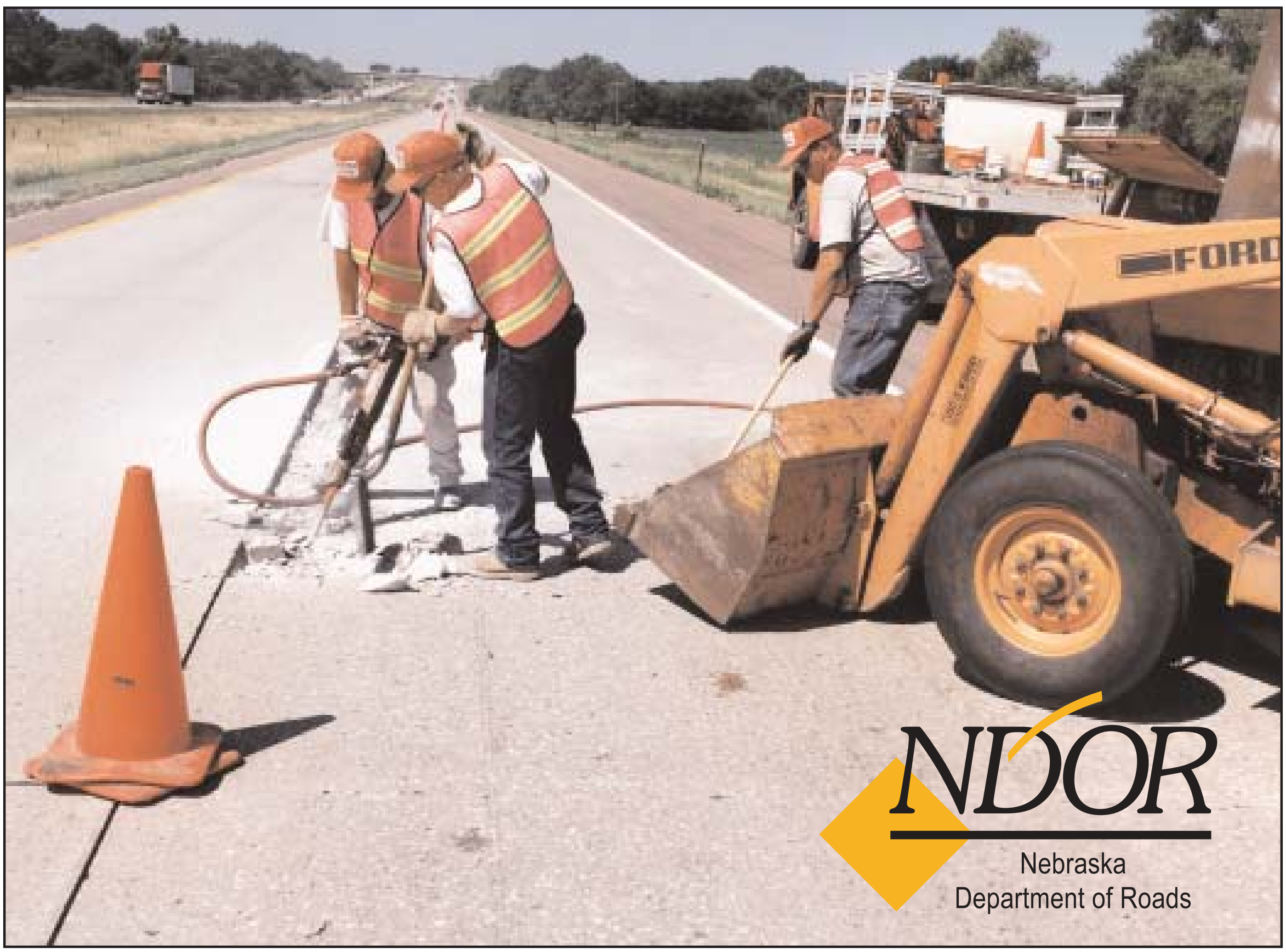
Pavement Maintenance

M A N U A L





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Pavement Maintenance Manual

Acknowledgements

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The following Nebraska Department of Roads employees and/or Divisions were involved:
District Engineers, District Maintenance Superintendents, District 1 Maintenance Supervisors,
Transportation Planning Division[1], Materials and Research Division,
Information Systems Division, and Communication Division.
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The AASHTO Subcommittee on Maintenance provided the Glossary of Terms.

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[1] Transportation Planning Division has since been eliminated but their previous responsibilities are being performed in various reorganized Divisions. The Pavement Management Section, formerly in Transportation Planning Division, is now part of Materials & Research Division.

Introduction

Nebraska has approximately 10,000 miles of State Highways. With few exceptions, our roads are something to be proud of. Since our beginning in 1895, we have been concentrating on new construction and upgrading our standards. We have reached a point where pavement preservation must share the funding spotlight.

Pavement preservation is a program of activities aimed at preserving our highway system where millions of dollars have been invested. It is now apparent that additional emphasis must be placed on maintenance if we are to preserve and prolong the life of the system that has evolved over the last 100+ years.

The purpose of this manual is to assist those responsible, in making good decisions related to the maintenance and preservation of pavement surfaces. Obviously, there are many factors such as traffic, weather, soil type, availability of equipment and crews, etc. that make it difficult to identify *the* correct treatment, *the* service life and *the* cost for every case. Hopefully, this manual will help in the selection of consistent, effective and efficient strategies and will provide guidance to ensure uniform, quality maintenance practices.

Chapter 1:

Types of Pavement Maintenance

Pavement maintenance is the key to pavement preservation. An effective pavement preservation program integrates many maintenance strategies and treatments. There are three types of pavement maintenance:

> **Preventive Maintenance:** 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 increasing the structural capacity). Surface treatments that are less than two inches in thickness are not considered as adding structural capacity.
>
> **Corrective Maintenance:** Performed after a deficiency occurs in the pavement, such as moderate to severe rutting, raveling or extensive cracking. This may also be referred to as "reactive" maintenance.
>
> **Emergency Maintenance:** Performed during an emergency situation, such as a blowup or severe pothole that needs repair immediately. This could also include temporary treatments that hold the surface together until a more permanent treatment can be performed.

There are no clear boundaries between when a treatment is preventive versus corrective, or corrective versus emergency. All types of maintenance are needed in a complete pavement preservation program. However, emphasizing preventive maintenance may prevent or prolong the need for corrective maintenance.

Preventive maintenance is *completing the right repair on the right road at the right time.*

Although all three types of maintenance are important for pavement preservation, this manual will primarily focus on preventive maintenance since it is the most cost-effective. However, as stated earlier, due to the overlap in maintenance types, there will be some limited discussion of the others. The following figures and explanations are provided to help the reader better understand the differences and importance of each type.

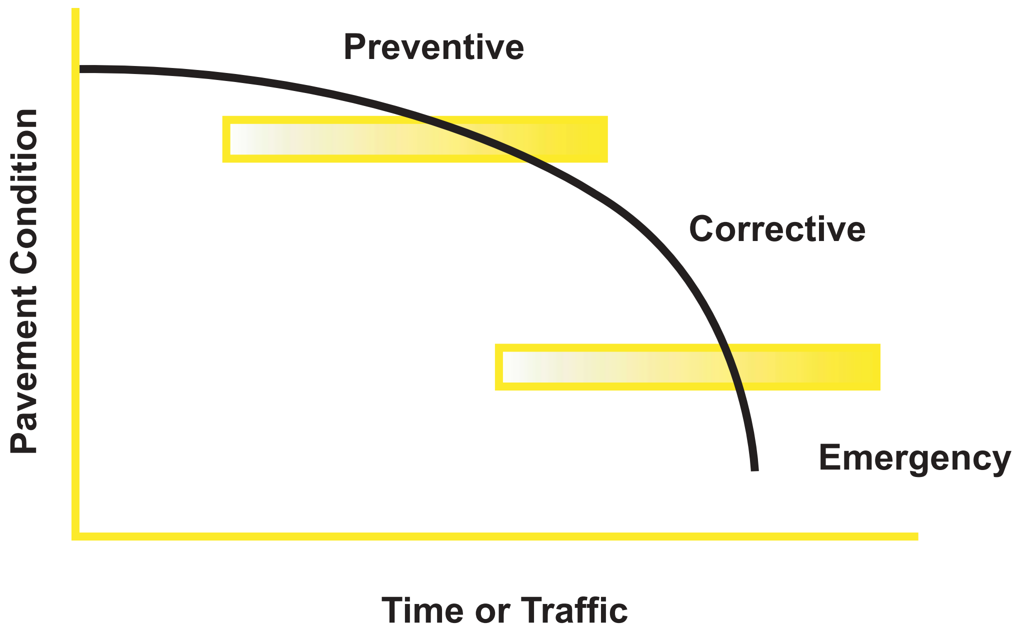


Figure 1.1 Categories of Pavement Maintenance

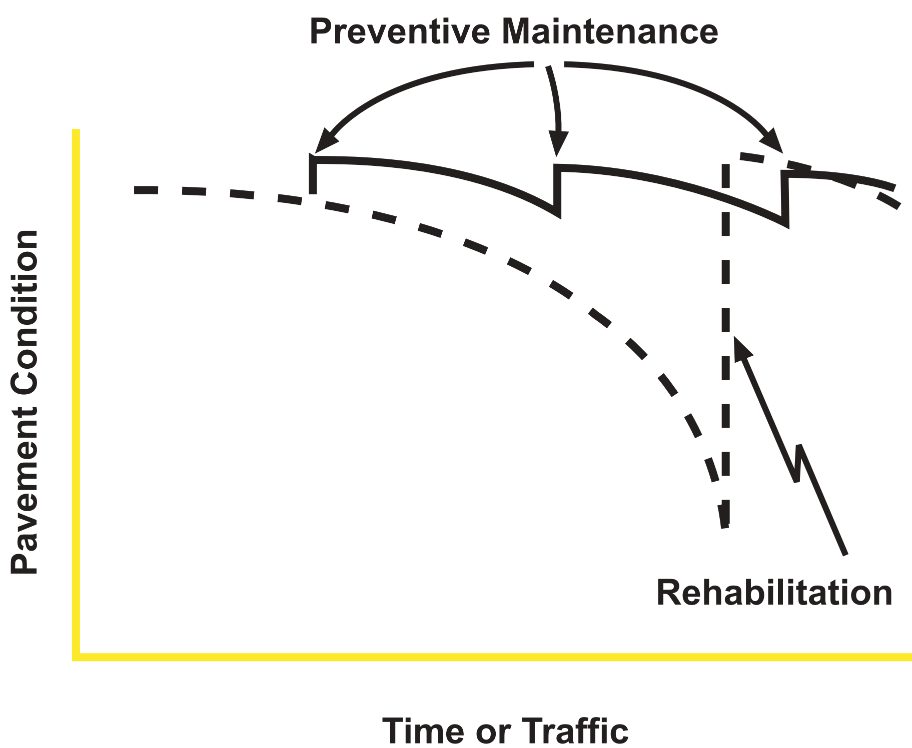


Figure 1.2 Performance of Preventive Maintenance Treatments

Preventive Maintenance

A preventive maintenance program has been shown to often be six to ten times more cost-effective than a "do nothing" strategy. Conservatively, $1.00 spent for preventive maintenance will provide the same pavement condition that costs $4-5.00 if rehabilitation is needed. By extending the life of a pavement until it needs rehabilitation, preventive maintenance allows the Department to even out its budget for both maintenance and construction.

Preventive maintenance should be planned. The intent is to repair early pavement deterioration, delay failures and reduce the need for corrective or emergency treatments. Although preventive maintenance does not include activities that are intended to increase the structural or load carrying ability of a pavement, it does extend the useful life and level of service (e.g. ride). Performing preventive maintenance activities on pavements in good condition will be very effective in extending the life. The effectiveness of the treatment is directly related to the condition of the pavement. A discussion of the tools from the Pavement Management System that are available for determining the right time to do preventive maintenance can be found in Chapter 2.

Preventive maintenance treatments include: dowel bar retrofitting, crack sealing, armor coating/chip sealing, fog sealing, broom or scrub seals, rut filling (in some cases), and thin overlays.

For the Department to have an effective preventive maintenance program, all personnel associated with the care of our highways must understand the basis for such a program and then be prepared to educate the public. It is quite likely that motorists will question why work is being done on roads that appear to be in good shape. We must be able to explain the timing needs and benefits. Finally, for the Department to have an effective preventive maintenance program, adequate funding must be set aside to provide the treatments that are needed.

Corrective Maintenance

The differences between preventive and corrective maintenance occur in the timing and cost. Corrective maintenance is reactive, i.e., it is done after a road is in need of repair so the cost is greater. Delays in corrective maintenance result in even larger costs since defects and their severity continue to increase.

Corrective maintenance treatments include: structural overlays (3 inches or greater), milling, patching and crack repair.

Emergency Maintenance

Emergency maintenance is often related to safety and time, with cost not being a primary consideration. Likewise, materials that may not be acceptable for preventive or corrective maintenance may be the best choice for emergency situations.

Chapter 2:

Pavement Management Information

Introduction

Since 1984, personnel in the Pavement Management Section have been collecting data on the surface condition of Nebraska's highways. This data is just a small part of the information that is available on the Nebraska Pavement Management System (NPMS). The Pavement Management System was developed as a tool for the Department's administration to more efficiently manage the highways.

There are two main parts to the system: 1) a computer master file, and 2) interpreting programs. The master file is the real foundation to the system and contains the following data for all rural and urban highways by highway number and reference post:

- ✔ Length, width and other layer geometric data
- ✔ Pavement structure, layer types, and design thickness
- ✔ Pavement distress condition data for bituminous and concrete pavement, Present Serviceability Index (PSI) and International Roughness Index (IRI) data
- ✔ Skid resistance data
- ✔ Traffic volume data (ADT), equivalent 18-kip axle load information, loads, frequencies, and vehicle classifications
- ✔ Pavement temperature and variation ranges during skid testing
- ✔ Regional weather data, highs, lows, precipitation amounts, and other miscellaneous items.
- ✔ Construction and maintenance rehabilitation costs by activity
- ✔ Bridge deficiency
- ✔ Safety records (fatalities and property damage data)
- ✔ Nebraska Highway Program data for the next six fiscal years

Deflection data, which is considered a valuable tool, is available on a limited project by project basis.

All historical information will be kept for a 50-year time period.

The master file is then used to: 1) report existing pavement conditions, 2) track progression of distress over the service life of a pavement, 3) list pavement section surface deficiencies, the extent of deficiencies, and valid rehabilitation repairs, and 4) report sections programmed for construction

Procedures

Pavement Management personnel gather pavement condition data annually. Inspections are made of the pavement surface at sample locations. For rigid pavements, test sections of ten panels and joints at each mile or reference post are rated. Bituminous pavements are done by taking one-tenth mile test sections every mile as near to the reference post as practical. An overall "windshield" survey is done at highway speeds to verify the sample sections are representative of the entire segment.

Chapter 3 of this manual provides descriptions and illustrations of the various distresses. Results of the condition survey are generally available by September of the year in which they are taken.

The various distress factors are combined to provide an overall rating of each section. Ratings of greater than 70 are considered good and ratings of below 50 are considered poor, indicating the need for rehabilitation. Ratings of 50-70 are considered fair and indicate only a few years of service life remain.

On the average, the rating of a bituminous road decreases three points per year for the first ten years and two points per year after that. In other words, a new asphalt road will rate 70 after ten years and rate 50 after twenty years. Ratings on concrete roads (>8") decrease at the rate of 1.25 points per year, so in forty years, a new concrete surface reaches a rating of 50.

More details on ratings may be found in Nebraska Department of Roads <u>Pavement Management System</u> dated January 1996.

Measurements of the roughness, or ride quality, are also taken each year. The measurements are expressed in terms of millimeters per meter (mm/m). Surfaces with ratings greater than 2.00 are considered rough and greater than 3.00 are very rough.
Maps showing the overall surface condition rating, referred to as the Nebraska Serviceability Index (NSI), the amount of rutting, and the roughness (IRI) for each highway are available from Materials & Research Division.

Uses of Pavement Management Data

The amount of data available is enormous. Interpreting programs are used to summarize the information and provide reports listing candidate sections of pavement suitable for rehabilitation. A list of pavement conditions is provided to the District Engineer each year to assist in establishing the six-year rehabilitation program. Another list is generated from which the Pavement Extension Program (PEP) projects are selected.

On a statewide basis, the Pavement Management data is used in preparation of the Department's annual 20-year Needs Assessment. In turn, the Needs Assessment is used to determine the amount of funding allocated to each District for highway improvements.

At the project level, life cycle cost analysis is available for rehabilitation strategies. Work is underway to develop life cycle cost analysis for maintenance strategies.

A review of the surface condition rating by Maintenance decision makers may help in selection of the proper preventive maintenance treatments.

The following section provides a detailed description of how to access the material available from the Pavement Management Section.

How to Access Pavement Management Data

Shown below is a step-by-step procedure you may use to obtain current and historical data for highways in your area.

1. Open a Mainframe Session.
2. Type C1, press enter.
3. A "Production CICS1 Region" screen will appear, press enter.
4. Type in your User ID: (if your number is DOR 26002 use DR26002).
5. Type in your Password, press enter.
6. Next screen choose selection "8" (IHI1) IHI Integrated Highway Inventory System, press enter.
7. On the Main Menu screen choose "18" Roadway Condition, press enter.
8. On the Roadway Condition Menu choose "02" Query, press enter.
9. On the Roadway Condition Query Menu choose what data you want to review. For example: choose "03" Bituminous Condition Ratings, press enter.
10. Enter highway Number: Example "002"
    a. Enter Beg Ref Post, if desired.
    b. Enter End Ref Post, if desired.
    c. Enter Lane Dir Cde, if desired.
    d. Enter Lane Typ Cde, if desired.
    e. Enter Lane Num, if desired.
    f. Enter Start/End Dates, if you want to see more than the current data.
    g. Enter Restrn Idx Low/Hi, select range of Restoration Index values, if desired.
    h. Enter Crking Idx Low/Hi, select range of Cracking Index values, if desired.
11. Press enter.
12. Follow the directions on the lower portion of the screen in reference to the "PF" keys ("F" keys on the keyboard, the upper row of keys). The "PF" keys 13 and above can be accessed by pressing the "Shift" + "F" key. Example: "PF19" = Shift + F7; "PF20" = Shift + F8; etc.

If at step # 9 above, you chose to look at "01" Roadway Condition Summary Query; Pavement Management Data can also be accessed there. However, it will only be for the section being summarized. The process would then be Steps 1 thru 8 as above, then:

9. Choose "01" Roadway Condition Summary Query, press enter.
10. Enter District number on this screen, press enter.
11. Scroll down list (F8) and choose a section and place an "X" in the "Sel" column on the line of your selection, press enter.
12. Press enter on the next screen.
13. The next screen is the "Nebraska Pavement Management System Summary Query" screen. If you place

the cursor in front of the IRI data on the lower portion of the screen or Rutting data, if this is a bituminous section or Faulting if this is a PCC section and press “F4”, the profiler data for this section will be displayed. If the cursor is placed in front of the Cracking Index, Trans. Cracking, NSI or Hist Low NSI, if bituminous and press “F4”, the bituminous ratings for this section will be displayed. Likewise, if the cursor is placed in front of the PCC rating elements and “F4” is pressed, the PCC ratings for this section will be displayed.

14. There are other types of data that are also accessible from this screen. “F7” calls up all the Crew Card Transactions for this section. “F9” shows the Maintenance Costs and various activities for the last 5 years. “F10” shows the condition history and the ratings for this section for the last 10 years.

Additional information may be accessed from those locations that have high-speed T1 lines. These locations include the District offices, about 90% of the Maintenance Superintendents’ offices and a few others. The following procedures apply to information that may be accessed if served by a T1 line.

Pavement Management System, Version 1.0, Procedure for Access

1. When your computer is booted up, there will be an icon that is a green box with a red car in it, double click on this icon or highlight it and press enter.
2. A short movie is displayed while the program loads.
3. The next screen shows a file folder with several tabs on it and the option of Current Pavement Management Data or Historic Pavement Management Data. Choose selection from the Current Pavement Management Data.
   a. Statewide Data displays all highway data.
   b. District Data displays only the chosen district.
   c. Highway Data displays only the chosen highway.
   d. Other displays only Interstate, Priority Commercial or Expressway by District and/or Highway.
4. You may select data by the entire road system, district, highway, district and highway, or other. A number must be added in the dropdown box next to the District Data and the Highway Data buttons if those selections are used. To continue, just single click on one of these four buttons. The data will then be displayed.
5. The top half of the screen shows the selected statistics for the segment highlighted in yellow on the lower portion of the screen. You may navigate this screen by one of several methods.
   a. Using the four buttons on the upper right corner of the screen, you can to go to the top of the file, next record, previous record or go to the bottom of the file.

b. Use the find button to search for a highway.

c. You may also use the scroll bar on the right side of the lower half of the screen to locate a highway segment, and then use the mouse to select a segment by clicking on it once.

d. You may also use the up and down arrows to locate a segment.

e. The return button takes you back to the previous screen.

f. Below the return button is a button with a camera on it. When you click on it, thumbnail images of the road surface will be displayed. Single click on the Slide Show button at the next screen and the slide show will begin. If you double click on an image, that image will be enlarged. That image will also be enlarged when you single click on the small button with the square in it next to the button with the "X" in the upper right corner of that window. Use the "X" in the top right corner of the screen to return to the previous screen.

6. The bottom half of the screen lists the complete information on each highway segment. You can view this data by using the left and right arrow keys or using the scroll bar on the bottom of the screen. A definition of the column of data is displayed if the mouse button hovers over the column for a few seconds.

7. When you finish viewing the data, single click on the Return button or the "X" in the top right corner of the screen to exit.

8. Single click on the Exit button to quit the program.

If any problems are encountered or if you have any questions regarding the use of either of these data sources, contact Gary Brhel at (402) 479-3620.

Chapter 3:

Distress Identification

The purpose of this chapter is to help the user recognize the distresses typically found on pavements in Nebraska and understand the possible causes.

Distress is defined as a condition of pavement structure that reduces serviceability or leads to a reduction in serviceability. Serviceability is defined as the ability of a pavement to provide a safe and comfortable ride to its users.

Distresses may be treated with a range of repairs, each having a varying degree of success. Some of the treatments shown for the distresses will provide only a short term solution, which may be all that is needed.

Selection of the best treatment is complicated and the decision on which to use should not be made until you review the material in Chapter 4.

Flexible Pavement Distresses

Flexible pavement surface distresses include a wide variety of pavement defects that generally fall into the following categories:

- I. Cracking
    - A. Alligator
    - B. Edge
    - C. Longitudinal
    - D. Random/Block
    - E. Transverse
- II. Raveling/Weathering
- III. Distortion
- IV. Rutting
- V. Excess Asphalt

Rigid Pavement Distresses

The most significant and severe distresses in rigid pavements generally occur along joints. Joint deterioration reduces pavement performance substantially and increases the need for maintenance. Other distresses occur within a concrete slab away from joints, leading to a loss of ride quality and structural failure of the pavement.

Types of distresses in portland cement concrete (PCC) pavements include:

- A. Joint Distress
- B. Faulting
- C. Transverse Cracks
- D. Pattern Cracking
- E. Surface Distress
- F. Slab Cracking

Each of these distresses is described in the following pages along with photographs and possible causes. Similar photographs are used as guides by Pavement Management personnel when doing the annual rating of the highways. **For each distress a number of possible maintenance treatments are also shown. It must be emphasized that the treatments shown here are those that could be applied by maintenance forces, that may be effective in treating the distresses. Treatments applied under contract work are included in the tables in Chapter 4.** Note that under certain circumstances, the Do Nothing strategy may be the most appropriate.

Two important points should be remembered: ***(1) in many instances, multiple types of distress occur, so the treatment selected must be appropriate for all distress that is present. (2) the appropriate treatment may require a combination of treatments.*** **Again before selecting any strategy, the decision matrix in Chapter 4 should be reviewed, since some of the treatments shown will only provide a temporary fix.** In some cases, total reconstruction may be the most appropriate strategy.

FLEXIBLE PAVEMENT

I. Cracking

A. Alligator Cracking

1. Description

Alligator cracking is a series of interconnected cracks in an asphalt layer forming a pattern, which resembles an alligator's hide or chicken wire. The cracks indicate fatigue failure of the asphalt layer generally caused by repeated traffic loadings and this distress allows water to penetrate the surfacing materials and subgrade, which furthers the damage. Alligator cracking, also called fatigue cracking, usually first begins as a single longitudinal crack in the wheel path.

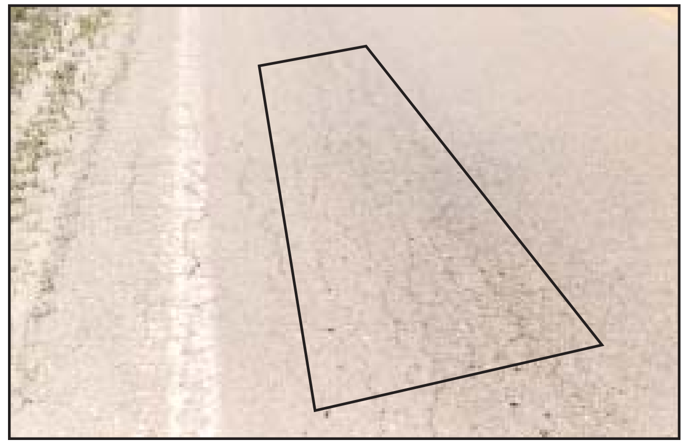
2. Possible Causes

- ✔ Insufficient pavement structure
- ✔ Inadequate base support
- ✔ Poor base drainage
- ✔ Aging and traffic loading

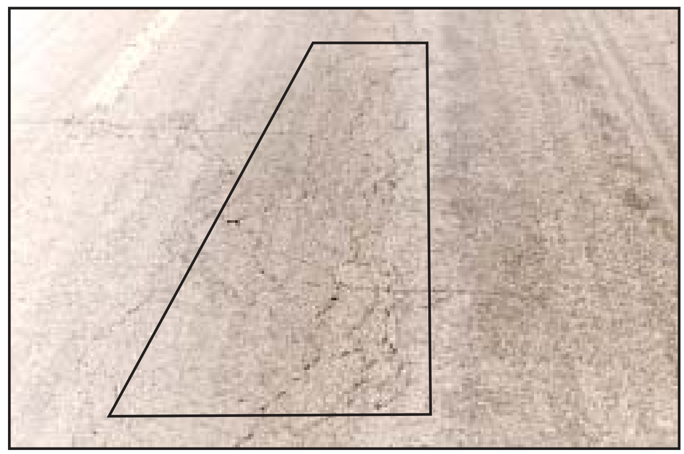
3. Maintenance Treatments[1]

- ✔ Do Nothing
- ✔ Fog Seal
- ✔ Scrub Seal
- ✔ Slurry Seal
- ✔ Chip Seal/Armor Coat
- ✔ Thin Cold Mix Overlay
- ✔ Thin Hot Mix Overlay
- ✔ Patching

[1] Except for patching, most of these treatments will probably fail rapidly, since additional structure is needed.



Low - Longitudinal disconnected hairline cracks no greater than ⅛- inch wide.



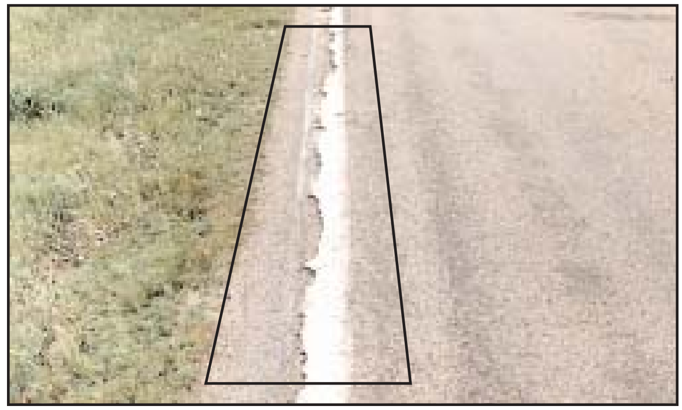
Moderate - Longitudinal cracks in wheel paths forming an alligator pattern; cracks may be lightly spalled and about ⅛- to ¼-inch wide.

High - Pieces appear loose with severely spalled edges; cracks are ¼-inch or greater and pumped fines may appear on the surface.

B. Edge Cracking

1. Description

Edge cracking is similar to alligator cracking only located within 1 to 2 feet of the edge of the pavement. Failure begins at the edge of the pavement and progresses toward the wheel path. Pavement edge distress can result in worsening of the wheel path condition and allow moisture into the subgrade soils and base materials. Edge cracking also includes the longitudinal cracking associated with concrete base course widening.



Low - Hairline cracks just beginning to show; random with no pattern; may be up to ⅛-inch wide.

2. Possible Causes

- ✔ Traffic Loading
- ✔ Environmental
- ✔ Construction Related
- ✔ Low Shoulder
- ✔ High Shoulder Holding Water

Moderate - Cracks ⅛- to ¼-inch located 1 to 2 feet from the edge of the road; may have an alligator pattern.

3. Maintenance Treatments

- ✔ Do Nothing
- ✔ Crack Fill
- ✔ Thin Cold Mix Overlay
- ✔ Shoulder Maintenance

High - Cracks greater than ¼-inch; may have loose or missing pieces or potholes or alligator cracking.

C. Longitudinal Cracking

1. Description

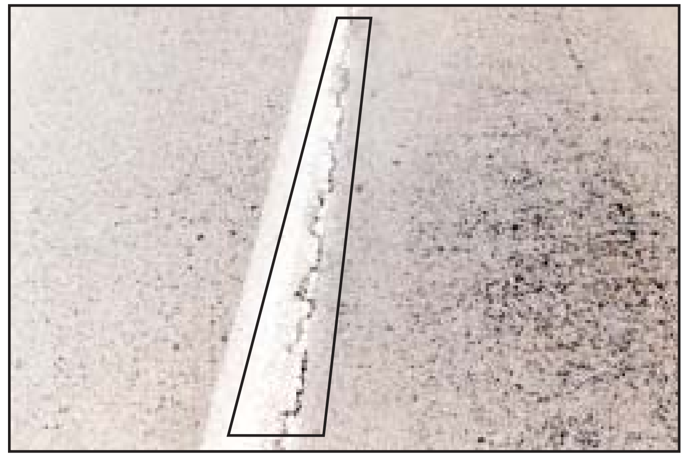
Longitudinal cracking denotes cracks that run predominantly parallel to the centerline. These cracks may be in the wheel paths, between wheel paths and/or at lane joints such as centerline or shoulder/surface.

2. Possible Causes

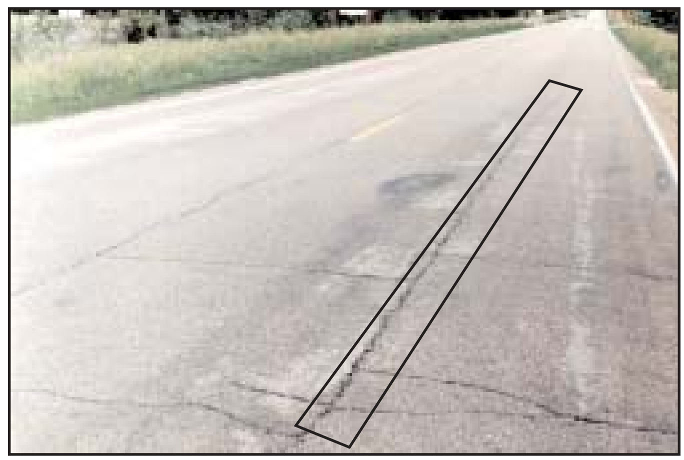
- ✔ Traffic Loading (wheel path cracks)
- ✔ Environmental (frost action)
- ✔ Improper Construction Practices (joint cracks)
- ✔ Poor Drainage
- ✔ Reflection Cracks

3. Maintenance Treatments

- ✔ Do Nothing
- ✔ Crack Seal/Fill
- ✔ Scrub Seal
- ✔ Chip Seal/Armor Coat
- ✔ Patching



Low - Hairline crack(s) running parallel to centerline.



Moderate - Cracks parallel to centerline are about ⅛-inch wide.

High - Single cracks are wider than ⅛-inch.

D. Random/Block Cracking

1. Description

Random or block cracks divide the pavement into rough, approximately rectangular pieces and typically occurs at uniformly spaced intervals.

2. Possible Causes

- ✔ Environmental (thermal)
- ✔ Aging

3. Maintenance Treatments

- ✔ Do Nothing
- ✔ Crack Seal/Fill
- ✔ Fog Seal
- ✔ Scrub Seal
- ✔ Slurry Seal
- ✔ Chip Seal/Armor Coat
- ✔ Thin Cold Mix Overlay
- ✔ Thin Hot Mix Overlay

Low - Hairline cracks, essentially transverse but may connect to longitudinal; spacing of 50 to 100 feet.

Moderate - Cracks range from hairline to ⅛-inch wide and may be slightly spalled.

High - Cracks greater than ⅛-inch wide that are random or have a block pattern, similar to a turtle shell.

E. Transverse Cracking

1. Description

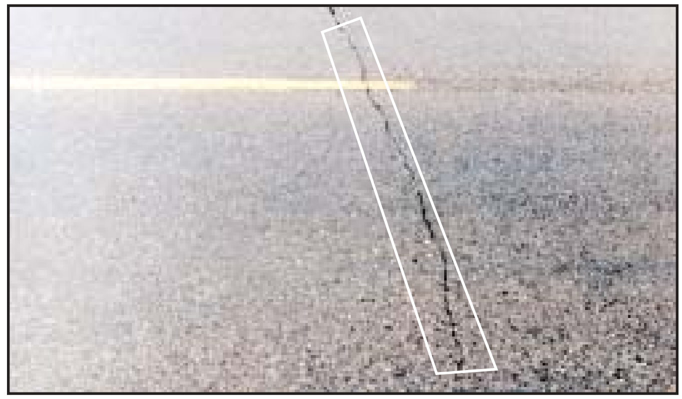
Transverse cracks are those considered to extend three-fourths of the width of the pavement or more, generally perpendicular to centerline.

2. Possible Causes

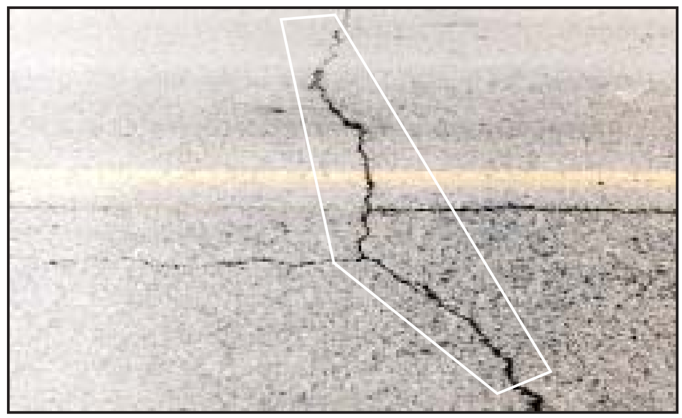
- ✔ Environmental (thermal)
- ✔ Swelling or shrinkage of the subgrade
- ✔ Reflection cracks
- ✔ Settlement (trench, backfill)

3. Maintenance Treatments

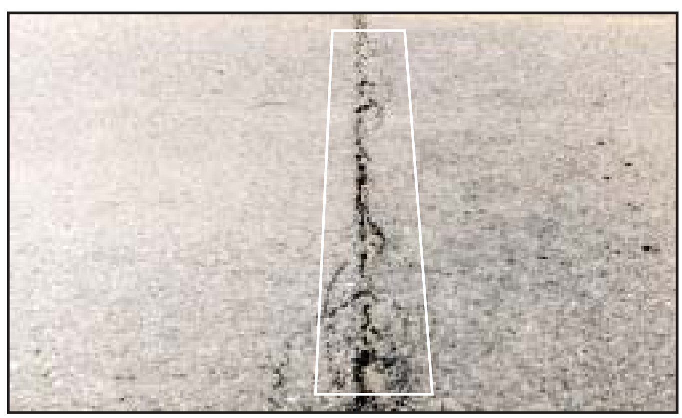
- ✔ Do Nothing
- ✔ Crack Seal/Fill
- ✔ Fog Seal
- ✔ Scrub Seal
- ✔ Slurry Seal
- ✔ Chip Seal/Armor Coat
- ✔ Mill
- ✔ Patching



Low - Hairline to ¼-inch wide cracks perpendicular to centerline with no distortion.



Moderate - Cracks ¼- to ½-inch in width, perpendicular to centerline and the full width of the pavement; slight distortion.



High - Cracks ½- to 2-inch wide; larger cracks often are spalled and/or have noticeable distortions near them. Cracks greater than 2 inches wide and causing extremely rough ride are rated “X”.

II. Raveling/Weathering

A. Description

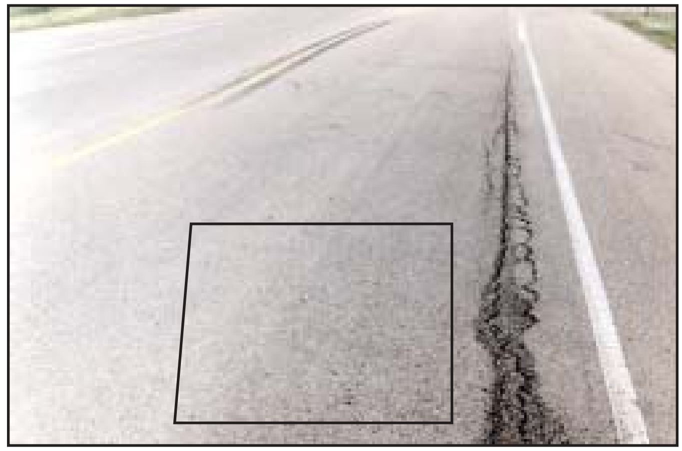
Raveling is the progressive wearing away of the pavement from the surface downward caused by the loss of asphalt binder and the dislodging of aggregate particles.

B. Possible Causes

- ✔ Poor mixture quality
- ✔ Asphalt hardening due to aging
- ✔ Insufficient asphalt content
- ✔ Improper construction methods

C. Maintenance Treatments

- ✔ Do Nothing
- ✔ Fog Seal
- ✔ Scrub Seal
- ✔ Slurry Seal
- ✔ Chip Seal/Armor Coat
- ✔ Thin Cold Mix Overlay
- ✔ Thin Hot Mix Overlay



Low - Minimal loss of aggregate or binder.

Moderate - Some aggregate loss; small areas may be stripped away.

High - Sections greater than one square foot may be pitted, stripped or eroded away.

III. Distortion[2]

A. Description

Distortion is defined as that distress in the pavement caused by densification, consolidation, swelling, heave, creep or slipping of the surface or foundation.

B. Possible Causes

- ✔ Inadequate support or overloading
- ✔ Thermal and moisture stresses (freeze-thaw)
- ✔ Loss of bonding between base layer and surface layer
- ✔ Static load (depressions)
- ✔ Soft AC (shoving)

C. Maintenance Treatments

- ✔ Do Nothing
- ✔ Crack Seal
- ✔ Chip Seal/Armor Coat
- ✔ Mill
- ✔ Thin Cold Mix Overlay
- ✔ Thin Hot Mix Overlay
- ✔ Patching

Low - Slight waves, sags, humps, corrugations or wash boarding of the pavement.

Moderate - Similar to low except distortions can be felt while riding in a vehicle.

High - Shoving and major changes in pavement profile that require vehicles to slow from normal speeds.

[2] No longer rated separately by Pavement Management personnel.

IV. Rutting

A. Description

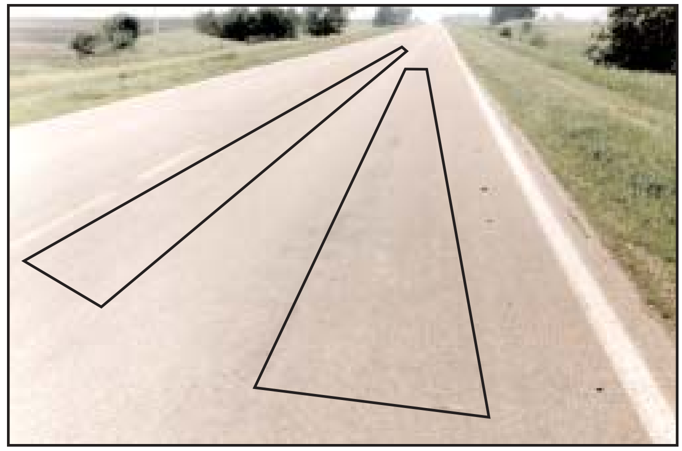
A rut is a surface depression in the wheel path after pavement layers or subgrade deform from traffic load applications.

B. Possible Causes

- ✔ Poor mixture quality
- ✔ Insufficient support
- ✔ Improper construction procedures

C. Maintenance Treatments[3]

- ✔ Do Nothing
- ✔ Chip Seal/Armor Coat
- ✔ Mill
- ✔ Thin Cold Mix Overlay
- ✔ Thin Hot Mix Overlay



Low - Depressions in the wheel path less than 1/8-inch.

Moderate - Wheel path depressions of 1/4- to 1/2-inch.

High - Wheel path depressions greater than 1/2-inch.

[3] No preventive applications available.

V. Excess Asphalt

A. Description

Excess asphalt, also called bleeding or flushing, is used to describe a free film of asphalt on the surface of the pavement that creates a smooth, shiny, greasy, and reflective surface. It is usually found in the wheel paths and becomes quite sticky when hot.

B. Possible Causes

- ✔ Mixture problems (bad oil, stripping aggregate, low air voids, high AC content, etc.)
- ✔ Improper construction practices
- ✔ Paving over excess asphalt

C. Maintenance Treatments

- ✔ Do Nothing
- ✔ Chip Seal/Armor Coat
- ✔ Mill
- ✔ Thin Cold Mix Overlay
- ✔ Thin Hot Mix Overlay

Low - Intermittent films of bituminous material create a shining, reflective surface.

Moderate - Large areas or continuous strips of bituminous films where little, if any, aggregate can be seen.

High - Excess bituminous material appears wet and actually liquefies during hot weather.

RIGID PAVEMENT

A. Joint Distress

1. Description

Joint distress reflects the deterioration of the concrete within 2 feet on either side of a joint. Breaking or chipping of the pavement joints usually results in fragments with feathered edges.

2. Possible Causes

- ✔ Expansive internal pressure due to alkali-aggregate reactivity between the cement and aggregates.
- ✔ Expansive internal pressure due to corrosion and deterioration of dowel bars.[4]
- ✔ Seized dowel bars combined with thermal expansion (freeze-thaw).
- ✔ Misaligned dowel bars.[4]
- ✔ Lack of support at joint due to pumping action and voids.[5]
- ✔ Overloading.[5]

3. Maintenance Treatments

- ✔ Partial/Full Depth Slab/Joint Repair
- ✔ Crack & Joint Seal/Fill
- ✔ Thin Hot Mix Overlay

Low - A few hairline cracks from the joint and/or discoloration at the joint.

Moderate - Frequent hairline to ⅛-inch cracks radiating from the joint forming a web like pattern.

High - Cracks ⅛-inch or larger forming multiple patterns and often having a white appearance.

[4] Causes spalling

[5] Causes corner cracks

B. Faulting

1. Description

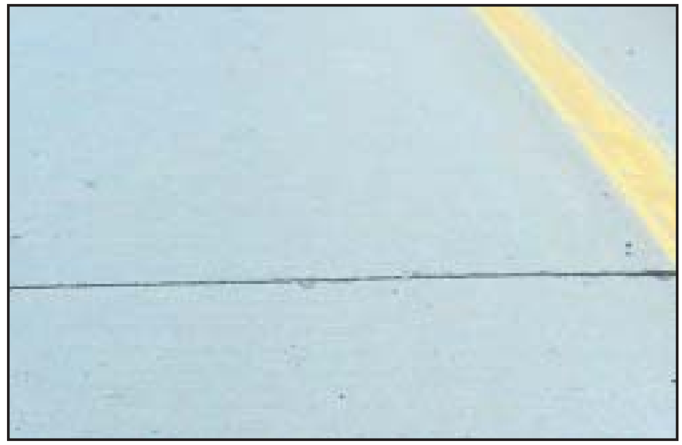
Faulting is a differential vertical displacement of a slab or other member adjacent to a joint or crack. Faulting may be either longitudinal or transverse and creates a "step" deformation of the pavement surface. Faulting commonly occurs in transverse joints of portland cement concrete pavements that do not have load transfer devices (dowels). Usually the "upstream" slab is higher than the "downstream" slab.

2. Possible Causes

- ✔ Uneven roadbed support.
- ✔ Thermal and moisture stresses (frost action).
- ✔ Pumping of slabs due to lack of load transfer (dowel) devices
- ✔ Insufficient pavement structure

3. Maintenance Treatments

- ✔ Mudjacking
- ✔ Slab replacement
- ✔ Thin Hot Mix overlay



Low - Less than 1/8-inch vertical displacement between adjacent panels.

Moderate - Displacement of 1/8- to 1/4-inch between adjacent panels.

High - Displacement greater than 1/4-inch between adjacent panels.

C. Transverse Cracks

1. Description

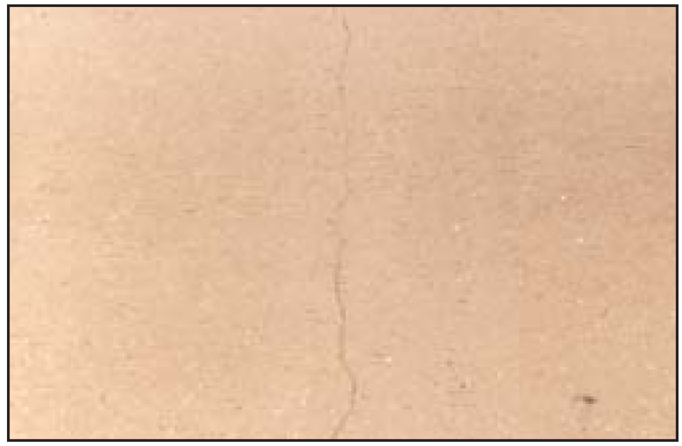
Transverse cracks are cracks that run perpendicular to centerline, resulting in a panel that is broken into two or more pieces. Panels broken into two pieces are rated as Class I and panels broken into more than two pieces are rated as Class II.

2. Possible Causes

- ✔ Thermal contractions
- ✔ Over-long joint spacing
- ✔ Overloading
- ✔ Swelling/shrinkage/settlement of subgrade

3. Maintenance Treatments

- ✔ Crack & Joint Seal/Fill
- ✔ Partial/Full Depth Slab Repair
- ✔ Thin Hot Mix Overlay



Low - Hairline to ¼-inch wide cracks extending the full width of a panel.

High - Transverse cracks greater than ¼-inch wide extending the full width of panel.

D. Pattern Cracking

1. Description

Pattern cracking refers to occasional to extensive interconnected cracks that may appear anywhere within a panel but do not extend throughout the entire depth of the slab.

2. Possible Causes

- ✔ Shrinkage cracks
- ✔ Materials: related distress (including alkali-aggregate reactivity)

3. Maintenance Treatments

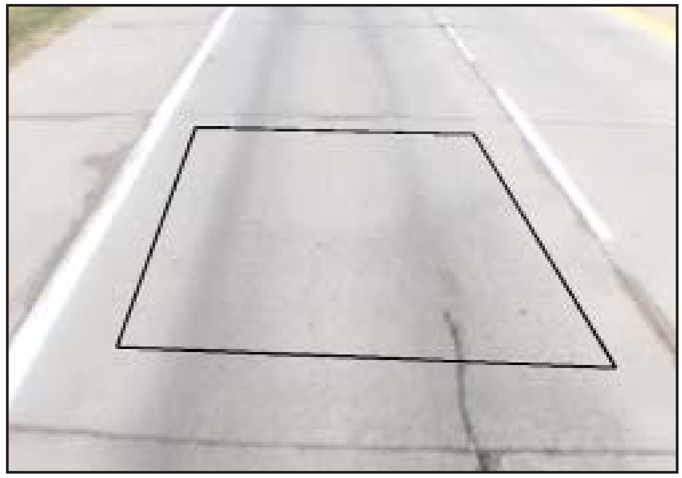
- ✔ Do Nothing
- ✔ Thin Hot Mix Overlay

Low - Negligible or occasional interconnecting 1⁄16-inch wide or less cracks.

Moderate - Interconnected cracks between 1⁄16- to 1⁄8-inch wide throughout the panel.

High - Occasional to extensive interconnecting cracks 1⁄8-inch wide or greater. Spacing between cracks is usually only a few inches.

E. Surface Distress



1. Description

Surface distress is the scaling, spalling, chipping or disintegration of the concrete wearing surface that leads to roughness and poor durability. It is measured in square feet per panel but does not include any distresses within 2 feet of the joint.

2. Possible Causes

- ✔ Poor materials or construction (e.g. too much water, overworking of surface, etc.)
- ✔ Thermal and moisture stresses (freeze-thaw)
- ✔ Corrosion of reinforcing steel
- ✔ Reinforcing steel too close to surface

3. Maintenance Treatments

- ✔ Partial/Full Depth Patching
- ✔ Slab Replacement
- ✔ Thin Hot Mix Overlay

F. Slab Cracking

1. Description

Slab cracking is used to describe any unplanned longitudinal or diagonal structural crack(s) that extend through the depth of the slab

2. Possible Causes

- ✔ Overloading
- ✔ Long joint-spacing
- ✔ Shallow or late joint sawing
- ✔ Pumping of the subgrade
- ✔ Curling or warping of slab
- ✔ Culvert or utility trench subsidence

3. Maintenance Treatments

- ✔ Crack & Joint Seal/Fill
- ✔ Full Depth Slab Repair
- ✔ Thin Hot Mix Overlay

Low - Hairline, single structural cracks in a panel that may be longitudinal or diagonal in nature and extend from joint to joint.

Moderate - Two or three major structural cracks with no faulting or displacement.

High - Multiple structural cracks or cracks with evidence of faulting, displacement or spalls.

Chapter 4:

Pavement Maintenance Treatments

The selection of the right maintenance strategy at the right time is of utmost importance for an effective management of highway pavements. The appropriate maintenance strategy will be influenced by the type, severity, and extent of the pavement surface distresses and the structural and roughness condition of the pavement. The photos in Chapter 3 depict the type and severity of various distresses. Choosing the right treatment also depends on the extent or frequency that the distress occurs. Some of the treatments may be most applicable when very little distress is present. The photos on the following pages may be used to help identify the extent when using the Flexible Pavement Decision Matrix shown as Table 4.1 later in this chapter.

Where the extent of the distress is described as a “Trace” or “Occasional”, it may also be regarded as occurring in localized areas only and affecting less than 30% of the pavement surface. If the extent is described as “Frequent”, “Extensive”, or “Complete”, the distress affects more than 30% of the pavement surface and occurs more or less evenly throughout the section.

Application of the extent rating is generally the same for Flexible and Rigid pavements. However, the Rigid Pavement Decision Matrix shown as Table 4.2, points out some exceptions; i.e., in the rating of Transverse Cracks and Surface Distress.

A. Extent-Environmental Related

Some of the flexible pavement distresses that are normally environmental related include: transverse cracking, random/block cracking, and raveling/weathering. Others such as edge cracking, longitudinal cracking, and distortion may be due to either environmental or loading influences.

Frequent - 30% to 50%

Trace - less than 10%

Extensive - 50% to 80%

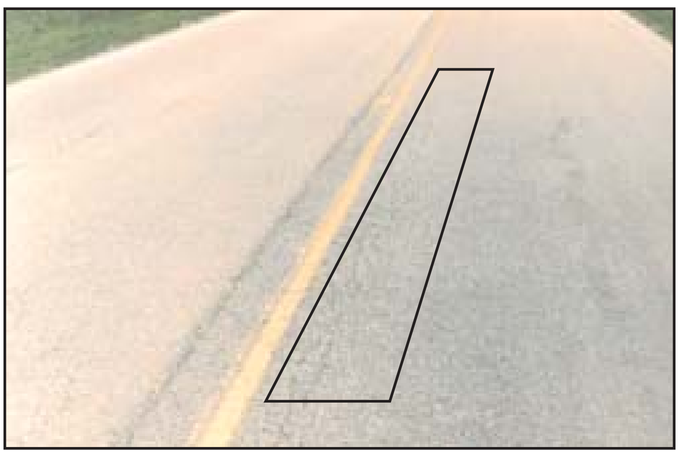
Occasional - 10% to 30%

Complete - greater than 80%

B. Extent - Load Related

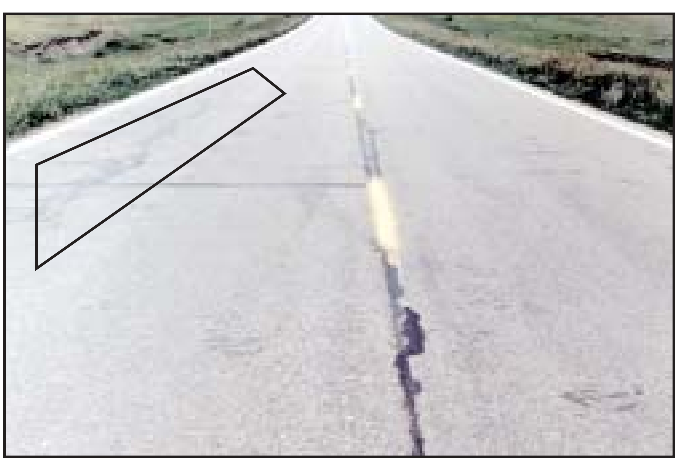
Some of the distresses commonly associated with loading include: alligator cracking, longitudinal cracking in wheel paths and rutting. Preventive maintenance will not correct most load-related distresses. Percents relate only to wheelpaths and not to the entire pavement surface.

Frequent - 30% to 50%



Trace - less than 10%

Extensive - 50% to 80%



Occasional - 10% to 30%

Complete - greater than 80%

Table 4.1: Flexible Pavement Maintenance Decision Matrix[1]						
Flexible Pavement Distresses	Low		Moderate		High	
	Occasional	Frequent	Occasional	Frequent	Occasional	Frequent
Alligator Cracking[2]	3,1	3,6	6,3,11,4	6,5	13,6,11	15,13
Edge Cracking	1,2	2,1	2,13	2,13	13	13
Longitudinal Cracking	2,1	2,6,1	2,6	2,6	13,2,6	6,2,13
Random/Block Cracking	2,1	2,3	2,6	2,6	6,11,12	12,6,14
Raveling/Weathering	3,1,6	3,6,5	6,4	6,7	6,11,5	6,12,11
Distortion	1,8,13	13,1,8	8,13,2	8,13,6,2	8,11,6,13	8,14,13
Rutting	1	1	8 + 6	8 + 6	8 + 6, 12	8,14,12
Excess Asphalt	1	1,6	6,1,8	6,8	8 + 6	8 + 6 or 12
Transverse Cracking	2,1	2	2,6	2,6	2,6	2,6,13

Pavement Treatments

1 Do Nothing
2 Crack Seal/Fill
3 Fog Seal
4 Scrub Seal (Broom Seal)
5 Slurry Seal
6 Chip Seal/Armor Coat
7 Micro Surfacing
8 Mill
9 Cold-in-place Recycle
10 Hot-in-place Recycle
11 Thin Cold Mix Overlay
12 Thin Hot Mix Overlay[3]
13 Patching
14 Thick Overlay
15 Total Reconstruction

[1] Based on recommendations of the eight District Maintenance Superintendents and Materials & Research Division. Treatments are listed based on the frequency with which they were selected. Only treatments shown are those which were selected by more than two of the group. Other possible treatments are listed on the pages showing the distresses.

[2] Effectiveness of treatments other than 13, 14 & 15 will be minimal and short-lived.

[3] Pavement Extension Program (PEP) projects are typically 2 inches thick and are considered the maximum thickness of this treatment.

Table 4.2: Rigid Pavement Maintenance Decision Matrix						
Rigid Pavement Distresses	Low		Moderate		High	
	Occasional	Frequent	Occasional	Frequent	Occasional	Frequent
Joint Distress	1,2	1,2	2,3	2,3	3,4	3,4
Faulting	1	1	1	6,4,1	6,4	6,4
Transverse Cracks	1,2	1,2	NR*	NR*	2,8,4	2,4,8
Pattern Cracking	1	1	1	1	1,4	1,4
Surface Distress**	3,8,4					
Slab Cracking	2	2,4	2,7	2,7,4	3,9	3,9

* Not Rated

** Measured as square feet/panel

Pavement Treatments

1 Do Nothing
2 Crack & Joint Seal/Fill
3 Partial/Full Depth Slab/Joint Repair
4 Thin Hot Mix Overlay (1½")
5 Mudjacking
6 Diamond Grinding (may include dowel bar retrofit)
7 Cross Stitching
8 Slab Replacement
9 Thick Hot Mix Overlay

Table 4.3: Flexible Pavement Maintenance Treatment Cost and Expected Life		
Treatment	**Average Cost [1] *(Mile)***	**Expected Life *(Years)***
Crack Seal/Fill	$0.55 - $0.60/lin.ft. [2]	3 - 5
Fog Seal	$1,750 - $2,500	1 - 4
Scrub Seal	$7,000 - $8,000	2 - 5
Slurry Seal [3]	$40,000 - $45,000	3 - 8
Chip Seal / Armor Coat	$8,000 - $9,000	3 - 6
Microsurfacing	$41,000 - $43,000	3 - 8
Mill (1")	$7,500 - $8,500	1 - 4
Cold-in-Place Recycle	$100,000 - $115,000	8 - 12
Hot-in-Place Recycle	$22,000 - $25,000	3 - 6
Thin Cold Mix Overlay	$18,000 - $25,000	3 - 5
Thin Hot Mix Overlay (1")	$45,000 - $55,000	5 - 8
Pavement Extension Program (2" PEP)	$80,000 - $120,000	7 - 9
Thick Overlay (5")	$195,000 - $215,000	8 - 15
Total Reconstruction	$525,000 - $550,000	20+

1 Costs shown are for a 24' roadway unless otherwise noted.

2 Varies depending on extent of cracking. Amounts to $7,000 - $9,000/mi. assuming transverse crack spacing of 30' and two full-length longitudinal cracks.

3 Includes a ½" surface treatment over a leveling course. Cost for leveling course alone = $9,000 - $12,000.

Table 4.4: Rigid Pavement Maintenance Treatment Cost and Expected Life

Treatment	Average Cost [1]	Expected Life *(Years)*
Crack & Joint Seal/Fill	\$1.00 - \$1.75/lin.ft. [2]	4 - 7
Partial/Full Depth Slab/Joint Repair	\$95 - \$110/sq.yd.	10 - 15
Thin Hot Mix Overlay (1½")	\$65,000 - \$75,000	6 - 10
Mudjacking	\$80 - \$120/sq.yd.	10 - 15
Diamond Grinding	\$38,700 - \$115,400 [3]	12 - 15
Cross Stitching	\$9 - \$10/bar [4]	10 - 15
Slab Replacement	\$50 - \$100/sq.yd. [5]	20+
Thick Hot Mix Overlay (5")	\$195,000 - \$215,000	8 - 12

[1] Since some treatments are often limited to one lane, costs shown are per lane-mile, unless otherwise noted.

[2] Varies but ranges from \$25,000 - \$35,000 per two-lane mile with surfaced shoulders. Random, working cracks on high end of estimate.

[3] Diamond grinding = \$38,700/ lane-mile; diamond grinding + dowel bar retrofit = \$115,400/ lane-mile. Both figures include all associated repairs and sealing.

[4] Cross Stitching bars placed at 2' intervals.

[5] Smaller per unit cost for large quantities (\$700,000/ two-lane mile).

Chapter 5:

Recommended Treatment Practices

As stated in the Introduction, there are many variables that influence the selection of the right treatment. After the treatment is selected, there are still many choices as to the proper procedures and materials to use.

The information presented in this Chapter is believed to represent "good, sound practice" for a number of the treatments that have been previously identified. Various Districts prepared this information based on what has been found to work best in their areas under the circumstances where they were tried. Nothing being presented is intended to keep supervisors and superintendents from using his/her own methods, if previous performance has been satisfactory. However, Districts are encouraged to try the practices described in this Chapter, if your current efforts are not producing the desired results. The detailed tracking system being implemented by Materials and Research Division will help determine the effectiveness of the various methods and will provide guidance for future decision making. A copy of the electronic form that is to be completed by the Districts is shown on the following page.

The Materials and Research Division should be contacted for information regarding strategies not described in this Chapter.

PREVENTIVE MAINTENANCE TRACKING FORM

The following section of highway has recieved a Preventive Maintenance treatment:
(Do not submit unless both lanes of a 2-lane or at least two lanes of a 4-lane and the section length is equal to or greater than 1/2-mile.)

Submitted by:

Date:

Highway:

Reference Posts: Beg End

(Provide lane direction for 4-lane roads)

Type of Work:

- ☐ Crack Seal/Asphalt
- ☐ Fog Seal
- ☐ Scrub Seal
- ☐ Slurry Seal
- ☐ Armor Coat/Chip Seal*
- ☐ Milling
- ☐ Cold-in-place Recycle*
- ☐ Hot-in-place Recycle*
- ☐ Thin Cold Mix Overlay*
- ☐ Thin Hot Mix Overlay*
- ☐ Joint Sealing/PCC
- ☐ Dowel Bar Retrofit / Grinding
- ☐ Microsurfacing
- ☐ Diamond Grinding

Work Done By:

○ State Forces ○ Contractor

Control Number **Project Number**

Date Started: **Date Completed:**

<u>Optional Data</u>

Surface Temperature Range: to

Air Temperature Range: to

Vendors:

Aggregate Information (washed / crushed / limestone, etc.):

Type of Oil:

Crack or Joint Sealant Information (brand / variety, etc.):

Comments:

INFORMATION TO BE COMPLETED BY TRANSPORTATION PLANNING / PROJECT DEVELOPMENT:

NSI prior to Preventive Maintenance Treatment: ________ **Date:** _____/_____/________

Preventive Maintenance

Crack Filling and Sealing Procedures-Asphalt Pavements

In the past, there has been little distinction between **Crack Sealing** and **Crack Filling**. In addition to the definitions provided in the Glossary, remember that the working cracks requiring sealing are usually transverse. Non-working cracks, that may be filled, are usually diagonal, longitudinal, or some block cracks.

Crack filling and sealing is probably the most important and cost effective preventive maintenance strategy. Because of this importance, detailed information is provided for your use. Procedures used by Districts 7 and 8 are listed below, as are some of the guidelines supplied by Materials and Research Division. Suggested personnel and equipment needs are also included.

Crack filling and sealing is our first line of defense in roadway maintenance. **Crack sealing should be done within 2 years after an asphalt overlay. Cracks ¼-inch or wider should be filled or sealed before rainfall seasons or before maintenance surface treatments, such as fog seals, scrub seals, slurry seals, chip seals, maintenance overlays, etc., are applied.**

Cracks should be routed and cleaned before filling or sealing. When moisture is present or suspected, it is recommended hot compressed air (heat lance) be used to prepare cracks immediately before filling or sealing materials are applied. All cracks should be squeegeed during filling and sealing (if product is left above the surface) to save materials, prevent road noise, improve ride quality, prevent bleeding or masking through future surface treatments, and prevent compaction problems on future overlays.

Crack sealing operations can be very labor intensive. A value engineering study concluded that 66 percent of the total cost for these projects was for labor, 22 percent for equipment, and 12 percent for materials. Because crack sealing takes a lot of time, workers are exposed to traffic and motorists encounter delays. **Therefore, it is safer and usually more cost-effective to use a product that will last longer, even if it is more expensive.**

Figure 5.1 Heat Lance

Filling or sealing pavement cracks to prevent water from entering the base and subbase likely will extend the pavement life by 3 to 5 years.

Sealing the cracks with flexible rubberized asphalt that bonds to the crack walls and moves with the pavement will prevent water intrusion. Because fillers do not expand or contract, we can conclude that sealing is the better option. Sealing will last longer and cost less.

Sealing prior to surface treatments enhances the treatment and further extends the pavement life. At a time when highway crew manpower is shrinking, along with the funds to support road maintenance, crack sealing stands out as an economical maintenance technique.

The overall success of pavement maintenance systems that include crack sealing, combined with their generally low cost, make crack sealing a desired maintenance treatment. Crack sealing provides the most cost-effective use of dollars over time compared to other pavement maintenance techniques.

Equipment

Using the right equipment is an important part of any crack sealing program. There are two major areas of consideration: crack preparation and sealant application. In the same way that a dentist prepares a tooth before filling a cavity, crews must prepare cracks to receive sealants. The better the preparation, the better the chance that the sealant will last and perform. Cracks must be free of all dirt, dust and debris. The sealant must have a clean, dry bonding surface.

Surface preparation can be accomplished with compressed air and a simple blowpipe. This technique works well when the dirt is dry and not packed hard. If the cracks are filled with wet dirt, the dirt needs to be removed and the crack must be completely dried. An air compressor or a hot air lance generating temperatures of approximately 2,500 degrees Fahrenheit is the best tool. In simple terms, a heat lance uses hot, compressed air that blows cracks clean while drying them out. **Results from the Strategic Highway Research Program (SHRP) study showed there is almost a 40 percent greater chance of sealant success if cracks are routed prior to sealing.** Cutting a reservoir above the crack allows adequate sealant expansion and contraction. The reservoir also ensures that the proper amount of sealant penetrates the crack. An operator passes the pavement cutter or router over the crack and cuts a reservoir into the crack. Modern routers can follow even the most random pavement cracks. Once the routing is complete, simply use

Figure 5.2 Router

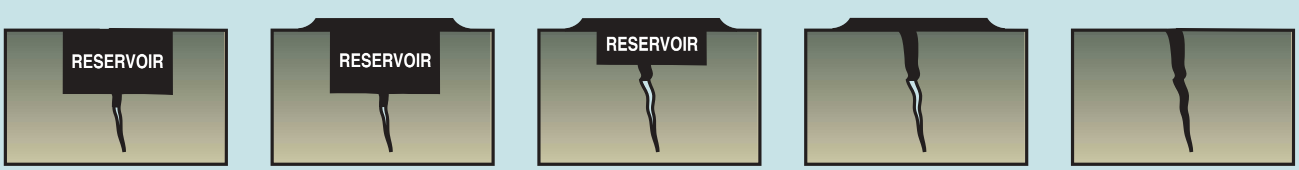
compressed air (hot or cold) to remove the dust created by the router. Engine-powered steel wire brushes also can be used to clean routed and non-routed cracks. *(Note: Older-aged asphalt pavements and thin asphalt pavements may not be suitable for routing.)*

Although tar pots are still used for applying mineral-filled materials, they will burn or destroy crack and joint sealants that utilize polymers or rubbers. Melters eliminate this problem by using a high-temperature heat-transfer medium, such as oil. These types of melters are known as “oil jacketed” melters or “double boilers.” Hot pour sealants are effectively applied through a delivery hose and wand. These materials are commonly applied at 375 degrees Fahrenheit To prevent sealant cooling, set up, and clog, the hose is placed under constant pressure and the sealant constantly circulates back into the main tank. Crew members, therefore, must be trained not only in proper safety procedures, but also in proper operation of the melter. Recent innovations in melter designs have greatly improved melter safety. Melters with “on demand” pumping and thermostatically controlled delivery hoses reduce the chances of mistakes and improve productivity. These newly designed melters also reduce operator confusion. Digital temperature controls, the absence of flush clean up systems and perplexing timing of valves and rapid heat up times have given operators more precise control over sealing. This ease reduces costs, increases productivity and greatly improves safety. Many melter manufacturers claim superior features and benefits for their equipment.

It is in your best interest to fully examine individual features and keep in mind not only the manufacturer’s general reputation but also the availability of parts and services. Product and service support often is important to on-time job completion.

Sealant Application

Sealant application can be accomplished in a variety of ways. Twelve methods are outlined in the Strategic Highway Research Program



Configuration A.
Standard Reservoir-and-Flush

Configuration B.
Standard Recessed Band-Aid

Configuration C.
Shallow Recessed Band-Aid

Configuration D.
Overband

Configuration E.
Flush Fill

The combination of reservoir and an overband helps to maximize sealant performance. Life cycle costs show that by utilizing either crack sealing configuration B or C, the cost of crack sealing is 50% less than that of using configuration D.

Figure 5.3 Sealing & Filling Diagram

(SHRP) publication Materials and Procedures for Sealing and Filling Cracks in Asphalt-Surfaced Pavements. (SHRP-H-348). The success of each method is not only determined by configuration but also by cleaning technique and sealant selection. Sealants applied in routed cracks perform longer. A recessed configuration dispenses material into the confines of a routed crack. The sealant can be placed flush with the pavement, slightly below the surface of the pavement or slightly overfilled on the surface.

Pavement Selection

Pavement selection is often a forgotten element in determining the success or failure of a crack sealing program. If the road has alligator cracking, high-density multiple cracking, poor subbase drainage or structural damage, crack sealing will not solve the problem. In these cases, the damage is too severe. If you try to save a pavement with too much cracking, you will be disappointed with your efforts. The best candidates for crack sealing are newer pavements that are beginning to form cracks. You certainly can extend the life of these roads. More sealant is not always better. The new sealants are not designed to be "road glue." They are very sticky and have tremendous bonding power, but they are not made to "hold the road together." Crack sealing has one objective: to prevent water from further damaging roads. Sealing buys time and saves money by delaying the expense of major reconstructive pavement work.

Priority

Crack filling and sealing operations are to be performed as part of a comprehensive maintenance program. This will take time to accomplish and a greater dedication of resources until we achieve the goal of making these operations a routine maintenance function throughout the State.

Criteria for Crack Filling and Sealing

Crack filling and sealing on newer pavements should be considered a high priority item and cracks should be filled as soon as possible after detection, preferably in the first fall crack filling period after they initially appear.

Priority for crack filling and sealing on older pavement should be based on the condition of the pavement and on the condition of the cracks. The potential for moisture related pavement damage must be evaluated in order to establish both the need and urgency for resealing.

The factors that should be considered in establishing the priority for crack filling on older pavements include:

- ✔ Weather
- ✔ Age of pavement
- ✔ General pavement condition
- ✔ Type and condition of crack

On existing pavements, cracking may be so severe that crack filling or sealing may not be appropriate and other repair methods must be considered.

When to Fill Cracks

Crack maintenance at the proper time with the proper material and methods will reduce overall maintenance costs and prolong the life of pavements. Crack filling and sealing should be a high maintenance priority, whether it is corrective or preventive. Crack filling and sealing can correct the problem of moisture intrusion and help prevent or slow the development of more serious problems thereby extending the life of the pavement.

The optimum environment for performing the crack filling and sealing operations are as follows:

- ✔ Temperature above freezing
- ✔ Minimal moisture present in the pavement
- ✔ Cracks open to approximately the midpoint

It is important to remember that, although crack filling and sealing is not totally dependent on the size of the opening and that the operation can be performed at any time of the year, **moisture in the crack is the critical factor in preventing a quality seal.** The fall of the year usually provides the best conditions because of the moderate temperatures, minimal rainfall, and the cracks are reaching their midpoint in width. This time-frame also prevents the intrusion of water and chemicals during the winter months. During the summer, crack openings would be too small to seal. During the spring, although temperatures are often moderate, crack filling crews may have to contend with the moisture in the pavement.

Since moisture has been identified as a leading cause of failure, additional efforts would be necessary to ensure the crack was dry enough to fill. During the winter, crews would be faced with temperature fluctuations, frozen moisture, and wide crack considerations.

These many considerations do not preclude a quality seal, but would require extra work on the part of the crew to ensure proper preparation of the crack.

It is important to remember that even though crack filling and sealing is not totally dependent upon the crack opening and can be done at all times of the year, the critical factor is moisture.

To minimize the problem of moisture in cracks, a commercial heating unit (heat lance) should be used. Heat lances capable of producing approximately 2,500 degrees Fahrenheit air, with operating velocities of approximately 3000 FPS at the nozzle orifice, have produced good results.

Material

To obtain a good seal, it is important to use a quality product. For cracks 1" wide or less, an ASTM D5078-90 sealant should be used. Application should be made under pressure using a ⅛" diameter nozzle. The use of pour pots is discouraged because very little material gets into the crack and a lot is wasted on the surface. Asphalt with crumb rubber has been shown to work satisfactorily on cracks over 1" wide and up to 1½", but caution must be used. With rubber asphalt products, it is very important to follow the manufacturer's recommended specifications for handling and placing the sealant.

Procedures

Before crack filling and sealing, a pavement analysis should be made to determine the type and scope of work. This analysis is made to determine if crack filling or sealing will be cost effective for the particular pavement being evaluated. See paragraph 2.1 of the SHRP Materials and Procedures For Sealing and Filling Cracks In Asphalt-Surfaced Pavements manual of practice.

Crack filling and sealing can only be effective as long as the sealant prevents the intrusion of water. It cannot be effective when the integrity has failed due to extensive cracking. The pavement analysis may indicate that a chip seal, slurry seal, or an overlay may be needed with badly deteriorated areas being appropriately patched.

Cleanliness and dryness are important factors when crack filling and sealing. Using compressed air with a heat lance is a good method for removing dust, sand and other foreign matter from the crack and will usually provide a clean face for bonding. In addition to drying the crack, the asphalt surface is heated and the asphalt binder softened, which helps bond the sealant.

Crack Filling Prior to Overlay Operations

Crack filling and sealing should be performed well in advance (at least 1 year) and independent of any type of overlay operation in order to allow sufficient cure time for the sealant. This is particularly important on overlays 2 inches or less in thickness, where tearing, shoving, and/or wash boarding can occur during rolling due to the influence of crack filler material expanding up into the fresh hot asphalt pavement.

When traffic picks up or pulls out filler material, sand should be used for blotting. In general, this situation can be avoided by not overfilling and by using squeegees on the freshly filled cracks and confining any excess to a 4" band over the crack.

Training Requirements

Prior to beginning crack filling and sealing operations, all personnel involved should receive the following training:

A 1-hour session covering the following items:

- ✔ Importance of crack filling and sealing operations
- ✔ Equipment requirements
- ✔ Manpower requirements
- ✔ Safety requirements and equipment
- ✔ *Specialized equipment
    - *Melter operations
    - *Hot compressed air lance operations
    - *Air compressor operations
    - *Router operations

*Use/operation of each piece of specialized equipment should be demonstrated to people that may operate such equipment prior to use on the job site. New operators should demonstrate proficiency prior to being required to operate specialized equipment.

Equipment and Manpower Requirements

Equipment and personnel requirements are listed below. As stated previously, crack filling and sealing is very labor intensive. Approximately 3 to 5 people are needed for a routing operation (depending on flagging needs). An additional eight people are required for efficient and safe crack filling operations.

- ✔ One person to drive melter truck
- ✔ One to operate melter
- ✔ One to pour/fill cracks
- ✔ One to squeegee cracks
- ✔ One to drive air compressor vehicle
- ✔ One to operate HCL (hot compressed air lance)
- ✔ Two flaggers for safety

Not routing reduces personnel needs by about 4 people, which represents about 33% lower labor costs. A supervisor must weigh that against the increased performance of routed and sealed cracks.

For example, if routed and sealed cracks have a service life of 5 years and non-routed and sealed cracks have a service life of 3 years, it is still more cost effective to rout and seal. However, not all surfaces are candidates for routing and if the necessary life of the treatment is relatively short, routing may not be appropriate.

Equipment needs for the sealing operation are:

- ✔ One towed air compressor
- ✔ One pickup or other truck to tow air compressor
- ✔ One propane bottle mounted in bed of pickup
- ✔ One hot compressed air lance
- ✔ One melter
- ✔ One pickup or other truck to tow melter and haul material to be added to melter
- ✔ Two flagging vehicles for transportation of flaggers, barricades and traffic control signs as per the Maintenance Manual and Section 900 of the Standard Plan for traffic control.
- ✔ Two hand-held two-way radios for flaggers
- ✔ One squeegee

Equipment and flagging needs for the routing operation is dependent on whether it is done separately, ahead of the sealing, or as part of the sealing operation.

Normal productivity is 3800 lineal feet of crack filling per day, which represents treatment of approximately 1 mile of 2-lane pavement.

Safety Considerations

In addition to the recommended flagging operation and warning signs, the following equipment and safety considerations are necessary:

- ✔ One type 4A4OBC 10-pound fire extinguisher to be mounted in the bed of the vehicle towing the air compressor

- ✔ One type 4A4OBC 10-pound fire extinguisher mounted on the melter
- ✔ One first aid kit in each of the air compressor and melter vehicles
- ✔ Suitable eye protection (goggles or face shield) for HCL operator, crack sealer/pourer and router operator
- ✔ Gloves for HCL operator, crack sealer/pourer and router operator
- ✔ Safety vests and caps for each person
- ✔ Steel toed boots for all people

Care should be taken when using the heat lance. Burns may be possible from super heated air and flying debris. Care should be taken around dry or flammable material. Care should be used when using the melter, wand or squeegee. Burns may be possible from the hot tar. Propane bottles should have approved valve protection and be secured in the pickup.

References

The crack sealing and filling information presented above, was gathered from a number of sources. District 7 personnel conducted interviews with highway personnel from Colorado, Kansas and Nebraska. Current crack filling procedures from these states were also reviewed. Finally, two additional documents, the SHRP <u>Materials and Procedures For Sealing and Filling Cracks In Asphalt-Surfaced Pavements</u> and The U.S. Army Corps Of Engineers, Cold Regions Research and Engineering Laboratory (CRREL) <u>Report 92-18</u> were extensively consulted.

The information in this manual should be used in conjunction with those two documents.

There are no hard and fast rules to follow in crack filling and sealing. One has to consider: 1) traffic volume, 2) age of surface, 3) density of cracks, 4) deterioration of cracks, 5) when is next rehabilitation project scheduled, 6) personnel resources, 7) equipment resources, 8) safety of personnel, 9) other maintenance problems, etc.

Sealing materials that are currently being used are ranked as follows:

- ✔ Crafco AR-2, the lowest quality we are using, is recommended for Sealing (possibly Filling). **For FILLING wider, non-working cracks this material is most practical in either flush or overbanded installation when not routing.** The presence of crumb rubber chunks limits its placement in very narrow cracks.

- ✔ Type I, contains recycled rubber, being a little softer for cold weather locations and it is recommended for Sealing (possibly Filling). **Whether FILLING or SEALING, flush or overbanded installation, we recommend routing which will increase length of time of good performance.**

- ✔ Type II, contains recycled or virgin rubber, and is more resilient than Type I and it is recommended for Sealing. **Again, we recommend routing cracks, with flush or overbanded material installations. They should perform TWICE as long as non-routed cracks. It is also VERY important that the cracks are clean and dry.**

✔ Crafco 231 Low-modulus, very good cold temperature properties and it is recommended for Sealing. **Routing is required to insure the sealant is below the surface. It is also VERY important that the cracks are clean and dry.**

Note: Do not use Low-Modulus material in longitudinal cracks which are anywhere near the wheel path because it will track and pull out!

Cracks less than ¼-inch wide have little movement during temperature variations. It is recommended that these cracks be routed and filled with a material such as AR-2. If not routed and filled, a hot kettle of PG58-28 left over from an asphalt project may be the most practical to use. It's quick and easy to place (pour), it has a short cure time, and any PG Binder has good adhesion properties.

The most successful crack treatments consist of at least three and up to five steps, depending on the type of treatment (sealing or filling). These steps are:

1. **Crack routing or sawing**
2. **Crack cleaning and drying**
3. **Material preparation and application**
4. Material finishing/shaping
5. Blotting

Steps 4 and 5 are considered optional. **Concentrate on 1, 2 and 3 at all times to insure the greatest success.** Crack routing or sawing isn't as critical in filling operations, but needs to be done in sealing operations. With Nebraska's significant annual temperature variations, crack routing or sawing in sealing operations is even more important to achieve shape factors that provide added flexibility for withstanding high crack movements.

Note: When routing, insure that you rout through any surface treatments down into the hot mix asphalt. You may lose the sealant and the surface treatment adjacent to the crack, if the sealant is bonded only to the surface treatment. This can get very ugly and be cause for added maintenance problems.

Joint Resealing-Concrete Pavements

Many of the recommendations presented in this section are the result of 5 years of research done through the Federal Highway Administration, Long Term Pavement Performance Program (LTPP). This research validated earlier research done as part of the Strategic Highway Research Program (SHRP-H-349) and is presented in detail in a manual of practice (FHWA-RD-99-146).

Joint sealants serve two primary purposes; prevention of incompressible materials and water from entering the joint. To be effective, the sealant must resist the embedment of incompressible material. It must also maintain adhesion to the concrete sidewalls.

Since joints in concrete pavement are sealed as part of new construction, the issue becomes "When is resealing appropriate?" Excessive delay in resealing can result in a more rapid deterioration of the pavement. Spending money to replace the sealant too early is not cost-effective either.

Four things should be considered when deciding whether to reseal joints: 1) climatic conditions, 2) sealant condition, 3) pavement condition, and 4) traffic. Since Nebraska is in a Wet/Freeze region, sealants are very important. Also, since most of the concrete pavements have medium to high traffic volumes (>5000ADT), good sealants are again important. A sealant such as the Low Modulus Rubberized Asphalt meeting a modified ASTM D 3405 specification that we use (Crafco 231), should last for 5 years.

If pavement condition dictates the need for a surface treatment in fewer years than that, the joints should still be sealed but a less expensive, temporary seal such as a Rubberized Asphalt, Type II may be used.

In general, the FHWA manual recommends that under Nebraska climatic and traffic conditions, joints should be resealed when the sealant condition rating is Fair to Poor.

A sealant condition is rated **Fair** when water cannot enter in more than 10-30% of the length, and stone intrusion is limited to mostly being stuck to the top of the sealant with very little being deeply embedded. It is recommended that 10 or more joints, that are considered representative of the section, be inspected carefully and rated before making a decision.

Once the decision has been made to reseal, other repairs such as corner breaks, spalls, grinding, etc. should be done before resealing begins. Also, evaluate the sealing needs of the longitudinal joints, lane-shoulder joints, and transverse cracks since considerable water can enter through these if open.

Like sealing cracks in asphalt, **the proper joint preparation and final cleanliness of the concrete joint walls prior to installation and the proper installation procedures are critical for a long-lasting, successful sealant operation.**

Procedures found to be effective are as follows:

- ✔ Plow or saw the joint to remove as much of the existing sealant as possible. If the existing sealant does not gum-up the blades, then saw. If it does gum-up the saw blades, plowing is the way to go.
- ✔ Next, consider water washing when you feel additional cleanliness of the joint is needed. This will seldom, if ever, be needed.
- ✔ Give the joints a good initial air blasting to remove loose material in the joint.
- ✔ Next, **Sand Blast the Joints! This procedure has been found to be a MUST if the seal is to perform to our expectations.** Using this procedure and the Low Modulus material should provide a joint seal that will last at least 5 years.
- ✔ Give the joints another air blast to remove any debris left after the sand blasting.
- ✔ Properly install the Backer Rod. Correct size backer rod will be at least 25 percent larger than the joint width. The backer rod should be place at such a depth so the “shape factor” of the sealant is proper for the sealant material being used. The shape factor for the Low Modulus and the Type II sealants mentioned above is 1:1, width to thickness. When figuring the depth for placement of the backer rod, keep in mind an allowance for the sealant to be recessed below the pavement surface.
- ✔ Installation of the sealant is the final step in the sealing operation. **Make sure Low Modulus material is recessed below the pavement surface, it will track and pull out if exposed to traffic contact.** Although not as critical with the Type II, it is recommended that it also be recessed.

Joint resealing will not perform as intended if the surfaces are not completely clean (no dust when running a finger along the joint wall). The surface must also be dry.

Seal Coats

Asphalt roadway surfaces tend to deteriorate over time as the elements of nature cause the asphalt to become hard and brittle. This often occurs in the form of raveling or surface cracks. Application of a seal coat can restore the resilient properties of the asphalt surface and prevent further deterioration. Seal coats will **not** help the load carrying ability of a roadway.

Experience has shown when proper preparation has been done in areas scheduled for seal coat type surface treatments, the life of the surface treatments can be greatly extended and help in reducing life-cycle cost. It is critical that all necessary preparation work such as crack filling, pothole repair, patching, leveling, core outs, etc., be done prior to surface treatments being placed.

Seal coats commonly used in roadway maintenance are fog seals, scrub seals, slurry seals, and chip seals. Seal coats should not be placed over AC mixes with a history of moisture sensitivity or stripping problems.

The type of seal coat selected should be dictated by the following guidelines and site-specific field conditions.

A. Fog Seal

A fog seal is a light application (0.12 gal./sq.yd.) of a slow-setting asphalt emulsion diluted with water, similar to a tack coat, to an existing surface. It can be diluted in varying proportions up to one part emulsion to five parts water, but in most cases a one to one dilution is used. Grades of asphalt emulsion normally used for this purpose are SS-1, SS-1h, CSS-1, or CSS-1h.

A fog seal should be considered for application, 4 years after an asphalt overlay, and be completed by August 31st. It is important that fog seal not be applied until sealed cracks have undergone at least 2 seasons of oxidation. Also, a fog seal should not be applied to any pavement with existing low skid numbers (signed slippery when wet).

A fog seal can be a valuable maintenance aid when used for its intended purpose. It is neither a substitute for an asphalt surface treatment nor other types of seal coats. It is used to renew old asphalt surfaces that have become dry and embrittled with age and to seal very small cracks and surface voids. Open-graded asphalt surfaces such as the MQ mix require fog seals on a two to three year basis to prevent raveling. The fairly low viscosity diluted emulsion flows easily into the cracks and surface voids. It also coats aggregate particles on the surface. This corrective action will prolong pavement life and may delay the time when major maintenance or reconstruction is needed.

Typically, fog seals are used to seal shoulders and dikes, dig outs, blankets, and patches. Also, they are used as a flush coat (with good success) on newly applied chip seals to provide better rock retention, which can assist in preventing broken windshields and other damages to vehicles. Normally, sand is used as a cover material after applying a flush coat.

Care should be taken to keep traffic off of the newly sealed surface until the emulsion has broken which usually occurs in one to two hours. Even though the application is light, special care must be used when going around curves to keep traffic away from the oil that has a tendency to flow because of the super elevation.

Normal crew size for fog sealing is five. Unless special traffic control is required, equipment needs are a distributor truck and a pickup. The operation proceeds rapidly and daily productivity is approximately 25,000 square yards on non-Interstate and 20,000 square yards on Interstate highways.

B. Scrub Seal (Broom Seal)

A scrub seal may be used effectively to fill cracks in cases of low to moderate non-working cracks, as long as the roadway profile is good.

A scrub seal is normally an application of a polymer modified asphalt that is broomed into the pavement surface followed by a cover of fine aggregate (sand), and a second brooming. The seal should then be rolled with a pneumatic roller. These seals may be used to improve skid resistance, prevent oxidation, and to seal hairline cracks against water infiltration.

Figure 5.4 Apply asphalt

Figure 5.5 Apply fine aggregate

Figure 5.6 Drag broom

Figure 5.7 Drag broom

C. Slurry Seal

A slurry seal is a mixture of slow setting emulsified asphalt, well-graded fine aggregate, mineral filler, and water. It will fill fine cracks in the pavement surface, fill in slight imperfections and give a uniform color and texture. It slows down the rate of surface oxidation but most importantly it seals the highway, thus preventing the infiltration of water, which is the most frequent cause of pavement failure. **Generally, this strategy performs best when ten percent or less alligator cracking is present (i.e. when extent rating = trace).**

Figure 5.8 Slurry Seal

The product may be used as a substitute for our traditional "chip seal" and "hot mix" paving methods. Unlike "chip seal," there are no loose stones or dust to contend with. There is a residue (sandy grit) that remains loose on the finished surface, but it dissipates in a short time.

Slurry seals can be placed in areas with pavement and ambient temperatures as low as 50 degrees Fahrenheit when approved by the Maintenance Superintendent. Normally, slurry seals are not placed if the wheel paths on the surface to be treated have depressions greater than ½-inch, or if the treatment must be placed at night. If these two conditions exist, the use of a slurry seal should be evaluated on a case-by-case basis.

It is suggested that if a slurry seal is believed to be the appropriate treatment, contact Materials and Research Division for verification. Although some of this type of work has been done with State forces, contracting with firms that specialize in this type of work may be more cost effective.

D. Chip Seal (Armor Coat)

Chip seal should be used in cases where light to moderate cracking, light to moderate "raveling", or light to moderate polishing or flushing is occurring. Additionally chip seal should be used to seal "machine patches".

Chip seals provide skid resistance and improve ride quality, as well as seal the roadway. This work should be scheduled so it can be completed by September 30th.

Chip seals generally consist of applying asphaltic emulsions or liquid paving grade asphalts (with additives) and then covering them with aggregate and rolling. Chip seals are a very good surface treatment if they are placed correctly. Consideration should be given not to place them at politically sensitive areas (e.g., high ADT due to special events), high percentage of truck traffic, or where extremely heavy snow and ice removal operations are common.

All cracks should be sealed prior to chip sealing, as chip sealing is not a substitute for crack sealing. Also, centerline tabs must be placed before chip sealing.

It is recommended that sand/gravel aggregate be crushed to provide the gradation shown in the table below.

Table 5.1 Chip Seal Aggregate Gradation Limits

Sieve Size	Percent Passing Target	Tolerance
3/8 inch	100%	---
No. 4	70%	±10%
No. 10	30%	+5% *
No. 50	5%	±5%
No. 200	2%	±2%

* Pay penalty for value > 35% passing

The use of crushed material should provide better performance and the smaller, "one size" gradation should provide a quieter ride. Where crushed limestone is available, it is recommended that ¼" chips be specified. ***Regardless of which crushed material is used, it is important that clean material be used***. With too much #200 sieve material, the emulsion may not stick to the aggregate.

The use of non-crushed aggregate should be limited to only the very lowest volume roads (if used at all).

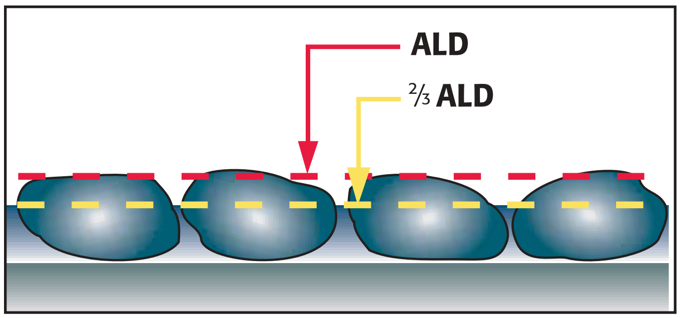


Figure 5.9 Armor Coat Placement

Figure 5.10 Apply

There is also a tendency to apply more aggregate than is required, which ultimately just gets swept off the road and wasted. With the correct amount, trucks backing on the aggregate will give the appearance of nearly bleeding and a sweep of the hand will brush very little excess aggregate off the surface. Application rates should be about 200 tons/mile (24′ wide), or approximately 28 lbs/sq. yd.

The emulsion should be applied at a rate of 0.27 gal./sq.yd. and at a temperature of 160-170 degrees Fahrenheit. Although there are many choices of oils to use, the best success has come from using CRS-2P, CRS-2L and CRS-2, with the CRS-2P being used for higher ADT's and CRS-2 for low ADT's.

Nozzles on the distributor bar should be set at 12 inches above the pavement surface and angled so all areas are covered.

The distributor truck should be operated immediately ahead of the trucks applying the aggregate (no more than 20 seconds ahead). When necessary to switch trucks hauling the aggregate, the distributor must stop to prevent applied oil from becoming cool.

After the oil and aggregate have been placed, the surface should be rolled two to three times with a pneumatic roller(s). Excess aggregate may be lightly swept from the road at the end of the day or no later than the next morning.

During the chip sealing operation, at a minimum, traffic should be controlled by flaggers. If traffic volumes are high, the use of a pilot vehicle is recommended.

Proper warning signs and reduced speed signs should remain in place until all excess material has been removed.

The chip sealing operation may be done with a crew of 8 people and the following equipment: 1 Distributor Truck, 4 Tandem Trucks, 1 Roller, 1 Chip Spreader, 2 Pickups, 1 Rotary Broom, and possibly a Loader and Portable Traffic Control Device.

An operation such as described above can accomplish about 10,000 square yards or roughly ¾ mile of two-lane highway in a day. Since this represents only about one-half the amount of oil on a normal semi-load, some Districts combine forces in order to use one, two or even three loads in a day. For example, a District 7 chip seal operation consists of 5 Tandem Trucks, 2 Distributors, 1 Loader, 2 Rubber-tired Rollers, 1 Chip Spreader (2 people to operate), 2 Flaggers and a pilot car, 2 people to set tabs and move signs and 2 supervisors for a total of 19 people. The broom crew consists of 3 Brooms, 2 Flaggers and a pilot car, and 1 Water Truck (to control dust while brooming). An operation such as this can expect to chip seal two to three miles per day.

Microsurfacing

Microsurfacing refers to a mixture of polymer modified asphalt emulsion, mineral aggregate, mineral filler, water, and other additives, properly proportioned, mixed, and spread on a paved surface. Microsurfacing differs from slurry seal in that it can be used on high volume roads to correct wheel path rutting and provide a skid resistant pavement surface.

Although Nebraska has limited experience with the use of Microsurfacing, literature such as FHWA – SA-94-051, State of the Practice Design, Construction, and Performance of Micro-surfacing and from the International Slurry Surfacing Association (ISSA) provided much of the following insight.

Using various design mixes, techniques, and equipment, Microsurfacing can be used successfully in these situations:

- ✔ Capable of filling wheel ruts up to 1½ inches deep when the pavement has stabilized and is not subject to plastic deformation. Microsurfacing creates a new, stable surface that is resistant to rutting and shoving in summer and to cracking in winter. Microsurfacing has the unique ability to solve this problem without milling.
- ✔ In quick-traffic applications as thin as ⅜-inch, Microsurfacing can increase skid resistance, color contrast, surface restoration, and service life to highways. Such projects are often reopened to traffic within an hour.
- ✔ Modern, continuous-load pavers can lay 500 tons of Microsurfacing per day, with no long traffic delays. This equates to an average 6.6-lane miles per day for surfacing applications.
- ✔ As a thin, restorative surface source on heavy traffic intersections, Microsurfacing does not alter drainage; there is no loss of curb reveal.
- ✔ Because Microsurfacing can be effectively applied to most surfaces at ⅜-inch or less, more area per ton of mix is covered, resulting in cost-effective surfacing.
- ✔ Applied to both asphalt and portland cement concrete surfaces (usually preceded by a tack coat on concrete), Microsurfacing is often used to restore a skid-resistant surface to slick bridge decking with minimum added dead weight.

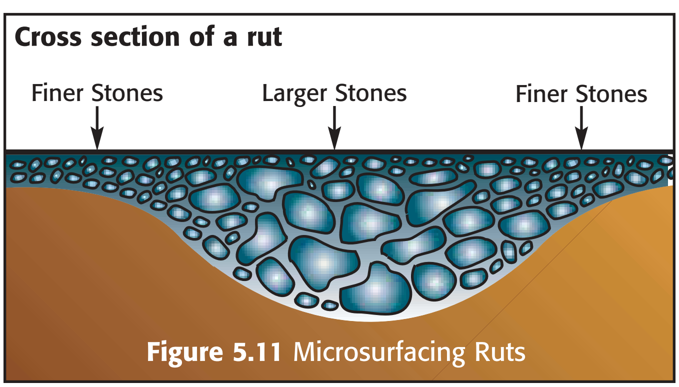


Figure 5.11 Microsurfacing Ruts

Figure 5.12 Surface

- ✔ Because of its quick-traffic properties, Microsurfacing can be applied in a broad range of temperature and weather conditions, effectively lengthening the paving season. Applied at ambient temperatures, Microsurfacing has low energy requirements and it is environmentally safe, emitting no pollutants.
- ✔ Microsurfacing's life expectancy usually exceeds 7 years.

How is Microsurfacing Made and Applied?

Microsurfacing is made and applied to existing pavements by a specialized machine, which carries all components, mixes them on site, and spreads the mixture onto the road surface.

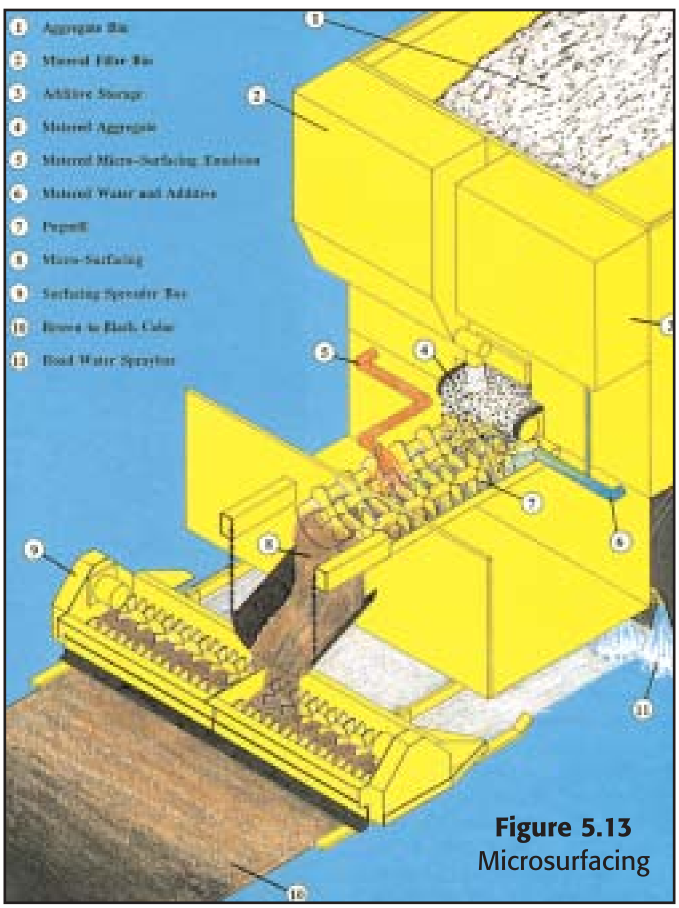


Figure 5.13
Microsurfacing

Materials are continuously and accurately measured, and then thoroughly combined in the Microsurfacing machine's mixer.

As the machine moves forward, the mixture is continuously fed into a full-width "surfacing" box, which spreads the width of a traffic lane in a single pass. Specially engineered "rut" boxes, designed to deliver the largest aggregate particles into the deepest part of the rut to give maximum stability in the wheel path, may also be used. Edges of the Microsurfacing are automatically feathered.

The new surface is initially a dark brown color and changes to the finished black surface as the water is chemically ejected and the surface cures, permitting traffic within one hour in most cases.

Continuous-load pavers utilize support units, which bring the materials to the job site and load the machine while it is working, thus maximizing production and minimizing transverse joints.

A Product of Quality

Successful Microsurfacing incorporates carefully selected materials, scientific mix designs, and advanced technical specifications.

Microsurfacing begins with the selection of high-quality materials—asphalt, aggregate, emulsifiers, water, and additives—which must pass special laboratory tests, both individual and when combined, as a Microsurfacing system.

The ISSA's broad range of specialized mix design tests help to insure that the mixture has these Microsurfacing characteristics:

1. Is capable of being spread in various thick cross-sections (wedges, ruts, scratch course), which
2. After initial traffic consolidation, does not further compact (i.e. resists compaction) throughout the entire design tolerance range of bitumen content and variable thicknesses to be encountered, and
3. Maintains good macro-texture (high wet coefficient of friction) in variable thick sections throughout the service life of the Microsurfacing.

Successful Microsurfacing projects depend on strict adherence to technical specifications. Many users find it helpful to design their individual job specifications around those recommended by ISSA (Technical Bulletin A-143).

The resulting "mix design" and job specifications are carefully adhered to in the field, where ISSA member contractors use specialized job-calibrated equipment and thoroughly trained crews to maintain consistent quality control.

Shoulder Maintenance

Every maintenance supervisor is well aware of the liability associated with shoulder drop-offs.

Since the primary purpose of this manual is to provide information that will aid in pavement preservation, it would not be complete without a reminder that proper shoulder maintenance also plays a major role in how a pavement performs whether it be asphalt or concrete.

It is important to keep the earth shoulders of the roadway graded to the pavement edge with sufficient vegetation. The shoulders provide an escape for run-off.

If water is allowed to stand next to the surfaced roadway, the subgrade may be compromised and major surfacing problems will be the result. This is most likely to occur at the bottom of hills as build-up from sanding operations, natural silting, etc. This problem is not limited to roads with earth shoulders. Often surfaced shoulders trap water on the pavement.

If the shoulders are too high on grades, run-off will be directed along the roadway, causing concentrated flow resulting in shoulder erosion and subgrade failure.

Immediate action to resolve these problems is vital.

Corrective Maintenance

Figure 1.1 on Page 3 shows the overlap between preventive and corrective maintenance. Corrective maintenance is reactive, i.e. it is done after a road is in need of repair.

As the Department proceeds with a more aggressive preventive maintenance program, the need for corrective maintenance will decrease but will never be eliminated. For the last 5 years, nearly 60% of the surface maintenance budget has been spent on various forms of patching (e.g. spot patching, full depth asphalt and concrete repair, hot mix asphalt skin patching, cold mix asphalt patching, and spray-injection patching). The following sections provide a brief description of some corrective maintenance methods used by the identified Districts.

Full Depth Asphalt Repair

Full depth asphalt repair should be considered anytime you have rutting greater than ¾", corrugations and shoving, surface depressions, or a series of potholes. Work should normally be planned between May 1 and September 30 unless frost boils or other problems dictate emergency repair.

The first step of full depth patching is to cut an area, 1-2 feet larger than the distressed area needing repair, by using a wheel cutter or pavement saw. Use a backhoe, milling machine, or front-end loader to remove as much of the pavement as needed, making sure the subgrade is stable. If the subgrade is unstable, remove it also. Restabilize and compact the subgrade to proper depth, using a plate packer. Clean all edges and apply a tack coat to all vertical edges and to the base, if desired. Dump hot-mix asphalt directly into the excavated area, making sure to use enough to allow for compaction. Compact the edges first, then compact from the low to the high side, overlapping about 6-10 inches with each pass. When finished, the patch should match the existing surface.

Equipment required for the above described operation: small milling machine, backhoe, front-end loader, self-propelled roller, pavement cutter, plate packer, oil distributor, power broom, dump truck(s).

Full Depth Concrete Patching

Full depth concrete patching should be considered anytime there is considerable displacement, settlement, spalling, or cracking of panels. The easiest time to handle pavement repair (PR) concrete (i.e. finishing, etc.) is during the spring and fall. Working with PR concrete in the summer is difficult due to its rapid-set properties. In the winter, or any season when the air temperatures are cool, the concrete will not set sufficiently to allow traffic to use it in the normal 4-hour cure time.

It is important to remember that ***PR*** concrete requires the use of 799 pounds of Type III cement and the addition of calcium chloride. Temperatures should be 40 degrees Fahrenheit and rising. The patch must be covered with black jack boards for 4 hours to achieve strength, if air temperatures are above 60 degrees Fahrenheit, and for 8 hours if temperatures are between 40 and 60 degrees. ***If Type I cement is used instead of Type III, the patch should not be opened to traffic for 24 hours.***

Since most of Nebraska's concrete highways are located where traffic volumes are significant, it is recommended that efforts should be made to accurately calculate and only remove the amount of distressed area that can be replaced and cured during a day. ***Also, keep in mind the distance between repair locations, since all concrete should be removed from the truck within 30 minutes after adding the calcium chloride.***

If less than a full panel is to be repaired, start by making a diamond saw blade cut, 2" deep ± ¼" along the area to be removed. Move in 2" ± ½" towards the area to be patched and make a full depth cut with a wheel cutter. Use a bobcat with a breaker on it to break up the concrete and to remove the broken concrete (or a loader if a large area). When the concrete is removed, use a chipping hammer to chip the face of the hole at an angle downward to make a wedge.

Fine grade the hole to a depth 2" more than the existing concrete depth. Compact the subgrade with a walk behind vibrator compactor. Install either bond breaker or tie bars along centerline joint, as applicable.

Add calcium chloride to the concrete, pour concrete, vibrate and finish, cure with curing compound, and cover with black jack boards for a minimum of 4 hours. Do not over vibrate, as this will cause segregation.

Do not add water to the mix or spray water on the concrete when finishing. Adding water lowers the strength and spraying water on concrete brings the cement to the top and will result in scaling.

Saw and seal appropriate joints the following day.

Equipment needed for doing full-depth concrete repair includes: Walk behind saw with diamond blade, wheel saw for bobcat, air compressor and chipping hammer, bobcat with breaker & bucket, dump truck, walk behind plate tamper, concrete vibrator, loader, water supply (truck), generator for power source, concrete power screed (if large area) or strike off board (if small area), cure applicator (sprayer), concrete forms (steel and/or wood), concrete tools such as floats, edgers, shovels,etc., chalk line and black jack insulation boards with plastic protection (bottom).

Production is often limited to one panel per day for a six-person crew due to spacing between panels needing repair and the desire to restore traffic operations before dark.

Spray Injection Patching

Spray injection patching is a quick and safe method that can be used to repair alligator cracking, transverse cracking, edge breaks, depressions, rutting and potholes.

Asphalt mixes basically consist of two components – the aggregate, which provides the structure for the mix, and the asphalt binder, which “glues” it all together. The spray-injection pothole patcher has two separate storage tanks – one for the aggregate and the other for the asphalt binder. The asphalt and aggregate are mixed as they travel under pressure through the machine's spray hose; the mix is then sprayed into the pothole, filling it. A layer of aggregate is then placed on top of the patched area.

This procedure is fast, simple, and efficient. Work crews spend less time toiling dangerously close to traffic, and motorists spend less time waiting for the patch to be applied. The pavement can be opened to traffic almost immediately after patching.

Figure 5.14 Spray Injection (AMZ)

Figure 5.15 Spray Injection (AMZ)

Machine Patch Using Cold-Mix Asphalt

There are numerous types of distress that may be encountered in our highways. The reason for the distress should be determined and action taken to correct the condition that caused the problem.

Some of the surface evidence of various types of pavement distress are: weathering, raveling, longitudinal cracks, alligator cracks, chuck holes, bleeding and instability, depressions, wheel rutting and edge breaking. Frequently there will be more than one of these surface characteristics that will be in evidence at the same time. Sometimes one type of distress may progress to a more serious type of distress.

Alligator cracks are usually caused by a base failure and should be repaired prior to repairing the surfacing. Depressions usually occur because of subgrade settlement or traffic rutting. They may be in the form of rat runs, long swales or may have sheared sides because of sudden earth movement.

These types of distresses may be corrected by machine patching of the roadway surface with maintenance cold mix using a motor grader to eliminate potential surface hazards.

Cold-mix asphalt is a combination of unheated aggregates, fillers, and asphaltic oils. Although gravel and/or sand are the most commonly used aggregates, asphalt millings and crushed concrete have also been used successfully. Clay is the most commonly used filler. Emulsified asphaltic oil is recommended but cutbacks can also be used.

If properly tested and controlled, quality cold mix can be produced from a wide variety of materials as described in the next section.

Figure 5.16 Machine Patching

Cold-Mix Production

The first step is to determine the needed quantity of mix. As a "rule of thumb", 400 tons of cold mix will patch ½ to 1 mile of roadway, depending on the condition of the surface, e.g. a severely rutted road will take about 400 tons per ½-mile or 800 tons per mile.

Second, sample the materials and submit the sample to a Testing Lab for performance of gradation tests, pulverization tests, P.I. determination, and mix design.

Using the mix design, compute the windrow quantities for oil, aggregate, and filler. The windrow site should then be staked for delivery of individual loads of aggregate. ***Prior to hauling gravel and filler, check gradations to make sure they are the same as the mix design. A change in materials can create major problems.*** After all aggregate has been hauled and evenly distributed, place the gravel in a windrow on one side of the mixing platform. The filler should then be computed and staked in a similar manner.

Before hauling the filler to the windrow site, spread a portion of the gravel to a uniform depth, and then dump the filler directly onto the gravel, placing one load between each set of flags. A motor grader can be used to spread the filler uniformly. After all the gravel and filler are in place, mix thoroughly, being careful to not overwork the mixture. At the completion of the mixing, sample the mixture and do a gradation test and a moisture test. The gradation should be close to the mix design or adjustments must be made prior to application of the oil. The desired moisture content of the mixture prior to oil application is 5 to 9%. If too dry, it may be necessary to add water; if too wet, additional mixing will be needed. ***The moisture content and gradation are very critical to producing a quality, consistent mix.***

When the oil tanker arrives, verify that the correct oil has been delivered and that the temperature of the oil is between 105 and 220 degrees Fahrenheit. ***Always use safety gear when working with oil, including gloves, eye protection and protective clothing.***

Although the oil can be applied directly from the tanker, a distributor with a meter is the recommended method of oil application. This will provide the desired, uniform oil application on any windrow site, whether hilly or flat. Determine the number of passes needed to add the entire quantity of oil to the windrow. The application rate when using a distributor can be adjusted by the truck speed and pump pressure. (Consult the manufacturer's recommendations for the proper settings). Pull out the appropriate portion of the windrow needed for one pass of the distributor and spread into a uniform layer. Apply the oil and immediately move the material to the opposite side of the mixing surface. Repeat this process until all of the required oil has been applied.

Mixing should continue with any combination of equipment available, such as blades and rotovaters. The heat in the oil will enhance the mixing operation, speed uniform mixing, and allow proper aggregate coating. When using motor graders, the proper vertical and horizontal angle of the blade should create a rolling action of the cold mix material which speeds the mixing and aggregate coating process. When using emulsified oil, the material should be ready to use as soon as all aggregates are thoroughly coated and the mix is uniform. An experienced operator can tell when the material is ready. The material will appear to crawl when being moved. ***There is a tendency on the part of operators used to working with cutbacks, to mix emulsified windrows too long, as cutbacks require more time for mixing and aerating.***

Generally, if the moisture content is correct when the oil is applied and no additional moisture is received, an emulsified windrow is ready as soon as it is thoroughly mixed. A sample can be taken to a testing lab to determine the actual moisture content. A moisture content of 2 to 5% is optimum for laydown operations.

When the mixing process has been determined to be complete, sample the material and submit to a testing lab for gradation tests and determination of asphalt content. These test results can be useful in determining why a mix was "good" or "not so good".

The residual oil content with an emulsified oil should be approximately 67% of your target; e.g. if the target is 6%, residual asphalt should be 4%.

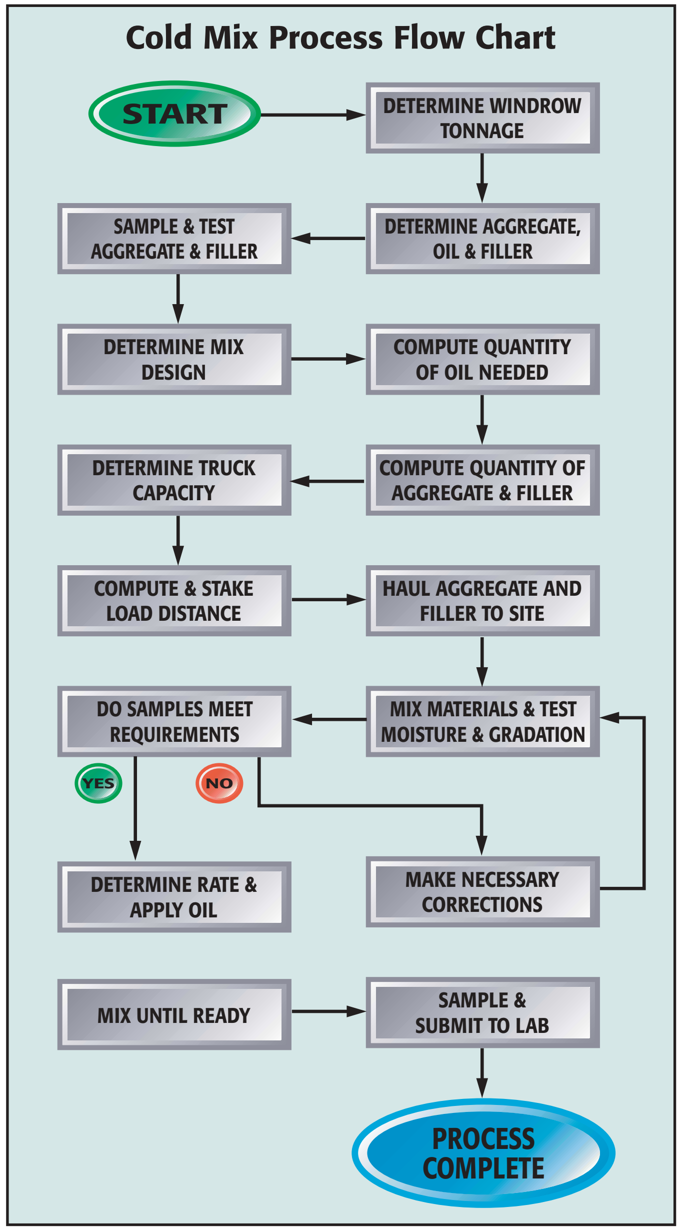


Figure 5.17 Cold Mix Process Flow Chart

A flow chart showing the cold mix process is illustrated above. To obtain additional information regarding cold mix preparation, contact Roger Klasna, District Maintenance Superintendent, (308) 535-8031.

Hot Mix Asphalt Patch

When hot mix asphaltic concrete (HMAC) is available, this is often the material of choice for repairing ruts, corrugations, depressions or raveling. This practice is commonly referred to as skin patching or surface patching. Most skin patches are 1 to 4 inches deep depending on what distress is being remedied. Skin patches may be feathered at the ends to meet an existing grade, the grade at the ends of the patch may be milled to get a better transition, or a portion or the entire distressed pavement may be milled.

After milling, broom the surface and apply a tack coat, waiting until the oil breaks before starting to lay the hot mix. Use enough trucks to assure material can be supplied to keep from having a cold joint in a lane. The lay down machine speed should be consistent and the use of the vibratory screed is recommended since about 80% of the density occurs as a result of its use.

The breakdown roller should stay as close as possible to the lay down machine. The speed should be consistent and no faster than 4 mph. One pass with the breakdown roller (vibratory) and two passes with a finish roller (static) should provide adequate compaction. The finish roller needs to make the final pass before the asphalt cools to 185 degrees Fahrenheit. On small jobs, all compaction can be accomplished with one roller.

The material should cool to around 100 degrees Fahrenheit before allowing traffic to drive on it.

Never allow the use of diesel as a release agent in truck boxes, the lay down machine, or on hand tools. Always use commercial release agents from the Approved Products List that are available locally.

Equipment required for hot mix patching: small milling machine, large milling machine, self-propelled roller (2), lay down machine, trucks, oil distributor, power broom.

Profile Milling

Profile milling may be considered as a possible treatment to restore roadway cross-sections, when wheel rutting is greater than ½”. This may be followed up with either a chip seal or machine patch. Milling may also be used to treat roads with excess asphalt or extreme cases of raveling.

If rutting is caused by poor materials or weak base, milling should be considered as a “temporary fix”, since the ruts will likely reappear in 1 to 3 years. Also, caution must be used if the surface thickness is marginal for the traffic loading.

Determining whether milling is the proper treatment is often a judgment call, considering the severity of the ruts, the cause of the ruts and the overall condition of the road.

When wheel rutting is greater than ½" deep and the asphalt pavement has sufficient thickness, profile milling may be performed to restore roadway cross-sections.

Emergency Maintenance

Safety and time are often the differences between corrective and emergency maintenance. Emergency maintenance needs are unique and specific procedures cannot be defined. However, never take short cuts that sacrifice the safety of the workers performing the emergency maintenance!

One of the most common emergency maintenance needs is patching. Information follows on various patching methods.

Hand Patching

The Strategic Highway Research Program looked at three methods of repairing potholes:

- ✔ The throw-and-roll method, in which the crew simply fills the pothole with patching material, then compacts the patch by driving over it.
- ✔ The semi-permanent method, which involves squaring up the edges of the pothole with a saw or other equipment, placing the repair material, and compacting it with a small vibratory compactor. The technique is effective but very labor-intensive.
- ✔ The spray-injection method, which employs special truck- or trailer-mounted equipment that shoots asphalt and aggregate into the pothole. Although the spray-injection equipment is expensive, the technique is extremely fast and can be done by a crew of just one or two workers. (See detailed description under corrective maintenance).

SHRP found that it is the quality of the materials rather than the repair method used that has the biggest effect on the performance of the pothole patch.

Materials

Conventional asphalt hot and cold mixes typically use certain percentages of asphalt cement (hot-mix) or emulsion or cutback asphalts (cold-mix) and strictly graded aggregate.

Modified/proprietary asphalt materials include the addition of modifiers (rubber, fiber, sulfur, antistripping agent) and specially employed production processes. Examples of the more commonly used materials are Sylvax UPM, Perma-Patch, Fiber Pave, Bonifibers, Omega Mix and QPR 2000.

Performance

Proprietary materials are designed to improve performance under cold and wet conditions.

Hot-mix asphalt is still the #1 patch material

"Bituminous hot-mix has shown the longest service life of all materials when it is placed properly in a dry hole."

Glossary of Terms

Adhesion – Bond between a sealant material and the crack or joint sidewall.

Agency Costs – See Annual Costs

Aggregate Interlock – The projection of aggregate particles or portions of aggregate particles from one side of a joint or crack in concrete into recesses in the other side of the joint or crack so as to affect load transfer in compression and shear and maintain mutual alignment.

Alligator Cracking – See Fatigue Cracking

Analysis Period – The period of time used in making economic comparisons between rehabilitation alternatives. The analysis period should not be confused with the pavement's design life (performance period).

Annual Costs – Any costs associated with the annual maintenance and repair of the facility.

Application Temperature - The manufacturer's recommended temperature to be used when installing sealant. For hot-applied sealants, the application temperature is any temperature between the minimum application temperature and safe heating temperature.

Asset Management – A systematic process of maintaining, upgrading, and operating physical assets cost-effectively. It combines engineering principles with sound business practices and economic theory, and it provides tools to facilitate a more organized, logical approach to decision-making. Thus, asset management provides a frame work for handling both short and long-range planning.

Backer Rods – A compressible material that is placed in joints or cracks before applying sealant to prevent bonding of the sealant on the bottom of the joint, control sealant depth, and prevent sagging of the sealant.

Bituminous Pavement - A pavement comprising an upper layer or layers of aggregate mixed with a bituminous binder, such as asphalt, coal tars, and natural tars for purposes of this terminology; surface treatments such as chip seals, slurry seals, sand seals, and cape seals are also included.

Bleeding – Excess asphalt binder occurring on the pavement surface. The bleeding may create a shiny, glass-like surface that may be tacky to the touch. Bleeding is usually found in the wheel paths.

Block Cracking – A rectangular pattern of cracking in asphalt pavements that is caused by hardening and shrinkage of the asphalt. Rectangular blocks range in size from approximately 1 sq. ft. to 100 sq. ft.

Blow-up – Buckling and shattering of PCC pavement resulting from thermal expansion and the resultant compressive forces exceeding the strength of the material. Occurs at transverse joints or cracks.

Bond Breaker – Any material used to prevent bonding or to separate adjacent pavement layers. Thin bituminous layers are often used as bond breaker layers between a concrete pavement and an unbonded concrete overlay.

Bonded Concrete Overlay – Increase in the pavement structure of a concrete pavement by addition of concrete thickness in direct contact with and adhering to the existing concrete surface. May be used to correct either functional or structural deficiencies. (Based on but not taken verbatim from 1993 AASHTO Guide, p. III-136)

California Profilograph – Rolling straight edge tool used for evaluating pavement profile (smoothness) consisting of a 7.5m (25-ft) frame with a sensing wheel located at the center of the frame that senses and records bumps and dips on graph paper or in a computer.

Cape Seal – A surface treatment that involves the application of slurry seal to a newly constructed surface treatment or chip seal. Cape seals are used to provide a dense, waterproof surface with improved skid resistance and ride quality.

Carbide Milling – Surface removal or sawing done with a carbide milling machine. Machine uses a blade or arbor equipped with carbide-tipped teeth that impact and chip concrete or asphalt.

Chemically Curing Sealant – A material that reaches it final properties through the reaction of the component materials when mixed.

Chip Seal – A surface treatment in which the pavement is sprayed with asphalt (generally emulsified) and then immediately covered with aggregate and rolled. Chip seals are used primarily to seal the surface of a pavement with non load-associated cracks and to improve surface friction, although they also are commonly used as a wearing course on low volume roads.

Cohesion – The internal bond within a joint sealant material. Cohesion loss is seen as a noticeable tear along the surface and through the depth of the sealant.

Cold Applied Sealant – A crack-sealing compound that is applied in an unheated state (generally at ambient temperature) and then reaches final properties through a curing process.

Cold In-Place Recycling (CIR) – A process in which a portion of an existing bituminous pavement is pulverized or milled, and then the reclaimed material is mixed with new binder and, when needed, virgin aggregates. The binder used most often is emulsified asphalt with or without a softening agent. The resultant blend is placed as a base for a subsequent overlay or surface treatment.

Cold Milling – A process of removing pavement material from the surface of the pavement either to prepare the surface to receive overlays (by removing rutting, and surface irregularities) or to restore pavement cross slopes and profile. Also used to remove oxidized asphalt concrete. [Also see carbide milling.]

Compressible Insert – Material used to separate freshly placed concrete (such as from a partial-depth or full-depth repair) from existing hardened concrete. This usually consists of a 12-mm thick Styrofoam or compressed fiber material that is impregnated with asphalt.

Concrete – See Portland Cement Concrete

Construction Joint – A joint constructed in a transverse direction in PCC pavements to control cracking of the slab as it cures. Highway construction joints are created by sawing the concrete.

Continuously Reinforced Concrete Pavement (CRCP) – PCC pavement constructed with sufficient longitudinal steel reinforcement to control transverse crack spacings and openings in lieu of transverse contraction joints for accommodating concrete volume changes and load transfer.

Contract Maintenance – The range of contracting methods and vehicles used by public transportation agencies to accomplish maintenance programs and supplement activities which may be performed in-house. Contracts may be activity based where the agency provides specifications and compensation is either on a lump sum or unit price basis; or performance based, long term total asset management contracting which requires the contractor to provide turn-key maintenance to an established level of service.

Corner Break – A portion of a concrete slab separated by a crack that intersects the adjacent transverse or longitudinal joints at about a 45° angle with the direction of traffic. The length of the sides is usually from 0.3 meters (1-ft) to one-half of the slab width on each side of the crack.

Corrective Maintenance – Maintenance performed once a deficiency occurs in the pavement; i.e., loss of friction, moderate to severe rutting, extensive cracking, or raveling.

CPR (Concrete Pavement Restoration) – CPR refers to a series of repair techniques used to preserve or improve the structural capacity or functional characteristics of a PCC pavement. CPR techniques each have a unique purpose to repair or replace a particular distress (kind of deterioration) found in PCC pavement and to manage the rate of deterioration. CPR techniques include:

- ✓ Full-depth repair
- ✓ Partial-depth repair
- ✓ Diamond grinding
- ✓ Joint and crack resealing
- ✓ Slab stabilization
- ✓ Dowel Bar Retrofit
- ✓ Cross-stitching cracks or longitudinal joints
- ✓ Retrofitting concrete shoulders
- ✓ Retrofitting edge drains

Crack – Fissure or discontinuity of the pavement surface not necessarily extending through the entire thickness of the pavement. Cracks generally develop after initial construction of the pavement and may be caused by thermal effects, excess loadings, or excess deflections. Also see Alligator Cracking, Block Cracking, Longitudinal Crack, Reflection Cracking, Slippage Cracking, Transverse Crack, and Working Crack.

Crack Filling – The placement of materials into non-working cracks to substantially reduce the intrusion of incompressibles and infiltration of water, while also reinforcing the adjacent pavement. Crack filling should be distinguished from crack sealing (see below).

Crack Sealing – A maintenance procedure that involves placement of specialized materials into working cracks using unique configurations to reduce the intrusion of incompressibles into the crack and to prevent infiltration of water into the underlying pavement layers. (See Working Crack.)

Cross Stitching – A repair method that involves the drilling of holes diagonally across a crack in PCC pavement into which steel reinforcement bars are inserted and epoxied in place. The holes are alternated from side to side of the crack on a pre-determined spacing. This technique is generally used for longitudinal cracks that are in fair condition. Cross-stitching increases load transfer by adding steel reinforcement to hold the crack together.

Cure – A period of time following placement and finishing of a material such as concrete during which desirable engineering properties (such as strength) develop. Improved properties may be achieved by controlling temperature or humidity during curing.

Curing – The maintenance of a satisfactory moisture content and temperature in concrete during its early stages so that desired properties may develop.

Curing Blanket – A built-up covering of burlap sacks, matting, straw, waterproof paper, or other suitable material placed over freshly finished concrete.

Curing Compound – A liquid that can be applied as a coating to the surface of newly placed concrete to retard the loss of water, or in the case of pigmented compounds, also to reflect heat so as to provide an opportunity for the concrete to develop its properties in a favorable temperature and moisture environment. See also Curing.

Dense-Graded Asphalt Pavement – An overlay or surface course consisting of a mixture of asphalt binder and a well-graded (also called dense-graded) aggregate. A well-graded aggregate is uniformly distributed throughout a full range of sieve sizes.

Depression - Localized pavement surface areas at a lower elevation than the adjacent paved areas.

Design Life – The expected life of a pavement from its opening to traffic until structural rehabilitation is needed. The typical reporting of pavement design life does not include the life of the pavement with the application of preventive maintenance. (See also Analysis Period and Performance Period.)

Diamond Grinding – A process that uses a series of diamond-tipped saw blades mounted on a shaft or arbor to shave the upper surface of a pavement to remove bumps, restore pavement rideability, and improve surface friction. (See also CPR)

Discount Rate – The rate of interest reflecting the investor's time value of money used to determine discount factors for converting benefits and costs occurring at different times to a baseline date. Discount rates can incorporate an inflation rate depending on whether real discount rates or nominal discount rates are used. The discount rate is often approximated as the difference between the interest rate and the inflation rate.

Dowel – Most commonly a plain round steel bar (usually coated, such as with paint or epoxy), which extends into two adjoining slabs of a PCC pavement at a transverse joint placed perpendicular to the joint so as to transfer shear loads.

Dowel Bar Retrofit – A rehabilitation technique that is used to increase the load transfer capability of existing jointed PCC pavements by placement of dowel bars across joints and/or cracks that exhibit poor load transfer. (See also CPR)

Emulsified Asphalt – A liquid mixture of asphalt binder, water, and an emulsifying agent. Minute globules of asphalt are suspended in water by using an emulsifying agent. These asphalt globules are either anionic (negatively charged) or cationic (positively charged).

Equivalent Uniform Annual Cost (EUAC) – The net present value of all discounted cost and benefits of an alternative as if they were to occur uniformly throughout the analysis period. Net Present Value (NPV) is the discounted monetary value of expected benefits (i.e., benefits minus costs).

Fatigue Cracking – A series of small, jagged interconnecting cracks caused by failure of the asphalt concrete surface under repeated traffic loading (also called alligator cracking)

Faulting – Difference in elevation across a joint or crack. Faulting commonly occurs at transverse joints of PCC pavements that do not have adequate load transfer.

Fiber Modified Sealant – Generally a hot-applied sealant that is composed of unmodified or modified asphalt cement and heat resistant polymeric fibers and is used for sealing cracks in asphalt concrete pavements.

Fog Seal – A light application of slow setting asphalt emulsion diluted with water and without the addition of any aggregate applied to the surface of a bituminous pavement. Fog seals are used to renew aged asphalt surfaces, seal small cracks and surface voids, or adjust the quality of binder in newly applied chip seals.

Free edge - An unrestrained pavement boundary.

Fuel Resistant Sealant – A joint or crack sealant compound that is resistant to and maintains serviceability after being exposed to jet fuel or other petroleum products.

Full-Depth Patching – Removal and replacement of a segment of pavement to the level of the subgrade in order to restore areas of deterioration. May be either flexible or rigid pavement.

Functional Performance – A pavement's ability to provide a safe, smooth riding surface. These attributes are typically measured in terms of ride quality (see International Roughness Index) or skid resistance (see International Friction Index).

Grinding Head – Arbor or shaft containing numerous diamond blades or carbide teeth on diamond grinding or cold milling equipment.

Grooving – The process used to cut slots into a pavement surface (usually PCC) to provide channels for water to escape beneath tires, improving skid resistance and reducing the potential for hydroplaning.

Heater Scarification – The initial phase of a hot in-place recycling (HIPR) process in which the surface of the old pavement is heated and mechanically raked before being removed and recycled.

Hot Air Lance – A device that uses heated compressed air to clean, dry, and warm cracks prior to sealing.

Hot Applied Sealant – A crack or joint sealing compound that is applied in a molten state and cures primarily by cooling to ambient temperature.

Hot In-Place Recycling (HIPR) – A process which consists of softening the existing asphalt surface with heat, mechanically removing the surface material, mixing the material with a recycling agent, adding virgin asphalt and aggregate to the material (if required), and then replacing the material on the pavement.

Hot Mix Asphalt Concrete (HMAC or HMA) – A thoroughly controlled mixture of asphalt binder and well-graded, high quality aggregate thoroughly compacted into a uniform dense mass. HMAC pavements may also contain additives such as anti-stripping agents and polymers.

Hydroplaning – Loss of contact between vehicle tires and roadway surface that occurs when vehicles travel at high speeds on pavement surfaces with standing water.

Initial Costs – All costs associated with the initial design and construction of a facility, placement of a treatment, or any other activity with a cost component.

International Friction Index (IFI) – A measure of pavement macrotexture and wet pavement friction at 60 miles per hour determined using measured friction at some test speed and macrotexture determined using ASTM E-965 or ASTM E-1845. (Based on "Assessment of LTPP Friction Data", publ. # FHWA-RD-99-037, p.6)

International Roughness Index (IRI) – A measure of a pavement's longitudinal surface profile as measured in the wheelpath by a vehicle traveling at typical operating speeds. It is calculated as the ratio of the accumulated suspension motion to the distance traveled obtained from a mathematical model of a standard quarter car traversing a measured profile at a speed of 80 km/h (50 mph). The IRI is expressed in units of meters per kilometer (inches per mile) and is a representation of pavement roughness.

Joint – A pavement discontinuity made necessary by design or by interruption of a paving operation.

Joint Depth – The measurement of a saw cut from the top of the pavement surface to the bottom of the cut.

Joint Deterioration – See Spalling.

Joint Filler – Compressible material used to fill a joint to prevent the infiltration of debris.

Joint Sealant – Compressible material used to minimize water and solid debris infiltration into the sealant reservoir and joint.

Joint Seal Deterioration - Break down of a joint or crack sealant, such as by adhesion or cohesion loss, which contributes to the failure of the sealant system. Joint seal deterioration permits incompressible materials or water to infiltrate into the pavement system.

Joint Shape Factor – Ratio of the vertical to horizontal dimension of the joint sealant reservoir. Factor can vary depending on type of sealant specified.

Jointed Plain Concrete Pavement (JPCP) – PCC pavement constructed with regularly spaced transverse joints to control all natural cracks expected in the concrete. Dowel bars may be used to enhance load transfer at transverse contraction joints (depending upon the expected traffic), but otherwise there is no mid-slab temperature reinforcement.

Jointed Reinforced Concrete Pavement (JRCP) – Portland cement concrete pavement containing regularly spaced transverse joints and embedded steel mesh reinforcement (sometimes called distributed steel) to control expected cracks. Steel mesh is discontinued at transverse joint locations. Dowel bars are normally used to enhance load transfer at transverse joints. The transverse joint spacing of JRCP is typically longer than the joint spacing of JPCP.

Lane-to-Shoulder Dropoff – (highways, roads and streets only) Difference in elevation between the traveled surface and the shoulder surface.

Life Cycle Costing – An economic assessment of an item, system, or facility and competing design alternatives considering all significant costs of ownership over the economic life, expressed in terms of equivalent dollars.

Life Extension – The extension of the performance period of the pavement through the application of pavement treatments.

Load-Transfer Assembly – Most commonly, the basket or carriage designed to support or link dowel bars in the desired alignment during jointed PCC pavement construction.

Load Transfer Efficiency – The ability of a joint or crack to transfer a portion of a load applied on one side of a joint or crack to the other side of the joint or crack.

Longitudinal Crack – A crack or discontinuity in a pavement that runs generally parallel to the pavement centerline. Longitudinal cracks may occur as a result of poorly constructed paving lane joints, thermal shrinkage, inadequate support, reflection from underlying layers, or as a precursor to fatigue cracking.

Longitudinal Joint – A constructed joint in a pavement layer that is oriented parallel to the pavement centerline.

Low Modulus Sealant – A joint or crack sealing material, which is less stiff at low temperatures than standard grade sealants.

Maximum Heating Temperature – The maximum temperature, as recommended by the manufacturer, to which a hot-applied joint or crack sealant can be heated while conforming to all specification requirements and result in appropriate application characteristics.

Melter – A piece of equipment designed specifically to heat hot-applied joint or crack sealant accurately and controllably to a temperature where it will flow.

Melter Applicator – A piece of equipment designed specifically to melt, heat accurately and controllably, and apply hot-applied sealants to pavement cracks or joints.

Microsurfacing – A mixture of polymer modified asphalt emulsion, mineral aggregate, mineral filler, water, and other additives, properly proportioned, mixed, and spread on a paved surface. Microsurfacing differs from slurry seal in that it can be used on high volume roadways to correct wheel path rutting and provide a skid resistant pavement surface.

Minimum Application Temperature – The minimum temperature, as recommended by the manufacturer, to which a hot-applied sealant for pavement cracks or joints must be heated while conforming to all specification requirements and result in appropriate application characteristics.

Modified Asphalt Chip Seal – A variation on conventional chip seals in which the asphalt binder is modified with a blend of ground tire or latex rubber, or polymer modifers to enhance the elasticity and adhesion characteristics of the binder.

Net Present Value – The value of future expenditures or costs discounted to today's dollars using an appropriate discount rate.

Open-Graded Friction Course (OGFC) – A thin HMA surface course consisting of a mix of an asphalt binder and open-graded (also called uniformly graded) aggregate. An OGFC helps to eliminate standing water on a pavement surface, which reduces tire spray and hydroplaning potential.

Overbanding – Overfilling of a joint or crack reservoir so that a thin layer of crack or joint sealant is spread onto the pavement surface center over the joint or crack.

Partial-Depth Patching – Repairs of localized areas of surface deterioration of PCC pavements, usually for compression spalling problems, severe scaling, or other surface problems that are within the upper one-third of the slab depth.

Patch – Placement of a repair material to replace a localized defect in the pavement surface.

Pavement Distress - External indications of pavement defects or deterioration.

Pavement Preservation – The sum of all activities undertaken to provide and maintain serviceable roadways. This includes corrective maintenance and preventive maintenance, as well as minor rehabilitation projects.

Pavement Preventive Maintenance – 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 increasing the structural capacity).

Pavement Reconstruction – Replacement of an existing pavement structure by the placement of the equivalent of a new pavement structure. Reconstruction usually involves complete removal and replacement of the existing pavement structure and may include new and/or recycled materials.

Pavement Rehabilitation – Structural enhancements that extend the service life of an existing pavement and/or improve its load carrying capability. Rehabilitation techniques include restoration treatments and structural overlays.

Performance Period – The period of time that an initially constructed or rehabilitated pavement structure will perform before reaching its terminal serviceability.

Point Bearing – Concentration of compressive stressed between small areas. May occur when a partial-depth patch in portland cement concrete pavement is made without the compressible insert. Also, slab expansion in hot weather forces an adjacent slab to bear directly against a small partial-depth patch and causes the patch to fail by delaminating and popping out of place.

Polishing – Wearing away of the surface binder, causing exposure of the coarse aggregate particles. A polished pavement surface is smooth and has reduced skid resistance.

Portland Cement Concrete Pavement–(PCC) A pavement constructed of portland cement concrete with or without reinforcement. Conventional PCC pavements include JPCP, JRCP, and CRCP.

Potholes – Loss of surface material in an HMA pavement to the extent that a patch is needed to restore pavement rideability. Exhibits bowl-shaped holes of various sizes. Minimum plan dimension is 150 mm (6 inches).

Preformed Compression Sealant – An extruded joint sealing material for PCC pavement that is manufactured ready for installation and is supplied in rolls. Preformed sealants incorporate an internal web design so that the material, when compressed and inserted into the sealant reservoir, remains in compression against the sides of the joint.

Present Serviceability Index (PSI) – A subjective rating of the pavement condition made by a group of individuals riding over the pavement. May also be determined based on condition survey information.

Present Worth – See Net Present Value.

Pumping – Ejection of fine-grained material and water from beneath the pavement through joints and cracks caused by deflection of the pavement under traffic loadings.

Raveling – Wearing away of the pavement surface caused by the dislodging of aggregate particles and loss of asphalt binder. Also see segregation.

Reactive Maintenance – Maintenance activities such as pothole repairs performed to correct random or isolated pavement distresses or failures.

Recycling Agents – Organic materials with specific chemical and physical characteristics selected to address binder deficiencies and to restore aged asphalt material to desired specifications in pavement recycling.

Reflection Cracking – Cracking that appears on the surface of a pavement above joints and cracks in the underlying pavement layer due to horizontal and vertical movement of these joints and cracks.

Rejuvenating Agent – Similar to recycling agents in material composition, these products are added to existing aged or oxidized HMA pavements in order to restore pavement surface flexibility and to retard block cracking.

Reservoir – The part of a portland cement concrete pavement joint that normally holds a sealant material, usually formed by a widening saw cut above the initial saw cut. Reservoirs may also be found in HMA pavements where joints are sawed and sealed above existing PCC pavements.

Retrofit Dowel Bars – Dowels that are installed into slots cut into the surface of an existing concrete pavement to restore load transfer.

Rideability – A measure of the ride quality of a pavement as perceived by its users or roughness measuring equipment.

Router – A mechanical device, with a rotary cutting system, that is used to widen, cut, and clean cracks in pavements prior to sealing.

Rubberized Asphalt Sealant – A sealant, generally hot applied, that is composed of asphalt cement, various types of rubber or polymer modifiers, and other compounding ingredients used for pavement crack and joint sealing. Many grades and ranges of properties are available.

Rutting – Longitudinal surface depressions in the wheel path of an HMA pavement, caused by plastic movement of the HMA mix, inadequate compaction, or abrasion from studded tires. It may have associated transverse displacement.

Sandblasting – A procedure in which sand particles are blown with compressed air at a pavement surface to abrade and clean the surface. Sandblasting is a construction step in partial-depth patching and joint resealing.

Sand Seal – An application of asphalt binder, normally an emulsion, covered with a fine aggregate. It may be used to improve the skid resistance of slippery pavements and to seal against air and water intrusion.

Sandwich Seal – A surface treatment that consists of application of asphalt emulsion and a large aggregate, followed by a second application of asphalt emulsion that is in turn covered with smaller aggregate and compacted. Sandwich seals are used to seal the surface and improve skid resistance, especially on asphalt pavement surfaces that are bleeding or flushing.

Scrub Seal – Application of a polymer modified asphalt to the pavement surface followed by the broom scrubbing of the asphalt into cracks and voids, then the application of an even coat of sand or small aggregate, and a second brooming of the aggregate and asphalt mixture. This seal is then rolled with a pneumatic tire roller.

Sealant – A material that has adhesive and cohesive properties to seal joints, cracks, or other various openings against the entrance or passage of water or other debris in pavements (generally less than 76 mm (3 in) in width. *See also: Backer Material, Chemically Curing Sealant, Cold Applied Sealant, Fiber Modified Sealant, Fuel Resistant Sealant, Joint Filler, Joint Sealant, Low Modulus Sealant, Performed Compression Sealant, Rubberized Asphalt Sealant, Silicone Sealant, Single Component Sealant, and Two Component Sealant.*

Sealant Reservoir – See Reservoir.

Sealing – The process of placing sealant material in prepared joints or cracks to minimize intrusion of water and incompressible materials. This term is also used to describe the application of pavement surface treatments. *See also: Cape Seal, Chip Seal, Crack Filling, Crack Sealing, Fog Seal, Modified Asphalt Chip Seal, Sand Seal, Scrub Seal and Slurry Seal.*

Sealing Compound – See Joint Sealant.

Secondary Sawing – The sawing that takes place to establish shape in the joint. Many times this shape is the reservoir of the joint.

Segregation – Separation of aggregate component of asphaltic or portland cement by particle size during placement.

Serviceability – Ability of a pavement to provide a safe and comfortable ride to its users.

Settlement – A depression at the pavement surface that is caused by the settling or erosion of one or more underlying layers.

Shoving – Localized longitudinal displacement of an HMA pavement surface. Shoving is often caused by braking or accelerating vehicles. It may have associated vertical displacement.

Silicone Sealant – A type of joint or crack sealant compound either self leveling or non-sag in application characteristics, that is based on polymers of polysiloxane structures and cures through a chemical reaction when exposed to air.

Single Component Sealant – A sealant supplied as one component.

Skid Resistance – A measure of the frictional characteristics of a surface.

Slab Stabilization – Process of injecting grout or bituminous materials beneath PCC pavements in order to fill voids without raising the pavement.

Slippage cracking - Cracking associated with the horizontal displacement of a localized area of an HMA pavement surface.

Slurry – Mixture of a liquid and fine solid particles that together are denser than water.

Slurry Seal – A mixture of slow setting emulsified asphalt, well graded fine aggregate, mineral filler, and water. It is used to fill cracks and seal areas of old pavements, to restore a uniform surface texture, to seal the surface to prevent moisture and air intrusion into the pavement, and to improve skid resistance.

Spalling, Compression – Cracking, breaking, chipping, or fraying of slab edges within 0.6 meter (2-ft) of a transverse crack.

Spalling, Sliver – Chipping of concrete edge along a joint sealant, usually within 12 mm (1/2 in) of the joint edge.

Spalling, Surface – Cracking, breaking, chipping, or fraying of slab surface, usually within a confined area less than 0.5 square meters (0.6 sy).

Stone Matrix Asphalt (SMA) – A mixture of asphalt binder, stabilizer material, mineral filler, and gap-graded aggregate. SMAs are used as a rut resistant wearing course.

Stress-Absorbing Membrane Interlayer (SAMI) – A thin layer that is placed between an underlying pavement and an HMA overlay for the purpose of dissipating movements and stresses at a joint or crack in the underlying pavement before they create stresses in the overlay. SAMIs consist of a spray application of rubber- or polymer-modified asphalt as the stress-relieving material, followed by placing and seating aggregate chips.

Structural Condition – The condition of a pavement as it pertains to its ability to support repeated traffic loadings.

Structural Overlay – An increase in the pavement load carrying capacity by adding additional pavement layers. (Based on but not taken from 1993 AASHTO guide, p. III-79).

Surface Texture – The microscopic and macroscopic characteristics of the pavement surface that contribute to surface friction and noise.

Surface Treatment – Any application applied to an asphalt pavement surface to restore or protect the surface characteristics. Surface treatments include a spray application of asphalt (cement, cutback, or emulsion) and may or may not include the application of aggregate cover. Surface treatments are typically less than 25 mm thick. They may also be referred to as surface seals, or seal coats or chip seals.

Swell - A hump in the pavement surface that may occur over a small area or as a longer, gradual wave; either type of swell can be accompanied by surface cracking.

Terminal Serviceability – The lowest acceptable level before resurfacing or reconstruction becomes necessary for the particular class of highway.

Thin Overlay – A HMA overlay with 1 lift of surface course generally with a thickness of 38 mm (1½-in) or less.

Transverse Crack – A discontinuity in a pavement surface that runs generally perpendicular to the pavement centerline. In HMA pavements, transverse cracks often form as a result of thermal movements of the pavement or reflection from underlying layers. In PCC pavements, transverse cracks may be caused by fatigue, loss of support, or thermal movements.

Treatment Life – The period of time during which a treatment application remains effective. Treatment life is contrasted with Life Extension.

Two Component Sealant – A sealant supplied in two components which must be mixed at a specified ratio prior to application in order to cure to final properties.

Ultrathin Overlay – An HMA overlay over an existing HMA or PCC pavement, generally less than 25 mm (1 in) in thickness.

Ultra-thin Whitetopping (UTW) – A thin (2 to 4 inch [50 to 100 mm]) PCC overlay over an existing HMA pavement. UTW is a functional overlay that provides a stable surface that is resistant to deformation from static, slow moving, and turning loads.

Unbonded Overlay – Increase in the pavement structure of an existing concrete or composite pavement by addition of jointed plain, jointed reinforced or continuously reinforced concrete pavement placed on a separator layer (usually an asphalt layer) designed to prevent bonding to the existing pavement. (Based on but not taken directly from 1993 AASHTO guide, p. III-145).

User Costs – Costs incurred by highway users traveling on the facility, and the excess costs incurred by those who cannot use the facility because of either agency or self-imposed detour requirements. User costs typically are comprised of vehicle operating costs (VOC), crash costs, and user delay costs. To be differentiated from agency costs.

Waterblasting – The use of a high-pressure water stream (8500 to 10,000 psi) to clean PCC. It may be used in PCC joint resealing to remove sawing laitance or in patching to produce a clean surface prior to placement of the sealer or patch material. Also referred to as hydroblasting.

Working Crack – A crack in a pavement that undergoes significant deflection and thermal opening and closing movements greater than 2 mm (1/16 in), typically oriented transverse to the pavement centerline.

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