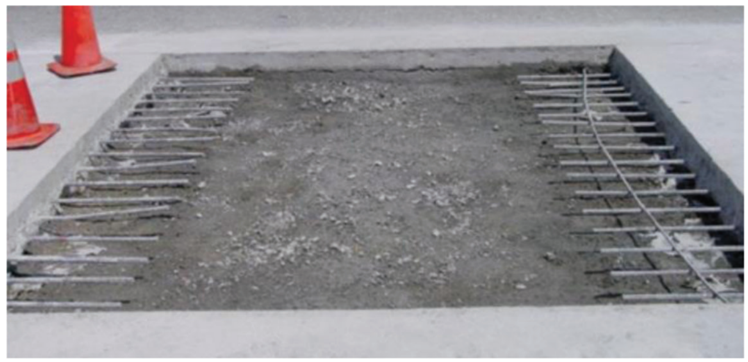
3. *Concrete removal:*
   a. ***JPCP and JRCP:*** The saw-cut slab should be removed from the repair area using two methods.
      - *Lift-out method:* In this method, lift pins are placed in drilled holes in the distressed slab and hooked with chains to a front-end loader or other equipment capable of vertically lifting the distressed slab, such as vacuum suction equipment.
      - *Breakup and clean-out method:* In this method, the saw-cut slab should be broken into smaller pieces using a mechanical hammer or rammer and removed by a backhoe.

Removal (Step 3) of distressed concrete pavement using lift-out method for FDP implementation: chain lift-out (left), and vacuum suction lift-out (right) (Smith et al., 2022).

Removal (Step 3) of distressed concrete pavement using breakup and clean-out method for FDP implementation (© Photo by Applied Pavement Technology (APTech)).

b. ***CRCP:*** The method of removing the distressed slab is also a function of the utilized repair method.

- In the traditional method, the removal of the concrete between the full depth cuts and the partial-depth cuts may be challenging. Ensure that the reinforcing steel in the distressed slab is exposed so that new steel can be lapped to carry it through the repair area.
  – Use jackhammers, pry bars, picks, and other hand tools while being careful to avoid damage to the reinforcement.
  – To prevent underbreaking of the bottom half of the slab, the face of the concrete below the partial-depth sawcut should be inclined slightly into the repair, as any significant underbreaking that occurs will require a new partial-depth sawcut outside of the damaged area.
  – Separation of the surrounding concrete from the reinforcing steel must be done without nicking, bending, or damaging the steel in any way.
  – Do not use a drop hammer or hydro-hammer on the pavement section under treatment since doing so can damage the reinforcement or cause spalling below the saw-cut.
  – Carefully inspect the reinforcement for any damage after removal. If more than 10% of the bars are seriously damaged or corroded or if three or more adjacent bars are broken, the boundary of the repair (in the horizontal direction as shown in the figure) should be extended another lap distance.
- In the modified procedures, the steps for removing concrete from the CRCP repair area are the same as those for the removal of concrete in JPCP/JRCP repair areas.



Prepared CRCP repair area (Step 4) with exposed reinforcing steel (Smith et al., 2022).

4. *Repair area preparation:* If disturbed, the base and the subgrade should be compacted, treated, or replaced.
5. *Load transfer/Reinforcement restoration:*

a. ***JPCP and JRCP:*** FDP requires the installation of mechanical load transfer devices, dowels, and tie bars. Details on dowel bar locations and dowel sizes are provided in INDOT Standard Drawing No. E 506-CCPP-02 (INDOT, 2020b).

Installation of dowel bar (load transfer) (Step 5) in FDP implementation on a JPCP (© Photo by Applied Pavement Technology (APTech)).

b. ***CRCP:*** FDP requires that the continuity of reinforcement be maintained through the repair by splicing in new reinforcement materials in the repair area. Most agencies also require the provision of transverse steel to help position the longitudinal bars and to control any potential longitudinal cracking.

6. *Treatment of joints:* FDP requires the installation of dowels on transverse joints and tie bars for longitudinal joints. Details about dowel bar locations and dowel sizes are provided in INDOT Standard Drawing No. E 506-CCPP-02 (INDOT, 2020b).
7. *Placement:* Slightly overfill the treated area with concrete to counteract volume reduction during consolidation.
8. *Consolidation:* Consolidate the concrete using vibrators.
9. *Finishing:* Finish the patching area to the level of the adjacent pavement and match the texture of the patched surface to that of the adjacent pavement.
   a. For repairs less than 10 ft. in length, the concrete surface should be struck off with a screed perpendicular to the centerline of the pavement.
   b. For repairs greater than or equal to 10 ft. in length, the concrete surface should be struck off with the screed parallel to the centerline of the pavement.
10. *Curing:* Cure the freshly placed concrete to reduce the potential for shrinkage cracking and ensure proper hydration and adequate strength development. In colder weather, the use of insulating blankets and tarps can reduce the curing time.
11. *Diamond grinding (if necessary):* May be considered an optional treatment to improve surface smoothness. Grinding would be performed after the backfill material has been cured.
12. *Pressure-relief cut (if necessary):* Install pressure relief cuts using carbide-tipped wheel saw. If a wheel saw is used, diamond saw-cuts must still be made just outside the wheel saw-cuts. To prevent subbase damage, the wheel saw must not be allowed to penetrate into the subbase more than 0.5 in. As an alternative, the sawing operation could be scheduled to be performed during the cooler parts of the day or at night.
13. *Joint resealing:* Apply the joint resealing procedure, as described in the joint resealing section.

Restoration of both longitudinal and transverse steel in a CRCP FDP project (Step 5) (© Photo by Applied Pavement Technology (APTech)).

Placement (Step 7) of concrete pavement for FDP implementation for a CRCP (© Photo by Applied Pavement Technology (APTech)).

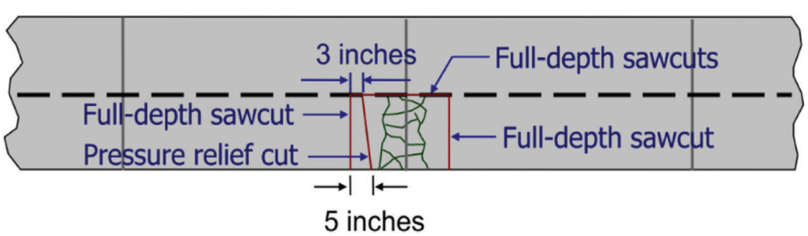


Illustration of placement of cutting joints (including pressure relief joint (Step 12)) in the FDP area (T. Nantung, personal communication, August 14, 2023).

Relevant Specifications and Standard Drawings

- INDOT Standard Specifications 506 and 509 (INDOT, 2022a)
- Standard Drawing E 503-CCPJ (INDOT, 2020a)
- Standard Drawing E 506-CCPP (INDOT, 2020b)
- Standard Drawing E 509-CCJR (INDOT, 2021)

Traffic

In accordance with INDOT Specification, Section 506.12(a) (INDOT, 2022a), the open-to-traffic guidelines for FDP are as follows.

- For FDP less than or equal to 15 ft. in length and constructed using concrete with calcium chloride accelerator, the open-to-traffic times are shown in Table 3.4. In general, traffic shall not be allowed on the PCC pavement until a modulus of rupture of 300 psi from flexural strength testing is achieved.
- FDP greater than 15 ft. in length, traffic shall not be allowed on the PCCP until a modulus of rupture of 425 psi from flexural strength testing is achieved.

For more detailed information about temporary traffic control for all pavement repair jobs, please review the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD), Part 6C (FHWA, 2009).

TABLE 3.4
Opening to traffic guidelines for FDP with calcium chloride (INDOT, 2022a)

T	H	HT	T	H	HT
40°F–42°F	30	26	61°F–63°F	14	9
43°F–45°F	27	23	64°F–66°F	14	9
46°F–48°F	27	21	67°F–69°F	14	8
49°F–51°F	21	19	70°F–72°F	14	7
52°F–54°F	19	16	73°F–75°F	14	6
55°F–57°F	16	14	above 75°F	14	5
58°F–60°F	16	11	–	–	–

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

Weather

Verify that air and surface temperatures meet contract document requirements (typically a minimum of 40°F and rising) for concrete placement. Repair work should not proceed if rain is imminent (FHWA, 2019e).

3.5 Cross-Stitching

Cross-stitching is a preservation method designed to strengthen nonworking longitudinal joints and cracks that are in relatively good condition (ACPA & IGGA, 2010). The purpose of cross-stitching is to maintain aggregate interlock and provide added reinforcement and strength to the cracks or joints. The tie bars used in cross-stitching prevent the vertical and horizontal movement of the cracks and joints or their widening.

Implementation of a cross-stitching method to repair a longitudinal crack (Daily Civil, n.d.).

3.5.1 Material and Design Considerations

TABLE 3.5
Materials for cross-stitching

Materials	**Properties**
Stitch Bars	#6 to #8 Grade 60 deformed bars. The length of the bar must be chosen to produce a 1-in. recess between the top of the bar and the pavement surface.
Epoxy	Two-component adhesive consisting of a resin and a hardener or catalyzing agent to be used in a 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.

3.5.2 Construction Considerations

Construction Steps (Adapted from Lee & Shields, 2010; FHWA, 2019f; & Smith et al., 2022)

1. *Drilling holes:* Drill holes at 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, to consistently cross at mid-depth.
2. *Cleaning holes:* Air-blow the holes to remove dust and debris after drilling.
3. *Pouring epoxy:* Inject epoxy into the hole, leaving some volume for the bar to occupy the hole.
4. *Tie bar installation:* Insert the tie bars into the holes, leaving about 1 in. from the top of the bar to the pavement surface.
5. *Cleaning:* Remove excess epoxy and finish flush with the pavement surface.

Drilling holes for cross-stitching (Step 1) (Smith et al., 2022).

Relevant Specifications and Standard Drawings

- INDOT Standard Specifications 503, 506, 507, and 509 (INDOT, 2022a)
- Standard Drawing E 503-CCPJ (INDOT, 2020a)
- Standard Drawing E 506-CCPP (INDOT, 2020b)
- Standard Drawing E 509-CCJR (INDOT, 2021)
- Standard Sketch (Smith et al., 2022, Figure 8.23)

Inserting a tie bar into a drilled hole (Step 4) (Smith et al., 2022).

Traffic

Traffic can be allowed on the surface as soon as the epoxy has fully set (Lee & Shields, 2010). For more detailed information about temporary traffic control for all pavement repair jobs, please review the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD), Part 6C (FHWA, 2009).

Weather

Air and/or surface temperature shall meet manufacturer requirements and all agency requirements (typically 40°F and rising) (Lee & Shields, 2010).

3.6 Retrofit Load Transfer (RLT) (Also Known as Dowel Bar Retrofit (DBR))

Load transfer retrofit involves installation of dowel bars in slots across existing transverse joints or cracks to re-establish load transfer across these discontinuities, reduce deflections, and prevent faulting. 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.

Completed retrofit load transfer (RLT) on a highway concrete pavement (© Photo by Applied Pavement Technology (APTech)).

3.6.1 Material and Design Considerations

TABLE 3.6
Materials for retrofit load transfer (RLT)

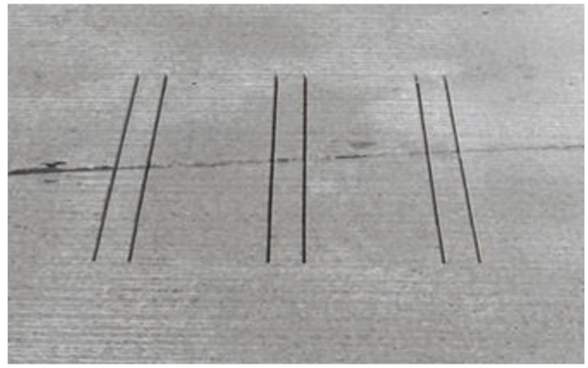
Type	References
Dowel[a]	INDOT Standard Spec. 2022, 910.01 (INDOT, 2022c)
Bond Breaker	ASTM, 2020a; INDOT, 2019
Expansion Caps	–
Dowel Bar Support Chairs	ASTM, 2020a; INDOT, 2019
Foam Core Insert	–
Caulking Filler	–
Non-Shrink Rapid Setting Concrete	INDOT, 2022c

[a] Minimum Dowel Bar Diameter (INDOT, 2020b): For slab thickness $\leq$ 10 in., 1 in., and for slab thickness $>$ 10 in, 1.5 in.

3.6.2 Construction Considerations

Construction Steps (Adapted from Lee & Shields, 2010; FHWA, 2019a; & Smith et al., 2022)

1. *Survey:* The slot location for the retrofit dowel bar should be identified and marked on the pavement surface.
2. *Slot creation:* Saw cutting is performed to make walls for slots. Concrete fins should be removed using lightweight pneumatic hammers which are not larger than 30-lb Class Paving Breaker (PB-30). The hammers should be applied at an angle of 45° to the plane of the pavement. The bottom of the slots should be smooth, level, and clean.
3. *Slot preparation:* The slots should be cleaned using sandblast, air blast, and vacuum. The slot should be free of dust, slurry, debris, and moisture.
4. *Dowel/tie bar placement:* 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 INDOT Standard Drawing E 507-RLTC (INDOT, 2004) 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. If applicable, tie bars must be also restored.
5. *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.
6. *Diamond grinding (if necessary):* Diamond grinding may be considered an optional treatment to improve surface smoothness. Grinding would be performed after the backfill material has been cured.
7. *Sealing existing joints:* 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 (typically less than 0.5 in. outside of the joint).



Slot creation (Step 2) of concrete pavement (Photo from J. Uhlmeyer, personal communication,) May 14, 2024.

Dowel bar placement (Step 6) into the slots (Photo from J. Uhlmeyer, personal communication, May 14, 2024).

Relevant Specifications and Standard Drawings

- INDOT Standard Specifications 507 (INDOT, 2022a)
- Standard Drawing E 507-RLTC (INDOT, 2004)

Traffic (FHWA, 2019c)

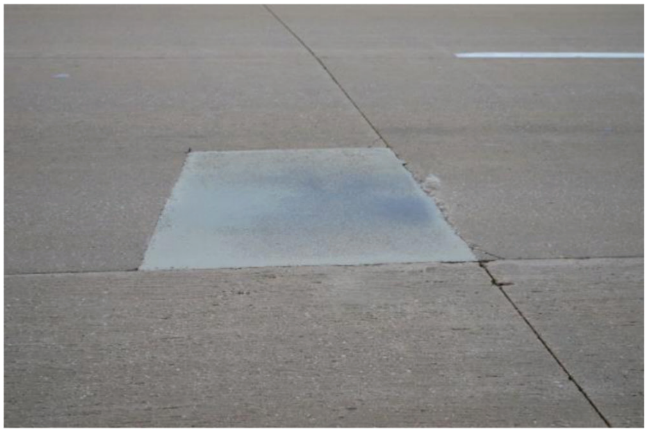
In cases where slot sawing is allowed to proceed faster than concrete removal and dowel installation, ensure that traffic is not allowed to drive on the saw cuts for a period greater than that specified in the contract (typically five days). Furthermore, ensure that the repaired pavement is not open to traffic until the dowel slot patching material has attained the specified strength or was cured for a period of time required by the contract documents. For more detailed information about temporary traffic control for all pavement repair jobs, please review the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD), Part 6C (FHWA, 2009).

Weather (FHWA, 2019c)

The air and/or surface temperature shall meet manufacturer requirements and all agency requirements (typically 40°F and rising) for patching material placement. Neither dowel bar installation nor patching should proceed if rain is imminent.

3.7 Partial Depth Patching (PDP)

Partial depth patching (PDP) entails removal and replacement of small, shallow (less than half the slab thickness) areas of deteriorated concrete, in order to restore the rideability and structural integrity of concrete pavements and extend pavement service life. PDP is an alternative to full depth patching (FDP) in areas where slab deterioration is located primarily in the upper half of the slab and where the existing load transfer devices (if present) are still functional.



Completed concrete partial depth patch at the corner of a concrete slab (© Photo by Applied Pavement Technology (APTech)).

3.7.1 Material and Design Considerations

TABLE 3.7
Materials for concrete partial depth patching (PDP)[a]

Type	Materials	References
Curing Materials and Admixtures	–	INDOT Standard Spec. 912.01 & 03 (INDOT, 2022c)
Calcium Chloride	Type L	INDOT Standard Spec. 913.02 (INDOT, 2022c)
Chemical Anchor System	–	INDOT Standard Spec. 901.05 (INDOT, 2022c)
Coarse Aggregate	Class AP, Size No. 8	INDOT Standard Spec. 904.03 (INDOT, 2022c)
Fine Aggregate	Size No. 23	INDOT Standard Spec. 904.02 (INDOT, 2022c)
Portland Cement (including CSA)	–	INDOT Standard Spec. 901.01 (b) & (b) (INDOT, 2022c)
Water	–	INDOT Standard Spec. 913.01 (INDOT, 2022c)
Non-Shrink Rapid Setting Concrete	–	INDOT Standard Spec. 901.07 (INDOT, 2022c)
Bond Breaker	–	ASTM, 2020a, INDOT, 2019

[a] *INDOT Design Manual* (INDOT, 2024) does NOT allow HMA to be used for PCCP PDP.

3.7.2 Construction Considerations

Construction Steps (Adapted from Lee & Shields, 2010; FHWA, 2019a; & Smith et al., 2022)

1. *Survey:* Locate the unsound concrete using the sounding technique (typically by striking the concrete surface with a steel rod or ball-peen hammer). Patch boundaries should be marked on the pavement surface. The repair area is usually extended 3 to 4 in. beyond the visible area of the unsound concrete.

2. *Removal:* A saw cut should be made to the needed depth (1 in. to 3 in.) over the marked length. The saw-cut slab should be broken into smaller pieces using a light pneumatic hammer, a carbide-tipped milling machine, or a rammer and all unsound concrete should be removed. The bottom of the repair area should consist of sound concrete.
3. *Repair area preparation:* Prepare the repair area to provide a clean, rough surface to facilitate a good bond with the repair material.
   a. Sandblasting or high-pressure water blasting followed by air blowing can be used to remove loose particles, oils, dust, and other contaminants from within the repair area.
   b. If the repair area is 3 ft. or larger, it is recommended that No. 5 hook bars be drilled and grouted into the bottom of the repair area at 1 ft. intervals in both transverse and longitudinal directions.
4. *Joint preparations:* Maintain joints in the area of interest using bond breakers.
5. *Apply a bonding agent:* Apply a non-vapor-barrier type bonding agent (e.g., cement grout or epoxy) to vertical and horizontal surfaces.
   If any proprietary repair material is used, the manufacturer's recommendations for allowable temperature and moisture conditions at the time of placement and the thickness of lifts must be followed.
6. *Repair material placement:* Slightly overfill to allow counteracting for volume reduction during consolidation.
7. *Consolidation:* Consolidate PCCP filler using the following.
   a. Small-head vibrator (with a diameter ≤ 1 in.) or rodding/tamping (for small projects).
   b. Vibrating screed for larger repairs.

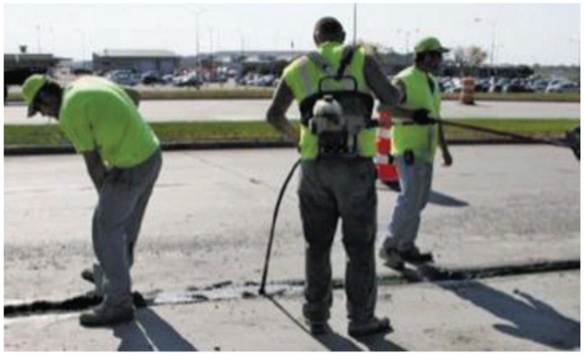
Properly marked PDP area (Step 1) (Smith et al., 2022).

Partial Depth Patching (PDP)

Placement of bond breaker on a PDP project (Step 4) (Smith et al., 2022).

Application of cement grout as bonding agent (Step 5) (Smith et al., 2022).

Placement of PDP material for longitudinal joints using mobile concrete truck (Step 6) (Smith et al., 2022).



Consolidation of PDP material using small-head vibrator (Step 7) (Smith et al., 2022).

8. *Finishing:* Finish the patching area to the level of the adjacent pavement and match the texture of the patched surface to that of the adjacent pavement.
   a. For repairs less than 10 ft. in length, the concrete surface should be struck off with a screed perpendicular to the centerline of the pavement.
   b. For repairs greater than or equal to 10 ft. in length, the concrete surface should be struck off with the screed parallel to the centerline of the pavement.
9. *Curing:* Cure the freshly placed concrete to reduce the potential for shrinkage cracking and ensure proper hydration and adequate strength development. In colder weather, the use of insulating blankets and tarps can reduce the curing time.
10. *Joint resealing:* Follow the joint resealing procedure, as described in the joint resealing section (Section 3.3).

Insulating blanket being placed on finished PDP in cold weather conditions (Step 9) (Smith et al., 2022).

Relevant Specifications and Standard Drawings

- INDOT Standard Specifications 506 and 509 (INDOT, 2022a)
- MnDOT Concrete Pavement Rehabilitation Guide, Section 5-2 (MnDOT, 2023)
- Standard Drawing E 503-CCPJ (INDOT, 2020a)
- Standard Drawing E 506-CCPP (INDOT, 2020b)
- Standard Drawing E 509-CCJR (INDOT, 2021)

Traffic

In accordance with INDOT Specification, Section 506.12(a) (INDOT, 2022a), in general, traffic shall not be allowed on the PDP-repaired PCC pavement until a flexural modulus of rupture of 300 psi is achieved. For more detailed information about temporary traffic control for all pavement repair jobs, please review the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD), Part 6C (FHWA, 2009).

Weather

Verify that air and surface temperatures meet contract document requirements (typically a minimum of 40°F and rising) for concrete placement. Repair work should not proceed if rain is imminent (FHWA, 2019d). At temperatures below 55°F, additional precautions (warm water, insulation cover, and longer cure time) should be considered (FHWA, 2019d).

3.8 Diamond Grinding

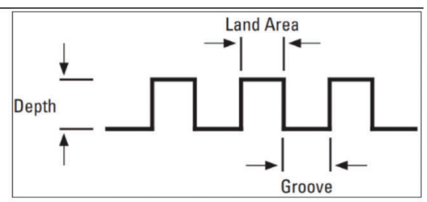
Diamond grinding is the removal of a thin layer of hardened concrete pavement surface (typically 0.2 in. to 0.25 in.) using a self-propelled machine outfitted with a series of closely spaced diamond saw blades mounted on a rotating shaft. Diamond grinding is one of the cost-effective concrete pavement restoration techniques that corrects surface irregularities such as faulting or roughness, restores ride quality, improves surface texture (and therefore safety), and reduces noise levels (Lee & Shields, 2010; Smith et al., 2022).

A close view of a uniformly diamond-ground surface of a concrete pavement (© Photo by Applied Pavement Technology (APTech)).

3.8.1 Grinding Texture and Design Considerations

TABLE 3.8
Range of typical dimensions for diamond grinding operations

Characteristics	Class AP Aggregate	Limestone and Dolomitic Limestone
Groove Width	0.1–0.16 in.	0.1–0.16 in.
Land Area	0.08 in.	0.1 in.
Groove Depth	0.06 in.	0.06 in.
Grooves per foot	53–60	50–54



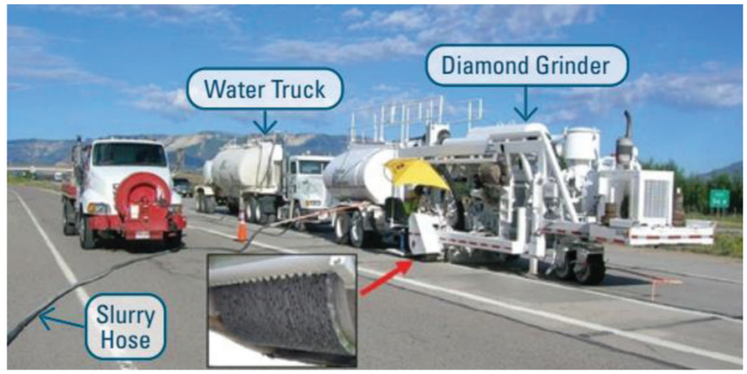
Lee & Shields, 2010

Note: Image source is Lee and Shields, 2010

3.8.2 Construction Considerations

Construction Steps (Adapted from Lee & Shields, 2010; FHWA, 2019a; & Smith et al., 2022)

1. *Preparation:* All structural/material deficiencies of PCCP should be restored before the diamond grinding operation commences. For example, the contractor must complete all partial depth patching and full depth patching, or preventive repair activities (except for joint resealing) before diamond grinding.
2. *Grinding:* Grinding is performed along a traffic lane and is a continuous operation. 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 on large projects. One machine and several passes with 2 in. of minimum overlap are used for small projects.
3. *Cleaning:* The slurry/residue from the grinding operation should be removed using a vacuum truck and be properly disposed.
4. *Filling/Resealing:* Joints and cracks should be sealed or filled.



Diamond grinding equipment (Smith et al., 2022).

Relevant Specifications and Standard Drawings

– INDOT Standard Specifications 507 (INDOT, 2022a)

Traffic

Traffic can be allowed on the ground surface provided the following is true.

1. The grinding residue is cleaned (Lee & Shields, 2010).
2. All equipment and personnel have been removed from the work zone (FHWA, 2019b).
3. The repairs are capable of sustaining traffic (FHWA, 2019b).

For more detailed information about temporary traffic control for all pavement repair jobs, please review the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD), Part 6C (FHWA, 2009).

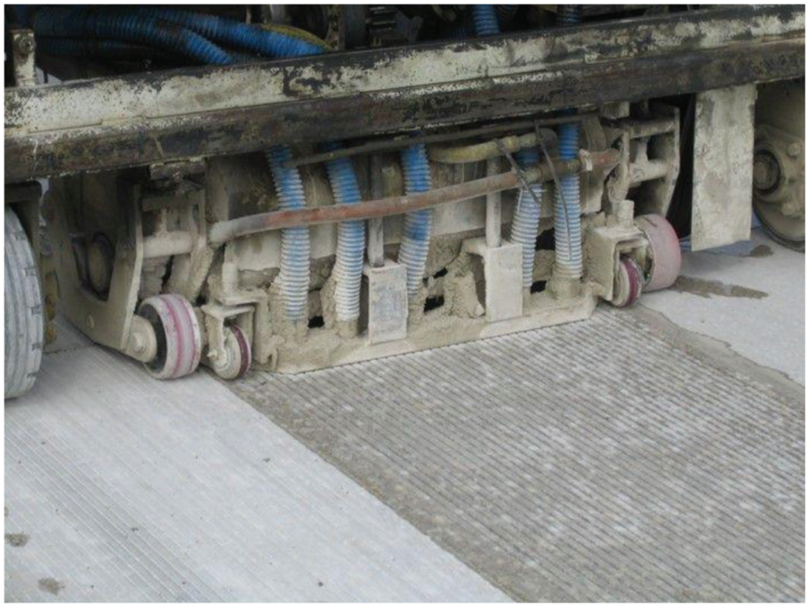
Weather

Air and/or surface temperature shall meet minimum agency requirements (typically 35°F and rising) (Lee & Shields, 2010). Diamond grinding shall not proceed if icy weather conditions are imminent (FHWA, 2019b).

Stacking spacers and blades on a diamond grinding machine's cutting head (Smith et al., 2022).

3.9 Diamond Grooving

Diamond grooving is a process in which parallel grooves are cut into the pavement surface using diamond saw blades with a typical center-to-center blade spacing of 0.75 in. Diamond grooving is generally used to reduce hydroplaning and accidents by providing escape channels for surface water. Diamond grooving should only be applied to pavements that are structurally and functionally adequate (Smith et al., 2022; Lee & Shields, 2010).

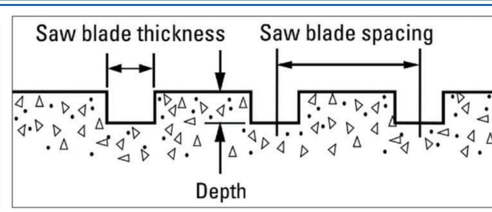


Diamond grooving of concrete pavement (© Photo by Applied Pavement Technology (APTech)).

3.9.1 Grooving Texture and Design Considerations

TABLE 3.9
Range of typical dimensions for diamond grooving operations

Characteristics	Dimensions (Smith et al., 2022)
Groove Depth	0.125–0.25 in.
Saw Blade Thickness	0.1–0.125 in.
Saw Blade Spacing	0.75 in.



(adapted from Smith et al., 2022)

3.9.2 Construction Considerations

Construction Steps (Adapted from Lee & Shields, 2010; FHWA, 2019a; & Smith et al., 2022)

1. *Preparation:* All structural/material deficiencies of PCCP should be restored before the diamond grooving operation commences. For example, the contractor must complete all partial depth patching and full depth patching, or preventive repair activities (except for joint resealing) before diamond grooving.
2. *Grooving:* Grooving is performed longitudinally along a pavement; If multiple passes are required, additional passes should be performed to maintain the same groove spacing across the adjacent passes. Grooves are typically not cut closer than about 3 in. to a parallel longitudinal joint.
3. *Cleaning:* The slurry/residue from the grooving operation should be removed using a vacuum truck and properly disposed of.
4. *Filling/Resealing:* Joints and cracks should be sealed or filled.

Diamond grooving cutting head (Smith et al., 2022).

Relevant Specifications and Standard Drawings

- INDOT Standard Specifications 507 (INDOT, 2022a)

Traffic

Traffic can be allowed on the grooved surface provided that the following is true.

1. The grooving residue is cleaned (Lee & Shields, 2010).
2. All equipment and personnel have been removed from the work zone (FHWA, 2019g).
3. The repairs are capable of sustaining traffic (FHWA, 2019g).

For more detailed information about temporary traffic control for all pavement repair jobs, please review the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD), Part 6C (FHWA, 2009).

Weather

Air and/or surface temperature shall meet minimum agency requirements (typically 35°F and rising) (Lee & Shields, 2010). Diamond grooving shall not proceed if icy weather conditions are imminent (FHWA, 2019g).

3.10 Undersealing (Also Known as Slab Stabilization)

Voids under PCCP cause faulting, pumping, corner breaks, and joint failures. Undersealing, which is also referred to as Slab Stabilization, is used to restore support to slabs by filling voids in the support layers, thereby reducing deflections and retarding the development of additional pavement deterioration (Lee & Shields, 2010; Smith et al., 2022).

3.10.1 Materials and Design Considerations

TABLE 3.10
Materials for undersealing

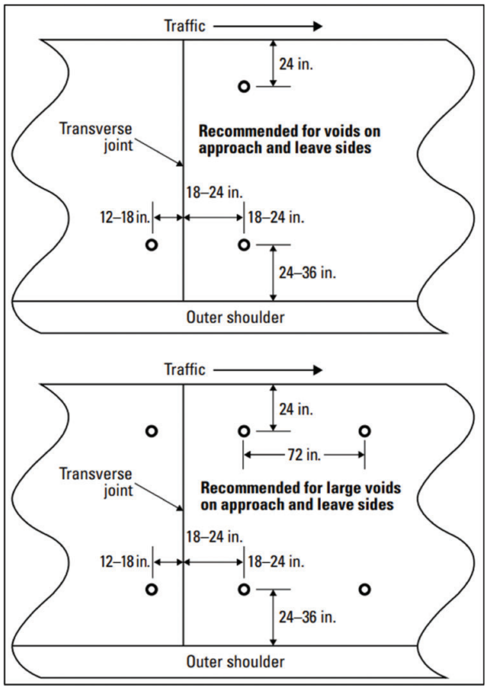
Materials	References
Polyurethane	Smith et al., 2022
Cement Grout Mixtures	Smith et al., 2022
Asphalt [Utility Asphalt (UA-2 and UA-3)]	ASTM, 2021; Smith et al., 2022

3.10.2 Construction Considerations

Construction Steps (Adapted from Lee & Shields, 2010; & Smith et al., 2022)

1. *Void detection:* The PCCP slabs needing undersealing application should be identified based on deflections from FWD testing, and the injection holes should be marked in these slabs.
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. Water can be poured into the holes. The level of water in the holes can indicate the presence of voids under the slab.


Polyurethane stabilization hole pattern (Smith et al., 2022).



Typical grout insertion hole patterns for slab stabilization of jointed concrete pavements (Smith et al., 2022).


Mechanical methods of monitoring slab uplift using cement grout injection (Smith et al., 2022).

3. *Preparation:* Prior to pumping, the surface of the pavement in the area around each hole should be sprinkled with water to prevent the undersealing material from adhering to the pavement surface.
4. *Material preparation and injection:* The material chosen for slab stabilization must be able to penetrate very thin voids while having the strength and durability to withstand pressures caused by traffic, moisture, and temperature. Polyurethane and cement grout mixtures have been commonly used in the past.

   a. Polyurethane undersealing operations use injection equipment consisting of plastic nozzles that screw onto hoses and deliver the material into the holes (ACPA, 1994). The injection of polyurethane materials uses a smaller injection hole, typically 0.625 in. After the injection has been completed, the excess polyurethane material is cleaned from the area and the hole can be left unpatched because of its small size (and since it will be already filled with the polyurethane material). Traffic can be opened on the roadway in as little as 15 to 30 minutes.
   b. If cement-grout mixtures are used for slab stabilization, positive-displacement injection pumps or non-pulsing progressive-cavity pumps are employed. The pump should be capable of maintaining low pumping rates and injection pressures (ACPA, 2003). Maintaining a low pumping rate (ideally about 1.5 gallons per minute) and low pumping pressure ensures better placement control and lateral coverage, and also keeps the slab from rising (AASHTO, 2020). Typical pumping pressures are in the 40 to 60 lbf/in^2 range (ACPA, 2003).

   Cement-based grouts are typically injected using a grout packer to prevent material extrusion or backup during injection. Two types of grout packers are used, depending on the size of the hole. Drive packers are pipes that taper and fit snugly into the injection hole by tapping with a small hammer (ACPA, 2003). Drive packers are generally used with 1-in. diameter holes. Expandable packers consist of a threaded inner pipe, a thin-walled steel outer sleeve, and a short rubber sleeve at the bottom (near the nozzle) that expands to fill the hole during injection (ACPA, 2003). Expanding rubber packers require 1.5 in. or larger diameter holes (ACPA, 2003).

Injecting polyurethane for slab stabilization (Smith et al., 2022).

Patching drill holes after removal of temporary plug-in cement grout slab

Undersealing

The injection equipment should include either a return hose from the injection device (packer or tapered nozzle) to the material storage tank or a fast-control reverse switch to stop grout injection quickly when slab movement is detected on the uplift gauge (ACPA, 2003). Use a grout-recirculation system to help eliminate the problem of grout setting in the injection hoses (Darter et al., 1985). It is generally recommended that the cement grout not be held in the mixer or pump hopper for more than 1 hour after initial mixing.

After grouting has been completed, the packer is withdrawn, and the hole is plugged immediately with a temporary wooden plug. When sufficient time has elapsed to permit the grout to set, the temporary plug is removed, and the hole is sealed flush with an acceptable patching material. Slab stabilization should not be performed when the ambient temperature is below 40°F. Unless a fast-setting material is used, traffic should be kept off a stabilized slab for at least 3 hours after grouting to allow adequate curing of the grout (Darter et al., 1985).

c. Asphalt undersealing consists of pumping 375°F to 450°F liquid asphalt under pressure beneath the concrete pavement on both sides of the joint. Safety equipment is required to protect traffic and crew from the hot liquid asphalt that may squirt out of the pavement. The roadway cannot be opened to traffic until the asphalt cools, which can be a minimum of 30 minutes after pumping.

Injection of asphalt undersealing material (Smith et al., 2022).

5. *Cleaning:* All material extruded during the pumping process should be removed from the surface of the pavement immediately after completion of the undersealing operation.

Relevant Specifications and Standard Drawings

- INDOT Standard Specifications 507 (INDOT, 2022a)
- INDOT Standard Specifications 612 (INDOT, 2022b)
- *Concrete Pavement Preservation Guide* (Smith et al., 2022)

Traffic

Traffic must be kept off the pavement during hole drilling and material application. Once holes are plugged with hardwood plugs, traffic may be permitted on both lanes (Lee & Shields, 2010).

For more detailed information about temporary traffic control for all pavement repair jobs, please review the *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD), Part 6C (FHWA, 2009).

Weather

Undersealing should not be applied when pavement surface temperature is below 40°F, or when the subgrade or subbase is frozen (Lee & Shields, 2010).

Consideration

For more information about undersealing (slab jacking) procedure, please contact Mr. Frank Sailer atfrsailer@indot.in.gov.

CHAPTER 4: TROUBLESHOOTING AND STOPGAP MEASURES

4.1 Introduction

This chapter lists common issues that a contractor or inspector may encounter in the field during and after the implementation of M&P strategies and provides recommendations to address these issues. A brief overview of emergency repair (stopgap) measures is also provided in this chapter.

4.2 Troubleshooting

There are several situations in which a contractor or inspector may encounter problems in the field during the implementation of M&P strategies. This chapter lists the common issues related to the construction of each M&P strategy, performance problems that may be observed sometime after construction, and recommended solutions for these issues.

4.2.1 Joint Resealing and Crack Sealing

TABLE 4.1
Potential joint resealing and crack sealing construction problems and associated solutions (Smith et al., 2022)

Problem	Typical Solutions
Sealant Not Adhering to a Crack	Reclean the crack. Allow the sidewalls to dry before sealing. Heat sealant to the correct temperature or verify temperature gauges (for hot-applied sealants). Wait for a higher ambient temperature before sealing and make sure no condensation has accumulated in the crack. Use the correct recess for crack width (especially important for cold-applied sealants).
Sealant Gelling in the Melting Chamber (Also Called the "Melter")	If it is suspected that the sealant is overheating, check the melter's temperature gauges. If it is suspected that the sealant has been reheated too many times, use fresh sealant. Use sealant with a longer pot life or conform to the manufacturer's recommended pot life.
Bumps or Irregularities in the Surface of the Tooled Sealant Application	Check the tooling utensil or squeegee and ensure it is leaving the correct finish; repair or replace as necessary. Ensure that tooling is being conducted within the time after application recommended by the manufacturer. Decrease the viscosity of the sealant (if applicable).
Cold-Applied Sealants Not Setting Up	Use fresh sealant. Use the correct mix ratios and mixing systems.
Sealant Picks Up or Pulls Out When Opened to Traffic	Close pavement to traffic and delay opening. Seal during cooler temperatures. Apply sealant flush with the surface or with a specified recess. Use a stiffer sealant if the sealant is too soft for the climate. Use a detackifier or blotter to reduce any initial tack on hot-applied sealants. Install at the correct temperature and continuously verify the temperature gauges on the melter. If crack faces are contaminated with old sealant or other contaminants, repeat the preparation process.
Voids or Bubbles in Cured Sealant	Apply sealant from the bottom up to avoid trapping air. If it is suspected that moisture is building up in cracks, ensure cracks are dry.
Sealant Cracking or Debonding in Winter	If (hot pour) sealant is too stiff, use sealant that is more extensible at low temperatures. If poor cleaning during installation is suspected, improve cleaning methods.

TABLE 4.1
Potential joint resealing and crack sealing construction problems and associated solutions (Cont'd) (Smith et al., 2022)

Problem	Typical Solutions
Punctured or Stretched Backer Rod	Remove the existing backer rod and install a new backer rod using the recommended procedure.
Burrs Along the Sawed Joints	Drag a blunt pointed tool along the sawed joint to remove the sharp edges (*Note:* The joint or crack will have to be recleaned prior to sealing).
Raveling, Spalling, or Other Irregularities of the Joint Walls Prior to Sealant Application	Agency and contractor should agree on an appropriate method for repairing potential problem areas.
Sinkholes in the Sealant	If the sealant is flowing past gaps in the backer material, use larger-diameter backer rod material, reapply (top off) sealant to the correct level, or—for silicone—use a non-sag sealant. If the backer rod is melting when using hot-applied sealants, use a heat-resistant backer rod.

4.2.2 Full Depth Patching (FDP)

TABLE 4.2
Potential FDP-related construction problems and associated solutions (Smith et al., 2022)

Problem	Typical Solutions
Undercut Spalling (Deterioration on the Bottom of the Slab) is Evident After the Removal of Concrete From the Patch Area	Saw back into the adjacent slab until sound concrete is encountered.
Saw Binds When Cutting Full Depth Exterior Cuts	Shut down the saw and remove the blade from the saw. Wait for the slab to cool, then release the blade if possible (or make another full depth angled cut inside the area to be removed to provide a small pie-shaped piece adjacent to the stuck saw blade). Make transverse saw-cuts when the pavement is cool. Use a carbide-tipped wheel saw to make pressure-relief cuts 4 in. wide inside the area to be removed.
Lifting Out Deteriorated Slab Damages an Adjacent Slab	Adjust the lifting cables and position the lifting device to ensure a vertical pull. Resaw to remove the broken section of the adjacent slab. Ensure the lifting device is capable of performing the operation.
The Slab Disintegrates When Attempts Are Made to Lift it Out	Complete removal of the patch area with a backhoe or manual labor, taking care to avoid damaging the adjacent concrete slab and existing subbase. Angle the lift pins and position the cables so that the fragmented pieces are bound together during lift-out. Keep lifting height to an absolute minimum on fragmented slabs.
Patches Become Filled With Rainwater or Groundwater Seepage, Saturating the Subbase	Pump the water from the patch area or drain it through a trench cut into the shoulder. Recompact the subbase to a density consistent with the contract documents, adding material as necessary. Allow small depressions in the subbase to be filled with aggregate dust or fine sand before the repair material is placed. Permit the use of aggregate dust or fine sand to level small surface irregularities (of 0.5 in. or less) on the surface of the subbase before the concrete repair is placed.
The Grout Around the Dowel Bars Flows Back Out of the Holes After the Dowels Are Inserted	Place the grout or epoxy in the back of the hole first. Use a twisting motion when inserting the dowel. Add a grout retention disk around the dowel bar to prevent the grout from leaking out.
Dowels Appear to Be Misaligned Once They Are Inserted Into the Holes	If the misalignment is less than 0.25 in. per 12 in. of dowel bar length, do nothing. If the misalignment is greater than 0.25 in. per 12 in. of dowel bar length on more than three dowel bars per joint, resaw the FDP patch boundaries beyond the dowels and redrill holes. Use a gang-mounted drill rig referenced off the slab surface to drill the dowel holes.
Tie Bar Restoration for Long Patches	Do not restore the tie bars if the patching length is less than 100 ft and if the patching is not in the superelevation or in the bridge approach.

TABLE 4.3
Potential FDP performance problems and prevention techniques (Smith et al., 2022)

Problem	Typical Solutions
Longitudinal Cracking in the Patch	Verify repair dimensions to ensure they are not excessively wide. Verify that the proper isolation material and technique have been used. Verify that the proper curing material and application have been used. Determine if extreme environmental conditions occurred during placement.
Transverse Cracking in the Patch	Verify repair dimensions to ensure they are not excessively long. Verify that joints are active and not locked and dowels are properly sized and located. Verify that the proper curing material and application have been used.
Surface Scaling	Investigate the adequacy of the mix design. Investigate whether excess water was applied during placement or finishing. Investigate whether the surface was over-finished. Verify the proper curing material and application have been used. Assess the quality of the air-void system.
Spalling of Transverse or Longitudinal Joint	Verify that steel placement is correct and transverse joints are not locked. Verify that there are no incompressible materials in joints. Verify that no point-load conditions have occurred in the repair area.
Deterioration of Material Surrounding the Repair	Investigate whether inadequate boundary marking, or removal techniques were used. Investigate whether full depth sawing techniques were used.
Repair Settlement	Investigate the technique used for base preparation. Investigate the presence of excess moisture. Investigate the effectiveness of load transfer devices.

4.2.3 Cross-Stitching

TABLE 4.4
Cross-stitching-related construction problems and associated solutions (Smith et al., 2022)

Problem	Typical Solutions
Drill Wanders or Dances When Initiating the Drilling Operation and May Cause Shallow Spalling	Drill a shallow pilot hole at the prescribed location to establish a "bite."
The Drill Breaks Through the Bottom of the Slab	Verify the actual pavement thickness and check the angle and depth requirements. Adjust as necessary for future holes.
The Epoxy Coating on the Tie Bars is Damaged	Recoat the tie bar with a manufacturer-approved coating.
The Tie Bar Extends Above the Pavement Surface	Remove the tie bar before the epoxy sets and re-drill the hole. If the tie bar is still too long, cut the tie bar to accommodate the hole depth.
Epoxy Not Setting Properly	Consult the manufacturer's instructions and verify the shelf life of the epoxy.

4.2.4 Retrofit Load Transfer (RLT or DBR)

TABLE 4.5
RLT-related construction problems and associated solutions (Smith et al., 2022)

Problem	Typical Cause(s)	Typical Solutions
Slots Are Not Cut Parallel to the Roadway Centerline	Improper alignment of slot-cutting machine.	Fill the original slots with concrete and recut at different locations. (Note 1: If the material between the saw-cuts has not yet been removed, fill the saw-cuts with an epoxy resin and recut at different locations; Note 2: Do not reuse the left-over concrete after 2 hours from mixing; water tempering and/or remixing is not allowed). Multiple-saw slot-cutting machines can ensure that slots are parallel to one another.
Lower Slab Deterioration is Uncovered During Slot Cutting	Subsurface deterioration, such as from materials-related distress.	If lower slab deterioration is significant, an FDP will be required. Additional cores from other joints may be required to determine the extent of deterioration.
Dowel Bar Slots Are Too Shallow	Improper slot-cutting techniques.	Saw the slots more deeply, remove the concrete to the proper depth, and complete as specified.
Dowel Bar Slots Are Too Deep	Improper slot-cutting techniques. Improper jackhammer weight. Improper jackhammering techniques.	Use a lightweight jackhammer (generally 30 lb. maximum). Do not lean on the jackhammer. Do not orient the jackhammer vertically; use no more than a 45° angle and push the tip of the hammer along the bottom of the slot. Stop chipping after a little more than mid-depth of the slab.
The Concrete Fin is Not Easily Removed	Concrete containing mesh reinforcement.	If mesh reinforcement is observed in the concrete, sever the steel at each end before attempting to remove the fin of the concrete.
Jackhammer is Punching Through the Bottom of the Slot	Improper jackhammering technique. Extremely deteriorated concrete.	Make an FDP across the entire lane width at the joint/crack.
Factory-Applied Dowel Coating is Missing From One or More Areas on the Dowel	Nonuniform application of the factory-applied dowel coating. Mishandling of dowels in the field.	Recoat the dowel with a manufacturer-approved coating substance prior to placing the dowel in the slot. (Do not coat dowels in the slots because the sides and bottoms of the slots may become contaminated).
The Dowel Cannot Be Centered Over the Joint/Crack Because the Slot Does Not Extend Far Enough	Improper slot preparation.	Chip out additional slot length with a jackhammer to facilitate proper placement of the dowel in accordance with the contract documents.

TABLE 4.5
RLT-related construction problems and associated solutions (Cont'd) (Smith et al., 2022)

Problem	Typical Cause(s)	Typical Solutions
Joint/Crack Caulking Filler Material Does Not Extend All the Way to the Edge of the Slot	Improper caulking installation.	Extend the caulking to the edge of the slot prior to the placement of patching material. If patching material does enter the joint adjacent to the slot, it must be removed using a technique agreed upon by the agency and the contractor.
Caulking Material in a Joint or Crack Extrudes Onto a Sidewall of the Slot by More Than 0.5 in	Improper caulking installation.	Remove excess caulking before placing patching material.
Dowels Are Misaligned After Vibration	Vibrator contacts the dowel assembly. Over-vibration of the patching material. Improper width of the slots.	Do not allow the vibrator to touch the dowel assembly. Check for over-vibration; each slot should require only two to four short, vertical penetrations of a small-diameter spud vibrator. Ensure that the slots are sized the exact width of the plastic dowel bar chairs.

TABLE 4.6
Potential RLT-related performance problems and prevention techniques (Smith et al., 2022)

Problem	Typical Cause(s)	Typical Solutions
In-Place Patching Material Cracking	The joint is not well isolated. Dowels are not all properly aligned. The patching material is too strong. The patch was opened to traffic too soon. Material susceptible to excessive shrinkage.	Confirm that proper construction practices are followed, and patching material used is resistant to cracking.
In-Place Patching Material Popping Out	The slot was not properly cleaned or prepared. The repair material was not properly cured (causing unexpected material shrinkage during curing).	Verify that proper construction procedures are followed.
In-Place Patching Material Wearing Off	Nondurable repair material was used. The repair material was improperly mixed/handled. The patch is exposed to studded tires.	Check material specifications, material preparation, and placement conditions to be sure that repair material is being handled properly.

4.2.5 Partial Depth Patching (PDP)

TABLE 4.7
Potential PDP-related construction problems and associated solutions (Smith et al., 2022)

Problem	Typical Solutions
Deterioration Was Found to Extend Beyond the Originally Planned Repair Boundaries	Extend the limits of the repair area to encompass all of the deterioration. If the deterioration is found to extend significantly deeper than expected (i.e., deeper than one-half of the slab thickness), an FDP should be placed instead of PDP.
Repair Failures Associated With Inadequate Provision of Compression Relief	The typical solution is to replace the repair, being sure to provide adequate compression relief.
Dowel Bar Exposed During Concrete Removal	If only a small portion of the dowel bar is exposed and no further deterioration around the dowel is evident, place duct tape over the exposed area of the dowel bar and proceed with the PDP. If deterioration is present around and beneath the dowel bar, an FDP should be used instead of PDP.
Reinforcing Mesh in JRCP is Exposed During Concrete Removal	If the steel is in the upper half of the slab, the steel should be cut back to the edges of the repair area and the placement of the repair should continue as planned. If the exposed steel is below the upper half of the slab, however, an FDP should be used instead of PDP.
Repair Material Flows Into the Joint or Crack	Remove and replace the repair or mark the joint for sawing as soon as it can support a saw without raveling the mixture. *Note:* If repair material infiltrates a crack, it should be removed and replaced.
Shrinkage Cracking and/or Surface Scaling Due to Improper Finishing and/or Curing	If excessive scaling and/ or cracking is observed, the repair must be replaced.
Repair Cracking or Debonding of Repair Material	If the repair fails prematurely due to (a) poor compression relief, (b) improper curing/finishing, or (c) improper grout placement resulting in debonding, the only practical solution is to replace the distressed repair. It is important to try to determine the cause of the premature failure, to avoid repeating the same mistake in future repairs.

4.2.6 Diamond Grinding

TABLE 4.8
Potential diamond grinding construction/performance problems and associated solutions (Smith et al., 2022)

Problem	Typical Cause(s)	Typical Solutions
"Dog-Tails" (Pavement Areas That Are Not Ground Due to a Lack of Horizontal Overlap)	These are primarily caused by weaving during the grinding operation.	Maintaining the required horizontal overlap between passes (i.e., 1 to 2 in.) and steady steering by the diamond grinding machine operator will avoid the occurrence of dog-tails.
"Holidays" (Areas That Are Not Ground)	These are isolated low spots on the pavement surface.	Lower the grinding head and complete another pass. Typical specifications require 95% coverage for the diamond ground texture, but the required coverage can vary and will depend on the age and condition of the existing pavement.
Poor Vertical Match Between Passes	There is inconsistent downward pressure. This is often occurring when adjustments to the down-pressure are inadvertently made.	A constant down-pressure should be maintained between passes to maintain a similar cut depth.
Too Much or Too Little Material Removed Near Joints	Expansion joints or other wide gaps in the pavement can cause the cutting head to dip if the leading wheels drop into these openings. Slabs deflecting from the weight of the grinding equipment can cause insufficient material to be removed.	Wide gaps can be temporarily grouted to provide a smooth surface. If the slabs deflect excessively from the weight of the grinding equipment, stabilizing the slab or retrofitting dowel bars may be needed.
Fins That Remain After Grinding Not Quickly Breaking Free	This could be an indication of excessive wear on the grinding head, but most likely it is the result of incorrect blade spacing.	The grinding head should be checked for wear before or after each day of operation. When the cutting blades are not worn, if the fins remain after grinding and do not break free, the blade spacing should be reduced.
Large Amounts of Slurry Are Left on the Pavement During or After Grinding	Most likely this indicates a problem with the vacuum unit or skirt surrounding the cutting head.	If large amounts of slurry are left on the pavement or if slurry flows into adjacent traffic lanes or drainage structures, the diamond grinding operations should be stopped, the equipment inspected, and all necessary repairs made.
Vehicle Tracking is Experienced by Motorcycles and Other Lightweight Vehicles	This indicates a problem with the spacing between the blades.	Reduce the spacing between the blades.

4.2.7 Diamond Grooving

TABLE 4.9
Potential diamond grooving construction problems and associated solutions (Smith et al., 2022)

Problem	Typical Cause(s)	Typical Solutions
Lack of Horizontal Overlap	This is primarily caused by weaving during the grooving operation.	Maintain the required horizontal overlap between passes. The operator of diamond grooving equipment must steadily steer the equipment.
Isolated Areas With Inconsistent Groove Depth	There are isolated low spots on the pavement surface.	The grooving head may need to be lowered in areas known to contain isolated low spots.
Inconsistent Groove Depth Near Joints	Expansion joints or other wide gaps in the pavement can cause the cutting head to dip if the leading wheels drop into these openings. Slabs deflecting from the weight of the grooving equipment can cause insufficient material to be removed.	Wide gaps can be temporarily grouted to provide a smooth surface. If the slabs deflect excessively from the weight of the grooving equipment, stabilizing the slab or retrofitting dowel bars may be needed.
Large Amounts of Slurry Are Left on the Pavement During or After Grooving	This indicates a problem with the vacuum unit or skirt surrounding the cutting head.	If large amounts of slurry are left on the pavement or if slurry flows into adjacent traffic lanes or drainage structures, the diamond grooving operations should be stopped, the equipment inspected, and the necessary repairs made.

4.2.8 Undersealing (Slab Stabilization)

TABLE 4.10
Potential undersealing-related problems and associated solutions (Smith et al., 2022)

Problem	Typical Cause(s)	Typical Solutions
Cutting of Tie Bars to Facilitate Uplifting the Slab While the Dowel Bars Are Still Functioning	Since most of slab jacking operations are performed during daytime (when joints are expanded), joint locking may occur.	Complete undersealing/jacking at nighttime. If raising the slab is not feasible, it is advisable to explore patching as a more practical solution.
There is a Combination of: 1. No Evidence of Grout in Any Adjacent Hole, Joint, or Crack After 1 Minute, and 2. No Registered Slab Movement on the Uplift Gauge	Grout is flowing into a large washout cavity.	Stop the injection process. The cavity will have to be corrected by another repair procedure.
High Initial Pumping Pressure Does Not Drop After 2 to 3 Seconds	Spalled material at the bottom of the hole may be blocking the entrance to the void.	Material blockages may sometimes be cleared by pumping a small quantity of water or air into the hole to create a passage that will allow grout to flow into the void. If this activity does not solve the problem, it is possible that the hole was drilled outside of the boundaries of the void.
Testing After One Properly Performed Grouting Still Indicates a Loss of Support	The void was not adequately filled. The first assumption should be that the selected hole pattern did not provide complete access to the void.	Regrout the void using different holes from those that were initially used.
Testing After Two Properly Performed Groutings (i.e., after regrouting) Still Indicates a Loss of Support	The void is still not adequately filled even after regrouting has been attempted Typical causes are the following. The second selected hole pattern still does not provide complete access to the void. The void may be deeper in the pavement layer system.	If it is suspected that the selected hole pattern did not adequately locate the boundaries of the void, the contractor may choose to drill holes at additional locations, or if the contractor is confident that the boundaries of the void have been established, the injection holes may have to be extended into the subgrade.
The Uplift Gauge Exceeds the Maximum Specified Slab Lift (Typically 0.05 in.)	Over-grouting occurred.	Refer to the governing agency specification. If slab damage is immediately observed, the contractor will most likely be responsible for replacing the slab at no cost to the agency.
Grout Extrudes Into a Working Transverse Joint or Crack	This typically indicates that the void is filled or that the hole has been drilled too close to a joint or crack.	If this problem occurs at a joint, the solution is to restore the joint reservoir and joint sealant. If this problem occurs near a crack, the solution is to rout or saw and seal the crack.

4.3 Stopgap Measures

Stopgap repairs, also sometimes referred to as routine/reactive maintenance, are a series of activities that fix a defect temporarily, especially under harsh weather conditions, until a more permanent solution can be implemented. Stopgap repair temporarily helps traffic keep moving on pavements that are functionally failed. but rarely contribute to the long-term performance of the pavement (Applied Pavement Technology, Inc., 1999).

The two main maintenance strategies that are generally considered for stopgap repairs are crack sealing and partial depth patching (PDP). The details regarding these two strategies when used as regular M&P activities, have been discussed in Chapter 3. The primary differences between stopgap and preventive/preservation measures are the type of materials used in these strategies and the need to comply primarily with manufacturers' instructions for correct application of these materials. Table 4.11 lists the typical materials for crack sealing and PDP when used as stopgap measures.

TABLE 4.11
Materials for stopgap repairs

Stopgap Strategy	Materials	References
Crack Sealing/Joint Resealing	Asphaltic Sealant	INDOT Standard Spec. 906.02 (INDOT, 2022c)
	Mastic (e.g., Crafco, Inc. Products)	INDOT Standard Spec. 907.11(b) (INDOT, 2022c)
Partial Depth Patch (PDP)	Cold Asphalt Mix (as a temporary measure)	Refer to the Manufacturer's Instructions
	Rapid-Setting Concrete	INDOT Standard Spec. 901.07 (INDOT, 2022c)
	Conventional HMA Materials	INDOT Standard Spec. 902.01 (INDOT, 2022c)
	Spray Patch	Refer to the Manufacturer's Instructions
	Mastic/Other Proprietary Bituminous Materials	Refer to the Manufacturer's Instructions
	Polymer-Based/Resinous Materials	Refer to the Manufacturer's Instructions

CHAPTER 5: POST-CONSTRUCTION ACTIVITIES

5.1 Introduction

One crucial step in the implementation of M&P strategies is to regularly evaluate the performance of the repaired area. Careful project inspection by construction inspectors, during and after the construction process, helps to ensure M&P activities have been properly completed and show expected performance over their lifetimes. This chapter describes possible approaches for evaluating the performance of the repaired concrete pavements.

5.2 Post-Construction Evaluation

The following measures can be considered as recommended approaches for evaluating the performance of repaired concrete pavements.

1. Pavement roughness can sometimes increase as a result of the repair tasks, such as joint/crack sealing and patching. Hence, pavement roughness must be monitored as a part of the annual pavement condition assessment (Lee & Shields, 2010).
2. The performance of the patch also needs to be monitored using visual inspection and appropriate non-destructive testing (NDT) methods. The monitoring can be performed either at the project level or network level (Lee & Shields, 2010).
3. At least one inspection should be made after the first winter, and subsequent inspections should be conducted at regular intervals to chart the rate of failure and plan for subsequent maintenance.
4. A mid-winter evaluation is highly recommended, since at that time, joints will be near their maximum opening and, as a result, adhesion loss may be more easily/readily visible.
5. Performance of load transfer, crack sealing, and joint sealing installations needs to be monitored via periodic visual inspection and/or analysis of performance data obtained from an automated pavement data collection system. This can be performed either at the project level or network level.
6. To ensure uniform grinding, the ground surface must be surveyed via visual inspection (at the project level or network level) and/or analysis of transverse profile data obtained from automated pavement data collection systems (FHWA, 2019b).
7. The effectiveness of the undersealing process can be assessed both visually and from an examination of the pavement profile (Smith et al., 2022).

CHAPTER 6: SUMMARY

This chapter summarizes the appropriate M&P strategies for different types of distresses that can be encountered in PCC pavements.

TABLE 6.1
Applicability of treatments based on observed distresses

	Concrete Pavement Preservation Treatments								
Distress	**Undersealing (Slab Stabilization)**	**PDP**	**FDP**	**RLT (DBR)**	**Cross Stitching**	**Diamond Grinding**	**Diamond Grooving**	**Joint Resealing**	**Crack Sealing**
Corner Breaks	–	–	✓	–	–	–	–	–	✓[a]
"D" Cracking	–	–	✓	–	–	–	–	✓	–
Longitudinal Cracking	–	–	✓	–	✓	–	–	–	✓
Transverse Cracking	–	–	✓	✓	–	–	–	–	✓
Joint Seal Damage	–	–	–	–	✓[b]	–	–	✓	–
Joint Spalling	–	✓	✓	–	–	–	–	–	–
Map Cracking, Crazing, Scaling	–	–	✓[c]	–	–	–	–	–	–
Polishing/Low Friction	–	–	–	–	–	✓	✓	–	–
Popouts	–	–	–	–	–	✓[d]	–	–	–
Blowup	–	–	✓	–	–	–	–	–	–
Faulting	–	–	–	✓	–	✓	–	–	–
Lane-to-Shoulder Dropoff	**It can be addressed by rehabilitation/reconstruction strategies.**								
Lane-to-Shoulder Separation	–	–	–	–	✓	–	–	✓	–
Patch/Patch Deterioration	–	–	✓	–	–	–	–	–	–
Water Bleeding and Pumping	✓	–	–	✓	–	–	–	✓	✓
Transverse Construction Joint Deterioration	–	✓	✓	–	–	–	–	–	✓
Punchouts	–	–	✓	–	–	–	–	–	–

Note: Many of these treatments are commonly done in combination, in order to fully address the existing pavement deficiencies.
[a] Crack with limited vertical movements.
[b] For longitudinal joint seal damage only.
[c] When map cracking/scaling, due to ASR, extends over the entire area of the PCC pavement of high-priority highways with high-traffic volume.
[d] If popouts density is $\geq$ 3 popouts/yd^2.

REFERENCES

AASHTO. (2020). *Guide specifications for highway construction* (10th ed.). American Association of State Highway and Transportation Officials.

ACPA. (n.d.). *Preserving old pavements: Cross stitching*. American Concrete Pavement Association. https://www.acpa.org/solutions-and-markets/preservation-stabilization/#

ACPA. (1994). *Concrete paving technology: Slab stabilization guidelines for concrete pavements* (Technical Bulletin TB018P). American Concrete Pavement Association. https://www.pavementpreservation.org/wp-content/uploads/2010/12/Slab_Stabilization_Guidelines.pdf

ACPA. (2003). *Concrete pavement repair manual* (JP002P). American Concrete Pavement Association.

ACPA. (2008). *Concrete pavement field reference: Preservation and repair* (2nd ed.). American Concrete Pavement Association.

ACPA & IGGA. (2010). *Stitching concrete pavement cracks and joints* (SR903P). American Concrete Pavement Association, International Grooving and Grinding Association. https://www.pavementpreservation.org/wp-content/uploads/2010/12/Cracks_Joints_Stitching.pdf

Applied Pavement Technology, Inc. (1999, September). *Pavement preventive maintenance* (Publication No. FHWA-HI-00-006). Federal Highway Administration.

ASTM. (2020a). *ASTM A884/A884M-19e1: Standard specification for epoxy-coated steel wire and welded wire reinforcement*. American Society for Testing and Materials International. https://doi.org/10.1520/A0884_A0884M-19E01

ASTM. (2020b). *ASTM D6433-20: Standard practice for roads and parking lots pavement condition index surveys*. American Society for Testing and Materials International. https://doi.org/10.1520/D6433-20

ASTM. (2021). *ASTM D3141/D3141M-21: Standard specification for asphalt for undersealing Portland-cement concrete pavements*. American Society for Testing and Materials International. https://doi.org/10.1520/D3141_D3141M-21

Burger, G. (2017, September 11). *Rut in road injures motorcyclist*. Retrieved September 6, 2023, from https://burgerlaw.com/rut-in-road-injures-motorcyclist/

Daily Civil. (n.d.). [Photograph of conventional reinforcement for crack repair]. In *Methods of Repairing Concrete Cracks* [Webpage]. Retrieved September 6, 2023, from https://dailycivil.com/methods-of-repairing-concrete-cracks/

Darter, M. I., Barenberg, E. J., & Yrjanson, W. A. (1985). *NCHRP Report 281: Joint repair methods for Portland cement concrete pavements*. National Cooperative Highway Research Program.

FHWA. (2009). Part 6 temporary traffic control elements. In *Manual on Uniform Traffic Control Devices for Streets and Highways*. Federal Highway Administration. https://mutcd.fhwa.dot.gov/pdfs/2009r1r2r3/part6.pdf

FHWA. (2014, May). *Distress identification manual (DIM) for the long-term pavement performance program (LTPP)* (Publication No. FHWA-HRT-13-092). Federal Highway Administration. https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/13092/13092.pdf

FHWA. (2019a). *Pavement preservation checklist series #17: Joint and crack sealing of Portland cement concrete pavements* (Publication No. FHWA-HIF-19-045). Federal Highway Administration. https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19045.pdf

FHWA. (2019b). *Pavement preservation checklist series #18: Diamond grinding of Portland cement concrete pavements* (Publication No. FHWA-HIF-19-046). Federal Highway Administration. https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19046.pdf

FHWA. (2019c). *Pavement preservation checklist series #19: Dowel bar retrofit for Portland cement concrete pavements* (Publication No. FHWA-HIF-19-047). Federal Highway Administration. https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19047.pdf

FHWA. (2019d). *Pavement preservation checklist series #20: Partial-depth repair of Portland cement concrete pavements* (Publication No. FHWA-HIF-19-048). Federal Highway Administration. https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19048.pdf

FHWA. (2019e). *Pavement preservation checklist series #21: Full depth repair of Portland cement concrete pavements* (Publication No. FHWA-HIF-19-049). Federal Highway Administration. https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19049.pdf

FHWA. (2019f). *Pavement preservation checklist series #22: Cross-stitching for Portland cement concrete pavements* (Publication No. FHWA-HIF-19-050). Federal Highway Administration. https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19050.pdf

FHWA. (2019g). *Pavement preservation checklist series #23: Longitudinal diamond grooving of Portland cement concrete pavements* (Publication No. FHWA-HIF-19-051). Federal Highway Administration. https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19051.pdf

Harrington, D., & Fick, G. (2014, May). Figure 42. Unbonded concrete overlay of poor condition concrete pavement [Image]. In *Guide to Concrete Overlays: Sustainable Solutions for Resurfacing and Rehabilitating Existing Pavements, 3rd Edition* (ACPA Publication TB021.03P). National Concrete Pavement Technology Center, Iowa State University.

INDOT. (2004, September). *Standard drawings E 507-RLTC*. Indiana Department of Transportation. https://www.in.gov/dot/div/contracts/standards/drawings/sep22/500e/e500%20combined%20pdfs/E507-RLTC.pdf

INDOT. (2019, February 7). *Reinforcing bar, dowel bar, and welded wire reinforcement certification program ITM No. 301-19*. Indiana Department of Transportation Division of Materials and Tests. https://www.in.gov/indot/doing-business-with-indot/files/301_testing.pdf

INDOT. (2020a). *Standard drawings E 503-CCPJ*. Indiana Department of Transportation. https://www.in.gov/dot/div/contracts/standards/drawings/sep22/500e/e500%20combined%20pdfs/E503-CCPJ.pdf

INDOT. (2020b). *Standard drawing E 506-CCPP*. Indiana Department of Transportation. https://www.in.gov/dot/div/contracts/standards/drawings/sep22/500e/e500%20combined%20pdfs/E506-CCPP.pdf

INDOT. (2021, September). *Standard drawing E 509-CCJR*. Indiana Department of Transportation. https://www.in.gov/dot/div/contracts/standards/drawings/sep22/500e/e500%20combined%20pdfs/E509-CCJR.pdf

INDOT. (2022a). Section 500 – Concrete pavement. In *Indiana Department of Transportation Standard Specifications 2022*. Indiana Department of Transportation. https://www.in.gov/dot/div/contracts/standards/book/sep21/500-2022.pdf

INDOT. (2022b). Section 612 – Undersealing. In *Indiana Department of Transportation Standard Specifications 2022*.

Indiana Department of Transportation. https://www.in.gov/dot/div/contracts/standards/book/sep21/600-2022.pdf
INDOT. (2022c). Division 900 – Materials details. In *Indiana Department of Transportation Standard Specifications 2022*. Indiana Department of Transportation. https://www.in.gov/dot/div/contracts/standards/book/sep21/900-2022.pdf
INDOT. (2024, January). Chapter 603: Pavement distress, repair, and widening. In *Indiana Department of Transportation—2013 Design Manual*. Indiana Department of Transportation. https://www.in.gov/dot/div/contracts/design/Part%206/Chapter%20603%20-%20Pavement%20Distress,%20Repair,%20and%20Widening.pdf
INDOT Office of Aviation. (2022a). *Indiana 2022 IDEA: Blowup*. Retrieved September 6, 2023, from https://www.in.gov/indot/div/aviation/pavement-inspection/pci-review/distresses-pcc/blowup.html
INDOT Office of Aviation. (2022b). *Indiana 2022 IDEA: Faulting/settlement*. Retrieved September 6, 2023, from https://www.in.gov/indot/div/aviation/pavement-inspection/pci-review/distresses-pcc/faulting.html
INDOT Office of Aviation. (2022c). *Indiana 2022 IDEA: Joint seal damage*. Retrieved September 6, 2023, from https://www.in.gov/indot/div/aviation/pavement-inspection/pci-review/distresses-pcc/joint-sealant-damage.html
INDOT Office of Aviation. (2022d). *Indiana 2022 IDEA: Large patch*. Retrieved September 6, 2023, from https://www.in.gov/indot/div/aviation/pavement-inspection/pci-review/distresses-pcc/large-patch.html
INDOT Office of Aviation. (2022e). *Indiana 2022 IDEA: LTD cracking*. Retrieved September 6, 2023, from https://www.in.gov/indot/div/aviation/pavement-inspection/pci-review/distresses-pcc/linear-cracking.html
INDOT Office of Aviation. (2022f). *Indiana 2022 IDEA: Small patch*. Retrieved September 6, 2023, from https://www.in.gov/indot/div/aviation/pavement-inspection/pci-review/distresses-pcc/small-patch.html
Lee, J., & Shields, T. (2010, January). *Treatment guidelines for pavement preservation* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP 2010/01). West Lafayette, IN: Purdue University. https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2618&context=jtrp
Marko, T. (2018, March 1). Cracks in the asphalt spread across an entire lane on Sheridan Boulevard across from Robert Road in Inwood [Photograph]. In *The Roads Are Cracking Up in the Five Towns Motorists Beware: Potholes Proliferate on Five Towns Streets*. LIHerald.com. Retrieved September 6, 2023, from https://www.liherald.com/stories/the-roads-are-cracking-up,100663
Maxwell Products. (n.d.). *Solution center: Flush fill crack seal*. Retrieved September 6, 2023, from https://maxwellproducts.com/solutions/Flush-Fill-Crack-Seal/Overview
MnDOT. (2023). Section 5-2: Partial depth repairs. In *Concrete Pavement Rehabilitation Guide*. [MnDOT web-based guideline]. Minnesota Department of Transportation. https://dot.state.mn.us/materials/concretedocs/concretepavementrepairguide/ConcreteGuide/story.html
Peshkin, D., Smith, K. L., Wolters, A., Krstulovich, J., Moulthrop, J., & Alvarado, C. (2011). *SHRP 2 Report S2-R26-RR-2: Guidelines for the preservation of high-traffic-volume roadways*. National Academies Press. https://doi.org/10.17226/14487
Ram, P. V., Olek, J., & Jain, J. (2013). *Field trials of rapid-setting repair materials* (Joint Transportation Research Program Report No. FHWA/IN/JTRP-2013/02). West Lafayette, IN: Purdue University. https://docs.lib.purdue.edu/jtrp/1595/
Rodeco Group. (n.d.). [Example photograph of partial-depth patching on concrete slabs]. In *Partial-Depth Patching on Concrete Slabs*. Retrieved September 6, 2023, from https://www.rodeco.it/en/product-services-main/mr-maintenance-and-rehabilitation/mr-preventive-maintenance/mr-9-partial-depth-patching-on-concrete-slabs/
Smith, K., Grogg, M., Ram, P., Smith, K., & Harrington, D. (2022, August). *Concrete pavement preservation guide* (3rd ed.). Iowa State University National Concrete Pavement Technology Center. https://intrans.iastate.edu/app/uploads/2022/08/concrete_pvmt_preservation_guide_3rd_edition_web.pdf
Smith, K., Harrington, D., Pierce, L., Ram, P., & Smith, K. (2014, September). Representation of definitions of pavement preservation, rehabilitation, and reconstruction [Image]. In *Concrete Pavement Preservation Guide, Second Edition* (FHWA Publication No. FHWA-HIF-14hyphen; 014). National Concrete Pavement Technology Center. https://www.fhwa.dot.gov/pavement/concrete/pubs/hif14004.pdf
Texas Transportation Institute. (2008, April 1). Join separation [Photograph]. In *Guidelines for Routine Maintenance of Concrete Pavements* (Report No. HWA/TX-08/0-5821-P1). Retrieved September 6, 2023, from https://static.tti.tamu.edu/tti.tamu.edu/documents/0-5821-P1.pdf
VEA Group. (2019, January 21). *Veatel turnkey solutions for civil works. Contact us for any deployment needs at admin@vea-tel.co.za* [Photographs]. Facebook. Retrieved September 6, 2023, from https://www.facebook.com/veagroup/photos/pcb.538120266675630/538119860009004/?type=3&theater
Zhang, J. (2013). *Investigation of deterioration of joints in concrete pavements* [Doctoral dissertation, Tongji University].

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at http://docs.lib.purdue.edu/jtrp.

Further information about JTRP and its current research program is available at http://www.purdue.edu/jtrp.

About This Report

An open access version of this publication is available online. See the URL in the citation below.

Mirzahosseini, M., Olek, J., Abraham, D. M., Ram, P., & Smith, K. (2024). *Field handbook for maintenance and preservation treatments of concrete pavements* (Joint Transportation Research Program Publication No. FHWA/IN/JTRP-2024/07). West Lafayette, IN: Purdue University. https://doi.org/10.5703/1288284317725