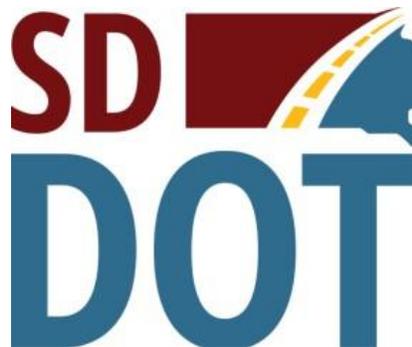


# Pavement Preservation Guidelines

South Dakota Department of Transportation

March 2021



## FOREWORD

This document provides information regarding the use of pavement preservation strategies for maintaining pavement condition by the South Dakota Department of Transportation (SDDOT). SDDOT policies and procedures regarding the use of pavement preservation techniques are also presented. The use of pavement preservation is an elective policy. However, proper adherence to the preservation policy and procedures specified in this document can provide any state or local agency with the opportunity to use federal funding for preservation activities. In addition, federal funding is dependent on the federal aid eligibility of the route. Local agencies will need to research route eligibility for federal aid.

Portions of this document were provided by the Illinois and Minnesota Departments of Transportation (DOTs) and they are included in these guidelines with permission.

## ORGANIZATION

The guidelines contained within this document are organized in the following three chapters:

1. Introduction to Pavement Preservation – this chapter presents selected definitions (pavement preservation, preventive maintenance, minor rehabilitation, and pavement maintenance) and basic concepts (objectives, benefits, and basic decision needs) important for a better understanding of the recommended pavement preservation guidelines.
2. Treatment Selection Guidelines – this chapter details the recommended process for selecting the optimum preservation treatment for a given pavement section. Activities in this process include: gathering relevant pavement information, assessing and evaluating pavement condition, identifying feasible preservation treatments, and selecting the most appropriate preservation treatment.
3. Preservation Treatments – this chapter discusses preservation treatments for flexible and rigid pavements, gravel roads, and drainage. For each treatment, a general description is included, along with information on pavement conditions addressed, application limitations, construction/traffic and other considerations, performance period, and relative costs.

The references used throughout the guidelines are provided at the end of the three chapters. In addition, the following three appendices are included with these guidelines:

- A. Preservation Project Eligibility (Federal Highway Administration [FHWA] memorandum dated February 26, 2019).
- B. SDDOT Maintenance Pavement Preservation Decision Guide (undated).
- C. Cost-Benefit Analysis and Tool Details (October 2020).

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## LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway Transportation Officials
AC	Asphalt concrete
ACPA	American Concrete Paving Association
ADT	Average daily traffic
ARRA	Asphalt Recycling and Reclaiming Association
AST	Asphalt surface treatments
CBA	Cost benefit analysis
CIR	Cold inplace recycling
CRC	Continuously reinforce concrete
DBR	Dowel bar retrofit
EUAC	Equivalent uniform annual costs
FAST	Fixing America Surface Transportation Act
FHWA	Federal Highway Administration
FWD	Falling weight deflectometer
HMA	Hot-mix asphalt
ISSA	International Slurry Surfacing Association
LOS	Level of service
LTAP	Local Technical Assistance Program
MAP-21	Moving Ahead for Progress in the 21 <sup>st</sup> Century
MPO	Metropolitan Planning Organization
NCPP	National Center for Pavement Preservation
PCC	Portland cement concrete
PCCP	Portland cement concrete pavements
PMS	Pavement management system
PPRA	Pavement Preservation Recycling Alliance
RPM	Rotations per minute
SDDOT	South Dakota Department of Transportation
STAs	State Transportation Agencies
STIP	State Transportation Improvement Plan
TIM	Transportation Inventory Management
UTBWC	Ultra-Thin Bonded Wearing Course

## CHAPTER 1. INTRODUCTION TO PAVEMENT PRESERVATION

### PAVEMENT PRESERVATION DEFINITIONS

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Many transportation agencies are using pavement preservation programs to more cost-effectively manage their pavement assets. Pavement preservation procedures have been in use for many years, but often agencies use the same pavement preservation terminology in different manners. Therefore, the Federal Highway Administration (FHWA) Office of Asset Management provided the following guidance regarding the definition of pavement preservation in a Memorandum dated September 12, 2005. (FHWA 2005)

*Pavement preservation represents a proactive approach in maintaining our existing highways. It enables State transportation agencies (STAs) to reduce costly, time consuming rehabilitation and reconstruction projects and the associated traffic disruptions. With timely preservation we can provide the traveling public with improved safety and mobility, reduced congestion, and smoother, longer lasting pavements. This is the true goal of pavement preservation, a goal in which the FHWA, through its partnership with the States, local agencies, industry organizations, and other interested stakeholders, is committed to achieve.*

The memorandum proceeds to further define the following terms: pavement preservation, preventive maintenance, minor rehabilitation (non-structural), and routine maintenance. These terms are described in more detail in the following sections of this chapter.

The referenced FHWA memorandum was updated on February 25, 2016 to be consistent with Moving Ahead for Progress in the 21<sup>st</sup> Century (MAP-21) and the Fixing America Surface Transportation (FAST) Act. (FHWA 2016) The guidance provided in this document supersedes the definitions given in the September 12, 2005 FHWA memorandum; however, the FHWA 2005 pavement preservation definition is more detailed and hence it has been provided above. The link to the new policy is: <https://www.fhwa.dot.gov/preservation/memos/160225.cfm> and the revised definitions for pavement preservation, preventive maintenance, minor rehabilitation, and pavement maintenance are discussed in the following sections.

#### **Pavement Preservation**

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 extend pavement service life, improve safety, and meet motorist expectations. (FHWA 2016)

Pavement preservation consists of work that is planned and performed to improve or sustain the condition of the transportation facility in a state of good repair. Preservation activities generally do not add capacity or structural value, but they do restore the overall conditions of the transportation facility. Further, a state transportation department can use Federal-aid funds to perform preservation work according to section 1103 of MAP-21, though MAP-21 does not mandate requirements for pavement preservation programs. Section 1201 of MAP-21, however, requires that Metropolitan Planning Organizations (MPOs) “provide for consideration to projects

and strategies that will emphasize the preservation of the existing transportation system.” Preservation is a critical component of an agency’s asset management plan to achieve and sustain a desired state of good repair over the life of the assets. The latest FHWA guidance on federal-aid eligibility of specific preservation activities in South Dakota is attached in [Appendix A](#).

### **Preventive Maintenance**

The main component of pavement preservation is preventive maintenance. As defined in the 2005 FHWA memorandum, preventive maintenance is a planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without significantly increasing the structural capacity). The general philosophy of the use of preventive maintenance treatments is to “*apply the right treatment, to the right pavement, at the right time.*” These practices result in an outcome of “keeping good roads in good condition.” When activities such as crack sealing and filling and the application of seal coats are placed on the pavement at the right time, they are examples of preventive maintenance treatments.

In the 2016 FHWA memorandum, preventive maintenance is defined as a “cost-effective means of extending the useful life of a Federal Aid highway.” (FHWA 2016)

### **Minor Rehabilitation**

The 2016 FHWA memorandum does not specifically address minor rehabilitation. However, in the 2005 FHWA memorandum, minor rehabilitation consists of non-structural enhancements made to the existing pavement section to eliminate age-related, top-down surface cracking that develop in flexible pavements due to environmental exposure, or to restore the functionality of concrete pavements. Because of the non-structural nature of minor rehabilitation techniques, these types of rehabilitation techniques are placed in the category of pavement preservation. (FHWA 2005) The placement of thin overlays or the conduct of recycling techniques such as hot in-place or cold in-place recycling to correct significant surface cracking can be considered minor rehabilitation activities. These techniques are included in the 2019 FHWA checklists for pavement preservation treatments and the recycling techniques are included in these guidelines (FHWA 2019). A mobile phone application containing many of these checklists was developed by the Iowa State University, The application, titled “Pavement Preservation Checklist,” may be accessed via <https://apps.apple.com/us/app/preservation-checklist/id1515273294> (Apple) or [https://play.google.com/store/apps/details?id=com.concretechecklists&hl=en\\_US](https://play.google.com/store/apps/details?id=com.concretechecklists&hl=en_US) (Android).

### **Pavement Maintenance**

As defined in the 2016 FHWA memorandum, maintenance describes the work that is performed to maintain the conditions of the transportation system or to respond to specific conditions or events that restore the highway system to a functional state of operation. It is a critical component of an agency’s asset management plan that includes both routine and preventive maintenance.

Routine maintenance includes work that is performed in reaction to an event, season, or overall deterioration of the transportation asset. This work requires regular, reoccurring attention. Federal funds cannot be used for routine maintenance.

## PAVEMENT PRESERVATION BASICS

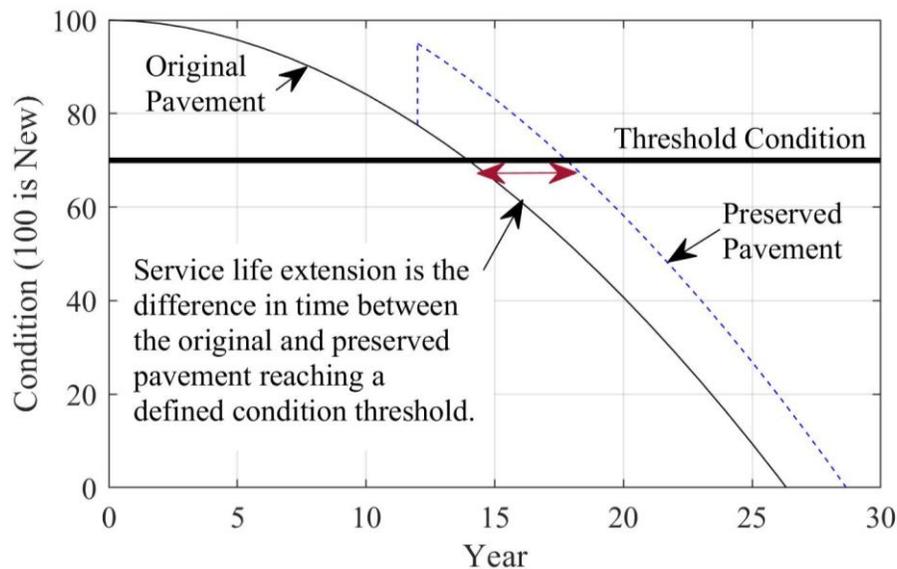
The intended purpose of a pavement preservation program is to maintain or restore the surface characteristics of a pavement and to extend service life of the pavement assets being managed. However, the improvements are such that there is no increase in capacity or strength, but they can have a positive impact on the structural capacity. Preventive maintenance treatments are used in the pavement preservation program to improve the functional condition of the network and reduce the overall rate of deterioration of the pavement asset. Since they are relatively inexpensive in comparison to resurfacing or reconstruction projects, the preventive maintenance treatments are an effective means to preserve the investment in the pavement asset.

An effective pavement preservation program has two main objectives:

1. Preserve the pavement investment.  
*This objective involves minimizing the structural failures and extending the structural life of the pavement to preserve the investment the agency has made in the pavement asset.*
2. Maintain a high level of service (LOS).  
*This objective involves maintaining acceptable smoothness and surface friction in order to provide a high level of service for roadway customers.*

The implementation of a pavement preservation program is good practice, as it focuses on maximizing the condition and life of a network of pavements while minimizing the network's life-cycle cost. The noted benefits of the use of a pavement preservation program vary from agency to agency, but have been documented as including:

- **Improved pavement performance**—preservation activities extend the performance of the pavement and help to improve the overall condition of the network, as illustrated in Figure 1.



**Figure 1. Illustration of Life Extension due to Preservation.**

- **Higher customer satisfaction**—use of preservation activities can lead to smoother roads and fewer construction delays.
- **Cost savings**—less expensive treatments and the extension of service lives of pavements help to lower or stabilize operating costs.
- **Increased safety**—preventive maintenance treatments are designed to provide safer surfaces through improved pavement texture and surface drainage, and correction of safety related defects (e.g., ruts).

A successful pavement preservation program requires appropriate treatment selection and proper timing of the treatment. To select the right treatment for the right pavement at the right time, the following should be known: (Peshkin et al. 2004)

- What is the structure and condition of the existing pavement?
- What is the expected performance of the pavement?
- How will different treatments affect their performance?
- What other factors affect how the treatments will perform (for example, construction quality control and agency inspection)?

These questions can often be answered by information that is available from a pavement management system (PMS). A pavement management system is a set of tools or methods that assist decision-makers in finding optimum strategies for providing, evaluating, and maintaining pavements in serviceable condition over time. (American Association of State & Highway Transportation Officials [AASHTO] 1993) Pavement management, in the broad sense, includes all the activities involved in the planning, programming, design, construction, maintenance, and rehabilitation of the pavement portion of a public works program. (Haas et al. 1994)

To have an effective pavement preservation program, it is imperative to have some type of pavement management system in place, whether it is proprietary software, public domain software, or a simple spreadsheet. Details of the South Dakota Department of Transportation's pavement management system can be found in SDDOT's Enhanced Pavement Management – System Synopsis; a copy is available at <https://dot.sd.gov/media/documents/Synopsis2020Final.pdf>.

The latest AASHTO Pavement Management Guide was developed in 2012, and it may be a useful resource for local agencies without a PMS in order to improve their selection of the best treatment for specific projects. While some local agencies, such as the city of Sioux Falls and Minnehaha County, have pavement management systems, most do not.

## CHAPTER 2. TREATMENT SELECTION GUIDELINES

The use of pavement preservation strategies to maintain the condition of the pavement network requires that an agency address the following three questions:

1. Is the pavement a good candidate for pavement preservation?
2. If so, what treatment(s) are feasible?
3. What is the recommended treatment?

Appropriate maintenance strategies are determined based upon a combination of the current condition of the pavement and the types of distresses present. In some cases, combinations of preservation strategies are needed to correct the combination of distress that is present on the pavement. The process of selecting the most appropriate combination of pavements and treatments for preservation activities includes the following general steps:

1. Gather pavement information.
2. Assess and evaluate pavement condition.
3. Identify feasible preservation treatments.
4. Select the most appropriate (recommended) preservation treatment.

Feasible treatments, as defined, may correct the distresses present and improve the functional condition of the pavement, but are not necessarily the best treatment option. Recommended treatments, on the other hand, represent those feasible treatments that will address the distresses present and improve the functional condition with a higher degree of certainty and in a cost-effective manner, taking into consideration project constraints.

### GATHER PAVEMENT INFORMATION

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The first step in selecting appropriate preservation techniques is the collection of historical pavement information. The types of information needed to select the right projects and treatments include:

- **Pavement type:** The pavement type dictates the choice of treatment, as different techniques are appropriate for various surface types. The pavements types used in South Dakota include flexible, rigid, and gravel surfaces.
- **Pavement age and design life:** The age and design life of the pavement can provide insight into how the pavement has performed over time and how it can be expected to perform in the future. If the pavement is near the end of its design life, it may be an indication that preservation is not appropriate.

- **Traffic:** Traffic level information, specifically the number of heavy trucks, is a critical detail for determining treatments that cannot provide appropriate performance for the expected traffic level.
- **Pavement cross section and materials.** Knowing the existing pavement structure and materials properties can also be very useful to determine what preservation treatments will work well with the current structure and how the pavement section might perform in the future. Coring and falling weight deflectometer (FWD) testing are normally used once a segment has been identified for rehabilitation or reconstruction. They are considered project-level rather than network-level assessments.

This is the type of information that is normally accessed from a pavement management system and used to select the “right treatment at the right time on the right road.” Agencies without a PMS still need to consider some of these items for each of the projects they are planning.

## ASSESS AND EVALUATE PAVEMENT CONDITION

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In addition to gathering historical pavement information, the current condition of the pavement must be assessed to determine feasible preservation treatments. Ideally, the condition would be determined by a standard condition rating procedure to include details of the types, severities, and extents of all distresses present on the pavement. Several references exist on this topic that local agencies may find useful. SDDOT’S **Enhanced Pavement Management – System Synopsis** provides detailed information on SDDOT’s pavement management system and how the distress data are collected with an automated profiling van; a copy is available at <https://dot.sd.gov/media/documents/Synopsis2020Final.pdf>. Also, the latest **SDDOT Distress Survey Manual** provides detailed information on how distress data are collected manually, which should be of use to local agencies; a copy is available at <https://dot.sd.gov/media/documents/DistressManual.pdf>. (SDDOT 2020) Similarly, SDDOT’s **Maintenance Pavement Preservation Decision Guide** (SDDOT 2016; often referred to as the pocket guide) provides valuable information on distress types and severities; this information has been removed from Appendix B in this document and has been placed [on](#) the SDDOT Intranet.

To determine whether a pavement section is a good candidate for pavement preservation treatments, the agency should consider the following:

- Is there excessive distress (large quantities and/or severe levels of distress) on the pavement section or are the occurring distresses a warning sign of an underlying structural problem?
- Is there evidence of structural problems?
- Has the time for applying a pavement preservation treatment to the pavement while it is in “good” condition passed?
- Are there other known pavement problems (e.g., material problems or signs of construction problems) on the pavement section?

- Is there a history of pavement problems in this location?
- Is the pavement already programmed for a treatment other than preservation?

If the answer to most of these questions is “no,” then the pavement section is likely to be a good candidate for pavement preservation techniques. For pavement sections for which the answer to most of these questions is “yes,” the agency should not consider preservation techniques and instead plan major rehabilitation or future reconstruction for the roadway. Consulting the Highway Needs and Project Analysis Report (Needs Book) or interactive State Transportation Improvement Plan (STIP) map would provide the answer to the last bullet in the above list. (SDDOT 2019)

## **IDENTIFY RECOMMENDED AND FEASIBLE PRESERVATION TREATMENTS**

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**The appropriate treatment strategy for those pavement sections identified as candidates for pavement preservation can be determined by looking at the type and severity of pavement distresses present on the pavement. Guidelines for determining recommended and feasible treatments are provided in**

Table 1 and Table 2 for flexible (asphalt concrete or AC) and rigid (Portland cement concrete or PCC) pavement treatments, respectively. These tables provide guidance for treatment selection based on distress type, severity, and extent. The definitions for each distress type, severity, and extent can be found in the SDDOT 2020 distress manual. Please note there have been some changes in these definitions from the 2020 Pavement Preservation Guidelines and the 2016 Maintenance Pavement Preservation Decision guide.

When multiple distresses exist, the appropriate treatment to address each distress type should be examined, and the recommended treatments must be considered in combination with engineering judgment to make final treatment decisions.

## **SELECT MOST APPROPRIATE PRESERVATION TREATMENT**

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Of the recommended or feasible preservation treatments, the most appropriate treatment is one that can provide the best cost/benefit while meeting the constraints of the project. There are several methods to identify the treatment with the most benefit for the associated cost. This analysis is done internally within many pavement management systems. Ideally, the selection of the right treatment at the right time is governed by optimization (maximizing benefits for given constraints). However, treatment selection can be accomplished through a manual assessment of the benefits versus the projected project cost.

Cost-benefit analysis (CBA) is a general approach that is used to evaluate whether to apply a preservation treatment or to determine which preservation treatment to select, among many other uses. CBA approaches depend on three factors: how costs are quantified, how benefits are quantified, and how costs and benefits are compared. The recommendations in this guide are that costs are defined as fully loaded, the benefits are defined using service life extension, and the costs and benefits are combined using Equivalent Uniform Annual Cost (EUAC). A Microsoft Excel® based tool has been developed as part of the updates to these guidelines; the tool details are provided in [Appendix C](#). Figure 2 outlines the CBA process recommended in this guide.

**Table 1. Treatment Selection Matrix – Flexible Pavement Treatments.**

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
1. Transverse Cracking	Low	Low or Moderate	1, 3, 9, 12	7, 8
		High	9, 10, 12	1, 3, 7, 8
		Extreme	9, 10, 12	17
	Medium	Low	1, 3	2, 6, 8, 9, 11, 12
		Moderate	1, 3	2, 4, 8, 9, 12, 15
		High	15, 17	2, 4, 9, 12
		Extreme	15, 17	4, 9, 12
	High	Low	2	1, 3, 4, 6
		Moderate	2, 10	4, 12, 14
	High or Extreme	15, 17	4, 14	

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
2. Fatigue Cracking	Low	Low	1, 2, 3, 7, 8, 9	11, 12, 13, 15, 16, 17
		Moderate or Higher	1, 2, 3, 7, 8, 9	10
	Medium	Low or Moderate	None	1, 2, 3, 4, 9, 10, 12
		High or Extreme	17	14, 15
	High	Low or Moderate	14, 15	4
		High or Extreme	14, 15, 17	4

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
3. Block Cracking	Low	Low or Moderate	1, 3, 7, 8	9, 11, 12
		High or Extreme	10, 15	9, 11, 12
	Medium	Low	1, 3	9, 10, 11, 12, 15, 17
		Moderate	1, 3, 8	9, 10, 12, 15, 17
		High	8, 10	6, 9, 15, 17
		Extreme	10, 17	6, 9, 15
	High	Low	10, 15	1, 3, 4
		Moderate or Higher	14, 15, 17	None

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
4. Rutting	Low	Low	9	4, 11, 12
		Moderate	9	4, 12, 13
		High or Extreme	9	12, 13
	Medium	Low	12, 15	4, 5, 9, 14
		Moderate or Higher	12, 15	5, 9, 14
	High	Low	12, 15	4, 14
	Moderate or Higher	12, 15	14	

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
5. Edge Cracking	Low	Low or Moderate	1, 2	3, 9, 13
		High or Extreme	1, 2	Patching (not on list)
	Medium	Low or Moderate	1, 2	3, 9, 13
		High or Extreme	9, 10	Patching (not on list)
	High	Low or Moderate	1, 2	3, 9, 13
		High or Extreme	9, 10, 13	Patching (not on list)

- 1 = Crack Treating
- 2 = Crack Leveling
- 3 = Route and Seal Cracks
- 4 = Spray Patching
- 5 = Rut Filling
- 6 = Micro-Milling
- 7 = Fog Seal\*
- 8 = Rejuvenating Seal\*
- 9 = Chip Seal\*
- 10 = Scrub Seal\*
- 11 = Slurry Seal\*
- 12 = Micro Surfacing\*
- 13 = Cape Seal\*
- 14 = Cold Milling\*
- 15 = Thin HMA Overlay\*
- 16 = Bonded Wearing Course\*
- 17 = Cold In-Place Recycling\*

\*These treatments should take into consideration prior application of treatments 1-6.

For definition of distress severities and extent please refer to SDDOT's "Pavement Distress Manual" (a link to this manual is available in the References section on page 81), and to SDDOT's "Maintenance Pavement Preservation Decision Guide" (guide is contained in Appendix B).

**Table 1. Treatment Selection Matrix – Flexible Pavement Treatments (Continued).**

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
6. Longitudinal Cracking	Low	Low or Moderate	1, 2	9, 11
		High or Extreme	1, 2	10, 11
	Medium	Low or Moderate	1, 2	10, 11
		High	9, 10	11, 12, 13
		Extreme	10, 13	11, 12
	High	Low	2,	3
Moderate or Higher		2, 9, 10	3	

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
7. Raveling and Weathering	Low	Low	1, 3	7, 8
		Moderate or Higher	1, 3, 4	7, 8
	Medium	All	8, 10, 11, 12	7
	High	Low	10, 11, 12, 13	17
		Moderate or High	10, 13, 17	14, 15
		Extreme	13, 17	14, 15

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
8. Potholes	Not Applicable	Low or Moderate	9, 10, 11, 12	Patching (not on list)
		High or Extreme	17	Patching (not on list)

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
9. Patching and Patch Deterioration	Low	Low or Moderate	1, 2, 3, 4	13, 15
		High or Extreme	15	13
	Medium	All	15	16
	High	Low	3, 4, 5	15, 16
		Moderate	14	15, 16
		High or Extreme	14, 17	15, 16

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
10. Distortion	Low	All	1, 2	6, 14
	Medium	All	1, 2, 4, 5	6, 14
	High	Low or Moderate	9, 14	9, 13, 15, 16
		High or Extreme	14, 15	9, 13, 15, 16

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
11. Roughness	Low	All	14, 15	13
	Medium	Low or Moderate	14, 15	13, 17
		High or Extreme	14, 15, 16	13, 17
	High	All	14, 15, 16	17

- 1 = Crack Treating
- 2 = Crack Leveling
- 3 = Route and Seal Cracks
- 4 = Spray Patching
- 5 = Rut Filling
- 6 = Micro-Milling
- 7 = Fog Seal\*
- 8 = Rejuvenating Seal\*
- 9 = Chip Seal\*
- 10 = Scrub Seal\*
- 11 = Slurry Seal\*
- 12 = Micro Surfacing\*
- 13 = Cape Seal\*
- 14 = Cold Milling\*
- 15 = Thin HMA Overlay\*
- 16 = Bonded Wearing Course\*
- 17 = Cold In-Place Recycling\*

\*These treatments should take into consideration prior application of treatments 1-6.

For definition of distress severities and extent please refer to SDDOT's "Pavement Distress Manual" (a link to this manual is available in the References section on page 81), and to SDDOT's "Maintenance Pavement Preservation Decision Guide" (guide is contained in Appendix B).

**Table 2. Treatment Selection Matrix – Rigid Pavement Treatments.**

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
1. Transverse Cracking	Low	Low or Moderate	1	None
		High or Extreme	1, 5, 7, 11	None
	Medium	Low or Moderate	1	None
		High or Extreme	1, 5, 7, 11	None
	High	Low or Moderate	1, 5	None
		High or Extreme	5, 7, 11	None
2. Joint Seal Damage	Low	All	None	2
	Medium	All	2	None
	High	Low or Moderate	2	None
		High	2, 5	None
		Extreme	2, 5, 7	None
	3. Joint Spalling	Low	Low or Moderate	None
High or Extreme			7, 11	2, 5
Medium		Low or Moderate	5	2
		High or Extreme	5, 7, 11	2
High		Low or Moderate	5	7
		High or Extreme	5, 7, 11	None
4. Longitudinal Cracking	Low	Low	None	None
		Moderate	1, 8	7
		High	7, 11	1, 8
		Extreme	7, 11	8
	Medium	Low	None	None
		Moderate	1, 8	7
		High	7, 11	1, 8
		Extreme	7, 11	8
	High	Low	None	None
		Moderate	1, 8	7
		High	7, 11	1, 8
		Extreme	7, 11	8
5. CRC Punch-Outs	Low	Low or Moderate	7	5
		High or Extreme	7, 11	5
	Medium	Low or Moderate	7	5
		High or Extreme	7, 11	5
	High	Low or Moderate	7	5
		High or Extreme	7, 11	5

- 1 = Crack Sealing
- 2 = Joint Sealing
- 3 = Diamond Grinding
- 4 = Diamond Grooving
- 5 = Partial Depth Repairs
- 6 = Dowel Bar Retrofits
- 7 = Full Depth Repairs/Slab Replacement
- 8 = Cross Stitching
- 9 = Pavement Subsealing
- 10 = Pavement Jacking
- 11 = Thin AC Overlay

For definition of distress severities and extent please refer to SDDOT's "Pavement Distress Manual" (a link to this manual is available in the References section on page 81), and to SDDOT's "Maintenance Pavement Preservation Decision Guide" (guide is contained in Appendix B).

**Table 2. Treatment Selection Matrix – Rigid Pavement Treatments (Continued).**

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
6. Corner Cracking	Low	All	1	9
	Medium	All	1, 5, 7	9
	High	Low	7	9, 10
		Moderate	7	9
	High or Extreme	7	None	

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
7. Pavement Blow-Ups	Not Applicable	Low-Moderate	5, 7	None
		High or Extreme	7	None

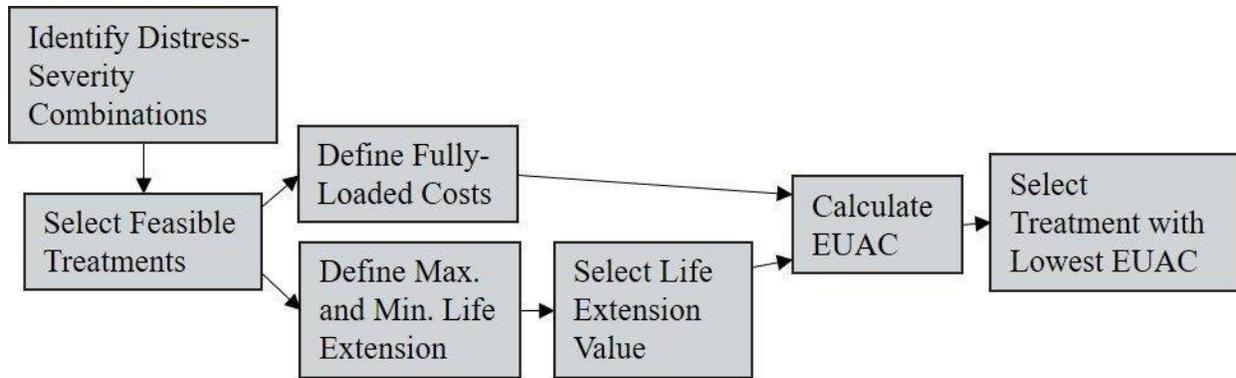
Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
8. Roughness	Low	All	3	9, 10
	Medium	All	3	9, 10
	High	All	3	9, 10

Pavement Distress	Severity Level	Extent	Treatments	
			Recommended	Feasible
9. Durability Cracking/Alkali Silica Reaction	Low	All	None	None
	Medium	All	None	5, 7
	High	All	7, 11	None

- 1 = Crack Sealing
- 2 = Joint Sealing
- 3 = Diamond Grinding
- 4 = Diamond Grooving
- 5 = Partial Depth Repairs
- 6 = Dowel Bar Retrofits
- 7 = Full Depth Repairs
- 8 = Cross Stitching
- 9 = Pavement Subsealing
- 10 = Pavement Jacking
- 11 = Thin AC Overlay

For definition of distress severities and extent please refer to SDDOT's "Pavement Distress Manual" (a link to this manual is available in the References section on page 81), and to SDDOT's "Maintenance Pavement Preservation Decision Guide" (guide is contained in Appendix B).



**Figure 2. Approach to Conducting CBA to Select Cost-Effective Preservation Treatments.**

Current literature shows that the life extension values for most preservation treatments are defined as a range (e.g., 5 to 7 years). The recommendations in this guide are to linearly interpolate the life extension values using the condition—if the results of all distress-severity combinations are ‘feasible,’ then the lower life extension value is used, and if the results are all ‘recommended,’ then the upper value is used. This is based on research that shows a direct correlation between the initial condition of the pavement and the life extension resulting from specific pavement treatments.

In addition to the benefits and costs of the feasible treatments, project constraints must be considered in the treatment selection process. The types of project constraints that must be considered when selecting the most appropriate preservation treatment include:

- Availability of qualified contractors.
- Availability of quality materials.
- Agency practice or local preference.
- Time (of year) of construction.
- Initial costs.
- User preferences.
- Pavement noise.
- Facility downtime.
- Surface friction.

The effect of these constraints will vary from project to project and should be taken into consideration as the final projects are selected for inclusion in a pavement preservation program.

**RECOMMENDED SURFACE TREATMENT FREQUENCY**

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Table 3 provides the recommended frequency of various preservation treatments for average pavements. Engineering judgment used to determine any adjustments to the treatment timing. This table is currently used by SDDOT area and region engineers to decide when roads should receive asphalt surface treatments (AST).

**Table 3. Recommended Surface Treatment Frequency.**

Surfacing Type	Surfacing Age				
	1st Year	2nd Year	3rd Year	4-20+ Years	>20 Years
Mainline overlay w/initial sand seal	Inspect for cracks and seal		AST with Fog Seal	Visually inspect for cracks and seal as cracks appear. AST w/ Fog Seal on 6-8+ yr. frequency as determined by visual inspections	Visually inspect condition and request recommendation for resurfacing from Pavement Design Engineer
Mainline overlay w/o initial sand seal – Material Office Approval Needed	Inspect for cracks and seal – Visual Insp. For AST	AST with Fog Seal		Visually inspect for cracks and seal as cracks appear. AST w/ Fog Seal on 6-8+ yr. frequency as determined by visual inspections	Visually inspect condition and request recommendation for resurfacing from Pavement Design Engineer
Asphalt shoulder adjacent to AC w/ initial sand seal	Inspect for cracks and seal		AST w/ mainline	Visually inspect condition of shoulders. Seal as cracks appear. Flush seal with subsequent mainline AST	Visually inspect condition and request recommendation for resurfacing from Pavement Design Engineer
Asphalt shoulder adjacent to AC w/o initial sand seal	Inspect for cracks and seal	AST with mainline		Visually inspect condition of shoulders. Seal as cracks appear. Flush seal with subsequent mainline AST	Visually inspect condition and request recommendation for resurfacing from Pavement Design Engineer
Asphalt shoulder adjacent to PCCP	Inspect for cracks and seal particularly longitudinal joint		AST between 3-5 years	Visually inspect condition of shoulders. Seal as cracks appear. Flush seal on 8-10 yr. frequency 2’-3’ edge along PCCP flushed more frequently	Visually inspect condition and request recommendation for resurfacing from Pavement Design Engineer
100% Asphalt Milling Shoulders	Visually Inspect, may require add’l flush seal	AST when mainline is done		Visually inspect condition of shoulders. Flush seal on a 5-8 yr. frequency. AST on subsequent treatments based on visual inspection	Visually inspect condition and request recommendation for resurfacing from Pavement Design Engineer
Granular Shoulders Adjacent to Asphalt or Concrete	Visually Inspect, may require add’l gravel and blading	Visually Inspect, may require add’l gravel and blading	Visually Inspect, may require add’l gravel and blading	Visually inspect condition of shoulders. Re-graveling on a 5-8 yr. frequency.	Visually inspect condition and request recommendation for re-graveling from Pavement Design Engineer

Notes: (1) Surfacing placed on new grade or processed in place projects may not require an initial crack seal.  
 (2) AC = asphalt concrete pavement  
 (3) PCCP = Portland cement concrete pavement

**CHAPTER 3. PRESERVATION TREATMENTS**

Many different pavement preservation techniques and treatments are available. These range from localized applications to treatments that are applied to the entire pavement surface. For all preservation treatments, the purpose is to minimize the effects of pavement distress or prevent them from occurring.

Commonly used preventive maintenance treatments and minor rehabilitation techniques are described in one-page summaries in this section. Further details regarding the treatments are available in the standard and supplemental specifications and the special provisions which can be found at the following link: <https://dot.sd.gov/doing-business/contractors/standard-specifications>. (SDDOT 2015)

Each treatment summary is followed by a simple pictorial representation of the major steps of the construction sequence for the treatment. The flexible and rigid pavement treatments that are presented are listed in Table 4, while treatments for drainage and gravel roads are given in Table. It should be noted that patching does not qualify as a preservation treatment, as stated in the FHWA project eligibility guidelines ([Appendix A](#)). As such, patching is not included as a stand-alone treatment, but it is still used as a prerequisite to other preservation treatments.

Prior to the presentation of each treatment type is a Special Considerations section that provides details that are applicable to a variety of treatments.

**Table 4. Pavement Preservation Treatments.**

<b>Flexible Pavements</b>	<b>Rigid Pavements</b>
<ol style="list-style-type: none"> <li>1. Crack Treatments</li> <li>2. Crack Leveling</li> <li>3. Rout and Seal Cracks</li> <li>4. Spray Patching</li> <li>5. Rut Filling</li> <li>6. Micro-milling</li> <li>7. Fog and Flush Seals</li> <li>8. Rejuvenators</li> <li>9. Asphalt Surface Treatments (AST)</li> <li>10. Scrub Seals</li> <li>11. Slurry Seals</li> <li>12. Micro-surfacing</li> <li>13. Cape seals</li> <li>14. Cold Milling</li> <li>15. Thin Asphalt Concrete Overlay &lt; 1.5"</li> <li>16. Bonded wearing course</li> <li>17. Cold in-place recycling</li> </ol>	<ol style="list-style-type: none"> <li>1. Crack Sealing</li> <li>2. Joint Resealing</li> <li>3. Diamond Grinding</li> <li>4. Diamond Grooving</li> <li>5. Partial-Depth Repairs</li> <li>6. Dowel Bar Retrofit (DBR)</li> <li>7. Full-Depth Repairs</li> <li>8. Cross Stitching</li> <li>9. Pavement Sub- sealing/ Under sealing</li> <li>10. Pavement Jacking / Mud Jacking</li> </ol>

**Table 5. Drainage and Gravel Road Preservation.**

<b>Drainage Treatments</b> (see Performance Standard 2290)	<b>Gravel Road Treatments</b> (see Performance Standards 2130 and 2158)
Cleaning, repairing, and maintaining of drainage and erosion control structures (drains, culverts, slopes, ditches, etc.).	<ol style="list-style-type: none"> <li>1. Blading</li> <li>2. Re-Gravelling</li> <li>3. Dust Abatement</li> <li>4. Otta Seals</li> </ol>

**SPECIAL CONSIDERATIONS**

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There are several special considerations that must be addressed prior to the construction of various pavement preservation techniques.

**Pavement Preparation**

Crack sealing, spot patching, rut filling, spray patching, micro-milling, and repair of other distresses are important prior to placing pavement preservation or minor rehabilitation treatments. For example, rut filling prior to a thin AC overlay and micro-milling prior to AST or slurry seals are common pre-treatment and treatment combinations. Transportation Inventory Management (TIM) has data on pavement distress, smoothness, and rutting numbers available for field use; this information may be obtained by calling the TIM office’s directly at (605)773-3278. All flexible pavement sections should be evaluated for the presence of bumps greater than ½" using a 10-foot straightedge, or TIM will provide pavement rutting and longitudinal profile data in mile and tenth of a mile averages when requested. Bumps should be evaluated and ground prior to placing of the flexible treatment options that do not include milling or recycling of the pavement surface.

Special attention should be given to properly cleaning all milled materials from the pavement surface prior to applying a treatment. A properly cleaned surface is imperative in order to obtain proper bonding to the underlying pavement for all flexible surface treatments.

When crack sealing or patching is needed prior to a pavement preservation treatment, the pre-treatment should be placed at least 3 months in advance to minimize difficulties and conflicts between treatment types and/or contractors.

**Pavement Markings**

A minimum of seven days of good drying weather is needed prior to the placement of paint striping on various flexible pavement treatments. Temporary striping of water-based paint or foil-backed tape are normally used until permanent markings can be applied.

**Traffic Control**

Proper traffic control is needed to ensure acceptable cure times for most preservation treatments. Without proper traffic control after placement, premature failure of the preservation treatment may occur. For rigid pavements, the use of conventional patch materials is usually best for the

long-term performance of the pavement but requires adequate curing, which may not be available in high traffic volume areas or at certain times of the year. If it is necessary to get traffic on sooner, the use of high early strength patching materials should be considered.

### **Treatment Sequencing**

When planning preservation work on flexible pavements, consideration should be given to proper sequencing of work. For example, pre-treatments should be done before placing preservation treatments.

When planning preservation work on rigid pavements, consideration should be given to the proper sequencing of treatments. For rigid pavements, an appropriate treatment sequence consists of the following: full- or partial-depth repairs, load transfer restoration, diamond grinding, and joint resealing.

Where epoxy or plastic pavement markings exists, treatments should be coordinated to maximize the life of the pavement markings.

### **Rumble Strips/Stripes**

During the design process, refer to Chapter 7 of the SDDOT Road Design Manual, which may be found at the following link: <https://dot.sd.gov/doing-business/engineering/design-services/forms-manuals>, and include the installation of rumble strips or rumble stripes per the guidance provided. In SDDOT experience, the rumble strips retain their effectiveness for one chip seal, after which they should receive only a fog seal.

## **FLEXIBLE PAVEMENT TREATMENT SUMMARIES**

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For each of the flexible pavement treatments listed in Table 4, the following items are included:

- Treatment description
- Pavement conditions addressed
- Application limitation
- Construction considerations
- Traffic considerations
- Special considerations
- Performance period
- Relative cost

Also, where available performance standards are identified for the treatment, Performance standards refer to the maintenance performance standards in the SDDOT Maintenance Manual. Performance standards exist for only a subset of the treatments in the guide.

Some of the treatments also have specifications/construction requirements included in the standard specifications, such as weather and equipment requirements. These can be found in the SDDOT standard specifications at the following link: <https://dot.sd.gov/doing-business/contractors/standard-specifications>. (SDDOT 2015)

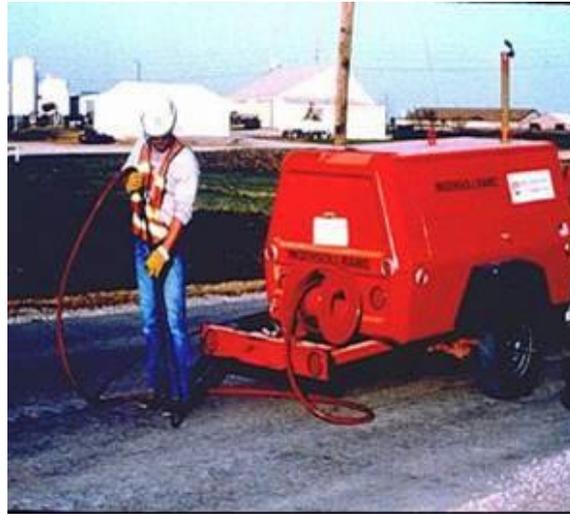
For the purposes of this document, relative costs for each treatment are shown with \$ symbols. The least expensive treatments are shown as \$ while the most expensive treatments are shown as \$\$\$\$\$. However, in the cost-benefit model referenced elsewhere in this document, actual costs are used for each treatment.

## 1. Crack Treatment – Performance Standard 2110

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Crack treating is effective at reducing or delaying moisture damage, further crack deterioration, and rutting. However, crack treating can also have a negative impact on roughness and friction. (See Figure 3.)

- **Treatment Description:** Crack treating is the process of placing material into working/non-working cracks to substantially reduce infiltration of water and to reinforce the adjacent pavement. Crack treating is characterized by minimal crack preparation and the use of lower quality bituminous filler materials.
- **Pavement Conditions Addressed:** Adds no structural benefit but does reduce moisture infiltration through cracks. Only practical if extent of cracking is minimal and if there is little to no structural cracking.
- **Application Limitations:** These treatments are not recommended when structural failures exist (i.e., extensive fatigue cracking or high severity rutting) or if there is extensive pavement deterioration, or little remaining life. Crack treating is appropriate for cracks up to 1 inch wide. Backer rod may be used in large cracks to minimize the sealant material usage, in which case, a minimum depth of 1 inch of sealant should be provided.
- **Construction Considerations:** Placement should occur during cool, dry weather conditions. Application during cool weather will allow for expanded crack widths. Proper crack cleaning and a dry crack are essential to achieve good bonding and maximum performance. During the placement, care should be taken when moisture is present in the pavement layers to ensure that proper bonding of the sealant occurs. Section 350 of the 2015 SDDOT Standard Specifications provides additional information on crack sealing, while the FHWA checklist for these treatments can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19028.pdf>.
- **Traffic Considerations:** Performance is not significantly affected by varying ADT or truck levels. However, improper installation can permit the filler to fail.
- **Special Considerations:** Crack treating may have negative effects. Undesirable visual impacts may occur, which include tracking of filling material by tire action, obscuring lane markings, and adversely affecting friction/skid resistance. Crack treating may result in a rougher pavement surface when the filler material is forced out of the cracks during warm months.
- **Performance Period:** 2 to 4 years.
- **Relative Cost (\$ to \$\$\$\$):** \$



**Step 1.** Crack cleaning. The crack treating process requires minimal crack preparation. This typically consists of using compressed air to clean the cracks.



**Step 2.** Application of crack filler. This photo shows the application of a crack filler using an “overbanded” configuration. A squeegee should be used to provide a 1 to 3-inch overband on each side of the crack.



**Step 3.** Application of blotter. For hot-applied materials, a blotter coat of sand is often used to reduce “tracking” of the material by vehicle tires. A more typical procedure is to use a single ply of toilet tissue to prevent tracking.

**Figure 3. Crack Filling General Construction Steps.**

## 2. Crack Leveling

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Crack leveling is effective at providing a smoother ride across cracks that are depressed due to thermal cracking. There is no performance standard for this treatment. (See Figure 4.)

- **Treatment Description:** Crack leveling involves using a specialized mastic material heated in a hot kettle mixer to level the cracks.
- **Pavement Conditions Addressed:** Does not add structural benefit but does address depressed transverse and longitudinal cracking.
- **Application Limitations:** This treatment is not recommended for structurally deficient pavements. Crack leveling should be considered when cracks are depressed a minimum of ¼".
- **Construction Considerations:** The application requires the use of specialized materials and equipment capable of placing the heated material. A squeegee is used to level the material transversally across the joint. An adequately sized squeegee should be used to assure the depression is completely filled to provide the best ride improvement. Multiple passes may be required after material has cooled to fill deeper cracks. Under sealing should be considered when excessive depression of the crack exists. There is no FHWA checklist for this treatment, but it is considered a preservation treatment by the FHWA division office in South Dakota and it is eligible for Federal-aid funding.
- **Traffic Considerations:** Crack leveling can be used at all traffic levels.
- **Special Considerations:** Crack leveling is an excellent treatment to be placed prior to subsequent treatments such as asphalt surface treatments or micro-surfacing.

Crack leveling will typically be done on thicker asphalt pavements.

- **Performance Period:** 5 to 8 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$



**Step 1.** Hot kettle equipped with chute facilitates placement across the joint prior to striking the material level with a squeegee.



**Step 2.** Finished product after leveling.

**Figure 4. Crack Leveling General Construction Steps.**

### 3. Rout and Seal Cracks – Performance Standard 2110

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The routing and sealing of cracks is effective at reducing or delaying moisture damage, further crack deterioration, and rutting. However, crack sealing can also have a negative impact on roughness and friction. (See Figure 5.)

- **Treatment Description:** Routing and sealing of cracks is the process of placing higher-quality material into “working” cracks (i.e., those that open and close with changes in temperature) to reduce water infiltration into a pavement. In contrast to crack “treating,” routing and sealing of cracks requires substantial crack preparation procedures and higher-quality sealant materials. Both thermosetting and thermoplastic materials are used.
- **Pavement Conditions Addressed:** Does not add structural benefit, but does reduce future intrusion of incompressible materials, water, and soluble chemicals (e.g., salts and brines) into the cracks. It is only practical if extent of cracking is minimal and if there is little to no structural cracking.
- **Application Limitations:** These treatments are not recommended when structural failures exist (i.e., extensive fatigue cracking or high severity rutting) or if there is extensive pavement deterioration, or little remaining life. Routing and sealing of cracks is appropriate for cracks up to 1" wide.
- **Construction Considerations:** Placement should occur during cool, dry weather conditions with moderate daily temperatures. SDDOT limits crack sealing activities to daylight hours between April 1 and June 30, and August 15 and November 15 (inclusive). Proper crack preparation and cleaning is essential to a good bond and maximum performance. Some agencies also use a hot compressed air lance prior to sealing. Cracks that are routed should be routed to a width of 3/4 inch and a depth of 3/4 inch. Cracks with a depth greater than 3/4 inch should have a backer rod inserted to a depth to provide a sealant depth equal to the sealant width. The condition of any routing bits used should be monitored to ensure routed reservoirs have vertical sides and flat bottom surfaces. During the placement, care should be taken when moisture is present in the pavement layers to ensure that proper bonding of the sealant occurs. Section 350 of the 2015 SDDOT Standard Specifications provides additional information, and the FHWA checklist for crack treatments can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19028.pdf>.
- **Traffic Considerations:** Performance is not significantly affected by varying ADT or truck levels. However, improper installation can permit the sealant to fail.
- **Special Considerations:** Routing and sealing of cracks may have negative effects. Undesirable visual impacts may occur, which include tracking of sealing material by tire action, obscuring lane markings, and adversely affecting skid resistance. Routing and sealing of cracks may result in a rougher pavement surface when the sealant material is forced out of the cracks during warm months. Sealing is best accomplished several months in advance of any other preventive maintenance surface applications.

- **Performance Period:** 2 to 8 years.
- **Relative Cost (\$ to \$\$\$\$):** \$



**Step 1. Crack Routing.** A uniform sealant reservoir increases the probability of a neater, better performing sealant installation.



**Step 2. Cleaning and drying.** Cracks must be clean and dry to facilitate sealant bonding.



**Step 3. Material application.** This photo shows the application of sealant using a “simple band-aid” configuration. A squeegee should be used to provide a 1 to 3-inch overband on each side of the crack.



**Step 4. Application of blotter.** For hot applied materials, a blotter coat of sand is often used to reduce “tracking” of the material by vehicle tires. A more typical procedure is to use a single ply of toilet tissue to prevent tracking.

**Figure 5. Crack Sealing General Construction Steps.**

#### 4. Spray Patching

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Spray (or blow) patching is effective at filling potholes, wide cracks, and other localized distressed areas in an asphalt pavement. (See Figure 6.)

- **Treatment Description:** Spray patching involves using a spray injection machine to apply a mixture of aggregate and emulsified asphalt to fill a pothole, wide cracks, or other distressed areas in a pavement. The application is typically used when the patch thickness is minimal, and the distressed area is small.
- **Pavement Conditions Addressed:** Spray patching will provide a filler in potholes, wide cracks, or other distressed areas in an asphalt pavement.
- **Application Limitations:** This treatment is not recommended for structurally deficient pavements.
- **Construction Considerations:** Spray patching requires a spray injection machine capable of applying the aggregate and emulsified asphalt such as CRS2. There is no FHWA checklist for this treatment.
- **Traffic Considerations:** Spray patching can be used with all traffic levels.
- **Special Considerations:** Spray patching treatment can be placed prior to subsequent treatments such as asphalt surface treatment or micro-surfacing.
- **Performance Period:** 2 to 6 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$



**Step 1.** A blow patch truck.



**Step 2.** The blow patch truck begins spraying a slurry of aggregates and emulsion into the pothole.



**Step 3.** The slurry is used to fill the pothole.



**Step 4.** Cover aggregate is used to protect the patch as the emulsion cures.

**Figure 6. Spray (or Blow) Patching General Construction Steps.**

## 5. Rut Filling

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Rut filling is effective at filling ruts in the wheel paths and restoring proper cross slope on the roadway.

- **Treatment Description:** Rut filling involves placing a hot asphalt mix, typically a fine mix, with the use of a wedge box in the wheel path or rut location by maintenance personnel. Rut filling could also be done with a micro-surfacing under a formal contract to address widespread consistent rutting along a project segment (see Figure 7).
- **Pavement Conditions Addressed:** Rut filling will correct ruts more than ½ inch in depth and will provide minimal structural benefit, depending on the thickness placed.
- **Application Limitations:** This treatment is not recommended for structurally deficient pavements.
- **Construction Considerations:** Rut filling requires the use of a wedge box, typically 4' wide, mounted on a front-end loader. If available, a fine mixture of hot mix asphalt should be used, but care should be taken to ensure that the material contains fractured aggregate to resist future rutting.
- **Traffic Considerations:** Rut filling can be used with all traffic levels.
- **Special Considerations:** Rut filling is an excellent treatment to place prior to subsequent treatments such as asphalt surface treatment or micro-surfacing. Transportation Inventory Management can provide rutting values in tenth of a mile increments to aid in determining potential routes needing rut filling.
- **Performance Period:** 4 to 6 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$



**Step 1.** Rutted pavement.



**Step 2.** Spraying tack coat.



**Step 3.** Placing mix with Yankton box.



**Step 4.** Raking mix to create a smooth transition.



**Step 5.** Rolling mix.



**Step 6.** Rut filling almost complete.

**Figure 7. Rut Filling General Construction Steps.**

## 6. Micro-Milling

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Micro-milling uses a milling head with about three times as many teeth as a conventional milling head to remove a thin layer of the existing pavement surface and restore pavement smoothness. (See Figure 8.) A good description of when and where to use micro-milling is given in the following links: <https://www.dot.state.mn.us/mnroad/nrra/newsletter/2017/june.html> and <https://www.dot.state.mn.us/materials/pavementpreservation/manualsandguides/documents/Micro%20Milling%20Investigation%202019.pdf>. Other good information on micro-milling may be found at the following Los Angeles County, California link:

<https://dpw.lacounty.gov/gmed/lacroads/TreatmentMicromilling.aspx>. In addition, information on an on-going micro-milling study by the Minnesota DOT may be found at:

<https://dot.state.mn.us/mnroad/nrra/structure-teams/flexible/milling-operations.html>.

- **Treatment Description:** The specialized milling head used in micro-milling produces smoother surface texture when compared to conventional milling and can improve surface friction of an existing roadway. Much of the smoothness comes from the fact that the ridge-to-valley depth, or the difference between the lowest and highest points of the micro milled surface, is much less than that of a conventionally milled surface. The milling machine has sonic levelling equipment, usually at the front and rear of the machine that will remove some of the undulations in the pavement profile. Because of the smooth surface texture achieved, a roadway can potentially be opened to traffic after the micro-milling operation is complete with no further treatment. Unlike conventional milling, micro-milling is also effective in preparation for treatments such as slurry surfacing, asphalt surface treatments and thin lift overlays. Mill depth should be limited to one inch – micro-milling should not be as deep as conventional milling. Cold milling, which is discussed later in these guidelines, can go to greater depths.
- **Pavement Conditions Addressed:** This treatment is applicable for low to moderate severity roughness and high severity friction loss or as a pre-treatment to other preservation treatments.
- **Construction Considerations:** Micro-milling requires a specialized milling head with roughly triple the amount of teeth of a conventional milling head. The milling head should be wide enough to cover an entire lane without the need for multiple passes. The forward speed of the milling machine must be slow enough and rotations per minute (RPM) of the milling head be such that all teeth across the width of the milling head make proper contact with the existing pavement surface. The pavement must be structurally sound. Micro-milling is not recommended where structural failures exist (e.g., significant fatigue cracking or deep rutting) or if there is high severity thermal cracking. It is also not recommended when there is extensive pavement deterioration or little remaining service life. Micro-milling is capable of withstanding high ADT volumes and truck traffic if performed on a structurally sound pavement. There is no FHWA checklist for this treatment, but important reference material was introduced at the top of this page.

- **Performance Period:** Dependent on the treatment placed on the milled surface.
- **Relative Cost (\$ to \$\$\$\$):** \$\$



**Figure 8. Micro-Milling General Construction Steps.**

## 7. Fog Seals or Flush Seals – Performance Standard 2108

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Fog or flush seals are effective at sealing the pavement, inhibiting raveling, enriching the hardened/oxidized asphalt, and providing some pavement edge-shoulder delineation. Fog seals include emulsion treatments only, whereas flush coats include the emulsion followed by an application of blotter sand. However, they can have a negative impact on friction and stripping in susceptible hot-mix asphalt (HMA) pavements. A fog seal is placed on top of most SDDOT's AST projects in the state. This helps to further seal microcracks that may still be present and, more importantly, surround the chip and give it greater adherence to the roadway. (See Figure 9.)

- **Treatment Description:** Fog seals are very light applications of a diluted asphalt emulsion placed directly on the pavement surface with no aggregate. Typical application rates range from 0.05 to 0.10 gal per yd<sup>2</sup>. This treatment is commonly used on mainline and shoulders.
- **Pavement Conditions Addressed:** Does not add structural capacity. Fog seals are placed primarily to seal the pavement, inhibit raveling, slightly enrich a hardened/oxidized asphalt, and provide some pavement edge-shoulder delineation. No structural benefit is added by this treatment. Prior to treatment placement, it may be necessary to perform other treatments to address other issues, such as rut filling, patching, crack treating or sealing, or spray patching.
- Vegetation control on the shoulder treatments should be considered and applied as per Performance Standard 2305 either prior to the treatment or as part of the treatment.
- **Application Limitations:** This treatment is not recommended when structural failures exist (e.g., significant fatigue cracking) or if there is already flushing/bleeding, friction loss, or thermal cracking.
- **Construction Considerations:** Typically, a slow-setting emulsion (e.g., CSS-1H, SS-1H) is used, which requires time to “break.” Because of this, the pavement is sometimes closed for 2 hours for curing before being re-opened to traffic. Section 330 of the 2015 SDDOT Standard Specifications contains more information on this treatment, while the FHWA checklist for fog seals can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19032.pdf>.
- **Traffic Considerations:** Increased ADT or truck levels can increase surface wear.
- **Special Considerations:** Special consideration should be given to the pavement markings and bump grinding prior to treatment placement. Prior to treatment application, care should be taken to prevent over-spraying onto the existing pavement marking by using the proper shield on the spray bar or if necessary, the pavement marking tape should be masked.
- **Performance Period:** 1 to 3 years.
- **Relative Cost (\$ to \$\$\$\$):** \$



**Step 1.** Surface preparation. The surface must be free of dust, dirt, and debris prior to applying the emulsion.



**Step 2.** Application of emulsion. The emulsion is applied using a distributor truck.



**Step 3.** Sand blotter and sweeping (if necessary). Sand blotters can help address a problem with delayed curing, as well as early opening to traffic. Sweeping may be required to remove excess sand.

**Figure 9. Fog Seal General Construction Steps.**

## 8. Rejuvenators (or Rejuvenating Emulsion Seals)

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Rejuvenators are effective at restoring the original properties to aged asphalt binder, thus reducing the effects of raveling or roughness. There is no performance standard for this treatment. (See Figure 10.) However, some references on this type of treatment are included in the reference list. (National Road Research Alliance 2019, National Center for Asphalt Technology 2019)

- **Treatment Description:** Rejuvenators are specialized emulsions that are sprayed on an existing asphalt surface with the intent of softening the existing binder, enriching the weathered pavement, and thereby inhibiting raveling. The emulsions used as rejuvenators are typically mixtures of asphalt, polymer latex, and other additives. Rejuvenating emulsions can be used in a fog seal, sand seal, scrub seal, or any other surface seal applied directly to the pavement surface.
- **Pavement Conditions Addressed:** While rejuvenators do not directly correct any distresses, they are effective at softening the existing binder; thereby, slowing the development of raveling, thermal cracking, and roughness. Prior to treatment placement it may be necessary to perform other treatments to address other issues, such as rut filling, patching, crack treating, crack sealing, or spray patching.
- **Application Limitations:** This treatment is not recommended when structural failures exist (e.g., fatigue cracking), where the surface has poor friction, or if there is extensive pavement deterioration or little remaining life.
- **Construction Considerations:** Choosing an appropriate rejuvenating agent and determining the correct application rate for the existing pavement's material characteristics and condition are the most important construction-related considerations. Field testing needs to be conducted to determine the correct application rate. There is no FHWA checklist for this treatment, but the checklist for fog seals would be appropriate.
- **Traffic Considerations:** Rejuvenators are effective on asphalt surfaces in all traffic conditions. However, traffic should not be allowed back on the surface until adequate friction is restored. This is often provided by the placement of manufactured sand prior to opening to traffic.
- **Special Considerations:** When selecting a rejuvenator for a project, questions regarding available materials can be directed to the SDDOT Materials Office.
- **Performance Period:** 3 to 5 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$



**Step 1.** Rejuvenator application. The rejuvenating emulsion is applied to the surface using a distributor truck.



**Step 2.** Light sanding. After the rejuvenator has been allowed to be absorbed for the recommended amount of time, a light application of sand is often applied to improve skid resistance.

**Figure 10. Rejuvenator General Construction Steps.**

## 9. Asphalt Surface Treatments (AST) Performance Standard 2108

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AST, also known as chip seals, are effective at improving poor friction, inhibiting raveling, correcting minor roughness and bleeding, and sealing the pavement surface. (See Figure 11.)

- **Treatment Description:** Asphalt binder (commonly an asphalt emulsion) is applied directly to the pavement surface (0.26 to 0.46 gal/yd<sup>2</sup>) followed by the application of aggregate chips (16 to 30 lb/yd<sup>2</sup>), which are then immediately rolled to imbed chips (50 to 70 percent). Application rates depend upon aggregate gradation and maximum size. This treatment can be applied in multiple layers (e.g., double chip seals) and in combination with other surface treatments.
- **Pavement Conditions Addressed:** Does not add structural capacity but will slow the effects of pavement distresses like longitudinal, transverse, and block cracking; raveling/weathering (loose material must be removed); friction loss; minor roughness; low-severity bleeding; and moisture infiltration. The flexible impermeable AC surface helps reduce cracking and is somewhat effective at sealing medium-severity fatigue cracks in comparison with other treatments. Prior to treatment placement it may be necessary to perform other treatments to address other issues, such as rut filling, patching, crack treating, crack sealing, or spray patching.
- **Application Limitations:** Not recommended for pavements with the following conditions: structural deficiency, cracks more than ¼-inch wide, medium- to high-severity alligator cracking, many potholes, rutting more than 1-inch, and very rough surface. AST can also accelerate the development of stripping in moisture susceptible AC pavements. Depressed cracks should be repaired before placing this treatment
- **Construction Considerations:** Surface must be clean. Treatment should be placed during warm weather with chip spreader immediately behind asphalt distributor and rollers close behind the spreader. AST are placed from May 15 to September 1 and when the temperature in the shade is above 70°F. Placement after September 1st is discouraged. Any depressed transverse cracks should be fixed before applying the AST. For more information on time and temperature for application, check Section 360 of the 2015 SDDOT construction and supplemental specifications. The FHWA checklist for chip seals can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19029.pdf>.

Approximately 2 hours of cure time are required before roadway may be re-opened to normal speed traffic. Brooming is usually required to remove loose chips. Pilot vehicles should be used to make sure traffic does not damage the fresh surface and to reduce windshield breakage and other vehicle damage. Lightweight aggregate can be used to help minimize claims. Flaggers may be needed at crossing intersections to control traffic. Avoid premature placement of pavement markers and striping.

A fog seal is recommended on all application to prevent aggregate loss and potential vehicle damage. Fog seal should be placed on mainline AST only. If shoulders do not receive AST, the fog seal should be placed on the shoulders' full width. Prior to fog seal,

the surface should be clean of excess chips. For more information on fog seals, please refer to the fog seal treatment section on page 31 of these guidelines.

The initial AST should be placed full width to include the shoulder. Subsequent AST should be done 23 feet wide on mainline. This will allow pavement marking paint to be recessed and extend the life of the pavement marking. Asphalt shoulders should be fog sealed when the subsequent mainline AST is applied.

When rumble strips are present, only one AST should be applied, as additional applications can fill the rumble strips and reduce its effectiveness, or the AST will need to be re-ground, which could result in early pavement deterioration. Therefore, second or third rumble strip treatment applications should make use of fog seals when the mainline is fog sealed.

- **Traffic Considerations:** With special design and proper placement, AST can perform well on high-volume roads. Traffic should be notified by flaggers while the work is being performed and of the potential for vehicle damage on the project.
- **Special Considerations:** The designer should use the Modified McLeod Design Procedure as a basis for use of the treatment and incorporate standard plan notes. Special consideration should be given to the bump grinding prior to treatment placement. The Minnesota Seal Coat Handbook provides a good reference on AST, including proper design and construction procedures. (MNDOT 2006)
- **Performance Period:** Single seals: 6 to 10 (or more) years depending on construction practices.
- **Relative Cost (\$ to \$\$\$\$):** \$\$



**Step 1.** Surface preparation. Surface must be clean and dry to ensure good bond with the asphalt.



**Step 2.** Binder application. The asphalt binder is applied to the surface with a distributor truck.



**Step 3.** Aggregate application. A self-propelled, pneumatic-tired, motorized unit has a hopper on the front where the chips are dumped.



**Steps 4 & 5.** Rolling and brooming. After the application of the aggregate, the surface is rolled with pneumatic-tired rollers and broomed to remove excess aggregate.

**Figure 11. AST General Construction Steps.**

## 10. Scrub Seals

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Scrub seals are effective at filling narrow cracks ½" wide, rejuvenating hardened/oxidized asphalt, and improving poor friction. They are a type of chip seal. There is no performance standard for this treatment. (See Figure 12.) A good reference for scrub seal specifications was developed by Minnesota DOT. (MNDOT 2016)

- **Treatment Description:** A scrub seal is a thin asphalt surface treatment constructed by spraying a polymer modified rejuvenating emulsion onto an existing pavement, dragging a broom across the surface to scrub the emulsified asphalt into the surface cracks, immediately spreading a thin layer of fine aggregate (i.e. sand or screenings) over the emulsified asphalt, dragging another broom over the surface to scrub the fine aggregate into the surface cracks, and rolling the surface with a pneumatic tire roller. The maximum size aggregate used in this treatment generally ranges from ¼ to 3/8 inch.
- **Pavement Conditions Addressed:** Does not add structural capacity. Scrub seals are primarily placed to fill narrow cracks, rejuvenate oxidized asphalt, and improve poor friction. No structural benefit is added by this treatment. Prior to treatment placement it may be necessary to perform other treatments to address other issues, such as rut filling, patching, crack treating or sealing, or spray patching.
- **Application Limitations:** This treatment is not recommended when structural failures exist (e.g., fatigue cracking) or if there is extensive pavement deterioration, or little remaining life. Scrub seals should not be applied to pavements with ruts greater than ¼" deep, unless a rut filling treatment is placed prior to the scrub seal.
- **Construction Considerations:** Scrub seals should be constructed when conditions are dry (i.e., the risk of rain is not likely, as that would hinder the proper construction of the scrub seal) and when the minimum air temperature is moderate (i.e., normally 50°F [10°C] or above). To assure good bond to the existing pavement, the surface should be clean and dry prior to emulsion placement. The FHWA checklist for this treatment can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19040.pdf>.
- **Traffic Considerations:** Scrub seals should generally be limited to lower volume traffic conditions with a low percentage of trucks.
- **Special Considerations:** Special consideration should be given to the pavement markings and bump grinding prior to treatment placement. Scrub seals are susceptible to snowplow damage. Pavement marking tape should be masked prior to placing treatment. At the present time, there are no contractors in the state that place this treatment.
- **Performance Period:** 5 to 7 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$



**Step 1.** Surface preparation. The surface must be free of dust, dirt, and debris prior to applying the emulsion.



**Step 2.** Emulsion application and drag-brooming. Drag-brooming is used to work emulsion into cracks and surface voids



**Step 3.** Sand application. A thin layer of sand is applied to the broomed emulsion.



**Steps 4 & 5.** Drag-brooming of sand and rolling. After the application of sand, the surface is drag-broomed again and rolled with pneumatic-tired rollers.

**Figure 12. Scrub Seal General Construction Steps.**

## 11. Slurry Seals

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Slurry seals are surface treatments effective at correcting or inhibiting raveling and oxidation of the pavement surface, improving surface friction, sealing the pavement surface, and filling minor surface irregularities and wheel ruts. (See Figure 13.)

A slurry seal is very similar to micro surfacing; the main difference is that slurry seals **do not** contain an additive that causes the chemical “breaking” action. Also, slurry seals cure through a thermal process, resulting in longer cure times.

- **Specifications:** Currently, SDDOT does not have a specification for slurry seals. An alternative source is the Recommended Performance Guidelines for Emulsified Asphalt and for Polymer–modified Emulsified Asphalt Slurry Seals, International Slurry Surfacing Association (ISSA), revised 2020. (These are guidelines, not specifications). Additionally, the National Center for Pavement Preservation (NCP) has a generic specification as shown at the following link: [https://www.pavementpreservation.org/wp-content/uploads/2017/03/FPCC335\\_Micro\\_Surfacing.pdf](https://www.pavementpreservation.org/wp-content/uploads/2017/03/FPCC335_Micro_Surfacing.pdf)
- **Treatment Description:** Slurry seal consists of a carefully designed mixture of asphalt emulsion (which may be polymer-modified), mineral aggregate, water, and additives. This mixture is proportioned, mixed, and uniformly spread over a properly prepared surface at a single stone thickness. Slurry seal is applied as a homogenous mat, which adheres firmly to the prepared surface and has a skid-resistant texture throughout its service life. Slurry seal is a quick-traffic system that allows traffic to return shortly (from one to four hours) after placement. The treatment is favorable due to the reasonable application times and disruption to traffic, as well as not producing loose chips, therefore eliminating risk of potential vehicle damage.
- **Pavement Conditions Addressed:** Slurry seals do not add structural capacity but may provide protection against surface distresses like low severity cracking, raveling/weathering (loose material must be removed), minor roughness, friction loss, and moisture infiltration. Slurry seals will also temporarily seal cracks (if severity is low) and can serve as a rut-filler (if the existing ruts are stable). Prior to treatment placement, it may be necessary to perform other treatments to address other issues, such as rut filling, patching, or crack treating. This treatment is applicable for low-severity transverse cracking, low-severity longitudinal cracking, low-severity block cracking, and low- and medium-severity raveling/weathering. It is also applicable for ADT less than 2,500 or pavements with poor friction.
- **Construction Considerations:** Slurry seals should be placed only when the air and pavement surface temperature is above 50°F (10°C) and rising. The weather also should not be foggy or rainy. No slurry seals shall be placed when there is a danger that the finished product will freeze within 48 hours. They should not be placed after September 15.

The FHWA checklist provides a list of key components that are necessary for a successful project. They are designed to help guide an Inspector or Project Engineer in

the field and can be found at

<https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19036.pdf>.

- **Performance Period:** 5 to 7 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$



**Step 1.** Prepare surface. Surface must be clean. All structures (manholes, valve boxes, etc.) need to be protected prior to placement.



**Step 2.** Slurry seal placement. This photo shows the placement of material using spreader box.

**Figure 13. Slurry Seal General Construction Steps.**

## 12. Micro-Surfacing

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Micro-surfacing is effective at correcting or inhibiting raveling and oxidation of the pavement surface, improving surface friction, sealing the pavement surface, and filling minor surface irregularities and wheel ruts up to 1 ¼ inch deep. There is no performance standard for this treatment. (See Figure 14.)

- **Treatment Description:** Micro-surfacing consists of a mixture of latex-modified emulsified asphalt, mineral aggregate, mineral filler, water, and additives. Micro-surfacing material is mixed in specialized, compartmented, self-powered trucks and placed on the pavement using an augured screed box. Recommended performance guidelines have been prepared by ISSA. These are guides, and not specifications, and are currently being updated. (ISSA 2014)
- **Pavement Conditions Addressed:** Does not add structural capacity but will provide protection of surface distresses like low-severity cracking, raveling/weathering (loose material must be removed), low- to medium-severity bleeding, minor roughness, friction loss, and moisture infiltration. Micro-surfacing will also temporarily seal fatigue cracks (if severity is low) and can serve as a rut-filler (if the existing ruts are stable). A scratch coat of the micro-surfacing can be used for light profile repairs. Prior to treatment placement it may be necessary to perform other treatments to address other issues, such as rut filling, patching, crack treating, crack sealing, or spray patching or micro-milling.
- **Application Limitations:** Micro-surfacing is not recommended when the pavement contains structural failures (e.g., significant fatigue cracking or rutting), high-severity thermal cracking, or extensive pavement deterioration. This treatment can also accelerate the development of stripping in moisture susceptible AC pavements.
- **Construction Considerations:** Avoid placement in hot weather if there is potential for flushing problems. Placement in cool weather can lead to early raveling. Do not place when freezing temperatures are expected. The micro-surfacing material shall be spread only when the surface temperature on a shaded portion of the existing surface is above 50°F (10°C) and rising and when the weather is not foggy or rainy. No micro-surfacing will be placed when there is a danger that the finishing product will freeze within 24 hours.

Avoid premature placement of pavement markers and striping. A minimum of 7 days of good drying weather should be allowed before placement of new markers or striping with temporary markers used prior to permanent placement. Micro-surfacing typically breaks within a few minutes of placement and can carry traffic after approximately an hour. The FHWA checklist for micro-surfacing can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19031.pdf>.

- **Traffic Considerations:** Very successful on both low and high-volume roadways. However, areas of heavy truck turning or down grade locations are best avoided as there is a high potential for early damage. The dusting of a blotter material can be used to allow for earlier opening of intersections and turning lanes.

- **Special Considerations:** The designer should use the SDDOT Special Provision for Polymer-modified micro-surfacing as a basis for use of this treatment. If micro-surfacing is being used to fill ruts, this must be specified on the plans along with appropriate gradation and application rate. Two lifts of micro-surfacing should be considered to fill the ruts. Special consideration should be given to the raised pavement markers and bump grinding prior to treatment placement.
- **Performance Period:** 4 to 7 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$



**Step 1.** Repair existing distress. Any structural failures should be patched and working cracks > 1/4" wide should be sealed.



**Step 2.** Prepare surface. Surface must be clean, and striping must be removed. All non-other in-pavement fixtures (e.g., manholes) need to be protected prior to paving.



**Step 3.** Micro-surfacing placement. This photo shows the placement of material using a micro-surfacing spreader box.



**Step 4.** Handwork. Some handwork may be required to smooth edges. Excessive handwork can segregate the mix as well as leave an unsatisfactory finish.

**Figure 14. Micro-Surfacing General Construction Steps.**

### 13. Cape Seals

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A Cape seal is used to both seal the road surface from moisture intrusion and improve ride, if preceded by micro-milling. It is a two-step roadway surface treatment consisting of a chip seal covered by a slurry seal or micro-surfacing treatment. Chip seals are sometimes less desirable by the public because they cause rougher pavement surface texture and do not improve ride. With the addition of the top treatment (slurry/micro), the road ends up with a smoother surface. (See Figure 15.)

Primary benefits of a Cape seal include sealing of the road surface to prevent moisture intrusion, protecting the pavement from oxidation, preventing raveling, and filling wheel path ruts and cupped cracks. Additionally, cape seals improve ride and skid resistance.

- **Specifications:** Currently, SDDOT does not have an explicit specification for cape seal. However, there are specifications for:
  - AST layer, and
  - Slurry seal/micro-surfacing layer.
- **Treatment Description:** A Cape seal is a process that includes placing a chip seal on the existing pavement surface. Then after a few days, a slurry seal or micro surfacing layer is placed on top of the chip seal. To place the chip seal, an asphalt distributor provides application of the binder to the pavement surface. A chip spreader immediately applies a uniform, predetermined rate of aggregate onto the binder. These two operations are at the heart of constructing a surface that is one stone thick and has enough asphalt to retain the aggregate, but not an excess amount of binder that causes the surface to bleed. Depending on the binder, aggregate, and actual type of chip seal being constructed, various rollers will be used to orient the aggregate to achieve appropriate embedment. Pneumatic rollers are typically found on all chip seal projects. The rollers are followed by the brooms that remove excess aggregate from the finished surface.

Slurry seal consists of a carefully designed mixture of asphalt emulsion (which may be polymer-modified), mineral aggregate, water, and additives, which are proportioned, mixed, and uniformly spread over a properly prepared surface at a single stone thickness. Slurry seal is applied as a homogenous mat which adheres firmly to the prepared surface and has a skid-resistant texture throughout its service life. Slurry seal is a quick-traffic system that allows traffic to return shortly (from one to four hours) after placement.

Micro-surfacing consists of a carefully designed mixture of polymer-modified asphalt, mineral aggregate, water, and additives, proportioned, mixed, and uniformly spread over a properly prepared surface which is typically greater than one stone thick. Micro-surfacing is applied as a homogenous mat which adheres firmly to the prepared surface and has a skid-resistant texture throughout its service life. Micro-surfacing is a quick-traffic system that allows traffic to return shortly (typically less than one hour) after placement.

- **Pavement Conditions Addressed:** Although cape seals do not add structural capacity, they can treat pavement distresses including low-severity transverse cracking, low-severity longitudinal cracking, low-severity block cracking, and low- and medium-severity raveling/weathering.
- **Construction Considerations:** For the chip seal, the surface must be clean and dry. The treatment should be placed during warm, dry weather. The chip spreader must be immediately behind the asphalt distributor, with the rollers closely behind the spreader. Pneumatic tire rollers should make a minimum of three passes immediately after chip placement. The pavement and air temperatures must be 60°F and rising. Construct only in daylight hours. Roads may be damp, but there must be no standing water. Do not construct in rain or foggy weather.

Sweep all pavements the same day as application. Re-sweep the following day to remove all additional loose rock. A cape seal may be used when a slurry seal or micro-surfacing treatment alone will not address the pavement surface distresses adequately.

The FHWA Cape Seal Pavement Preservation Checklist provides a concise list of important components that go into a successful project and can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19043.pdf>.

- **Performance Period:** 6 to 8 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$



**Step 1.** Prepare surface. Surface must be clean. All structures (manholes, valve boxes, etc.) need to be protected prior to placement. Striping may be pre-treated (as shown here) with emulsion. Large pavement messages (turn arrows, RR Xing, etc.) should be removed.



**Steps 2 & 3.** Emulsion and chip application. The asphalt emulsion is applied to the surface with a distributor truck. Chips are spread from a self-propelled, pneumatic tired unit with a hopper on the front from which the chips are placed onto the roadway.



**Steps 4 & 5.** Rolling and sweeping. After the application of the aggregate, the surface is rolled with pneumatic tired rollers and swept to remove excess aggregate.



**Step 6.** Prepare surface. Surface must be clean. All structures (manholes, valve boxes, etc.) need to be protected prior to placement.



**Step 7.** Micro-surfacing placement. This photo shows the placement of material using a micro-surfacing spreader box.

**Figure 15. Cape Seal General Construction Steps.**

## 14. Cold Milling

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Cold milling is effective at removing distresses in the top of the pavement, providing a smoother surface by removing vertical deformations, and improving surface friction. It is also used for mill and fill operations. There is no performance standard for this treatment. (See Figure 16.)

- **Treatment Description:** Cold milling involves the removal of part or all of an existing asphalt concrete surface. This treatment is frequently used to prepare an asphalt surface for an asphalt concrete overlay (mill and fill) and is not generally suggested as a standalone treatment. It also can be utilized to improve smoothness prior to applying other applications or correct bumps or dips, at box culverts, structure approaches, railroad grade crossings, or other locations.
- **Pavement Conditions Addressed:** Adds no structural benefit but removes surface rutting and roughness and restores friction. It can also be used to restore proper grades and cross-slopes on existing pavements.
- **Application Limitations:** This treatment is not recommended for structurally deficient pavements unless the asphalt overlay is designed to add structural capacity.
- **Construction Considerations:** The following are keys to obtaining a quality milled surface:
  - Use a good working milling machine with a 12-ft recommended width. However, the width of the roadway needs to be considered, which means using a 12-ft head so trucks can load from the side of the milling machine so progress is not hindered. For narrower roadways, smaller milling heads should be considered.
  - Control milling speed to achieve a smooth uniform surface (30 ft/min or slower for deep cuts).
  - Use a 28-ft ski to control grade and a string line for longitudinal guidance.
  - Perform pavement patching prior to milling.
  - Remove manhole castings and cover holes prior to milling.
  - Adjust manhole casting after milling to meet final surface elevation.
  - If this treatment is used as a stand-alone treatment, a fine-toothed milling drum is needed to improve the smoothness and safety of the milled surface.

There is no FHWA checklist for this treatment. For more information on this process, please see Section 332 of the 2015 SDDOT specifications book.

- **Traffic Considerations:** Cold milling can be used with all traffic levels.

- **Special Considerations:** While not generally suggested as a standalone treatment, if the SDDOT Materials Office reviews and agrees upon the implementation plan, cold milling without applying another treatment to the milled surface may be considered. In order for the milled surface to be used as standalone treatment, the pavement must be structurally sound with at least 3 inches of the existing asphalt concrete remaining in place and the removed material equal to an existing lift (at least 1 to 1 ½ inch of binder course remains). In addition, the existing mixture must have a high fines content and low air voids content to avoid raveling.
- **Performance Period:** Remaining life of the pavement (does not extend life).
- **Relative Cost (\$ to \$\$\$\$):** \$



**Step 1.** Prepare surface. Patching should be completed before milling. All other in-pavement fixtures (e.g., manholes) need to be protected prior to cold milling.



**Step 2.** Milling. Milling is used to remove distresses such as segregation, rutting, raveling, or block cracking.

**Figure 16. Cold Milling General Construction Steps.**

## 15. Thin HMA Overlay (less than 1.5 inches)

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The application of a thin HMA overlay is a viable option for improving ride ability and increasing surface friction, reducing hydroplaning and tire splash (using an open graded friction course), and improving the profile, crown, and cross slope (see Figure 17). There is no performance standard for this treatment, but Minnesota DOT has developed a Guide for Thin Overlays. (MNDOT 2016)

- **Treatment Description:** Plant-mixed combinations of asphalt binder and aggregate applied to the pavement in thicknesses between about  $\frac{3}{4}$  and  $1\frac{1}{2}$  inches. Dense-graded, open-graded, and stone matrix mixes are all used. Thin HMA overlays consist of placing a  $1\frac{1}{2}$  inch single pass overlay on a previously resurfaced pavement that is not in need of significant repair and is in good condition. If the overlay is applied at the correct time, it can delay serious distresses, extend the life of the pavement, and decrease the overall cost.
- **Pavement Conditions Addressed:** Structural capacity of the pavement is increased and benefits are provided to pavement distresses including low-severity cracking, raveling/weathering (loose material must be removed), friction loss, roughness, low-severity bleeding, and low-severity block cracking (may perform better with additional milling). Thin overlays may also be used to correct rutting but will require the use of a separate rut-fill application.
- **Application Limitations:** Thin HMA overlays are not recommended where there are serious structural failures (e.g., fatigue cracking), or if there is extensive pavement deterioration or high-severity thermal cracking. Surface should be uniform to ensure uniform compaction.
- **Construction Considerations:** Surface must be clean. A tack coat is required prior to overlay placement and will help improve the bond to the existing surface. Thin HMA overlays dissipate heat rapidly and therefore require minimum specified mix placement temperatures and timely compaction. A blade-laid leveling course of HMA should be considered prior to the overlay depending on the existing pavement condition. This pre-treatment is typically used on a mill and fill projects with depressed transverse cracks to fill some of the gaps. The FHWA checklist for this treatment can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19030.pdf>.
- **Traffic Considerations:** Performance is not affected by different ADT or percent trucks. Thin AC overlays are not structural layers, and as such, should not be subjected to strain from loadings. Such layers may be subject to top-down cracking under certain combinations of loadings, environmental conditions, and pavement structures.
- **Special Considerations:** Localized distressed areas should be repaired prior to the placement of the overlay. If milling is not used in conjunction with the thin HMA overlay, special consideration should be given to bump grinding prior to treatment placement.

- **Performance Period:** 10 to 15 years depending upon thickness.
- **Relative Cost (\$ to \$\$\$\$):** \$\$\$



**Step 1.** Pre-overlay repair & surface preparation. Localized areas of distress are repaired prior to overlay placement and milling may be used.



**Step 2.** Tack coat. A tack coat is used to promote bonding between the overlay and the existing pavement.



**Step 3.** AC Overlay. Material is placed with conventional equipment.



**Step 4.** Compaction. Steel-wheeled rollers are used to compact the overlay.

**Figure 17. Thin HMA Overlay General Construction Steps.**

## 16. Ultra-Thin Bonded Wearing Course

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An ultra-thin bonded wearing course (UTBWC) is a gap-graded thin hot mix asphalt surface course placed with a special spray paver. It effectively addresses minor surface distresses and increases surface friction. (See Figure 18.) Although this treatment has not been used in South Dakota, at least not at the time of the guidelines' publication, it has been used by the Minnesota DOT (MNDOT 2019) and several other state highway agencies including the California, Missouri and North Carolina DOTs (refer to <https://dot.ca.gov/-/media/dot-media/programs/maintenance/documents/fpntagchapter11-bondedwearingcourse-a11y.pdf>, [https://epg.modot.org/index.php/413.3 Ultrathin Bonded Asphalt Wearing Surface](https://epg.modot.org/index.php/413.3%20Ultrathin%20Bonded%20Asphalt%20Wearing%20Surface), and <https://connect.ncdot.gov/projects/construction/ConstManRefDocs/661,%202012%20Standard%20Specifications.pdf>, respectively).

- **Treatment Description:** An UTBWC is formed in one pass with the application of a heavy, polymer-modified asphalt emulsion tack coat and a gap-graded, polymer-modified 0.4-in. to 0.8-in. (10-mm to 20-mm) HMA layer. It is placed using a spray paver.
- **Pavement Conditions Addressed:** This treatment is appropriate for low-severity cracking (high-severity can be addressed with cold milling), raveling/weathering (remove loose material), high-severity friction loss, low-severity roughness, and low-severity flushing/bleeding. It provides some increased capacity and retards fatigue cracking, but is not suited for rutted pavements.
- **Construction Considerations:** This treatment requires special paving equipment to place the mix. Repair localized structural problems prior to overlay application. UTBWC courses are not recommended where structural failures exist (e.g., significant fatigue cracking, deep rutting) or if there is high-severity thermal cracking. An UTBWC is not recommended when there is extensive pavement deterioration or little remaining life. UTBWC is capable of withstanding high ADT volumes and truck traffic.
- UTBWC is usually placed on top of a new mill and overlay or a micro milled surface. Occasionally, it is placed directly on existing asphalt or concrete surface if the overall ride of the existing pavement is in good condition.
- **Performance Period:** 7 to 12 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$\$



**Step 1.** Prepare surface. This can be with a mill, a micro mill, or just a cleaning. Surface must be clean.



**Step 2.** Place the UTBWC using a spray paver and a shuttle buggy.



**Step 3.** Compact the UTBWC using rollers.

**Figure 18. UTBWC General Construction Steps.**

## 17. Cold In-Place Recycling (CIR)

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CIR is an effective treatment at correcting or inhibiting non-load cracking and other distresses in the surface layer; however, this treatment may not be eligible for FHWA funding. The treatment consists of milling 3–4 inches of the existing asphalt surface layer, remixing it with an engineering emulsion or foamed asphalt, and repaving in place. Depending on the traffic levels the treatment may require a surface treatment or a thin overlay (see Figure 19). The best reference on this process is the Basic Asphalt Recycling Manual. (Asphalt Recycling and Reclaiming Association [ARRA] 2015).

- **Treatment Description:** CIR consists of a mixture of recycled asphalt concrete and engineered emulsion or foamed asphalt that is mixed in place in a paving train and placed using a conventional paving machine. The mixture is compacted and a surface treatment (for residential streets) and/or asphalt overlay for (collectors or arterial roads) is placed on top, due in part to the higher air voids in the CIR.
- **Pavement Conditions Addressed:** The treatment adds some structural capacity and will address most types of cracking and aged, dry, or raveled pavement surfaces. It can also improve rideability. It will not correct base problems or poor drainage. It can also be a problem if there is a fabric or geo-textile in the roadway.
- **Anticipated Limitations:** CIR is not recommended where the existing asphalt layer is less than 4 inches.
- **Construction Considerations:** This treatment requires special recycling and mixing equipment to grind up the existing pavement, mix it with an emulsion or foamed asphalt, and repave it in place. The most common units used to do this are single-unit or multi-unit trains. The CIR mat remains tender for 3–4 days of curing when using engineered emulsions or foamed asphalt. It will require some sort of surface treatment depending on traffic level to prevent damage to the existing surface. The cost savings reported for this treatment is 20–40% compared with conventional construction. Section 370 of the SDDOT 2015 Standard Specifications provides additional information, while the FHWA checklist for CIR can be found at:  
<https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19035.pdf>
- **Traffic Considerations:** This treatment has been used on low- and high-volume roads. When used on low-volume roads, a surface treatment can be used to protect the CIR from scuffing. When used on higher-volume roads, the CIR is usually covered with an asphalt concrete layer.
- **Special Considerations:** The designer should consult with other state agencies that have used this product. Both engineered emulsions and foamed asphalt have been used in the CIR process.
- **Performance Period:** 8 to 12 years or more.
- **Relative Costs (\$-\$\$\$\$):** \$\$\$



**Step 1. Edge milling.**



**Step 2. Milling machine.**



**Step 3. Paving machine.**



**Step 4. Finish mat before rolling.**



**Step 5. Rolling.**



**Step 6. Finish mat after flush coat.**

**Figure 19. CIR General Construction Steps.**

## RIGID PAVEMENT TREATMENT SUMMARIES

For each of the rigid pavement treatments listed in Table 4 (on page 15), the following items are included:

- Treatment description
- Pavement conditions addressed
- Application limitation
- Construction considerations
- Traffic considerations
- Special considerations
- Performance period

Also, where available performance standards are identified for the treatment, they refer to the maintenance performance standards in the SDDOT Maintenance Manual. Performance standards exist for only a subset of the treatments in the guide.

Some of the treatments also have specifications/construction requirements included in the standard specifications such as weather and equipment requirements. These can be found in the SDDOT standard specifications at the following link: (SDDOT 2015) <https://dot.sd.gov/doing-business/contractors/standard-specifications>.

Other sources of information for concrete preservation treatments include the 2019 FHWA checklist <https://www.fhwa.dot.gov/pavement/preservation/ppcl100.cfm>, the report from the National Center on Concrete Technology at Iowa State (2014): <https://www.fhwa.dot.gov/pavement/concrete/pubs/hif14004.pdf>, and the best practices document developed for Missouri DOT. (Darter 2019)

In this document, relative costs for each treatment are shown with \$ symbols. The least expensive treatments are shown as \$ while the most expensive treatments are shown as \$\$\$\$.

However, as indicated earlier, actual costs should be used in the attached cost benefit model.

## 1. Crack Sealing – Performance Standard 2129

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Crack sealing is effective at reducing or delaying moisture damage, crack deterioration, and associated roughness. However, roughness can also be increased as a result of the sealing process itself, particularly if placed in an over band configuration. (See Figure 20.)

- **Treatment Description:** Crack sealing is an operation involving thorough crack preparation and placement of high-quality materials into or over candidate cracks to significantly reduce moisture infiltration and to retard the rate of crack deterioration. Cracks in PCC pavement that are sealed have slower deterioration rates than unsealed cracks and slow the overall deterioration rate of the pavement. PCC cracks are typically sealed with hot-poured sealant materials or silicone depending on the field conditions. The Concrete Engineer should be consulted prior to sealing cracks to ensure the proper material is used.
- **Pavement Conditions Addressed:** Crack sealing is effective at sealing low- or medium-severity transverse or longitudinal cracks where the crack width is  $\leq \frac{1}{2}$ " to  $\frac{3}{4}$ ". Joints that are wider than  $\frac{3}{4}$ " should be considered for other treatment. Full-depth working transverse cracks typically experience the same range of movement as transverse joints; therefore, it is recommended that these cracks be sealed to reduce water and incompressible infiltration.
- **Application Limitations:** Crack sealing is most effective when performed on PCC pavements that exhibit minimal structural deterioration and in which the cracks are not showing other significant distress such as faulting or spalling. Specific distresses such as corner cracking should be repaired with other treatment.

Small or hairline cracks may not be a working crack, in which case routing and sealing should not be done.

- **Construction Considerations:** Sealant performance is dependent on many construction factors, including material type and placement geometry, and application in a clean and dry substrate. A specialized saw used for routing concrete should be used to prepare the crack, and the use of blotting material such as toilet paper should be used to prevent pulling by traffic.

The FHWA checklist for joint and crack sealing can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19045.pdf>.

- **Traffic Considerations:** Performance is not significantly affected by varying average daily traffic (ADT) or truck levels, but sealant should be allowed to cure before opening to traffic. However, improper installation can permit the sealant to fail.
- **Special Considerations:** Crack sealing may have negative effects. Undesirable visual impacts may occur, which include tracking of sealing material by tire action, obscuring lane markings, and adversely affecting skid resistance. Crack sealing may result in a rougher pavement surface when the sealant material is forced out of the cracks during warm months.

- **Performance Period:** 4 to 8 years.
- **Relative Cost (\$ to \$\$\$\$):** \$



**Step 1.** Crack routing. Small crack saws are used to reface cracks and create a reservoir for the sealant.



**Step 2.** Cleaning. Cracks must be clean and dry to enhance sealant bonding.



**Step 3.** Application of sealant. The last step is to place the sealant in the refaced crack per governing specifications.

**Figure 20. Crack Sealing General Construction Steps.**

## 2. Joint Resealing – Performance Standard 2129

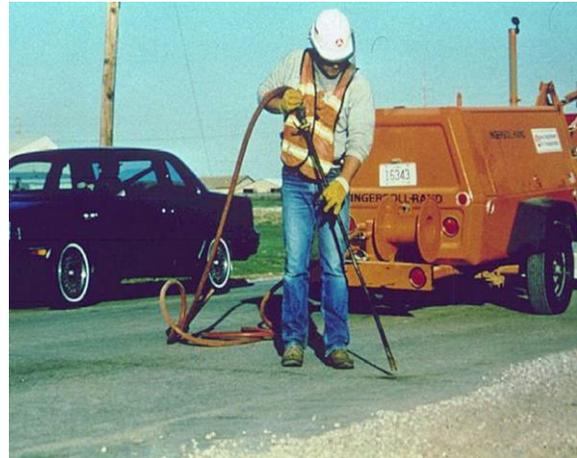
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Joint resealing is effective at keeping moisture out of the pavement layers and incompressible materials out of joints, which reduces faulting, pumping, and spalling. (See Figure 21.)

- **Treatment Description:** Resealing transverse joints in PCC pavements is intended to minimize the infiltration of surface water into the underlying pavement structure and to prevent the intrusion of incompressible materials into the joint. A range of materials from bituminous to silicone are used in various configurations. Typical application is done 10 to 20 years after the initial silicone sealant was placed and 4 to 15 years after placement for hot-poured asphalt sealant.
- **Pavement Conditions Addressed:** Joint resealing is effective at keeping moisture out of the pavement layers, and incompressible materials out of joints, which can result in less faulting, pumping, and spalling.
- **Application Limitations:** Joint resealing is most effective when performed on PCC pavements that exhibit minimal structural deterioration. Material selection should be based on the expected time until next treatment.
- **Construction Considerations:** Sealant performance is dependent on many construction factors, including material type and placement geometry, and application in a clean and dry substrate. Section 390 of 2015 SDDOT Standard Specifications includes some additional information on joint resealing, while the FHWA checklist for joint and crack sealing can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19045.pdf>.
- **Traffic Considerations:** Performance is not affected by different ADT or percent trucks. Silicone sealants which are not properly recessed are more likely to fail in the wheel path.
- **Special Considerations:** Joint resealing is necessary when the existing sealant has deteriorated to the point that it readily allows water and incompressible materials to enter the joint. The primary cause of sealant failure is improper installation (e.g., not preparing joint sidewalls and getting bonding).
- **Performance Period:** 4 to 15 years for hot-poured asphalt sealant; 10 to 20 years for silicone sealant.
- **Relative Cost (\$ to \$\$\$\$):** \$



**Steps 1 & 2.** Sealant removal & joint refacing. This photo shows the removal of existing sealant. Joints are refaced to create a uniform reservoir for the sealant.



**Step 3.** Cleaning. Joints must be clean and dry to enhance sealant bonding.



**Step 4.** Backer rod installation. Backer rod can be used to control the depth of the sealant in the joint.



**Step 5.** Application of sealant. The last step is to place the sealant in the refaced joint per governing specifications.

**Figure 21. Joint Resealing General Construction Steps.**

### 3. Diamond Grinding

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Diamond grinding is effective at removing joint faulting and other surface irregularities to restore a smooth-riding surface and increase pavement surface friction. Warping and curling is one type of surface irregularity that diamond grinding is used to correct, and it has been used for this purpose on some recent SDDOT projects. There is no performance standard for this treatment. (See Figure 22.) In recent years, the American Concrete Pavement Association (ACPA) has been promoting the use of the next generation concrete surface to achieve quieter and smoother roads (Scofield 2016, Scofield 2020)

- **Treatment Description:** Diamond grinding is the removal of a thin layer of concrete (generally up to about ¼") from the surface of the pavement, using special equipment outfitted with a series of closely-spaced diamond saw blades.
- **Pavement Conditions Addressed:** Diamond grinding is used to remove joint faulting and other surface irregularities to restore a smooth riding surface and increase pavement surface friction.
- **Application Limitations:** If significant faulting is present, or other signs of structural failure (such as mid-panel cracks or corner breaks), diamond grinding is not appropriate. The presence of materials-related distresses may also preclude the use of diamond grinding. Soft aggregate will wear much quicker and require more frequent grinding.
- **Construction Considerations:** Typically constructed with a moving lane closure with traffic operating in the adjacent lanes. Diamond grinding should be used in conjunction with all restoration techniques, including load-transfer restoration, full- and partial-depth repair, cross stitching, under sealing, and pavement jacking. Resealing of the joints may be necessary. The FHWA checklist for diamond grinding can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19046.pdf>.
- **Traffic Considerations:** Grinding may be used to remove faulting, which, if the mechanism is not addressed, can reoccur due to the continued application of truck traffic. If used to restore friction to a polished pavement (due to vehicle traffic), heavy volumes of traffic may cause the problem to reoccur.
- **Special Considerations:** Note that diamond grinding is a surface repair method because it corrects the existing faulting and other surface irregularities of PCC pavements. It does nothing to correct pavement distress mechanisms. Therefore, grinding usually is performed in combination with other rehabilitation methods to both repair certain pavement distresses and prevent their recurrence.

When diamond grinding is used to correct curling, the grinding should not be performed between the dates of June 10th to September 5<sup>th</sup>, as this is during the historical warmest temperatures. Diamond grinding should only be performed between the hours of 12:00 a.m. (midnight) to 10:00 a.m. to grind the pavement when the slabs are curled the most. If the shoulder is concrete, the outside 2-feet of shoulder may be ground outside of the midnight to 10:00 a.m. timeline.

- **Performance Period:** 8 to 15 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$\*

\*Cost on concrete with quartzite is significantly higher.



**Step 1.** Multiple passes of the grinding equipment are used to remove material from the pavement surface.



**Step 2.** Diamond grinding depth. Generally, roughly  $\frac{1}{4}$  inch of the surface is removed in a single pass.

**Figure 22. General Diamond Grinding Construction Steps.**

#### 4. Diamond Grooving

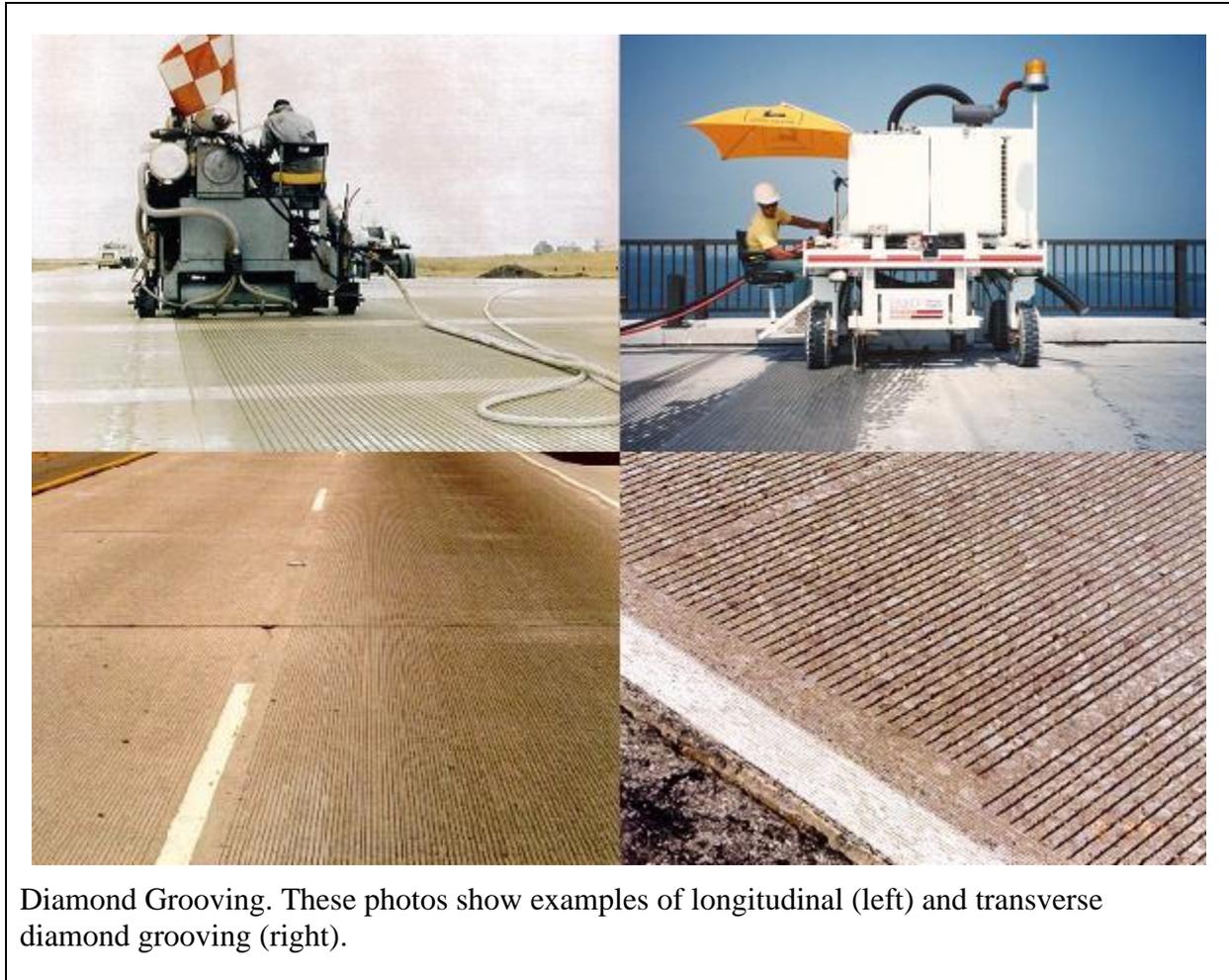
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Diamond grooving is effective at increasing wet-pavement friction and reducing splash and spray in identified problem areas. No performance standard is available for this treatment. (See Figure 23.)

- **Treatment Description:** Diamond grooving is the process of cutting narrow, discrete grooves in the PCC surface to reduce hydroplaning and wet-pavement crashes in localized areas. Grooving can be performed in both the longitudinal and transverse directions but is more commonly performed longitudinally.
- **Pavement Conditions Addressed:** Grooving is conducted to increase wet-pavement friction and reduce splash and spray. Diamond grooving is a local rather than systemic treatment performed in areas with histories of wet-pavement crashes (e.g., curves and intersections).
- **Application Limitations:** In general, candidate pavements for grooving should be structurally and functionally sound. The presence of materials-related distresses may also preclude the use of diamond grooving.
- **Construction Considerations:** Areas to be grooved should be clearly indicated on project plans. The grooves should be cut in accordance with the plan notes, which specify ¾-inch spacing. The width will vary depending on aggregate type in pavement. The entire lane area should be grooved; however, allowance should be made for small areas that were not grooved because of pavement surface irregularities. Longitudinal grooving is most common due to ease of construction. There is no FHWA checklist for this treatment.

Resealing of joints will be required after pavement is grooved.

- **Traffic Considerations:** Performance is not affected by varying ADT or truck levels.
- **Performance Period:** Information on performance is not readily available; however, life is expected to be 8 to 15 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$



**Figure 23. Diamond Grooving General Construction Steps.**

## 5. Partial-Depth Repairs

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Partial-depth repairs are primarily used to correct Type A Spalls. They can also be used to correct localized areas of distress that are limited to the upper 1/3 of the slab thickness. There is no performance standard for this treatment. (See Figure 24.)

- **Treatment Description:** Partial-depth repairs are defined as the removal of small, shallow areas of deteriorated PCC that are then replaced with a suitable repair material. These repairs restore structural integrity and improve ride quality, thereby extending the service life of pavements that have spalled or distressed joints.
- **Pavement Conditions Addressed:** Partial-depth repairs are primarily used to correct joint spalling caused by 1) the intrusion of incompressible materials into the joints, 2) localized areas of scaling, weak concrete, clay balls, or high steel, and 3) the use of joint inserts.
- **Application Limitations:** This treatment is not applicable for pavements with cracking and joint spalling caused by compressive stress buildup in long-jointed pavements; spalling caused by dowel bar misalignment or lockup; cracking caused by improper joint construction techniques (late sawing, inadequate saw cut depth, or inadequate insert placement depth); working cracks caused by shrinkage, fatigue, or foundation movement; and spalls caused by D-cracking or reactive aggregate.

Consideration of partial depth repairs in continuously reinforce concrete (CRC) pavements should be reviewed with the Materials and Surfacing Office.

- **Construction Considerations:** During construction, it is very important to properly determine repair boundaries, prepare the patch area, and finish, texture, and cure the new material per governing specifications. If distress is found to extend below the upper 1/3 of the slab, or if steel is exposed, a full-depth repair is required. The FHWA checklist for this treatment can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19048.pdf>.
- **Traffic Considerations:** Partial-depth repairs perform under all traffic conditions. High early strength concretes are used in cases in which early opening to traffic is required or when it is desirable to minimize the closure period.
- **Special Considerations:** Partial-depth patches should be a minimum of 4" by 4".
- **Performance Period:** 5 to 15 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$\$



**Step 1.** Repair boundary marking. Determine extent of unsound material, and mark repair boundaries.



**Step 2.** Concrete removal. Sawing the boundaries and removing deteriorated PCC.



**Step 3.** Repair area preparation. The repair area should be sandblasted and cleaned to promote good bonding.



**Step 4.** Joint preparation. It is important to maintain the existing joint reservoir during construction.



**Steps 5 & 6.** Bonding agent & material placement. Follow manufacturer's recommendations when placing material.



**Steps 7 & 8.** Curing & joint sealing. The final steps include texturing and providing adequate curing.

**Figure 24. Partial-Depth Repair General Construction Steps.**

## 6. Dowel Bar Retrofit (DBR)

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DBR is effective at restoring load transfer at joints and/or transverse cracks on pavements that have significant remaining structural life. This treatment is not widely used anymore, except by local agencies. There is no performance standard for this treatment. (See Figure 25.)

- **Treatment Description:** Dowel Bar Retrofit (DBR) is the placement of load transfer devices across joints or cracks in an existing jointed PCC pavement to restore load transfer at these locations. Poor load transfer can lead to pumping, joint faulting, and corner breaks.
- **Pavement Conditions Addressed:** Most effective on jointed concrete pavements that have poor load transfer at joints and/or transverse cracks but also have significant remaining structural life. The optimum time to apply this technique is when the pavement is just beginning to show signs of structural distress, such as pumping and the onset of faulting.
- **Application Limitations:** DBR is not appropriate when the pavement contains significant faulting, or other signs of structural failure (such as pumping or corner breaks). Pavements with little remaining life or materials-related distresses are also not good candidates.
- **Construction Considerations:** There are different dowel bar retrofit patterns, but three per wheel path is typical. Careful consideration must be given in the selection of the patch material and isolation of the joint. This treatment is often performed in conjunction with diamond grinding. The FHWA checklist for this treatment can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19047.pdf>.
- **Traffic Considerations:** The higher the ADT and percent trucks, the greater the potential need for DBR. Low-volume jointed concrete pavements that are not doweled may not need DBR.
- **Performance Period:** A minimum expected life is typically 15 to 20 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$\$



**Step 1 & 2.** Slot creation and material removal. Slots are cut and concrete material is removed.



**Step 3 & 4.** Sandblasting and cleaning. Slots are sandblasted and cleaned in preparation for dowel bars.



**Step 5.** Caulking the joint/crack. The joint/crack edges are caulked to stop the flow of material from the slot.



**Step 6.** Dowel bar placement. Dowels are placed parallel to the direction of traffic and at mid-slab.



**Step 7.** Repair material placement. Material should be placed per governing specifications.



**Steps 8 & 9.** Diamond grinding & joint sealing. Final steps often consist of diamond grinding and joint sealing.

**Figure 25. Load Transfer Restoration General Construction Steps.**

## 7. Full-Depth Repairs

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Full-depth repairs are effective at correcting slab distress that extend beyond one-third the pavement depth such as longitudinal and transverse cracking, corner breaks, and joint spalling. There is no performance standard for this treatment. (See Figure 26.)

- **Treatment Description:** Full-depth repairs are cast-in-place concrete repairs that extend through the full thickness of the existing PCC slab. The technique involves the full-depth removal and replacement of full or half lane-width areas of an existing deteriorated PCC pavement. The minimum specified repair length is typically 6 feet; however, for jointed PCC pavements, in many cases it may be more cost effective and reliable to replace an entire slab. In CRC pavements the size will vary depending on the distress or failure.
- **Pavement Conditions Addressed:** Full-depth repairs are used to repair localized distresses and to prepare distressed PCC pavements for a structural overlay to avoid premature failure of the overlay.
- **Application Limitations:** Full-depth repairs are not cost-effective if deterioration is widespread within a project. If the existing pavement is structurally deficient, or is nearing the end of its fatigue life, a structural enhancement (such as an overlay) is needed to prevent continued cracking of the original pavement.
- **Construction Considerations:** During construction, it is very important to properly prepare the base, restore joint load-transfer, and finish, texture, and cure the new material per governing specifications. Continuously Reinforced Concrete Pavement repairs will require details from the Materials & Surfacing Office. The FHWA checklist for this treatment can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19049.pdf>.
- **Traffic Considerations:** Because full-depth repairs have typically been completed using conventional PCC materials, curing time may be an issue in urban areas. High early strength concretes are used in cases where it is desirable to minimize the closure period.
- **Special Considerations:** It is not desirable to create a large number of closely spaced joints in a pavement—placing a large number of closely spaced patches should be avoided.
- **Performance Period:** 10 to 15 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$\$\$



**Step 1.** Concrete sawing. Repair boundaries are cut with full-depth, diamond-bladed sawing.



**Step 2.** Concrete removal. Removal of slab material is best accomplished using the lift-out method or by breakout.



**Step 3.** Repair area preparation. It is important that the repair area be dry and properly compacted.



**Step 4.** Load transfer provision. Proper restoration of load transfer should be considered.



**Step 5.** Material placement. Conventional PCC material is most common for full-depth repairs.



**Steps 6 & 7.** Texturing & Curing. The final steps include texturing and provide adequate curing.

**Figure 26. Full-Depth Repair General Construction Steps.**

## 8. Cross Stitching

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Cross stitching is effective at strengthening non-working longitudinal cracks. Preventing these crack movements helps prevent roughness and potential safety problems associated with such cracks. There is no performance standard for this treatment. (See Figure 27.)

- **Treatment Description:** Cross stitching is a longitudinal crack and joint repair technique that consists of grouting tie bars in holes drilled across non-working longitudinal cracks/joints at an angle to the pavement surface. Cross stitching prevents horizontal and vertical crack movements.
- **Pavement Conditions Addressed:** Cross stitching is effective at strengthening longitudinal cracks and preventing slab migration, mitigating the issue of tie bars being omitted from longitudinal contraction joints, tying roadway lanes or shoulders that are separating and causing a maintenance problem, and tying center lane joints that are starting to fault.
- **Application Limitations:** Cross stitching is not an appropriate treatment for slabs that have multiple cracks or are shattered into more than 4 to 5 pieces.

If joint separation is 5/8 inch or wider a filler material such as flowable fill, epoxy, or hot poured material should be used to fill the void.

- **Construction Considerations:** Holes should be drilled to intersect the slab/joint at mid-depth. Follow the SDDOT standard details. The FHWA checklist for this treatment can be found at <https://www.fhwa.dot.gov/pavement/preservation/2019checklists/hif19050.pdf>.
- **Traffic Considerations:** Performance is not significantly affected by varying ADT or truck levels.
- **Special Considerations:** The treatment is not recommended on transverse cracks.
- **Performance Period:** 15 to 30 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$\$



**Step 1.** Drilling of holes. Drill holes at a 35° to 45° angle to the surface so they intersect the crack/joint at mid-depth.



**Step 2.** Epoxy grout insertion. Clean holes with compressed air, and then insert epoxy to promote bonding.



**Step 3.** Bar insertion. Drive bars into holes containing epoxy.



**Step 4.** Final grouting. Remove excess material and finish surface of epoxy so that it is flush with the pavement surface.

**Figure 27. Cross Stitching General Construction Steps.**

## 9. Pavement Under-Sealing

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Under-sealing (often referred to as sub-sealing) fills voids under slabs, thereby reducing deflections and minimizing the development of pumping, corner breaks, faulting, and roughness associated with those distresses. There is no performance standard for this treatment. (See Figure 28.)

- **Treatment Description:** Under-sealing is the pressure insertion of a flowable material beneath a PCC slab to fill voids between the slab and base, thereby reducing deflections and, consequently, deflection-related distresses such as pumping or faulting. It is most often performed at areas where pumping and loss of support occur, such as beneath transverse joints and deteriorated cracks. This technique is generally used to fill voids less than 0.12 inches thick.
- **Pavement Conditions Addressed:** Under-sealing fills voids that, if left unfilled, will lead to pumping, faulting, and other structural deterioration. This treatment performs best if performed before faulting starts to develop.
- **Application Limitations:** Under-sealing is not appropriate on pavements with significant faulting, or other signs of structural failure (such as pumping, mid-panel cracking, or corner breaks). Such distresses suggest structural failures that require more costly rehabilitation. Additional strategies, such as dowel bar retrofitting, may be required for pavements without load transfer.
- **Construction Considerations:** Cement-fly ash grout is the most common undersealing material, although asphalt and polyurethane also have been used. Slab lift must be closely monitored to avoid damaging slabs. Overfilling voids can contribute to more severe problems than leaving them unfilled. There is no FHWA checklist for this treatment, but Section 391 of the 2015 SDDOT Standard Specifications contains more information on this treatment.
- **Traffic Considerations:** Performance is not known to be affected by different levels of ADT or percent trucks.
- **Special Considerations:** Pumping (indicated by the presence of holes, depressions, and/or ejected material) is almost certain evidence of voids. If areas do not exhibit physical evidence of voids but are suspect, a request for nondestructive testing assistance from the Transportation Inventory Office and Materials and Surfacing should be made. Pavement sections that contain voids often occur only on a portion of a project. Blanket under-sealing rarely is justified. If under-sealing is used on any portion of a project, bridge approaches within the project limits may also need to be under-sealed. The SDDOT Bridge Office should be contacted if work on bridge approaches is needed.
- **Performance Period:** Performance has been variable.
- **Relative Cost (\$ to \$\$\$\$):** \$\$



**Step 1.** Locating voids. Many methods are used to locate voids, including FWD testing (shown here).



**Step 2.** Drilling injection holes. Holes are drilled in a selected pattern at void locations. The drill should be connected to a compressor, but it is not in this photo.



**Step 3.** Injection of material. This photo shows an “expandable grout packer” used to inject cement grout material. Slab lift must be closely monitored during this process to avoid slab damage.



**Step 4.** Plugging holes. The next step is to plug each of the holes to keep grout material from flowing out through the holes. Then the plugs are removed after the grout is set. The holes are then filled with mortar, and the pavement is cleaned prior to opening the road to traffic.

**Figure 28. Under-Sealing General Construction Steps.**

## 10. Pavement Jacking/Mud Jacking – Performance Standard 2129

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Pavement/mud jacking is effective at filling voids beneath a pavement surface to raise the roadway surface and restore a smoother ride. (See Figure 29.)

- **Treatment Description:** Pavement jacking/mud jacking involves injection of a slurry grout mix to fill voids and restore the roadway surface or other facilities to an acceptable cross section and grade line.
- **Pavement Conditions Addressed:** Pavement settlement, dips in the roadway, or voids beneath a pavement or at bridge approaches.
- **Application Limitations:** Broken or highly cracked panels are not good candidates for this treatment.
- **Construction Considerations:** Pavement jacking should not be done when the ground is frozen. If pavement jacking is being done near or adjacent to bridge approaches, the bridge office should be contacted prior to completing the work. There is no FHWA checklist for treatment, but Section 392 of the 2015 Standard Specifications contains more information on this treatment..
- **Traffic Considerations:** Pavement jacking can be used with all traffic levels.
- **Special Considerations:** Pavement jacking can be used prior to other treatments such as cross stitching, dowel bar retrofit, or pavement grinding.
- **Performance Period:** 5 to 10 years.
- **Relative Cost (\$ to \$\$\$\$):** \$\$



**Step 1.** Drilling of injection holes.

- Cement grout mixtures
  - Mobile, self-contained grout plant for large projects
  - Small batch mixers for smaller projects
  - Cures in less than 3 hours
- Polyurethane materials
  - Truck and trailer with pumping equipment for mixing/injecting two-part material
  - Cures in less than 1 hour

**Step 2.** Prepare materials.



**Step 3.** Inject material beneath the slab.



**Step 4.** Plug injection hole.



**Step 5.** Monitor the amount of lift using traffic.



**Step 6.** Remove plugs and open lane to a water level meter or mechanical gauge.

**Figure 29. Pavement Jacking/Mud Jacking General Construction Steps.**

**DRAINAGE PRESERVATION PERFORMANCE STANDARD 2290**

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Improvement of subsurface drainage characteristics for pavement systems that show water-related damage or distresses can significantly increase the serviceability and life of the pavement. (See Figure 30.)

- **Treatment Description:** The improvement of subsurface drainage characteristics through the use of 1) ditch maintenance to prevent obstructed flow and provide proper cross section, 2) maintenance of existing drainage systems, including edge drains, or 3) the installation of localized drainage, specifically in low-lying areas. Additional information may be found in the SDDOT Maintenance Manual, Section 6 (Work Functions & Standards), Work Function 2290. Performance Standard 2290 has brief sections titled “Maintaining Drainage and Erosion Control Structures” and “Roadside Ditch Cleaning, Reshaping, and Erosion Repair.”
- **Pavement Conditions Addressed:** Stripping and structural distresses (such as fatigue cracking and rutting) related to loss of support under the bound layers.
- **Application Limitations:** Use of drainage preservation will not restore structurally inadequate pavements or repair existing distresses but should reduce worsening or appearance of new distresses. The installation of new drainage is only helpful if the existing pavement has a horizontally drainable layer. If not, only the water between the shoulder and the pavement will be removed, instead of removing the water between the base and the bound layers.
- **Construction Considerations:** Under drain installation should occur prior to patching, unless there is a valid reason to do otherwise.
- **Traffic Considerations:** Since the use of drainage preservation will improve the base and subgrade engineering properties, the treatment might help improve the load-carrying capacity of the pavement.
- **Special Considerations:** Drainage preservation is a very worthwhile preservation activity. However, the conduct of ditch maintenance is often considered routine maintenance instead of preventive maintenance.
- **Performance Period:** Varies.
- **Relative Cost (\$ to \$\$\$\$):** Varies.



(a) Ditch with obstructed flow.



(b) Cleaning drainage ditch.



(c) Culvert checks and cleaning.

**Figure 30. Drainage Preservation.**

## **BLADING AND GRAVELING OF ROADWAYS AND SHOULDERS**

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Blading and graveling of mainline roadways and shoulders are effective at reshaping or replacing granular material lost on the surface of either a roadway or shoulder. The FHWA 2015 report (<https://www.fhwa.dot.gov/construction/pubs/ots15002.pdf>) is the latest guide for gravel roads. (See Figure 31).

- **Treatment Description:** Graveling of mainline or shoulders involves shaping of the surface and a periodic addition of granular material to provide a smooth driving surface or shoulder that has a proper crown slope and is free of ruts and distortions. It will also include periodic dust abatement using approved dust palliatives such as magnesium chloride. Blading and graveling are also regularly done in South Dakota on gravel shoulders outside an AC or PCC mainline. There is a SDDOT performance standard for the maintenance of gravel shoulders – Function 2158 in the Maintenance Performance Standards.
- **Pavement Conditions Addressed:** Gravel roads and shoulders require much more frequent maintenance than paved surfaces, especially after wet periods and when accommodating increased traffic. The following deficiencies can be corrected:
  - **Rutting and Shoving of the Material:** Wheel motion of the traffic will shove material to the outside (as well as in between traveled lanes), leading to rutting, reduced water-runoff, and eventual road destruction if unchecked. Done early enough, simple blading is sufficient, with material being shaped to correct the deficiencies.
  - **Washboarding:** This is the formation of corrugations across the surface at right angles to the direction of travel. They can become severe enough to cause vibration in vehicles so that bolts loosen or cracks form in components. Blading performed under the correct moisture conditions will aid in removing the corrugations and the addition of a good quality gravel can help prevent them re-forming.
  - **Lane/Shoulder Drop-Offs:** The drop-off at the interface of the AC or PCC mainline pavement and shoulder should not exceed 1.5 inches to allow for a safe transition. The SDDOT performance standard referenced earlier specifies that any shoulder mile having a drop-off greater than 1.5 inches along 50% or more of its length needs to be repaired.
  - **Cross Slope:** The amount of crown in the roadway or shoulder should be maintained at a rate between 0.03 foot per foot to 0.05 foot per foot. This amount of crown will allow for adequate drainage of surface water without washing off surface materials.
  - **Loss of Fines:** When a gravel surfaced roadway or shoulder has dust blowing from the surface, the dust is fines and therefore the binder of the material is lost and causes the road to deteriorate. Typically, a roadway with average

traffic loses about one inch of material per year so periodic replacement with good quality material is a necessity.

- **Application Limitations:** This treatment is not recommended for structurally deficient pavements.
- **Construction Considerations:** Blading and reshaping of a roadway or shoulder should take place in moist weather conditions if possible. When blading, material should be pulled from the in-slope area back up onto the roadway or shoulder surface and smoothed, watered, and compacted to the proper grade and crown slope. The grader should be operated at a top speed of between 3 to 5 miles per hour. The grader moldboard should be operated at the correct angle and pitch to adequately move and mix the material.
- **Traffic Considerations:** Gravel roadways should generally be limited to lower volume traffic conditions with a low percentage of trucks.
- **Special Considerations:** Gravel surfaces produce dust. Stabilization with a dust palliative (to minimize the amount of airborne dust) should be considered.
- **Performance Period:** 4 to 6 years.
- **Relative Cost (\$ to \$\$\$\$):** \$

Note: In addition to blading and gravelling, an Otta seal may also be considered when upgrading an aggregate surfaced road. An Otta seal is an asphalt surface treatment constructed by placing a graded aggregate on top of a thick application of relatively soft bituminous binding agent. Minnesota DOT has used emulsified asphalt exclusively (HFMS-2s), but it could be constructed with cutback asphalt if desired. The binder works its way into the aggregate with rolling and traffic. Material and construction specifications are not as strict as for other surface treatments. Local aggregates that would not meet the requirements for high quality paving aggregate are often used in Otta seals. It can be used for traffic ranges from Very Low to High (AADT < 2000). Good references for these treatments can be found at:

- [https://www.dot.state.mn.us/materials/bituminousdocs/Pavement%20Maintenance/OttaSeal\\_4-pagerMRR\\_2008.pdf](https://www.dot.state.mn.us/materials/bituminousdocs/Pavement%20Maintenance/OttaSeal_4-pagerMRR_2008.pdf)
- [https://intrans.iastate.edu/app/uploads/2018/07/Otta\\_seals\\_for\\_low-vol\\_rds\\_w\\_cvr.pdf](https://intrans.iastate.edu/app/uploads/2018/07/Otta_seals_for_low-vol_rds_w_cvr.pdf)



(a) Placing Gravel Surfacing



(b) Washboard Surface



(c) Moldboard Angle and Pitch



(d) Moldboard Angle and Pitch

**Figure 31. Preservation of Gravel Roads.**

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**APPENDIX A. GUIDANCE ON FEDERAL-AID FUNDING ELIGIBILITY FOR  
HIGHWAY PRESERVATION AND MAINTENANCE – FEBRUARY 26, 2019**



## Guidance on Federal-aid Funding Eligibility for Highway Preservation and Maintenance

February 26, 2019

**PURPOSE:** Provide clarification to existing rules, regulations, and policies in determining Federal-aid eligibility for highway preservation and maintenance projects in South Dakota.

Preservation consists of work that is planned and performed to improve or sustain the condition of the transportation facility in a state of good repair. Preservation activities generally do not add capacity or structural value, but do restore the overall condition of the transportation facility. Preservation is now included in the definition for construction in 23 U.S.C. 101 and thus eligible and encouraged under the National Highway Performance Program (NHPP) and the Surface Transportation Block Grant Program (STBG).

Maintenance describes work that is performed to maintain the condition of the transportation system or to respond to specific conditions or events that restore the highway system to a functional state of operation. Maintenance is a critical component to the SDDOT asset management plan and is comprised of both routine and preventive maintenance. Routine maintenance encompasses work that is performed in reaction to an event, season, or overall deterioration of the transportation asset. This work requires regular reoccurring attention. Routine maintenance is not eligible for federal-aid funding. Preventive maintenance is a proactive approach and encompasses work that has proven to be a cost-effective means of extending the useful life of highways, bridges, and essential highway appurtenances. Preventive maintenance is eligible for federal-aid funding if the work is on a "Federal-aid highway." (23 U.S.C. § 116 (e)). A Federal-aid highway is defined as "a public highway eligible for assistance under this chapter other than a highway functionally classified as a local road or rural minor collector." (23 U.S.C. § 101 (a)(6)).

The key to making eligibility determinations is early communication with the FHWA Division Office. The Project Development Office will be responsible for contacting FHWA regarding any projects where eligibility may be in question.

### I. Preservation and Maintenance for Pavements

#### A. Eligible Activities

##### Asphalt Concrete Pavement

1. Route and/or Seal Cracks
2. Crack-Leveling
3. Rut Filling
4. Chip Seals
5. Thin Asphalt Concrete Resurfacing

6. Micro-Surfacing
7. Macro-Surfacing
8. Slurry Seal

Portland Cement Concrete Pavement

9. Joint/spall repair, Partial and Full-Depth Repairs
10. Cross Stitching
11. Dowel Bar Retrofit
12. Re-sealing Joints and/or Random Cracks
13. Undersealing and/or Pavement Jacking
14. Diamond Grinding

Miscellaneous

15. Pavement Drainage System
16. Prime and Seal Gravel Surfacing

**B. Non-Eligible Activities**

1. Pothole repair or patching (temporary repair with cold or hot mix)
2. Isolated concrete/asphalt patching (fixing isolated damaged areas or repairs, smoothing out a bump(s) for ride)
3. Joint replacement at isolated locations
4. Full width and depth slab replacement at isolated locations
5. Isolated asphalt overlays on PCCP defined as lengths less than 500 feet as per SDDOT Pavement Management System
6. Blading gravel surfacing
7. Stockpiling of gravel surfacing material
8. Isolated gravel surfacing placement
9. Blading shoulders to provide proper surface drainage

**II. Preservation and Maintenance for Bridges**

**A. Eligible Activities**

Approach Roadway and Approach Slab

1. Approach Roadway Grade Profile Correction to Minimize Impact Loading
2. Approach Slab Repair and/or Replacement

Deck

3. Bridge Deck Seal Coat
4. Bridge Deck Polymer Chip Seal
5. Bridge Deck High Friction Surface Treatment
6. Deck/Slab Repair
7. Deck Overlay
8. Bridge Joint Repair/Replacement
9. Eliminate Deck Joints
10. Bridge Deck Edge Beam Replacement

11. Bridge Railing Upgrade/Repair
12. Electrochemical Chloride Extraction Treatment
13. Drainage System Cleaning/Repair

Superstructure

14. Structural Steel Repair/Heat Straightening
15. Spot and Zone Painting/Coating
16. Painting/Coating or Overcoating of Structural Steel
17. Retrofit of Fracture Critical Members
18. Retrofit of Fatigue Prone Details

Substructure

19. Pier/Abutment Footing, Wall, Column, Cap Repair/Replacement
20. Foundation Stabilization
21. Bearing Reset/Repair/Replacement
22. Piling Repair
23. Semi-Integral/Integral Abutment Conversion
24. Installation of Scour Countermeasures
25. Scour Repair
26. Channel Debris Removal to Prevent Scour
27. Electrochemical Chloride Extraction Treatment

Deck, Superstructure and Substructure

28. Crack Sealing
29. Concrete Repair/Replacement
30. Concrete Sealants, Coatings and Membranes
31. Collision Damage Repair
32. Structure Widening for Safety
33. Bridge Cleaning and/or Washing Services
34. Cathodic Protection Systems

Bridge Length Culverts

35. Culvert Invert Repair
36. Culvert Joint Repair
37. Culvert Lining Installation/Repair
38. Culvert Extension
39. Remove and Reset RCP (reset sections must be tied)
40. Installation of Scour Counter Measures
41. Scour Repair
42. Channel Debris Removal to Prevent Scour

Other

43. Slope Protection Installation/Repair
44. Retaining Wall Installation/Repair
45. Mechanically Stabilized Earth Wall Repair
46. Tunnel Repair

**B. Non-Eligible Activities**

1. Deck Patching (temporary).
2. Temporary Structural Repair

**III. Preservation and Maintenance for Other Highway Features**

**A. Eligible Activities**

1. Installation or Upgrading of Substandard Guardrail or End-Treatments
2. Culvert Lining Installation/Repair
3. Remove and Reset RCP (reset sections must be tied)
4. Installation/Replacement of Traffic Signs and Delineators
5. Removal/Shielding of Roadside Obstacles.
6. Mitigation of Edge Drop-Offs
7. Addition of Paved or Stabilization of Unpaved Shoulders
8. Installation of rumble strips
9. Installation/Upgrade Lighting to Current Standards
10. Original Installation of Pavement Marking
11. Region Wide Installation and/or Repair of Durable Pavement Marking
12. Slope Flattening of In-slopes and/or Approaches
13. Installation and/or Replacement of Continuous Segments of Interstate Fence
14. Interstate Rest Areas/Port of Entries
  - a. Construct/Reconstruct Parking Lots
  - b. Chip Sealing/Sealing of Parking Lots
  - c. Joint Repair of Parking Lots
  - d. Installation/Upgrade of Luminaries to Current Standards
  - e. Installation/Replace shelters
  - f. Construct Waste Treatment Pond
  - g. Installation/Upgrade Security Systems to Current Standards
  - h. Replacement of Plumbing/Heating/Cooling/Electrical (etc.)  
Systems Requires prior FHWA Approval

**B. Non-Eligible Activities**

1. Pipe Cleanout
2. Maintenance of Pavement Markings (i.e. repainting of water-borne based pavement markings)
3. Isolated Repair of Durable Pavement Markings
4. Routine Maintenance on Signal/Lighting Fixtures (i.e. changing light bulbs, lens, lens seals, lubricating cable lowering system)
5. Purchase and Installation of Traffic Signs by State or Local Forces
6. Routine Repair of Interstate Fence to Fix a Broken Wire or Reattach to Posts

7. Replacement of Isolated Posts to Maintain Control of Access on Interstate Fence
8. Any Fencing on Non-Interstate Facilities
9. Repair Plumbing, Electrical, Heating, Cooling, or any Structural Element of the Interstate Rest Area Facility
10. Cleaning of Interstate Rest Area Waste Treatment Pond
11. Mowing of Interstate Rest Area

**Reference:**

*Guidance on Highway Preservation and Maintenance (FHWA Memo 2/25/2016)*

<https://www.fhwa.dot.gov/preservation/memos/160225.cfm>

**Additional information:** For additional information on Federal-Aid highway programs and projects, please visit the following:

*A Guide to Federal-Aid Programs and Projects:*

<http://www.fhwa.dot.gov/federalaid/projects.cfm>

*Eligibility of Replacement Parts for Safety-related Hardware (FHWA Memo 6/10/2008):*

<https://www.fhwa.dot.gov/federalaid/080610.cfm>

*Additional Guidance on 23 CFR 650A (Formerly Non-Regulatory Supplement - Storm Drainage Responsibility)*

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**APPENDIX C. COST BENEFIT ANALYSIS AND TOOL DETAILS – OCTOBER 2020**



### COST BENEFIT ANALYSIS AND TOOL DETAILS

Cost-benefit analysis (CBA) is an important tool for engineers when deciding whether to apply a preservation treatment or determining which preservation treatment to select, among many other uses. In simple terms, CBA is a method for comparing costs and benefits and should not be used as the sole factor in decisions, but instead as an important piece of information that engineers include in an overall decision process. This appendix describes the CBA approach recommended in these guidelines for flexible pavements, details how this is implemented in a Microsoft Excel® based tool and provides additional resources to supplement the steps in CBA. The matrices in these guidelines should be referenced for rigid pavements.

One important note is that the approach recommended in this guide is one of many approaches for CBA. For example, it is very common to monetize benefits by assigning specific dollar values to then compare with costs. Fundamentally, the variations in CBA approaches depend on three factors: how costs are quantified; how benefits are quantified; and how costs and benefits are compared. The recommendations in this guide are that costs are defined as fully loaded (i.e., including material, construction, and other costs), the benefits are defined using service life extension, and the costs and benefits are combined using Equivalent Uniform Annual Cost (EUAC). The next sections provide details of the recommended CBA approach.

#### Step 1: Evaluate/Input Pavement Distress and Severity Combination

Pavement distresses refer to load or non-load related defects in the pavement that show up at the pavement surface. Examples of load related distresses include fatigue cracking (often referred to as alligator cracking) and rutting, among others. Examples of non-load related distresses include transverse cracks and block cracking.

Differentiating among types and severities of distresses is very important to defining which preservation treatments are applicable. The types and severities of distresses are documented in this guide, but a wealth of other resources exist. The latest SDDOT Distress Survey Manual provides detailed information on manual collection of distress data and is available at <https://dot.sd.gov/media/documents/DistressManual.pdf>.

Another relevant resource is the Treatment Toolbox developed by the Pavement Preservation and Recycling Alliance (PPRA) and made freely available online at [roadresource.org](http://roadresource.org). The tool allows the user to explore pavement distresses and possible treatments by photos, which allows for visual understanding of many different severity/extent combinations. Users can navigate to the tool, search for photos that look similar to the field conditions of their pavements, click on the photo, and see a description of the present distresses and possible treatments.

The SDDOT CBA tool includes the severity and extent categories that are presented in these guidelines, and the user must select (via dropdown menu) – see Figure 32 for the distress severity selection process in the CBA tool.

Instructions		
Using the drop-down menus, select the appropriate severity and extent for each distress. The feasible treatments will show up in the 'Results' table with an associated EUAC.		
Distress	Severity	Extent
Transverse Cracking	Low	High
Fatigue Cracking	Low	Moderate
Block Cracking	None Present	Low
Rutting	Low	High
Edge Cracking	Medium	Low
Longitudinal Cracking	High	Low
Raveling/ Weathering	None Present	Low
Patching / Patch	None Present	Low
Deterioration	None Present	Low
Roughness (IRI)	None Present	Low
Potholes	None Present	Low
Distortion	None Present	Low

**Figure 32. Distress Severity Selection in CBA Tool**

## Step 2: Identify Feasible Treatments

Once the distress and severity data have been compiled, the feasible treatments must be identified. This is performed automatically in the CBA tool using the feasibility matrix in these guidelines. Alternatively, users can refer directly to the matrices in this guide to better understand what distresses are controlling specific treatment recommendations.

One topic related to identifying feasible treatments is the pavement surface type selection. Although many pavement surface types will remain the same (e.g., asphalt pavement will receive asphalt surface treatments) and that assumption is built into the CBA tool, it may be beneficial to consider alternatives for low-volume local roads. The North Dakota Local Technical Assistance Program (LTAP), along with many partners, developed an online tool for comparing the costs of different surface types. The tool is accessible via web browser at <https://dotsc.ugpti.ndsu.nodak.edu/SurfaceSelection/> and its accompanying instruction manual can be found at <https://www.ugpti.org/resources/reports/downloads/dp-293.pdf>. To use the North Dakota LTAP tool, users must be familiar with agency practices and have information on items such as blading frequency of gravel roads and unit costs associated with various practices, along with other inputs that depend on the scenario analyzed. The instruction manual provides thorough details about the input requirements along with screenshots and other aids for the users. The output of the tool includes the initial and future costs associated with different surface types.

## Step 3: Quantify Costs

The next item is the fully loaded cost associated with each treatment. This is contained in the “Cost” tab of the CBA tool, and the users should update these costs according to local values.

Fully loaded costs represent the sum of all costs associated with placing the treatment, which can contain multiple activities and costs. To demonstrate, an example from the Louisiana Department of Transportation and Development is presented below (Fillastre, 2011). The total expected cost of micro surfacing in 2011 for two lane-miles was estimated at \$64,000 and includes:

- \$46,200 for the cost of the treatment. This includes materials and transportation.
- \$3,700 for mobilization (8 percent of treatment costs).
- \$3,700 for temporary signs and barricades (8 percent of treatment costs).
- \$2,800 for temporary pavement markings.
- \$250 for reflectors on raised pavement.
- \$3,700 for pavement striping.
- \$3,700 for construction layout (8 percent of treatment costs).

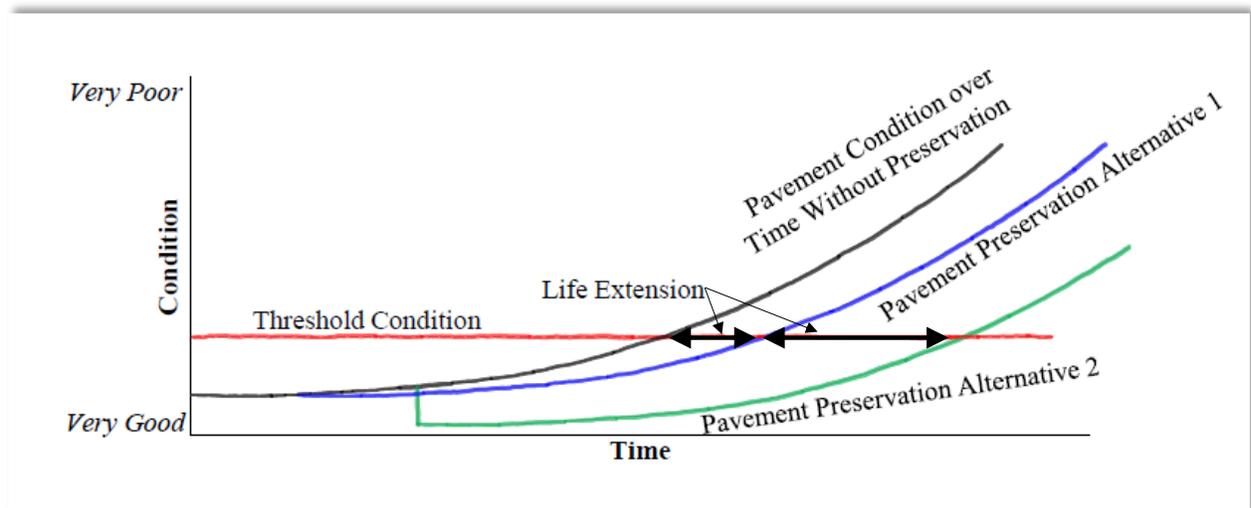
Another consideration is the cost of any pre-treatments, which may depend on the condition of the pavement. For example, many agencies have a practice of sealing cracks prior to application of the preventive maintenance treatment. In that case, the initial crack sealing should be included

in the loaded cost estimates and the cracking extent will impact the preventive maintenance treatment costs.

#### Step 4: Quantify Benefits

The primary benefits associated with pavement preservation are the immediate and/or long-term improvements to pavement condition and performance. Some treatments do not immediately affect the condition of a pavement but do change the performance (e.g., chip seals do not reduce roughness immediately but do reduce roughness growth rates). To capture the change in condition and performance, the recommended CBA approach uses the service life extension values associated with each treatment.

Service life extension is defined as the difference in time from when the pavement without a preservation treatment and the pavement with the treatment reach some defined threshold. The threshold is generally defined as the condition beyond which pavement preservation is no longer feasible. The service life extension is visually demonstrated in Figure 33 for two preservation treatment alternatives. For Alternative 1, the treatment does not have an immediate effect, but does slow deterioration (similar to the behavior of chip seals when roughness is the measure of interest). Alternative 2 shows a treatment with an immediate improvement in condition and some reduction in the rate of deterioration – if roughness is being considered, this is similar to the behavior of a pavement that received a thin asphalt overlay. The definition of life extension is the same for both alternatives (though the life extension values differ).



**Figure 33. Visualization of Service Life Extension**

The service life extension is contained in the “Life\_Ext” tab of the CBA tool, and the users should update these values if they differ from local expectation. The default life extension values within “Life\_Ext” tab were first obtained from Rada et al. (2018) for the available treatments, then Wu et al. (2010) was consulted for the remainder of the values. In a few cases (e.g., rejuvenating seals), the values were not found in the literature, and the expertise of the team that developed the tool was relied upon.

### Step 5: Calculate EUAC

The costs and benefits are combined in the CBA tool using the equivalent uniform annual cost (EUAC). The EUAC is calculated over an analysis period generally taken as the expected life extension resulting from application of the preservation treatment, and that is how it is implemented in the CBA tool. Equation 1 shows the calculation of the EUAC.

$$EUAC = NPV \left[ \frac{i(1+i)^n}{(1+i)^n - 1} \right] \quad (1)$$

Where:

$$NPV = \text{Net present value of all costs} = \frac{Cost_{Future}}{(1+i)^m}$$

$Cost_{Future}$  = expected future cost of the preventive maintenance treatment accounting for factors such as the cost of surface preparation, etc.

$i$  = Discount rate.

$n$  = Number of years considered in analysis.

$m$  = Number of years in the future that the preservation treatment is planned.

The CBA tool calculates the EUAC internally based on both the minimum and maximum expected service life extension and displays both values in the results. The CBA tool also displays an expected EUAC, which accounts for the condition of the pavement to interpolate between the maximum and minimum values. When no distresses are present, this expected EUAC is the average of the minimum and maximum EUAC values. The calculation for the expected values is as follows when distresses are present:

- For all distresses present, assign a value of 1 when the feasibility matrix considers the treatment to be ‘feasible’ and a value of 0 when it is ‘recommended’.
- Average the values to obtain a number between 0 and 1.
- Use the averaged number to linearly interpolate between the minimum EUAC (which is assigned a value of 1) and maximum EUAC (which is assigned a value of 0).

This process is automatically built into the CBA tool.

### Step 6: Select Preservation Treatment

The final step is to select a preservation treatment for the given conditions. The first criterion to account for in selecting the final preservation treatment is the results presented by the CBA tool. For example, Figure 34 shows the results from the CBA tool for a pavement with low severity and moderate extent transverse cracking, low severity and moderate extent fatigue cracking, and low severity and low extent raveling/weathering. The results show four feasible treatments: crack treating, routing and sealing cracks, fog seal and rejuvenating seal. In this example (which uses

sample numbers) the crack treatments represent the lowest cost preservation treatment that is also feasible. However, consideration may be given to a treatment for the entire surface (instead of just cracks) and therefore the rejuvenating seal represents the best value option when accounting for overall benefits.

<b>Results</b>				
The upper and lower values correspond to the range of life extensions, and the expected value is based on linearly interpolating the two based on scoring 1 for each 'feasible' and 2 for each 'recommended treatment. The average of feasible and recommended scores is used as the interpolant. A treatment that is not feasible for any treatment is not recommended below.				
<b>Treatment</b>		Lower EUAC	Upper EUAC	Expected EUAC
<b>Crack Treating</b>	.....	\$ 161.62	\$ 610.13	\$ 161.62
<b>Crack Leveling</b>	--	--	--	--
<b>Route and Seal Cracks</b>	.....	\$ 161.62	\$ 610.13	\$ 161.62
<b>Spray Patching</b>	--	--	--	--
<b>Rut Filling</b>	--	--	--	--
<b>Micro-milling</b>	--	--	--	--
<b>Fog Seal</b>	.....	\$ 905.08	\$ 1,741.87	\$ 1,462.94
<b>Rejuvenating Seal</b>	.....	\$ 579.84	\$ 1,368.61	\$ 1,105.69
<b>Chip Seal</b>	--	--	--	--
<b>Scrub Seal</b>	--	--	--	--
<b>Slurry Seal</b>	--	--	--	--
<b>Micro Surfacing</b>	--	--	--	--
<b>Cape Seal</b>	--	--	--	--
<b>Cold Milling</b>	--	--	--	--
<b>Thin HMA Overlay</b>	--	--	--	--
<b>Bonded Wearing Course</b>	--	--	--	--
<b>Cold In-Place Recycling</b>	--	--	--	--

**Figure 34. Example Results for Pavement with Low Severity and Moderate Extent Transverse Cracking, Low Severity and Moderate Extent Fatigue Cracking, and Low Severity and Low Extent Raveling/Weathering**

In addition to costs, consideration must be given to contractor familiarity and availability, facility type and other construction related issues. For example, referencing the results shown in Figure 34, if local contractors are not familiar with the placement of rejuvenating seals and do not have the necessary equipment, that preservation treatment should not be chosen.

**Discussion**

The CBA tool described in this appendix outputs predicted costs of each treatment over their respective life extension periods. It does not provide context for deciding whether to preserve the

pavement or defer preservation to future years. This CBA method and tool should be used after the decision to preserve the pavement has been made.

In addition to the specific distress severity-extent combinations, the inputs for the CBA approach are loaded costs and life extension values. Users should not assume that the default values for loaded costs input to the tool are accurate for their specific areas. Costs can vary considerably, so users of the CBA tool should input local values estimated using the process discussed in this appendix. Additionally, life extension values may vary based on climate, traffic, construction quality and many other factors. If local values are known for these, it is recommended that the user of the tool update those values.