# Chapter 3

# SMOOTH ROADS

## Table of Contents


| | | |
|---|---|---|
| **3-1.0** | **INTRODUCTION** | **4** |
| **3-2.0** | **GLOSSARY OF PAVEMENT MANAGEMENT TERMS AND DEFINITIONS** | **4** |
| 3-2.01 | Pavement Structure and Roadbed Components | 5 |
| 3-2.02 | Pavement Features | 6 |
| 3-2.03 | Pavement Defects | 7 |
| 3-2.04 | Performance Characteristics | 9 |
| **3-3.0** | **OPERATIONS SAFETY** | **10** |
| **3-4.0** | **MAINTENANCE OF ROADWAY SURFACE** | **10** |
| 3-4.01 | Maintenance Priorities | 11 |
| 3-4.01.01 | First Priority | 11 |
| 3-4.01.02 | Second Priority | 11 |
| 3-4.01.03 | Third Priority | 11 |
| 3-4.02 | Asphalt Pavement Maintenance | 12 |
| 3-4.03 | Criteria for Overlaying Bituminous Surfaces | 12 |
| 3-4.04 | Maintenance Surface Treatments for Asphalt Pavements | 14 |
| 3-4.04.01 | Seal Coats | 14 |
| 3-4.04.01.01 | Otta Seals | 14 |
| 3-4.04.01.02 | Fog Seals | 14 |
| 3-4.04.01.03 | Chip Seals | 15 |
| 3-4.04.01.04 | Slurry Seals | 15 |
| 3-4.04.01.05 | Microsurfacing | 16 |
| 3-4.04.02 | Thin Hot-Mix Overlays | 17 |
| 3-4.04.03 | Tight Blading or Wedge Paving | 18 |
| 3-4.04.04 | Pavement Patching | 18 |
| 3.4.04.04.01 | Pothole Patching | 18 |
| 3-4.04.04.02 | Crack Sealing | 20 |
| 3-4.04.04.03 | Crack Filling | 20 |
| **3-5.0** | **GENERAL CONCRETE PAVEMENT MAINTENANCE** | **21** |
| **3-6.0** | **CONCRETE PAVEMENT DEFICIENCIES/DISTRESS** | **22** |
| 3-6.01 | Blow-ups and Buckling | 23 |
| 3-6.02 | Durability (“D”) Cracking | 24 |
| 3-6.03 | Transverse or Longitudinal Cracking | 25 |
| 3-6.04 | Failure of Loaded Joints | 26 |
| 3-6.05 | Sags or Slab Settlement | 26 |

3-6.06 PUMPING ....27
3-6.07 POLISHED PAVEMENT ....27
3-6.08 SCALING ....28

**3-7.0 CONCRETE PATCHING ....28**
3-7.01 MUDJACKING/SLABJACKING OF PCC PAVEMENTS ....29
3-7.02 CONCRETE JOINT SEALING ....30

**3-8.0 MAINTENANCE OF SHOULDERS AND ROAD APPROACHES ....30**
3-8.01 SHOULDER OR EDGE OF HIGHWAY GENERAL ....31
3-8.02 FREQUENCY OF SHOULDER OR EDGE OF HIGHWAY REPAIRS ....32
3-8.03 PAVED SHOULDERS ....32
3-8.04 PATCHING HOLES AND ALLIGATORED SHOULDER AREAS ....33
3-8.05 SHOULDER SETTLEMENT ADJACENT TO CONCRETE OR BITUMINOUS PAVEMENT ....33
3-8.06 EARTH OR SOD SHOULDERS ....33
3-8.07 GRAVEL SHOULDERS ....34
3-8.08 OTHER SHOULDER MAINTENANCE NEEDS ....35
3-8.08.01 AVERAGE DEPTH OF RUTTING ....35
3-8.08.02 BERM BUILDUP AT JUNCTURE OF SHOULDER AND SLOPE ....35
3-8.08.03 EROSION OF GRAVEL BASE MATERIAL AT SHOULDER SLOPE ....35
3-8.08.04 EXCESSIVE LATERAL GRADIENT (SHOULDERS 6 FEET OR MORE WIDE) ....35

**3-9.0 PRIVATE ENTRANCE AND PUBLIC ROAD APPROACHES ....35**
3-9.01 INSTALLATION ....35
3-9.02 MAINTENANCE ....36

**INDEX OF LINKS ....37**


**Table of Figures**


FIGURE 1: TYPICAL ROADWAY CROSS SECTION (RURAL SECTION SHOWN) ....5
FIGURE 2: FALLING WEIGHT DEFLECTOMETER ....13
FIGURE 3: FOG SEALING OPERATION ....14
FIGURE 4: CHIP SEAL CROSS SECTION ....15
FIGURE 5: CHIP SEALING OPERATION ....15
FIGURE 6: DISTRESSED ASPHALT PAVEMENT ....16
FIGURE 7: TYPICAL MICROSURFACING ....16
FIGURE 8: ALLIGATOR CRACKING IN SPHALT PAVEMENT ....17
FIGURE 9: HEATED BITUMINOUS HOPPER ....17
FIGURE 10: RUTTED PAVEMENT ....18
FIGURE 11: TYPICAL TIGHT BLADING OPERATION ....18
FIGURE 12: HIGH SEVERITY POTHOLE ....19
FIGURE 13: POTHOLE REPAIR USING “BLOW PATCHER” ....19
FIGURE 14: CRACK SEALING OPERATION ....20
FIGURE 15: CRACK FILLING TECHNIQUE ....21

FIGURE 16: CONCRETE PAVEMENT BLOW-UP ........ 23
FIGURE 17: BLOW-UP REPAIR ........ 23
FIGURE 18: “D” CRACKING ........ 24
FIGURE 19: “D” CRACKING REPAIR ........ 24
FIGURE 20: SEVERE TRANSVERSE RANDOM CRACK ........ 25
FIGURE 21: LONGITUDINAL RANDOM CRACKS IN PCC PAVEMENT ........ 25
FIGURE 22: JOINT SPALLING DUE TO LOADED JOINT ........ 26
FIGURE 23: SLAB SETTLEMENT IN PCC PAVEMENT ........ 26
FIGURE 24: PUMPING IN CONCRETE PAVEMENT ........ 27
FIGURE 25: POLISHED AGGREGATE IN PAVEMENT SURFACE ........ 28
FIGURE 26: SCALING OF CONCRETE SURFACE ........ 28
FIGURE 27: CONCRETE PAVEMENT PATCHING ........ 29
FIGURE 28: MUDJACKING ........ 30
FIGURE 29: UNSAFE EDGE DROP CONDITION ........ 30
FIGURE 30: EDGE DROP (DROP-OFF) REPAIR WITH WEDGE PAVING ........ 31

# 3-1.0 INTRODUCTION

The primary purpose of this chapter is to provide guidance on the best practices for maintenance of smooth pavement on state-maintained roads and facilities. This guidance is not necessarily in the form of detailed instructions but rather the expected results or outcomes of a particular pavement maintenance activity. The terms used in this chapter are intended for use by engineers, supervisors, maintenance personnel, administrators, and others concerned with pavement maintenance, environmental stewardship, and decision-making related to traffic safety and providing smooth and reliable pavement.

The chapter discussion is not intended to provide a detailed and all inclusive "how to" procedure for accomplishing each and every pavement maintenance task. It does discuss the intended outcome or result of the task or operation performed. Information on how to accomplish a specific operation or task can be accessed through electronic "hot links" embedded in the text. A "click" on the highlighted word will take the reader to the referenced website. The chapter table of contents is also electronically linked to specific chapter sections. A list of referenced websites is given at the end of the chapter. Guidance on various topics can also be obtained by calling referenced MnDOT and other offices using the telephone numbers given or viewing the referenced publications from MnDOT or other state agencies, federal agencies, academia, or industry.

The Minnesota Local Road Research Board (LRRB) has been a consistent driving force in implementing smooth roads research and maintenance for the State of Minnesota. Many links contained in this chapter are the result of LRRB research activities. Users of this manual should frequent the LRRB webpage in addition to referring to links found in this chapter as an additional resource for Smooth Road activities.

Disclaimer: This chapter includes several photos which serve to illustrate typical equipment or techniques which may be used in MnDOT's pavement maintenance operations. Any vendor names displayed in the photos are not intended as an endorsement of the product.

# 3-2.0 GLOSSARY OF PAVEMENT MANAGEMENT TERMS AND DEFINITIONS

The terms and definitions provided in this glossary are recommended for use in describing features, defects, components, and characteristics of pavement systems. A good understanding of these terms and definitions will enable road maintenance staff to better identify and scope pavement maintenance needs. The usually accepted term is shown below along with a brief definition. More detailed information can be accessed via the websites linked in the text. Figure 1 shows a cross section of a typical roadway on which these terms appear.

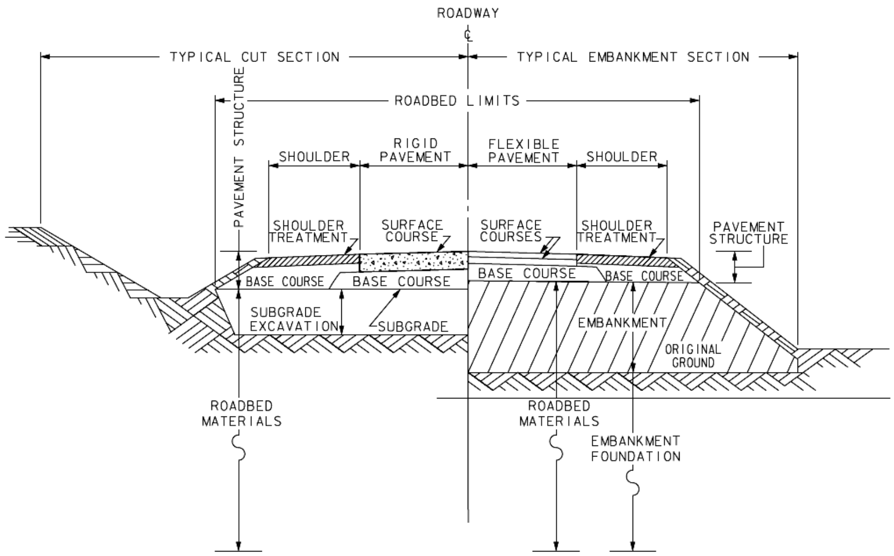



*Figure 1: Typical Roadway Cross Section (Rural Section Shown)*

## 3-2.01 PAVEMENT STRUCTURE AND ROADBED COMPONENTS

Base Course (base): The layer or layers of specified or selected material of designed thickness placed on a sub-base or a subgrade to support a surface course.

Composite Pavement: A pavement structure incorporating a bituminous layer over a concrete pavement. This structure is typically used to rehabilitate basically sound concrete pavement with a deteriorating surface. This process can be reversed where the concrete layer is above the bituminous layer.

Embankment (fill): A structure of soil, soil-aggregate, or crushed/broken rock between the embankment foundation and the subgrade.

Flexible pavement: A pavement structure that maintains intimate contact with and distributes loads to the subgrade and depends on aggregate interlock, particle friction, and cohesion for stability.

Pavement Joints: Both asphalt and Portland cement concrete pavements are constructed with joints as a part of the paving process or as expansion/contraction joints. Joints in asphalt pavement will generally be limited to the centerline or other lane paving joints. Joints in concrete pavement include regularly spaced transverse joints to control shrinkage and cracking, the longitudinal centerline and lane-shoulder joints, and transitions between pavement ends and bridge approach panels. Joints may be sawn and filled with bitumen only or a combination of backer rod and bituminous mixture.

Pavement structure: The combination of sub-base, base course, and surface course placed on a subgrade to support the traffic load and distribute it to the roadbed.

Rigid Pavement: A pavement structure that distributes loads to the subgrade using a one course Portland cement concrete slab of relatively high bending resistance.

Roadbed: The graded portion of a highway within top and side slopes, prepared as a foundation for the pavement structure and shoulder.

Roadbed material: The material below the subgrade in cuts and embankments and in embankment foundations extending to such depth as affects the support of the pavement structure.

Rumble StripE: Combination of rumble strips and pavement striping.

Rumble Strips: Rumble strips are raised or grooved patterns constructed on or in travel lane and shoulder pavements. Rumble strips come in four types: milled, rolled, formed or raised. See the FHWA website for more information on the use of rumble strips.

Select material: Suitable native materials obtained from roadway cuts or borrow areas or other similar material used for sub-base, roadbed material, shoulder surfacing, slope cover, or other specific purposes.

Stabilization: Modification of soils or aggregates by incorporating materials (lime, calcium chloride, etc.) that will increase load bearing capacity, firmness, and resistance to weathering or displacement.

Sub-base: Intermediate layer between the existing roadbed (sub-grade) and the base material.

Subgrade: The original soil or other material underlying the road structure (see “roadbed”).

Shoulder: Include edge of roadway in shoulder definition.

## 3-2.02 Pavement Features

Cold Mix Asphalt: The asphalt binder mix is maintained at temperatures below 300°F. Paving and compaction is performed at ambient air temperature.

Cross Section: A graphic/diagram of a roadway section drawn perpendicular to the centerline profile at a given roadway location which shows the representative portions of the road surface and substructure including typical dimensions of pertinent features (lane and shoulder widths, pavement depth, slope grades, etc.).

Hot Mix Asphalt: Hot Mix Asphalt (HMA) is produced by heating the asphalt binder to decrease its viscosity, and drying the aggregate to remove moisture from it prior to mixing. Mixing is generally performed with the aggregate at about 300 °F (roughly

150 °C) for virgin asphalt and 330 °F (166 °C) for polymer modified asphalt. Paving and compaction must be performed while the asphalt is sufficiently hot.

Pavement Roughness: Pavement roughness or ride quality is measured using the “serviceability-performance” concept developed from data gathered during the AASHTO 1957 Road Test. This pavement serviceability is often expressed as the Present Serviceability Rating (PSR) but MnDOT refers to the present serviceability rating as the Ride Quality Index or RQI. The RQI is determined using the International Roughness Index (IRI) obtained from data generated from the pavement profile. The RQI is a correlation of left wheel path roughness data gathered using the “pathways van” and customer opinion data gathered from customer surveys. The RQI rating ranges from 0.0 for a very rough ride to 5.0 for a very smooth ride. Additional information on RQI is contained in the May 9, 2006 MnDOT publication, “An Overview of MnDOT Pavement Condition Rating Procedures and Indices” available from MnDOT Materials Engineering/Pavement Management.

Profile: The outline or silhouette of the pavement surface as generally measured along or parallel to the pavement centerline (See Figure 1).

Texture: The appearance or character of the surface of a pavement that depends on the size, shape, arrangement, and distribution of the aggregates and cement or binder. A dense, smooth surface would have a fine texture; an open surface should have a course texture. The term rough or roughness should not be used for coarse texture (see roughness). Irregularities in the surface such as potholes, grooves, or rim-cuts are not textures. Coarseness of a concrete surface caused by screeding, brooming, or dragging is defined as texture.

## 3-2.03 Pavement Defects

Alligator Cracking: A pattern of interconnected cracks forming many sided, sharply angled pieces six inches or less in size. Alligator cracking typically occurs in the wheel paths or areas where traffic loads are concentrated.

Blow-ups/Buckling: A raising or shattering of concrete pavement at a joint due to expansion of the concrete with high temperature.

Cupping: Localized pavement settlement occurring in and near an existing crack.

Distortion: Any deviation in the pavement surface from its original shape.

Distress: Any indication of poor or unfavorable pavement performance or signs of impending failure. Distress may include cracking, rutting and potholes in asphalt pavement; and cracking, joint faulting and spalling of concrete pavements. Photos and descriptions of the various kinds of pavement distress for both asphalt and concrete pavements can be found in the FHWA Distress Identification Manual.

Edge Drop: Is the difference in elevation between the pavement and shoulder due to heavy vehicle traffic on the shoulder.

Failure: Performance failure of a pavement such that it cannot fulfill its intended purpose.

Faulting: The uneven raising of pavement joints or cracks due to slab settlement/movement which is more often found in concrete pavement.

Joint Seal Failure: The loss of effective joint seals in concrete pavement due to the intrusion of dirt, debris, and water into pavement joints. Joint failure may also be caused by joint movement due to base or sub-grade failure.

Longitudinal Cracking: A form of cracking generally occurring parallel to the pavement centerline due to failure of the underlying pavement foundation from applied traffic loadings. Longitudinal joint cracking may occur along the pavement centerline, lane division lines or the lane-shoulder joint.

Polished Aggregates: Aggregate that has a low coefficient of friction as a result of traffic action or natural causes.

Pop-outs: Loss of small and shallow areas of concrete due to traffic loadings, freeze- thaw action or aggregate-cement reactions.

Potholes: Localized and generally small pavement failure areas of partial or full depth caused by traffic loadings and freeze-thaw action.

Pumping: Ejection of water, sand, and fines from under the pavement through joints or cracks in the pavement.

Punch-outs: Similar to “pop-outs” but usually larger and deeper and caused by repeated traffic loadings.

Raveling/Weathering: The wearing away of the pavement surface in hot mix asphalt pavements caused by the dislodging of aggregate particles and/or loss of asphalt binder. Raveling generally occurs in the wheel path while weathering occurs in non-traffic areas. Raveling and weathering are considered to be present when the aggregate protrudes 1/16$^{th}$ inch or more and/or if the aggregate is being dislodged.

Roughness: Irregularities in the pavement surface that adversely affect riding quality of the vehicle. (See previous paragraph above on texture for a discussion of the difference between roughness and texture).

Rutting: Rutting consists of longitudinal depression of pavement in the wheel paths. It is a result of too high traffic loadings and/or inadequate asphalt mix design for asphalt pavements and abrasion on Portland cement pavements.

Sags/Settlement: Subsidence of pavement sections due to sub-grade failure caused by drainage issues, improper design, and/or compaction of the road bed and/or repeated heavy traffic loadings.

Scaling: Loss of concrete on the pavement surface due to freeze-thaw action or application of deicing chemicals.

Spalling: Loss of asphalt or concrete material at pavement joints due to traffic loadings and incompressible materials in the joints.

Stripping: Separation of bituminous films from aggregate particles in the presence of moisture.

Tenting: A phenomenon where pavement heaves adjacent to an existing crack or joint usually caused by freeze-thaw action, creating a ridge or peak along the joint or crack.

Transverse Cracking: Transverse cracking is generally the result of traffic loadings and temperature change. Transverse cracking may be accompanied by “cupping” or localized pavement settlement along the crack.

## 3-2.04 PERFORMANCE CHARACTERISTICS

IRI: International roughness index used to measure pavement roughness.

Pavement Condition: Pavement condition in Minnesota is measured using three indices, the RQI(Ride Quality Index formerly referred to as the PSR), the Surface Rating (SR) and the Pavement Quality Index (PQI).

Pavement Quality Index (PQI): The PQI is MnDOT’s overall pavement condition index. It is a combination of the RQI and SR as computed by the formula, PQI = $\sqrt{\mathrm{RQIxSR}}$.

Ride Quality Index (RQI): A numerical rating between 0 and 5 for each section of road surveyed with respect to its present serviceability or ability to serve both low and high speed automobile traffic and high/low volume mixed truck and automobile traffic in its existing condition. Measurement of present serviceability is now measured as the Ride Quality Index (See Section 3-4.0).

Service Life: The period of time over which a pavement performs its design purpose.

Surface Rating (SR): Serves as MnDOT's crack and surface distress index. A rating scale of 0.0 (worst) to 4.0 (best) is used.

Additional information describing these terms can be found in numerous pavement repair references including MnDOT's Best Practices Handbook on Asphalt Pavement Maintenance Manual 2000-04, the 2007 AASHTO Maintenance Manual for Roadways and Bridges (4th Edition), and the FHWA Pavement Preservation Information Depository.

## 3-3.0 OPERATIONS SAFETY

Safe operations in all aspects of pavement maintenance are of utmost importance. Maintenance operations in heavy traffic areas in urban areas and heavily traveled rural roadways require constant alertness and adherence to established safety procedures. Any maintenance activity on the roadway must be preceded by the set-up of proper traffic control. Guidance on the implementation of proper traffic control for pavement and shoulder maintenance is found in the current Minnesota Manual on Uniform Traffic Control Devices (Minnesota MUTCD) - Chapter 6, Temporary Traffic Control Zone Layouts.

Each roadway maintenance activity should be accomplished in accordance with a job safety analysis developed by the maintenance supervisor with input from affected field staff. Safety factors to consider include closeness to fast moving traffic, the use of large equipment (sometimes with limited visibility) and the use of hot materials or chemical additives. The basic elements of a job site safety analysis are outlined in literature given on the University of California Berkeley's JSA website. Other related safety information can be found on the following web pages: Cornell's Department of Environmental Health and Safety - MSDS/TSCA Query, The MSDS FAQ (Where can I get MSDS's?), and the SIRI MSDS Index from Vermont Safety Information Resource (SIRI). The Maintenance Manual Chapters 7 and 8 should also be reviewed.

Operational safety considerations to be addressed should include use of appropriate safety procedures, operational equipment, motorized equipment, traffic barriers (signs and warning devices, etc.), personal safety equipment (high visibility clothing, dust and/or chemical control masks, etc.) and controlled safe use of maintenance materials.

## 3-4.0 MAINTENANCE OF ROADWAY SURFACE

Roadway maintenance conducted by MnDOT field forces consists of a combination of reactive maintenance to repair existing/near-term pavement problems and pavement preservation to prevent pavement deterioration. Reactive maintenance is differentiated from pavement preservation in that the latter activity may include fixes beyond available district maintenance resources. Pavement rehabilitation or reconstructions are much more extensive measures used to provide a long-term solution and will typically be done under a construction contract. For more resources on pavement preservation refer to MnDOT Materials Engineering/Pavement Preservation.

MnDOT is in the process of providing Geographic Information Systems (GIS) information regarding pavement distress and conditions of highway pavement. Maintenance staff will review and update GIS information related to pavement condition when appropriate and will follow roadway maintenance procedures addressed in this manual. Current GIS information can be obtained by contacting MnDOT Materials Engineering/Pavement Management.

## 3-4.01 Maintenance Priorities

### 3-4.01.01 First Priority

First priority should be given to repairing road surface deficiencies (pavement and shoulder) which immediately affect the safety of the traveling public. Typical defects in this category are potholes, cupping at transverse cracks and abrupt vertical variations, “blow-ups” in PCC pavement, excessive raveling, surfaces with low skid resistance, rutting, expanded longitudinal joints on widened lanes and turn lanes, and pavement cracking.

### 3-4.01.02 Second Priority

Second priority should be given to the correction of material and roadbed defects which may be indicated by tenting and cupping, for example, which may have a long term effect on ride quality and service life. Other examples of defects in this category are roadway settlements and related pavement cracks.

### 3-4.01.03 Third Priority

Third priority should be given to surface repair. Prior to making surface repairs on a pavement, it should be determined by an engineer or others with pavement experience whether or not the damage was the result of a mix design failure or base or subgrade soil failure. Often the subgrade soil is the cause of failure and not the gravel base. Field maintenance staff will inspect and identify the problem. District staff will determine the “fix” and recommend appropriate repairs.

If the pavement is slippery, one of the most frequent causes is a film of water on a smooth surface which causes vehicle tires traveling at high speeds to leave the pavement surface and skim (hydroplane) over the water. The smooth pavement condition usually is the result of a film of asphalt on the surface, or polished aggregate in the surface course. Slipperiness may also develop from surface contamination, such as from oil spillage. The object of skid hazard improvement is to increase or restore skid resistance. Several types of treatments are recommended including cleaning the surface of contamination, grinding, or resurfacing. Other repair techniques will include placement of chip seals or micro-surfacing. Refer to the Minnesota Seal Coat Handbook 2006, MnDOT's Best Practices Handbook on Asphalt Pavement Maintenance Manual 2000-04 and MnDOT Materials Engineering/Pavement Preservation for more information.

## 3-4.02 Asphalt Pavement Maintenance

Asphalt or bituminous pavements are any pavement constructed with asphalt. Typically it consists of a surface layer comprised of mineral aggregate coated and cemented with asphalt supported by one or more layers which may consist of asphalt, crushed stone, gravel, stabilized soil or Portland cement concrete. The surface of an asphalt pavement must be strong/tough enough to resist the effects of repeated traffic and weathering and still provide a smooth, skid-free surface. It must be waterproof and sloped to protect the underlying base structure, or if open-graded, include drainage of water away from the surface. It must be strong enough to resist rutting, but yet resilient enough to minimize cracking.

Hot Mix Asphalt (Plant Mix) is prepared in a central batch plant and is considered the highest quality mix. It consists of well-graded aggregate and asphalt cement. Emulsifiers, polymers or other additives may be added to produce specific mix configurations to meet required traffic loading, existing damage, or environmental conditions. Hot mix asphalt is usually heated to 250ºF – 325ºF and transferred hot to the placement site.

Conversely, "Cold Mix" is formulated to be placed at "normal" ambient seasonal temperatures. Cold mix may be a conventional mix using a MC cutback with no or minimal additives to enhance performance. Newer high performance cold mixes typically use a greater mix of additives to modify asphalt viscosity and enhance seasonal performance. Typical target ambient temperature ranges for spring, summer and winter mixes range from 40ºF to 60ºF for a spring season mix, 60ºF and greater for a summer mix and 20ºF to 40ºF for a winter season mix. Detailed information and specifications on high performance mixes can be obtained from the Bituminous Unit in MnDOT Materials Engineering, the Asphalt Institute or from various vendor websites.

Long-term durable pavement repair and patching methods for bituminous surfaces are being researched by many agencies. MnDOT Materials and Road Research is a good resource for the latest developments and guidance.

## 3-4.03 Criteria for Overlaying Bituminous Surfaces

The principal reasons for overlaying a roadway are to improve the surface condition, ride quality, and/or skid resistance. MnDOT's Pavement Management Unit annually collects pavement condition data on about 60 percent of the state system. This data is used to monitor the performance of the system and identify pavement segments that need future maintenance and/or rehabilitation. MnDOT's pavement condition data is determined via three indices, the Ride Quality Index (RQI), the Surface Rating (SR) and the Pavement Quality Index (see Section 3-6.0). The Surface Rating of a road is determined by counting structural deficiencies such as cracking, alligatoring, patching, and rutting.

The calculation of the Surface Rating is different for asphalt and concrete pavements. For bituminous pavements the number of transverse cracks is converted to a percentage. For concrete pavements this index is represented by the percent of distressed slabs relative to the total number of slabs surveyed. These percentages are then adjusted by applying weighting factors (see MnDOT Distress Identification Manual) to get individual weighted distresses which are then summed to get the total weighted distress. These total weighted distresses are then related to surface ratings ranging from 1 to 4 as presented in the Distress Manual. MnDOT typically strives for a surface rating of 4.0.

The Ride Quality Index is a combination of the IRI (roughness) measurement and a survey of road user perceptions on roughness. The Pavement Quality Index is a combination of the RQI and SR to give an overall performance indicator. Detailed information for calculating the various indices is contained in the MnDOT Distress Identification Manual and the May 9, 2006 MnDOT publication, "An Overview of MnDOT's Pavement Condition Rating Procedures and Indices." Information for identifying different types and levels of asphalt pavement distress is found in the MnDOT Distress Identification Manual.

FIGURE 1: FALLING WEIGHT DEFLECTOMETER


The term "skid resistance" refers to the characteristics of pavement surfaces that resist skidding. Skid resistance is determined by measuring the force required to drag a tire that is prevented from rotating over a wetted pavement. See the June 17, 2005 FHWA Technical Advisory T-5040.36 for state of the practice for providing skid resistance on pavements. MnDOT determines skid resistance by the locked-wheel trailer method. Measurements are made by towing a trailer at 40 mph over dry pavement and applying water in front of the test wheel. The test wheel is locked and after it has been sliding along the pavement for a certain distance, the force that results from the friction between the tire and the pavement is measured and recorded. The results of this test are reported as a Skid Number (SN).

Roadway deflection under a load can be used as a measure of the load carrying capacity of a roadway. One tool that is currently used to measure this deflection is the Falling Weight Deflectometer (See Figure 2).

The Falling Weight Deflectometer is a trailer drawn device which employs a calibrated load on a bearing plate in contact with the pavement. Deflections of the pavement under load are recorded via load cells and correlated to pavement strength.

## 3-4.04 Maintenance Surface Treatments for Asphalt Pavements

### 3-4.04.01 Seal Coats

Seal coating is a common preventive maintenance measure used on asphalt pavements by MnDOT, counties and cities for pavement life extension. The primary reason to seal coat is to protect the pavement from the deteriorating effects of sunlight, wind and water. Continued exposure to these elements causes the asphalt in the pavement to oxidize and harden which in turn causes the pavement to be more brittle and prone to cracking. A seal coat provides a waterproof membrane which slows the oxidation process and helps the pavement to shed water. Descriptions of and procedures for applying the various types of seal coats are contained in the Minnesota Seal Coat Handbook 2006, the MnDOT Best Practices Handbook for Asphalt Pavement Maintenance, and the FHWA Pavement Preservation: Checklist Series No. 2.

#### 3-4.04.01.01 Otta Seals

The Otta seal is a Norwegian innovation which can be applied to Minnesota low- volume roads. An Otta seal is a low-cost surfacing alternative used to bridge the gap between asphalt and gravel road surfaces. Normally, it consists of two layers of binder followed by a layer of aggregate that is rolled into the binder. Otta seals are not widely used on the higher volume state road system but are more applicable to the county and local systems.

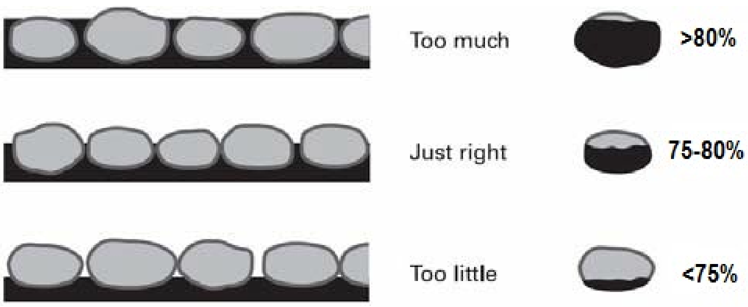
#### 3-4.04.01.02 Fog Seals

FIGURE 2: FOG SEALING OPERATION

Fog seals are a recommended application for sealing and enriching the asphalt surface, sealing minor cracks, helping prevent raveling on high volume open-graded friction courses and providing shoulder delineation. Fog seals can also be applied to centerline and pavement edge rumble strips. Caution in its use on high volume roads should be exercised as pavement friction (skid resistance) may be reduced until some of the asphalt material is worn off. Information on application techniques and material rates can be found in the Minnesota Seal Coat Handbook 2006, the MnDOT Best Practices Handbook for Asphalt Pavement Maintenance, and the MnDOT Distress Identification Manual. Fog sealing of a road shoulder is illustrated in Figure 3.

3-4.04.01.03 CHIP SEALS

FIGURE 3: CHIP SEAL CROSS SECTION




Chip seals or seal coats are applications of asphalt followed immediately with an aggregate cover layer. Applications with two layers are referred to as double chip seals. Seal coats are primarily used to protect the pavement from the deteriorating effects of sun (asphalt hardening and oxidation or “chalking”) and water. They also can waterproof the asphalt surface, provide low-severity crack sealing, repair raveled areas and restore skid resistance. Seal coats also have application as a preventive maintenance technique on aging pavements still in good condition. Rapid-setting asphalt emulsions are normally used when placing a seal coat. Refer to the MnDOT Distress Identification Manual for application techniques and material application rates. An

FIGURE 4: CHIP SEALING OPERATION
(Photo Courtesy of Iowa Center for Transportation Studies)

illustration showing asphalt coverage of the aggregate part of a chip seal is shown in Figure 4. A typical chip seal operation is illustrated in Figure 5.

### 3-4.04.01.04 SLURRY SEALS

Slurry seals are a mixture of fine aggregate range in size from approximately ½ to ¼ inch in diameter (International Slurry Surfacing Association Type III) asphalt emulsion, water, and mineral filler which is mostly Portland cement. Slurry seals, which are typically one stone thick, may be used to seal existing oxidized and hardened asphalt pavements, retard surface raveling, seal small cracks, and improve skid resistance. Caution needs to be exercised in their use as this material takes anywhere from two to eight hours to set up depending on the temperature and humidity. It is also noted that slurry seals are not intended for use where the underlying pavement is extensively cracked. Application techniques and material mixes and application rates are described in the Best Practices Handbook on Asphalt Pavement Maintenance Manual 2000-04 and on the International Slurry Surfacing Association website. Information on emulsions used for slurry seals is contained in "Comparative Analysis of Emulsion and Hot Asphalt Cement Chip Seal Performance" published by the Asphalt Emulsion Manufacturers Association (AEMA) and other industry sources.

### 3-4.04.01.05 MICROSURFACING

Microsurfacing is a mix of polymer-modified asphalt emulsion, well graded and crushed mineral aggregate, mineral filler (normally Portland cement), water, and chemical additives that control the "break" (separation of water from asphalt) and evaporation time.

FIGURE 6: DISTRESSED ASPHALT PAVEMENT

Microsurfacing is typically used when wheel ruts exceed ¾ inch or friction (skid resistance) and related traffic safety become unacceptable. Microsurfacing is primarily used as a preventive maintenance technique or surface treatment for asphalt pavements still in good general condition. They are also used to fill shallow wheel ruts, and reduce infiltration of water into the underlying pavement. Microsurfacing can also be effective in retarding raveling of aging asphalt pavements. A decided advantage of microsurfacing is that it develops strength faster than slurry seals and can be opened to traffic in about an hour. Application techniques, limitations and material mixes and application rates including Special Provisions are described in the Best Practices Handbook on Asphalt Pavement Maintenance Manual 2000-04 and on the International Slurry Surfacing Association website. A field handbook containing similar information can be found in the Asphalt Pavement Maintenance Field Handbook 2001-05.

FIGURE 7: TYPICAL MICROSURFACING

A distressed asphalt pavement requiring a surface treatment such as microsurfacing is shown in Figure 6. A typical microsurfacing operation is shown in Figure 7.

### 3-4.04.02 THIN HOT-MIX OVERLAYS

FIGURE 8: ALIGATOR CRACKING IN ASPHALT PAVEMENT


FIGURE 9: HEATED BITUMINOUS HOPPER

Thin hot-mix asphalt (HMA) overlays are blends of aggregate and asphalt cement. Typically, thin asphalt overlays are used to enhance surface smoothness, increase friction, and/or improve the profile of the roadway while adding little or no additional load-carrying capacity. They are particularly suitable for high volume roads in urban areas where extended pavement life and low noise levels are desired. Three types of HMA's are used in the U.S. and Minnesota: dense-graded, open-graded friction courses, and gap-graded courses. Thickness typically ranges from ¾ to 1 ½ inches. Polymers may be added to mixes to improve performance under specific temperature and load conditions.

The use of thin HMA overlays requires a stable pavement with a sound base, acceptable cross-section and good lateral support. Visible surface distress may include moderate to extreme raveling, prior pothole patching, longitudinal and transverse cracking and some secondary cracking ("Alligatoring," etc. See Figure 8). Surface milling is recommended where severe surface distress is evident as noted in Figure 8. Additional information on the use and limitations of HMA for pavement maintenance is found in the Best Practices Handbook on Asphalt Pavement Maintenance Manual 2000-04 and Preventive Maintenance Best Management Practices of Hot Mix Asphalt Pavements. An industry example of a heated bituminous hopper for transporting hot mix asphalt to the job site is shown in Figure 9.

### 3-4.04.03 Tight Blading or Wedge Paving

The repair of limited areas of pavement cracking such as alligator cracking, raveling or rutting may be accomplished using a grader or truck-mounted blade to spread a thin layer of hot mix on the pavement. This technique can also be used effectively to place a wedge at the pavement shoulder interface to correct a possibly dangerous shoulder drop-off condition. An example of rutting in asphalt pavement and tight blading for correction are shown in Figure 10 and Figure 11. Microsurfacing with a slurry mix or use of mastic material could be considered an alternative to tight blading (see Section 3-4.04.01.05 above for information on microsurfacing).

FIGURE 10: RUTTED PAVEMENT

FIGURE 11: TYPICAL TIGHT BLADING OPERATION

### 3-4.04.04 Pavement Patching

Pavement patching can be accomplished in different ways and with different materials depending on the type of distress to be corrected. The most frequently used measures include pothole patching (filling), crack sealing, and crack filling (patching).

### 3-4.04.04.01 Pothole Patching

Potholes in asphalt pavements (See Figure 12) are the result of any number of conditions including pavement aging, traffic volumes and loads, freezing and thawing of the pavement, etc.

FIGURE 12: HIGH SEVERITY POTHOLE

Pothole patching is accomplished using a variety of techniques and materials. Patching is utilized to repair potholes, failure of previous patches, utility cuts, depressions such as “cupping” at cracks, alligator cracking, etc. Pothole patching can be classified as temporary, semi-permanent, or permanent. Temporary patching is used when it is advisable not to close the road but repair is needed to minimize further pavement damage or affect the safety of the traveling public. Techniques for temporary patching using either “cold mix” or “hot mix” include “throw and go”, i.e., fill the pothole with a shovel and let the traffic compact the patch, or “throw and roll” where the patch is immediately rolled with the truck tire after placement. These techniques can be used for both cold mix and hot mix.

Semi-permanent patching involves more pothole preparation prior to placing the patching material. The pothole may be cleaned with air and debris removed but not saw cut. Permanent patching is used when the pavement is still in good condition, traffic control can be provided and needed resources are available.

FIGURE 13: POTHOLE REPAIR USING "BLOW PATCHER"

Patching may also be done using a spray injection technique (“blow patching”) where air pressure is used to apply a mix of fine aggregate and asphalt emulsion into potholes or large cracks. Still another effective patching technique involves the use of mastics which are a proprietary blend of asphalt sealants and aggregate. Specifications for patching materials and procedures are covered in MnDOT specifications and special provisions available from MnDOT Materials Engineering. An example of pothole repair using a truck-mounted pothole patcher ("blow patcher") is shown in Figure 13.

Some proprietary patching mixtures, including mastics, are currently available in statewide material contracts. These mixtures may prove to be cost effective and are being evaluated. Inquiries for current information and specifications for these mixtures should be directed to the Office of Maintenance, Operations Section and the Bituminous Section in the Materials Research Office.

### 3-4.04.04.02 CRACK SEALING

FIGURE 14: CRACK SEALING OPERATION

Crack sealing of asphalt pavements is a very important function in maintaining pavement life because it helps prevent moisture and incompressible material from infiltrating the pavement structure. Infiltrating moisture weakens the supporting structural subsurface layers. Crack sealing usually involves the cleaning of the cracks of debris (sand, organic material, etc), routing the crack if a reservoir is needed to retain the sealant, and filling with a sealant. Crack sealing is usually applied to cracks less than ¾-inch wide using any one of three methods; clean and seal, saw and seal, or route and seal. Note that "saw and seal" should only be applied on new pavement. Crack sealing may employ a variety of asphalt sealants including rubberized asphalts, crumb rubber, asphalt emulsions (CRS-2P, CSS-1, etc.), or cutback asphalts (RC, MC, and SC). Information on emulsions can be obtained from the Asphalt Emulsion Manufacturers Association Manual Series 19: A Basic Asphalt Emulsion Manual.

Detailed information on the techniques and materials used for crack sealing is found in the Best Practices Handbook, Recommended Practices for Crack Sealing HMA Pavement, the Asphalt Pavement Maintenance Field Guide, the Asphalt Handbook, and MnROAD publication "Crack Sealing 101: Hot Mixed Asphalt Pavements." Applicable material specifications are found in MnDOT Standard Specifications for Construction 3719, 3723, and 3725. Applicable special provisions are illustrated in Appendix B of the Best Practices Handbook on Asphalt Pavement Maintenance Manual 2000-04. An example of a crack sealing operation is shown in Figure 14.

### 3-4.04.04.03 CRACK FILLING

Crack filling on asphalt pavements differs from crack sealing in that it is mainly applied to wider cracks (> ¾ inch), involves somewhat different pre-treatment of the crack before filling and is generally reserved for older worn pavements. Crack filling also does NOT prevent water and incompressibles from entering the pavement as do sealers, but only reduces this intrusion. Crack fillers do coat the crack edges which helps reduce oxidation and crumbling of the crack edges. Application techniques and materials used for crack filling are found in the same references noted above for crack sealing.

FIGURE 15: CRACK FILLING TECHNIQUE

Full-depth and partial crack repair (filling) may also be needed to repair cracks that contain secondary cracking. The full depth repair is required to reestablish the underlying base or pavement material. A notable difference in this technique is that it will require milling the crack anywhere from 1 ½ inches to full depth to remove the secondary cracking. Application methods and materials are also given in the Best Practices Handbook on Asphalt Pavement Maintenance Manual 2000-04 and Recommended Practices for Crack Sealing HMA Pavement. The proper technique for crack filling is given in Figure 15.

Application methods and materials for crack filling and patching are described in the Best Practices Handbook on Asphalt Pavement Maintenance Manual 2000-04, FHWA-RD-99-147, the Asphalt Pavement Maintenance Field Guide, the Asphalt Handbook (7th Edition), and MnDOT Standard Specifications for Construction 2360.

## 3-5.0 GENERAL CONCRETE PAVEMENT MAINTENANCE

Portland cement concrete is basically a mixture of two parts: Aggregates and paste. The paste is comprised of Portland cement (which may also include fly ash) and water which binds the aggregates (sand and gravel or crushed stone) into a rock like mass as the paste hardens. The hardening occurs because of a chemical reaction of the cement and water. When fly ash is present, the fly ash combines with one of the chemical components generated during hydration to form a cementitious material. About one-third of the water in plastic (un-set) concrete is necessary for the chemical reaction with the cement. The remaining two-thirds of the water is required to permit placing, consolidating and finishing the concrete. Hydration of the cement in concrete is a slow process and continues as long as moisture is present when the temperature remains above freezing. Providing the concrete has reached strength greater than that attained at final set before freezing, the chemical reaction after thawing continues if moisture is present, although at a slower rate. The retention of sufficient moisture for hydration is the reason for the use of a membrane curing compound, wet burlap, poly sheeting, etc., immediately after the concrete is finished. The length of required curing varies depending on the structure in which the concrete has been placed. For paving, the Specifications require the curing method be continued a minimum period of 72 hours. However, hydration of the cement and therefore curing continues long after removal of the curing medium as long as moisture remains in the slab. Studies and extensive concrete experience have shown that loss of water (hydration) and achieved concrete strength is mostly complete within a month. Technical information on Portland cement can be obtained from the Portland Cement Association (PCA).

Nevertheless, about two-thirds of the water in a plastic (unset) concrete will leave the concrete as it dries to the relative humidity of its surroundings. The rate at which moisture leaves the concrete is rapid at first and slows with time. The departure of the moisture is the primary cause of shrinkage of the concrete. The combination of sub-grade friction on the bottom of the slab and shrinkage in the slab causes cracking. This cracking will be random if not controlled by forming joints by green sawing or insertion of preformed joint material to form a weakness plane. Sawed joints are later widened to provide a joint of sufficient width and depth for the best shape factor for the particular sealer to be used. Joints are sealed for two reasons: (1) to prevent moisture from entering the joint, and (2) to prevent incompressibles (sand, rocks, etc.) from entering the joint. Entrance of moisture into the joint may result in washing out the fines under the slabs at the joint. This can lead to “pumping” if the base materials are erodible. When the joint material has failed or there is a loss of bond, incompressibles also enter the joint when the joints are open during winter months. After incompressible materials (dirt and debris) have entered the joints, the joints are said to be “loaded.” When summer temperatures cause the pavement to expand the loaded joints resist the expansion which causes the joints to spall or blowup to relieve the stress. If it is impossible to reseal joints before distress becomes evident, four inch joints can be placed to buy time until the joints can be resealed.

## 3-6.0 CONCRETE PAVEMENT DEFICIENCIES/DISTRESS

Distress in jointed concrete pavements can take several forms. A typical concrete pavement may be afflicted by one or more of the following:

- Blow-ups or buckling from heat distress
- Durability or “D” cracking caused by freeze-thaw of the large aggregate
- Transverse or longitudinal cracking from repeated traffic loadings and thermal changes
- “Pop-outs” from freeze-thaw expansion
- “Punch-outs” caused by repeated traffic loadings, inadequate slab thickness or foundation support
- Partial or full depth pulling at slab corners and joints caused by traffic loads or intrusion of materials into joints
- Scaling or “crazing” of the concrete surface due to freeze-thaw, over finishing or deicing salts
- Pumping or ejection of foundation material due to deflection of slabs from passing loads
- Sags or slab settlement
- Slab faulting at joints and cracks

- Surface polishing from high traffic volumes
- Joint sealant failure
- Edge drop between the pavement and shoulder surfacing
- Corner breaks
- Alkali-silica reaction of concrete pavement

Some of the more common concrete pavement distresses are further described in the following paragraphs. Detailed information on concrete pavement distress is contained in the February MnDOT Distress Identification Manual and the February 2008 FHWA Concrete Pavement Preservation Workshop Reference Manual.

Methods and materials for repair of concrete pavement deficiencies are covered in the September 12, 2003 MnDOT Concrete Manual, and the LRRB – State Aid Concrete Pavement Rehabilitation Best Practices Manual 2006-31. Additional information on concrete pavement design, concrete mix and repair technology can be obtained from the Portland Cement Association (PCA), the Aggregate and Ready Mix Association of Minnesota, and the February 2008 FHWA Concrete Pavement Preservation Workshop Reference Manual.

### 3-6.01 Blow-ups and Buckling

Blow-ups occur in hot weather at a transverse joint or crack in PCC (Portland Cement Concrete) pavements which will not permit expansion of the concrete slabs. The insufficient expansion width of joints is usually caused by infiltration of incompressible materials into the joint space. When compressive expansion pressure cannot be relieved, a localized upward movement of the slab edges (buckling) or shattering occurs in the vicinity of the joint (see Figure 17). Blow-ups can also occur at utility cut patches and drainage inlets. Blow-ups are accelerated due to spalling away of the slab at the bottom creating reduced joint contact area. The presence of "D" cracking also weakens the concrete near the joint resulting in increased spalling and blow-up potential.

FIGURE 16: CONCRETE PAVEMENT BLOW-UP

FIGURE 17: BLOW-UP REPAIR

Temporary repairs are to be made as soon as possible by removing loose concrete and backfilling with bituminous material. A more permanent repair may be made using asphalt with greater preparation of the damaged section, use of new supporting base materials, and compaction of these materials backfilling with proven asphalt materials. High early strength concrete may also be used on roadways with high traffic to obtain quick re-opening to traffic. Even newer technology using pre-cast and reinforced concrete slabs inserted into the previously prepared blow-up area may be used to obtain quick re-opening of traffic.

### 3-6.02 Durability ("D") Cracking

FIGURE 18: "D" CRACKING

"D" cracking is a series of closely spaced crescent shaped hairline cracks that appear at a PCC pavement slab surface adjacent and roughly parallel to transverse and longitudinal joints causing cracks or the free edges of a pavement slab. The fine surface cracks often curve around the intersection of longitudinal joints/cracks and transverse joints/cracks. These surface cracks often contain calcium hydroxide residue which causes a dark coloring of the crack and immediate surrounding area (see Figure 18). This may eventually lead to disintegration of the concrete within 1-2 ft. of the joint or crack, particularly in the wheel paths. "D" cracking is caused by freeze-thaw expansive pressures of certain types of coarse aggregates. Repair of "D" cracking using cold or hot mix asphalt is illustrated in Figure 19.

FIGURE 19: "D" CRACKING REPAIR

Information on the causes and repair of D Cracking is contained in the MnDOT Distress Identification Manual, in the FHWA Pavement Preservation: Checklist Series No. 9, FHWA Pavement Preservation: Checklist Series No. 10, and the February 2008 FHWA Concrete Pavement Preservation Workshop Reference Manual.

## 3-6.03 TRANSVERSE OR LONGITUDINAL CRACKING

Random transverse or longitudinal cracking may occur in PCC pavements as a result of repeated and long-term traffic loadings and contraction and expansion due to thermal changes. Related pavement distress is seen as cracks transverse (perpendicular) to the pavement centerline that are more than ¾ inches wide or exhibit faulting greater than ¼ inch. Longitudinal cracking occurs generally parallel to the centerline and is typically measured (FHWA Distress Manual) at three levels of severity ranging from Low (< 1/8 inch width), Moderate (1/8 to ½ inch) and High (>1/2 inch, spalling at the crack >3/4 inch or faulting > ½ inch). Measurement of distress is made for observed cracks over a selected distance. Detailed guidance on measurement techniques is contained in the MnDOT and FHWA Pavement Preservation Manuals referenced earlier.

FIGURE 20: SEVERE TRANSVERSE RANDOM CRACK

Transverse random cracks may also be caused by late green sawing of the concrete or by excessive panel lengths as shown in Figure 20. Longitudinal cracks are caused by subgrade problems and excessive panel widths (see Figure 21).

Descriptive information for transverse and longitudinal cracking and related spalling is contained in the MnDOT Distress identification Manual. Repair techniques and procedures to exclude entry of debris and/or water into the joints are documented in Portland Cement Association (PCA) literature, and the LRRB – State Aid Concrete Pavement Rehabilitation Best Practices Manual 2006-31. An example of a longitudinal crack in need of repair is given in Figure 21.

FIGURE 21: LONGITUDINAL RANDOM CRACKS IN PCC PAVEMENT

## 3-6.04 Failure of Loaded Joints

Joint Failure in concrete pavement may be caused by improper construction, forming of the joint, misaligned dowel bar baskets, improper placement of the joint seal material or deterioration of the joint seal material itself. Loaded joints may often be identified by spalling at the joints.

FIGURE 22: JOINT SPALLING DUE TO LOADED JOINT

The intrusion of incompressible materials (sand, stones, etc.) can load the joint and causes joint spalling (see Figure 22). Failed concrete joints are normally repaired by removing the old joint sealing material, re-sawing and cleaning the joint and placing the new joint seal material. Specifications for joint seal materials are given in MnDOT Standard Specifications for Construction 3719 (Crumb Rubber), 3721 (Preformed elastomeric), 3722 (Silicone sealant), and 3723 (Hot poured elastic).

Techniques for proper installation of joint seals are given in the PCA technical literature, the LRRB – State Aid Concrete Pavement Rehabilitation Best Practices Manual 2006-31 and in FHWA Pavement Preservation: Checklist Series No. 6.

## 3-6.05 Sags or Slab Settlement

FIGURE 23: SLAB SETTLEMENT IN PCC PAVEMENT

Sags are areas in concrete pavement that are perpendicular to the pavement centerline. They frequently occur on bridge approach panels, over culverts and in swampy areas. They often may be located by observing severe cracking which is caused by subgrade subsidence (see Figure 23). Sags are generally due to non-uniformity of compaction or changes in soil types in the bridge approach panels and culverts. Sags in swampy areas are generally attributed to trapping of unstable materials under the roadbed or lack of lateral support of the roadbed. Sags are often evidenced by heavy oil drippings or tire marks in the vicinity of the sag. Descriptive information on sags in concrete pavement is given in the MnDOT Distress Identification Manual. The accepted methods of repair are mudjacking, bituminous overlay, and removal and replacement which are described in FHWA-RD-99-168 and the LRRB – State Aid Concrete Pavement Rehabilitation Best Practices Manual 2006-31.

Generally bridge approach slabs should be mud-jacked only once as repeated jacking tends to badly break up the concrete panel. (See Section 3-7.01).

Mudjacking other pavement surfaces usually should not be done more than two times as severe cracking often results. Repair may involve removal and replacement of the affected area or placement of a bituminous overlay over the sag area.

## 3-6.06 PUMPING

FIGURE 24: PUMPING IN CONCRETE PAVEMENT

Pumping is the ejection of material by water through joints or cracks, caused by deflection of the slab under moving loads. As the water is ejected, it carries particles of gravel, sand, clay, or silt, resulting in a progressive loss of pavement support. Surface staining or accumulation of base or subgrade material on the pavement surface close to joints or cracks is evidence of pumping (see Figure 24). However, pumping can occur without such evidence, particularly when stabilized bases are used. The observation of water being ejected by heavy traffic loads after a rainstorm also can be used to identify pumping. Water may also seep out of joints or cracks, particularly on the low side of super-elevated curves or on steep grades. Detailed information on pumping is also available in the MnDOT Distress Identification Manual.

## 3-6.07 POLISHED PAVEMENT

Polished pavement can be caused by either traffic wear on older concrete pavement (see Figure 25) which creates a polished surface or by poor construction practices when finishing the concrete. A polished surface can significantly reduce skid resistance, increase stopping distance, and contribute to hydroplaning during rain, snow or ice events.

Permanent repair requires surface grooving with mechanical grooving equipment built for this purpose or diamond grinding. Temporary repair can be made by overlaying the pavement with a dense graded bituminous mixture. Repair information is given in the FHWA Pavement Preservation: Checklist Series No. 7 and the LRRB – State Aid Concrete Pavement Rehabilitation Best Practices Manual 2006-31.

FIGURE 25: POLISHED AGGREGATE IN PAVEMENT SURFACE

### 3-6.08 SCALING

Scaling of concrete surfaces may be caused by deicing salts, traffic, improper construction practices or material mixes, or freeze-thaw cycles (see Figure 26). Minor surface scaling is not normally repaired as it is mostly an aesthetic issue. Deep scaling which adversely affects ride and/or road safety may be temporarily repaired with asphalt mix or mastic or permanently repaired under a pavement rehabilitation or reconstruction contract. Field repair information for minor to shallow (less than 1/3 of the pavement depth) is contained in the MnDOT Distress Identification Manual and the FHWA Pavement Preservation: Checklist Series No. 9 and the LRRB – State Aid Concrete Pavement Rehabilitation Best Practices Manual 2006-31.

FIGURE 26: SCALING OF CONCRETE SURFACE

## 3-7.0 CONCRETE PATCHING

PCC pavements in Minnesota are subject to “pop-outs” of concrete, potholes, and scaling to varying depths as a result of repeated traffic loadings combined with freeze-thaw cycles. Temporary repairs of smaller distressed areas can be made with either cold or hot bituminous mix, with proprietary asphalt mixes/mastic or with a variety of epoxy or otherwise modified Portland cement concrete. Asphalt patching is generally accomplished using the “throw and go” or “throw and roll” techniques (ref. LRRB – State Aid Concrete Pavement Rehabilitation Best Practices Manual 2006-31).

FIGURE 27: CONCRETE PAVEMENT PATCHING

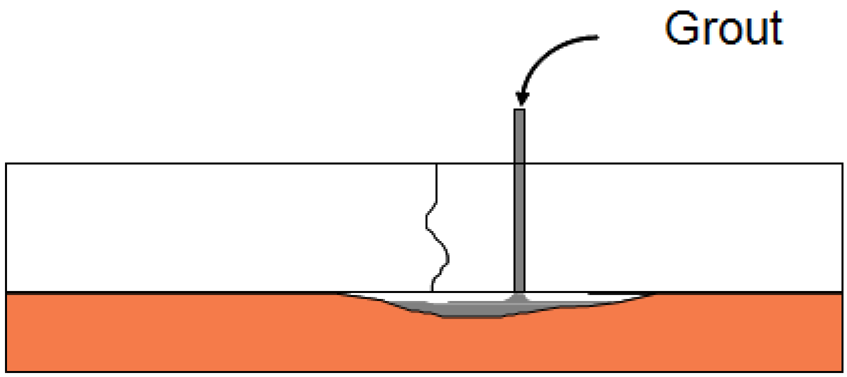
Concrete mixture for patching larger distressed areas should adhere to the following:

- Meet the MnDOT Standard Specifications for Construction 3105, and procedures outlined in the MnDOT Concrete Manual, Chapter 9.
- Should be high-early-strength to allow reopening the roadway within 24 to 48 hours. The mix design for such concrete can be obtained from the Concrete Engineering Section in MnDOT Materials Engineering. In most localities, concrete may be purchased from commercial producers.
- Prior to placing a full depth patch, brushing an epoxy bonding agent on the full face is recommended to insure a tight bond on the vertical face. The concrete patch shall be placed while the epoxy bonding agent is still tacky. The MnDOT Concrete Manual includes a list of approved bonding agents.
- In circumstances where comparatively long stretches of concrete pavement are so deteriorated as to render concrete patching impractical, they may be temporarily repaired by bituminous patching and/or a wearing surface of a designated bituminous mixture.
- Small areas of broken up concrete may be patched with pre-mixed bituminous material. The edges of the broken area should be squared and treated with cutback asphalt.

## 3-7.01 MUDJACKING/SLABJACKING OF PCC PAVEMENTS

Mudjacking or slabjacking is a procedure used to raise concrete panels that have sagged and cracked due to traffic loadings and voids occurring under the panel. The procedure (See sketch in Figure 28) involves the injection of a concrete mixture or proprietary foam mixture through a series of holes so that the underlying base is evenly consolidated, the void filled and the panel raised evenly. Mudjacking requires special equipment and trained personnel. The proper location of holes varies according to the defect being corrected. Only an experienced operator should make the decision on correct hole spacing. Technical information on the proper procedures and material mixtures may be found in the LRRB – State Aid Concrete Pavement Rehabilitation Best Practices Manual 2006-31 or from the District Materials Office.

FIGURE 28: MUDJACKING




### 3-7.02 CONCRETE JOINT SEALING

Concrete joint seal materials placed during the construction of the pavement consist of three types: preformed neoprene (MnDOT Standard Specifications for Construction 3721), silicone sealant (MnDOT Standard Specifications for Construction 3722), and hot poured elastic (MnDOT Standard Specifications for Construction 3723). Prior to sawing and resealing the joints, the preformed and hot pour joint materials must be removed by manual or mechanical methods. The proper field techniques for removing the old joint seals, sawing to reshape the joint and fill the joint are described in the MnDOT Concrete Manual and other references listed in Section 3-10.0. Applicable specifications and special provisions for placing concrete joint sealer can be obtained from MnDOT Concrete Engineering.

## 3-8.0 MAINTENANCE OF SHOULDERS AND ROAD APPROACHES

FIGURE 29: UNSAFE EDGE DROP CONDITION

Shoulders are the paved or, in some instances, unpaved areas adjacent to the travel lane which often provide lateral support to the travel lane. Shoulders also provide a safe area for pedestrian and bicycle travel along roadways. Maintenance of the shoulder to prevent or minimize shoulder "drop-off" or difference in lane-shoulder elevation is very important. Large differences in elevation can significantly impact driver safety for those intruding onto the shoulder. These elevation differences together with large longitudinal cracks also present a hazard to bicyclists using the shoulder. An example of an unsafe drop-off condition is shown in Figure 29. Shoulders are not designed to carry heavy traffic and improper use can cause extensive damage. Maintenance of shoulders and approaches is influenced by their design, condition and structural materials. Also, this maintenance work is influenced by the volume of traffic, traffic type and width of the traveled way. Correction of edge drops with wedge paving is illustrated in Figure 30.

FIGURE 30: EDGE DROP (DROP OFF) REPAIR WITH WEDGE PAVING

Maintenance of shoulders is also very important as pedestrians and bicyclists are permitted to travel on the shoulders; except on Interstate highways. In situations where there are pedestrian or bicyclists using the shoulders; efforts should be made to maintain shoulders in a condition free from obstructions or other unsafe conditions. Early spring sweeping of winter maintenance sand and debris should be done to minimize potential danger to bicyclists and pedestrians. MnDOT guidance relative to shoulder and pathway maintenance for bicyclists is discussed in Chapter 9 of the MnDOT Bikeway Facility Design Manual or general MnDOT bicycling responsibilities are on the MnDOT Bicycle Modal Plan and related guidance (Pg. 95) for road shoulder maintenance. Other useful and related guidance is found in the following federal documents:

- FHWA Designing Sidewalks and Trails for Access, Part II: Best Practices Design Guide
- FHWA Guidance for Bicyclists and Pedestrians

Road approaches are those portions of public or private roads that are within the highway right-of-way. They are usually at right angles to the traveled way and permit traffic to enter and leave the roadway. The sections below describe maintenance procedures for road approaches, bicycle and pedestrian access that are within a shoulder or edge of highway. If the traveled lane of the approach, bicycle or pedestrian access is outside of a shoulder or located within an approach main vehicle travel lane, the maintenance is the responsibility of the agency or private party with jurisdiction over the approach, bicycle or pedestrian facility.

## 3-8.01 SHOULDER OR EDGE OF HIGHWAY, GENERAL

The failure of many surfaces starts at the inside edge of the shoulder. All types of shoulders should be maintained, insofar as possible and practicable, smooth and flush with the edge of the adjacent surfacing. They should be sloped away from the pavement to assure proper drainage of the roadbed. Sections of shoulders that are used repeatedly as a turnout, such as at mailboxes and public roads, should be reviewed periodically and repairs scheduled as necessary. Repair of shoulder drop-off is usually accomplished by placing an asphalt “wedge” to provide a smooth and gradual transition to the shoulder area.

Some shoulders are little more than a compacted version of the adjoining fields. Some shoulders are surfaced with more than one type of material, the strip next to the travel way being better constructed and perhaps paved to accommodate vehicles driving off the travel way. The proper shaping of shoulders will prevent collection of water in pockets and assure good drainage.

The shoulder area on the inside of curves should be reviewed and repairs scheduled as necessary in order to prevent excess rutting because of vehicles cutting the curves. Earth, sod, or gravel shoulder areas on the inside of super-elevated curves and subject to excess rutting are sometimes paved with bituminous in order to achieve stability. Shoulder areas subject to sinking should be inspected for drainage problems.

Washouts on any type of shoulder may become a severe maintenance problem, especially in rough terrain. Shoulder washouts may be prevented by paving the shoulder or forming a low retaining curb or gutter for short lengths of shoulders where washing is particularly bad, as on steep grades or at low points in vertical curves where run-off water tends to accumulate. A bituminous paved flume or pipe drain should also be considered to eliminate erosion of the slopes in areas of high runoff.

## 3-8.02 Frequency of Shoulder or Edge of Highway Repairs

Maintenance of shoulders and approaches should be done as resources allow. Items to consider when prioritizing areas for repairs include the width of the traveled way, amount of traffic, general surface condition, the structural materials making up the shoulders and approaches and available funds, personnel and equipment.

It is the responsibility of the Sub-Area Supervisor to review roads in their sub-area, as time and conditions permit, looking for areas that need attention. See the following sections for more details on specific issues. When shoulders and approaches are identified that need repairs the appropriate repair work should be scheduled consistent with other maintenance needs and available resources.

## 3-8.03 Paved Shoulders

Paved shoulders offer better and safer facilities for acceleration and deceleration of vehicles. When a paved shoulder is patched, care should be taken to see that the new material is compacted and that the surface of the patch is flush with the existing shoulder surface. The material used in a permanent patch should match the existing shoulder surfacing if practicable.

The weakest point of the paved shoulder and the place where most failures start is the joint between the traveled way and the shoulder. Growth of weeds and grass may be treated with herbicides since plant roots gather water and destroy shoulder integrity.

Shoulder gutters and curbs may be constructed along the outside of the shoulder at selected locations to collect and channel heavy run-off water into paved ditches or pipes at low points in the grade or other selected locations. Areas that become distorted and which cause water to pond or flow in the wrong direction should be repaired. Curbs may be constructed of either hot-mix bituminous concrete or Portland cement concrete. When the bituminous treated surface of a paved shoulder becomes oxidized or dry, or too permeable to water, the surface should be given a seal coat (MnDOT Standard Specifications for Construction 2356) or a fog seal applied at a rate determined by the Bituminous Engineer.

The decision to fill cracks in bituminous shoulders should be made by the Area maintenance staff. MnDOT Bituminous Engineering or the District Materials Office may be consulted for an analysis of future life expectancy with or without a repair. Materials and placement procedure specifications and special provisions for shoulder crack filling are discussed in Section 3-8.02.

## 3-8.04 PATCHING HOLES AND ALLIGATORED SHOULDER AREAS

When patching holes, use the same type of material that was used to construct the shoulder wherever practicable. When this is not possible during the winter season, use a winter patching mixture. If it has failed before or continues, investigate the underlying base for potential cause of failure, correct the base and/or subgrade and fill the hole with bituminous mixture. Consult with the District Materials Office on procedures for correcting localized wetness in the shoulder sub-grade. When shoulders become alligatored, a bituminous seal coat or fog seal should be considered depending on the severity of the distress.

## 3-8.05 SHOULDER SETTLEMENT ADJACENT TO CONCRETE OR BITUMINOUS PAVEMENT

Settled areas should be corrected by placing a bituminous "wedge". When the edge drop off (shoulder settlement-see Figure 29) averages one inch or more on roads with 10,000 AADT or greater, shoulder work should be scheduled and the work should be completed within one year, if possible. When the edge drop off (shoulder settlement) averages one and one half inches or more on roads with less than 10,000 AADT, shoulder work should be scheduled and completed, if possible, within one year subject to the availability of MnDOT resources.

## 3-8.06 EARTH OR SOD SHOULDERS

MnDOT maintains very few earth or sod shoulder areas. However, where present, these earth or sod shoulders should contain a sufficient amount of granular material for stability. Vegetative growth on earth or sod shoulders should be low growing grasses and forbs, preferably perennials. Earth or sod will tend to build up and should be bladed lightly to maintain proper cross slope drainage. Blading should be done mostly when the earth is moist, often enough to keep ruts filled and lightly enough to prevent damage to grass roots. Ruts and soft spots appear after a rain or when ground frost has thawed and should get attention at these critical times. Shoulder material removed by erosion should be replaced.

In regions of heavy vegetative growth, mechanical mixing of the shoulder area followed by blading is recommended in early spring to break up roots and sprigs. This will assist the normal growth of grass on the shoulders. Reseeding, fertilizing and rolling are sometimes desirable to finish the surface and restore compaction. Maintenance operations should be performed so as to avoid clogging drainage facilities. Sod shoulders should not be mowed shorter than 3 to 4 inches or the effectiveness of the grass cover will be lost. Chlorides for snow and ice removal or dust control should be used discriminately in areas having sod shoulders.

## 3-8.07 Gravel Shoulders

Gravel shoulders provide better support for traffic than sod and are more desirable as an all-weather shoulder. Gravel, however, tends to wear down and rut unless it is worked regularly. Dragging or blading generally causes segregation of shoulder material with larger material coming to the top. Blading reshapes the shoulder surfacing material to the proper grade and slope to provide adequate drainage. It also removes excess material, and at the same time, it brings material flush with the edge of the pavement. A motor grader is well adapted for this work.

As a result of blading, ridges will be formed along guardrails and similar structures. These ridges should be spread and shaped to prevent pocketing of water, improve appearances, and reduce interference with mowing operations. Excess material on the edge of the pavement should be removed after each day's work to reduce traffic hazards.

As material is lost from this type of shoulder, it should be replaced with acceptable shouldering material, shaped, and compacted with a rubber-tired roller. Normally, compaction equipment is not used when shoulders are being re-graded and no new material is added; however, when compaction equipment is available it should be used.

The application of dust control agents on some shoulders may be advisable during the dry season particularly if there is a high traffic volume. Dust control agents, in addition to reducing dust as a nuisance to traffic and to property adjacent to the highway, serves as an additional superficial bonding agent and abates the loss of shoulder material. Calcium chloride is generally used because of its ability to collect moisture from the air. Guidance for the application of calcium chloride or other dust control agents can be obtained from MnDOT Materials Engineering. Similarly, guidance on the use of calcium chloride for shoulder stabilization can be obtained from that same office.

## 3-8.08 Other Shoulder Maintenance Needs

#### 3-8.08.01 Average Depth of Rutting

When the average depth of a rut of 2 inches or more is reported, that section of roadway shoulder should be scheduled for repair work. In the event this work cannot be accomplished within a reasonable time because of unfavorable weather conditions or unavailability of workers, materials or equipment, the Area Maintenance Engineer shall be notified. If necessary, the roadway will be posted with appropriate warning signs.

#### 3-8.08.02 Berm Buildup at Juncture of Shoulder and Slope

Berm buildup at the shoulder P.I. should be scheduled for repair work when it causes a drainage problem.

#### 3-8.08.03 Erosion of Gravel Base Material at Shoulder Slope

Shoulder slope work should be scheduled once rivulets begin to erode into the normal shoulder width.

#### 3-8.08.04 Excessive Lateral Gradient (shoulders 6 feet or more wide)

When the gravel shoulder slope exceeds 10 percent or more, shoulder work should be scheduled. This work will either require adding shoulder material or reclaiming shoulder material that has been bladed off the shoulder during prior maintenance in order to flatten the slope**.**

## 3-9.0 PRIVATE ENTRANCE AND PUBLIC ROAD APPROACHES

### 3-9.01 INSTALLATION

If an abutting property owner desires an entrance, they must apply for and possess a valid MnDOT permit for an entrance prior to any installation as covered in Minnesota rule 8810. Entrance culverts must meet MnDOT size, material and installation specifications as provided in current MnDOT Standard Specifications for Construction.

The requesting property owner is responsible for the initial installation and any owner requested relocation or modifications of culverts on entrances to existing state-maintained highways, including any costs related to installation.

The requesting abutting property owner is responsible for providing their own culverts for entrances to existing state maintained highways, unless the county or local road authority has adopted, by resolution, a policy to furnish such culverts. The property owner is responsible for determining whether such a policy is in effect. Property owners may purchase culverts from venders, contractors, county highway departments or local road authorities. Used culverts cannot be used. MnDOT will not furnish or sell entrance culverts to requesting abutting property owners.

All other expenses incurred by the property owner in constructing the entrance are the obligation of the property owner. Refer to Minnesota Statutes, Section 160.18 for further information on access to roads. Also refer to Minnesota Rules 8810.4100 through 8810.5600 and Standard Plate Number 7035N.

## 3-9.02 MAINTENANCE

MnDOT has an obligation to maintain drainage within the trunk highway right of way. It has been the practice of MnDOT to repair, replace, and maintain public road approach and private entrance culverts that have been installed on MnDOT right-of-way under Minn. Stat. §160.18, subd. 1. MnDOT will maintain and replace if necessary, to MnDOT standards and in accordance with our schedule, all culverts under private entrances and public road approaches located on our right of way.

Private entrances and public road approaches shall be maintained from the traveled way to the outside shoulder line of the trunk highway. Vegetation control will be provided within the entire trunk highway right-of-way. Abutting property owners, city, county, and other road authorities are responsible for the maintenance of the private or public approach roadway and roadbed to the shoulder line of the trunk highway.

When the department constructs a new highway or reconstructs (See MnDOT Design Manual Chapter 2-5.02 for Investment Category definitions) an old highway, suitable private entrance and public road approaches are provided at state expense within the limits of the right-of-way where the entrances and approaches are necessary and practicable to provide abutting owners and public roads a reasonable means of access to the highway.

If a public roadway or private entrance is reconstructed by a road authority or abutting property owner, the approach or entrance roadbed will also be reconstructed as needed. This includes but is not limited to providing a suitable approach to the highway within the limits of the right-of-way where the approaches are reasonably necessary and practicable to provide abutting owners a reasonable means of access to such highway, and includes any entrance culverts.

# INDEX OF LINKS

Aggregate and Ready Mix Association of Minnesota
http://www.armofmn.com/

An Overview of MnDOT's Pavement Condition Rating Procedures and Indices
http://www.dot.state.mn.us/materials/pvmtmgmtdocs/Rating_Overview_State.pdf

Asphalt Institute
http://www.asphaltinstitute.org/

Asphalt Pavement Maintenance Field Handbook 2001-05
http://www.lrrb.org/media/reports/200105.pdf

Best Practices Handbook on Asphalt Pavement Maintenance Manual 2000-04
http://www.lrrb.org/media/reports/200004.pdf

Comparative Analysis of Emulsion and Hot Asphalt Cement Chip Seal Performance
http://westernemulsions.com/articles/TexasChipSealStudy512(1).pdf

Cornell's Department of Environmental Health and Safety - MSDS/TSCA Query
http://sp.ehs.cornell.edu/lab-research-safety/research-safety/msds/Pages/default.aspx

Crack Sealing 101: Hot Mixed Asphalt Pavements
http://dotapp7.dot.state.mn.us/research/pdf/2010MRRDOC010.pdf

February 2008 FHWA Concrete Pavement Preservation Workshop Reference Manual
https://intrans.iastate.edu/app/uploads/2018/08/preservation_reference_manual.pdf

FHWA Rumble Strips
https://safety.fhwa.dot.gov/roadway_dept/pavement/rumble_strips/

FHWA Designing Sidewalks and Trails for Access, Part II: Best Practices Design Guide
http://www.fhwa.dot.gov/environment/bicycle_pedestrian/publications/sidewalk2/contents.cfm

FHWA Distress Identification Manual
https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/reports/03031/

FHWA Guidance for Bicyclists and Pedestrians
https://www.fhwa.dot.gov/environment/bicycle_pedestrian/guidance/design.cfm

FHWA Pavement Preservation Information Depository
http://www.fhwa.dot.gov/pavement/pres.cfm

FHWA Pavement Preservation: Checklist Series No. 10
http://www.fhwa.dot.gov/pavement/preservation/ppcl10.pdf

FHWA Pavement Preservation: Checklist Series No. 2.
https://www.fhwa.dot.gov/pavement/preservation/ppcl02.pdf

FHWA Pavement Preservation: Checklist Series No. 6
http://www.fhwa.dot.gov/Pavement/preservation/ppcl06.pdf

FHWA Pavement Preservation: Checklist Series No. 7
http://www.fhwa.dot.gov/pavement/preservation/ppcl07.pdf

FHWA Pavement Preservation: Checklist Series No. 9
http://www.fhwa.dot.gov/pavement/preservation/ppcl09.pdf

FHWA-RD-99-147
http://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/99147/99147a.pdf

FHWA-RD-99-168
http://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/99168/99168.pdf

International Slurry Surfacing Association
http://www.slurry.org/

June 17, 2005 FHWA Technical Advisory T-5040.36
https://www.fhwa.dot.gov/pavement/t504036.cfm

LRRB
http://www.lrrb.org/

LRRB – State Aid Concrete Pavement Rehabilitation Best Practices Manual 2006-31
http://www.lrrb.org/pdf/200631.pdf

Minnesota MUTCD
http://www.dot.state.mn.us/trafficeng/publ/mutcd/index.html

Minnesota Rules 8810.4100 through 8810.5600
https://www.revisor.leg.state.mn.us/rules/?id=8810

Minnesota Seal Coat Handbook 2006

http://www.lrrb.org/media/reports/200634.pdf

Minnesota Statutes, Section 160.18
http://www.revisor.leg.state.mn.us/stats/160/18.html

MnDOT Bicycle Modal Plan
http://www.dot.state.mn.us/bike/pdfs/modalplan.pdf

MnDOT Bikeway Facility Design Manual
http://www.dot.state.mn.us/bike/pdfs/manual/manual.pdf

MnDOT Design Manual Chapter 2
https://roaddesign.dot.state.mn.us/

MnDOT Distress Identification Manual
http://www.dot.state.mn.us/materials/manuals/pvmtmgmt/Distress_Manual.pdf

MnDOT Materials Engineering
http://www.dot.state.mn.us/materials/index.html

MnDOT Standard Specifications for Construction
http://www.dot.state.mn.us/pre-letting/spec/2014/2014-Std-Spec-for-Construction.pdf

Portland Cement Association (PCA)
http://www.cement.org/

Preventive Maintenance Best Management Practices of Hot Mix Asphalt Pavements
http://www.lrrb.org/media/reports/200918.pdf

Recommended Practices for Crack Sealing HMA Pavement
http://www.lrrb.org/media/reports/200854.pdf

Section 5-694.901
http://www.dot.state.mn.us/materials/manuals/concrete/Chapter9.pdf

September 12, 2003 MnDOT Concrete Manual
http://www.dot.state.mn.us/materials/concretemanual.html

SIRI MSDS Index from Vermont Safety Information Resource (SIRI)
http://www.hazard.com/msds/

Standard Plate Number 7035N
http://dotapp7.dot.state.mn.us/edms/download?docId=1080564

The MSDS FAQ (Where can I get MSDS's?)

http://www.ilpi.com/msds/faq/parta.html#where

University of California Berkeley's JSA
http://www.ehs.berkeley.edu/hs/325-job-safety-analysis-jsa-library.html