Appendix B
Preventive Maintenance Treatment Technical Profiles

Tools and Tactics for Roadway Pavement Preservation: An Implementation Guide to Preserving High-Traffic-Volume Roadways

Preventive Maintenance Treatment Technical Profiles

(An Appendix to the SHRP2 document, Tools and Tactics for Roadway Pavement Preservation, An Implementation Guide to Preserving High-Traffic-Volume Roadways)

This document contains technical profiles for each of the highlighted preservation treatments shown in Table 1 of ***Tools and Tactics for Roadway Pavement Preservation: An Implementation Guide to Preserving High-Traffic-Volume Roadways***. Each profile includes a description of the treatment and its performance objectives, the pavement deficiencies addressed by the treatment, design illustrations of the treatment, and photos of the constructed treatment.

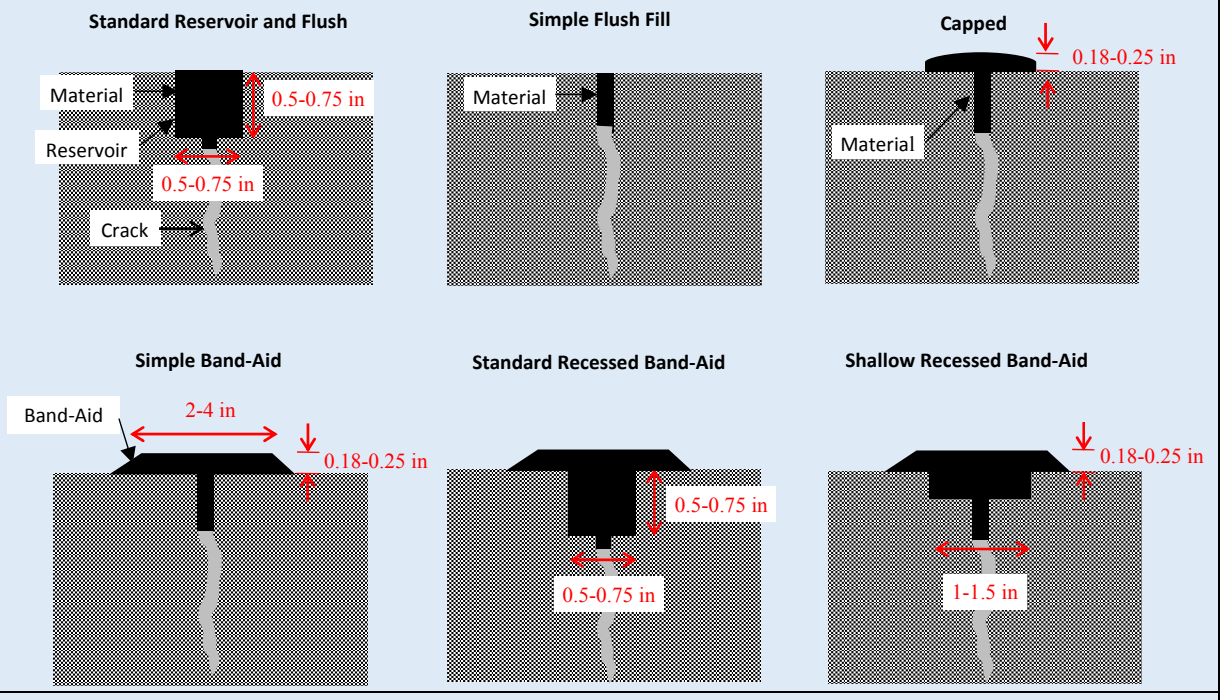
CRACK SEALING AND CRACK FILLING

Treatment Description

Crack Filling—Involves the placement of an adhesive material into and/or over non-working cracks (typically longitudinal cold-joint and reflective cracks, edge cracks, and distantly spaced block cracks) at the pavement surface in order to prevent the infiltration of moisture into the pavement structure and reinforce the adjacent pavement. Crack filling operations generally entail minimal crack preparation and the use of lower quality materials.

Crack Sealing—Involves the placement of an adhesive material into and/or over working cracks (i.e., those that open and close with temperature changes, such as transverse thermal and reflective cracks, diagonal cracks, and certain longitudinal reflective cracks) at the pavement surface in order to prevent the infiltration of moisture into the pavement structure. Crack sealing operations typically require good crack preparation (i.e., routing or sawing a reservoir over the crack and power cleaning the reservoir) and the placement of high-quality flexible materials (i.e., thermosetting or thermoplastic bituminous materials that soften upon heating and harden upon cooling) into and possibly over the reservoir.

There are many configurations in which crack filler and sealant materials can be placed. Commonly used configurations are illustrated below.



Performance Objectives

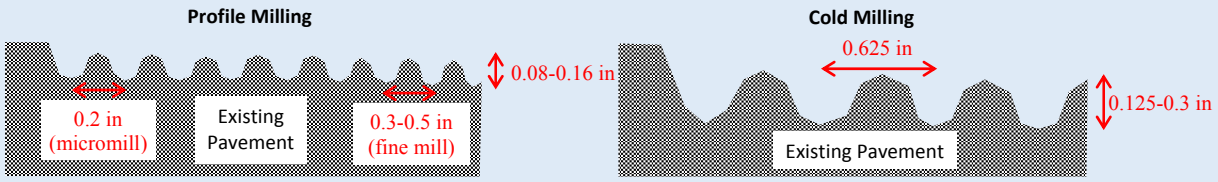
Seal/Waterproof Pavement—Prevent or slow the infiltration of moisture into the pavement surface.
Reduce/Eliminate or Stabilize Surface Defects (Cracking)—Restore the integrity of cracks through reinforcement and stabilization.

PROFILE MILLING AND MICRO MILLING

Treatment Description

***Profile Milling*—**Retexturing and/or reprofiling of the surface of an existing asphalt or composite pavement using a cold milling machine equipped with a fine-toothed, carbide-tipped cutting drum (700 to 1,000 teeth per 12.5-ft. wide drum). The depth of surface material removal is typically ≤0.6 in. for micromilling and ≤1 in for fine/precision milling. The resulting groove pattern includes a peak-to-valley depth of 0.08 to 0.16 in. and an approximate spacing of 0.2 in. for micromilling and 0.3 to 0.5 in. for fine/precision milling (see figure below).

***Standard Cold Milling*—**Correction or restoration of the transverse profile (e.g. rut removal) and/or longitudinal profile (e.g., increase smoothness) and/or removal of surface distress of an asphalt or composite pavement using a cold milling machine equipped with a conventional carbide-tipped cutting drum (264 teeth per 12.5-ft. wide drum). The depth of surface material removal is generally >1 in. but is dictated in part by the depth of rutting and/or other surface distresses. The resulting groove pattern includes an approximate spacing of 0.625 in. and a peak-to-valley depth of 0.125 to 0.3 in. (see figure below). Since the texture produced by standard cold milling is somewhat rough and noisy, the milled surface is most often accompanied by the application of an asphalt-aggregate seal or HMA overlay.



Performance Objectives

***Improve Texture for Friction*—**Improve surface micro-texture and macro-texture to correspondingly increase friction.

***Improve Profile (Surface Drainage and Ride)*—**Correct minor surface profile irregularities (including stable rutting) and correspondingly improve lateral surface drainage and ride quality.

***Improve Texture for Splash/Spray and Hydroplaning Concerns*—**Improve macro-texture to correspondingly reduce splash/spray generation and/or vehicle hydroplaning potential.

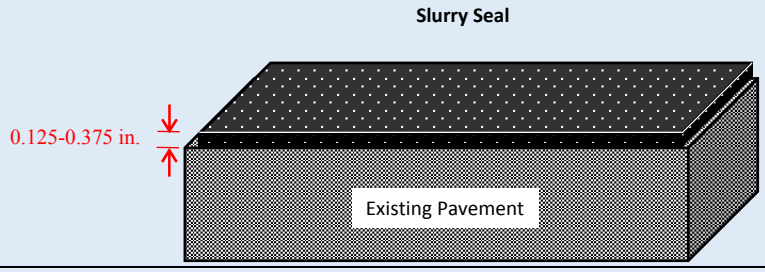
***Enhance Bond of New Surfacing Layer*—**Improve macro-texture of existing pavement resulting in greater bonding area for placement of new surfacing and less chance of slippage.

SLURRY SEAL

Treatment Description

***Slurry Seal*—**A mixture of well-graded aggregate (fine sand and mineral filler) and asphalt emulsion that is spread over the entire pavement surface with either a squeegee or spreader box attached to the back of a truck. Thickness application generally ranges between 0.125 and 0.375 in., as determined by the top-size of the aggregate. Slurry seals are effective in sealing low-severity surface cracks, waterproofing the pavement surface, and improving friction at speeds below 30 mi/hr.

Three types of slurry seal are available for use—Type I for parking areas and local roads/streets, Type II for collector roads/streets, and Type III for primary and interstate highways.



Performance Objectives

***Seal/Waterproof Pavement*—**Prevent or slow the infiltration of moisture into the pavement surface.

***Rejuvenate Surface/Inhibit Oxidation*—**Enrich the hardened/oxidized existing surface and inhibit raveling.

***Improve Texture for Friction*—**Improve surface micro-texture and macro-texture to correspondingly increase friction.

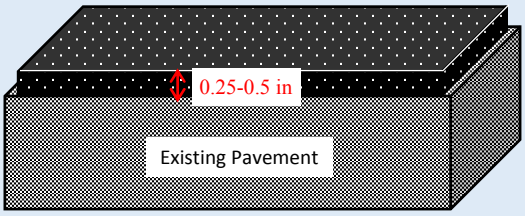
MICRO SURFACING

Treatment Description

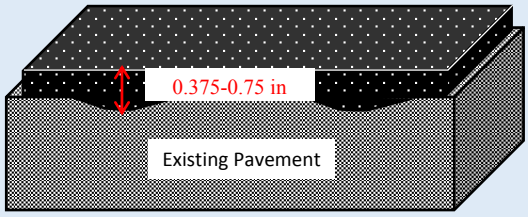
***Micro surfacing*—**A mixture of crushed, well-graded aggregate, mineral filler (portland cement), and polymer-modified emulsified asphalt spread over the full width of pavement with either a squeegee or spreader box. An extension of the slurry seal, micro surfacing is designed with high-quality, well-graded aggregates and advanced emulsions to allow for a thicker lift application without sacrificing stability. Micro surfacing is used primarily to inhibit raveling and oxidation and is particularly effective at improving surface friction and addressing rutting (up to 1.5 in. deep) and surface irregularities through multiple applications.

Micro surfacing is usually applied in either a single or double application. The thickness of a single application generally ranges between 0.25 and 0.5 in. (thickness is usually 2 or 3 times the top-size stone in the aggregate gradation), while the thickness of a double application generally ranges between 0.375 and 0.75 in. A double application typically involves a rut-filling application or scratch/leveling course followed by a full-lane width surface course. Two types of micro surfacing are available for use—Type II for surface courses on local and collector roads/streets surface courses and for scratch/leveling courses, and Type III for surface courses on primary and interstate highways and for rut-filling and scratch/leveling courses.

Single Micro



Double Micro Surfacing (w/ rut-filling)



Performance Objectives

***Seal/Waterproof Pavement*—**Prevent or slow the infiltration of moisture into the pavement surface.

***Rejuvenate Surface/Inhibit Oxidation*—**Enrich the hardened/oxidized existing surface and inhibit raveling.

***Improve Texture for Friction*—**Improve surface micro-texture and macro-texture to correspondingly increase friction.

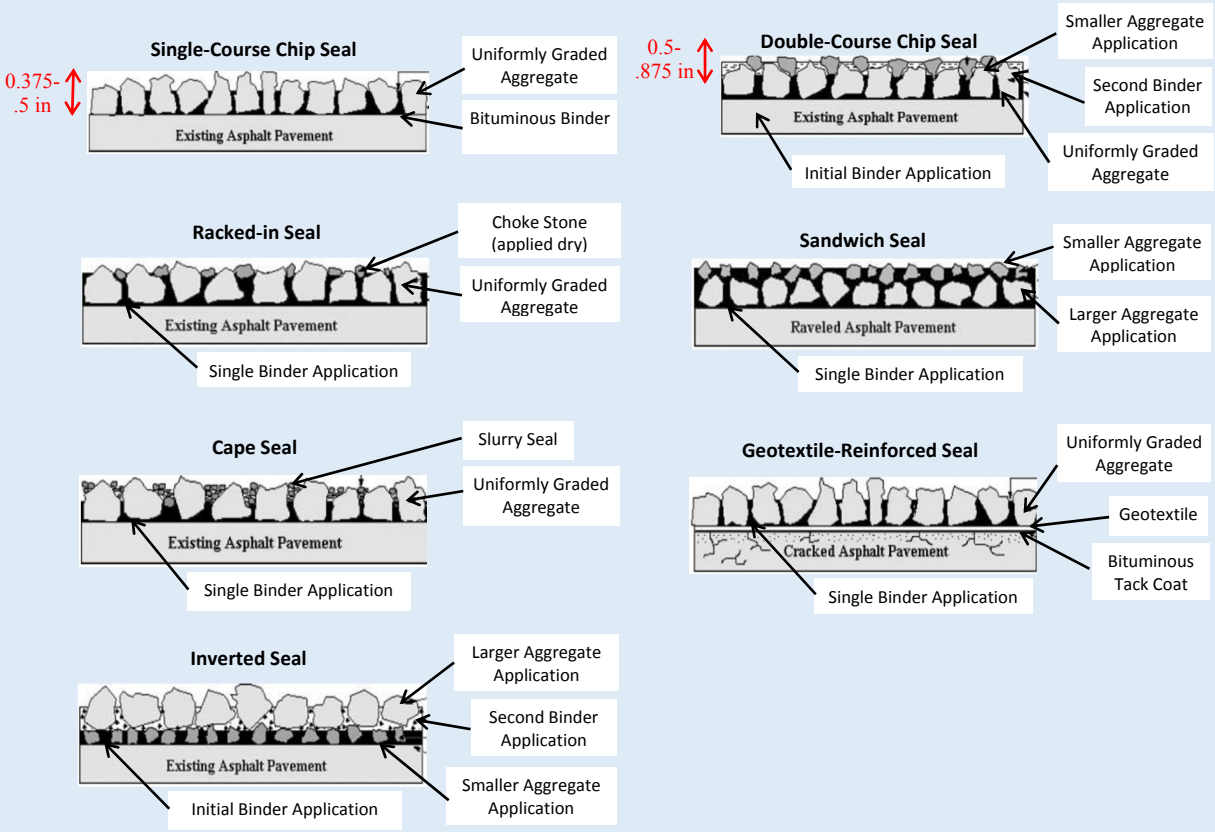
***Improve Profile (Surface Drainage and Ride)*—**Correct minor surface profile irregularities (including stable rutting) and correspondingly improve lateral surface drainage and ride quality.

CHIP SEAL

Treatment Description

Chip Seal—A chip seal consists of a sprayed application of asphalt (commonly emulsion, although heated asphalt cement and cutbacks are used as well) to the pavement surface followed by the application of aggregate chips, which are then immediately rolled to achieve 50 to 70 percent embedment. Emulsion-based chip seals include conventional unmodified, high-float, and polymer-modified emulsions. Chip seals can include precoated aggregate chips, with hot asphalt cement typically used for the coating. Chip seals can be applied in a single layer (typically between 0.375 and 0.5 in. thick), in multiple layers (e.g., a double chip seal is typically between 0.5 and 0.875 in. thick), or in combination with other treatments, such as micro surfacing/slurry seal, which is called a cape seal. Chip seal design variations include the following, which are also illustrated below (Gransberg and James 2005):

- **Racked-in Seal**—Chip seal that is temporarily protected from damage through the application of choke stone that becomes locked in the voids, preventing aggregate particles from dislodging before the binder is cured. Often used in locations where there are large numbers of turning movements.
- **Sandwich Seal (dry-matting)**—Chip seal involving one binder application sandwiched between two separate aggregate applications. Particularly useful for restoring surface texture on raveled surfaces.
- **Inverted Seal**—Inverted double chip seal, in which a smaller-sized aggregate chip seal is placed first, followed by a larger-sized aggregate chip seal. Typically used to correct bleeding.
- **Cape Seal**—Combination of a chip seal and micro surfacing/slurry seal, with the latter treatment placed atop the chip seal typically 4 to 10 days after placement of the chip seal. Primary purposes are the same as a chip seal; the micro surfacing/slurry seal finish increases the life of the chip seal by the enhanced binding of the aggregate chips and it reduces concerns associated with loose chips and a rough surface.
- **Geotextile-Reinforced Seal**—Application of geotextile over a tack coat, followed by application of a single-course chip seal.



Performance Objectives

Seal/Waterproof Pavement—Prevent or slow the infiltration of moisture into the pavement surface.
Rejuvenate Surface/Inhibit Oxidation—Protect pavement surface from further oxidation.
Reduce/Eliminate or Stabilize Surface Defects—Eliminate raveling/weathering and mitigate other surface defects, such as surface cracks and bleeding.
Improve Texture for Friction—Improve surface micro-texture and macro-texture to correspondingly increase friction.
Improve Profile (Surface Drainage and Ride)—Correct minor surface profile irregularities and correspondingly improve (to some extent) lateral surface drainage and ride quality.
Improve Texture for Splash/Spray and Hydroplaning Concerns—Improve macro-texture to correspondingly reduce splash/spray generation and/or vehicle hydroplaning potential.

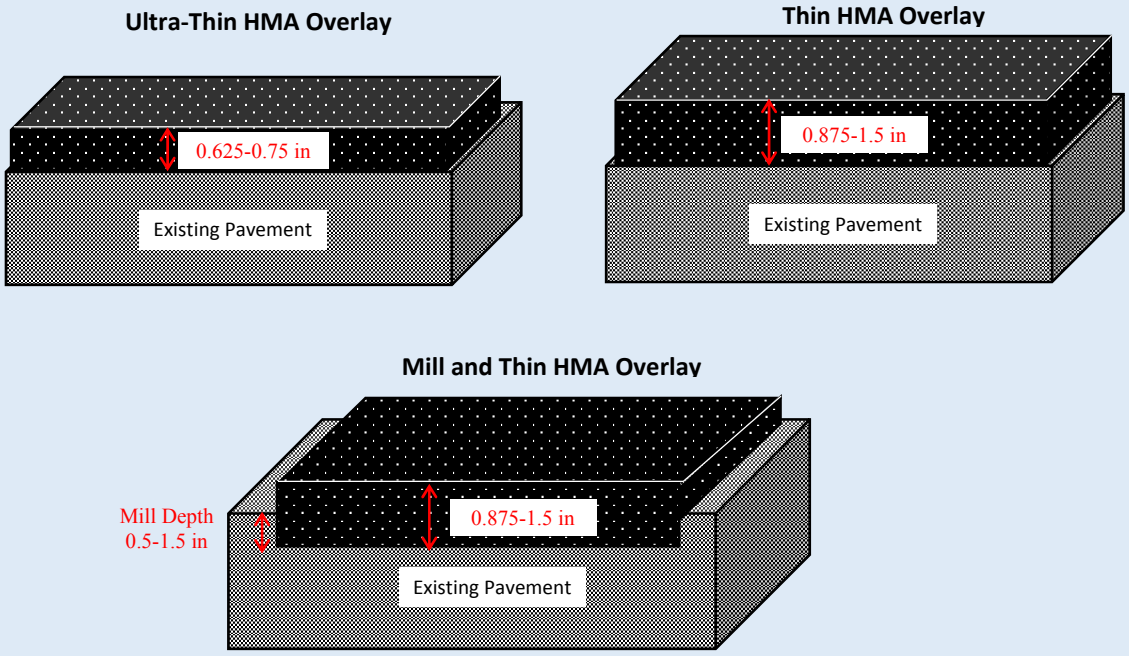
THIN AND ULTRA-THIN HMA OVERLAYS (WITH OR WITHOUT MILLING)

Treatment Description

***Thin and Ultra-Thin HMA Overlays*—**Composed of asphalt binder and aggregate combined in a central mixing plant and placed with a paving machine in thicknesses ranging from 0.625 to 0.75 in. for ultra-thin and 0.875 to 1.5 in. for thin. Conventional HMA overlays can be distinguished by their aggregate gradation:

- **Dense-graded**—a well-graded, relatively impermeable mix, intended for general use.
- **Open-graded**—an open-graded, permeable mix designed using only crushed aggregate and a small percentage of manufactured sand.
- **Gap-graded**—a gap-graded mix designed to maximize rut resistance and durability using stone-on-stone contact. Most commonly, this is stone matrix asphalt (SMA).

Additionally, it is recommended to mill the existing pavement surface when surface distresses (e.g., segregation, raveling, or block cracking) are evident; other benefits include improving surface friction, maintaining clearance of overhead structures, and providing an improved bonding surface.



Performance Objectives

***Seal/Waterproof Pavement*—**Prevent or slow the infiltration of moisture into the pavement surface.

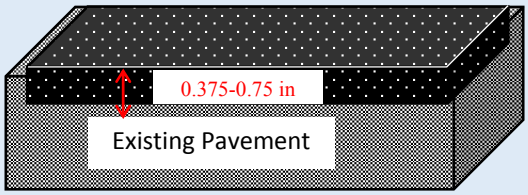
***Reduce/Eliminate or Stabilize Surface Defects*—**Eliminate raveling/weathering and mitigate other surface defects, such as surface cracks and bleeding.

***Improve Texture for Friction*—**Improve micro-texture and macro-texture to correspondingly increase friction.

***Improve Profile (Surface Drainage and Ride)*—**Correct minor surface profile irregularities and correspondingly improve (to some extent) lateral surface drainage and ride quality.

***Improve Texture for Pavement/Tire Noise*—**Improve micro-texture and macro-texture to correspondingly reduce noise.

***Improve Texture for Splash/Spray and Hydroplaning Concerns*—**Improve macro-texture to correspondingly reduce splash/spray generation and/or vehicle hydroplaning potential.

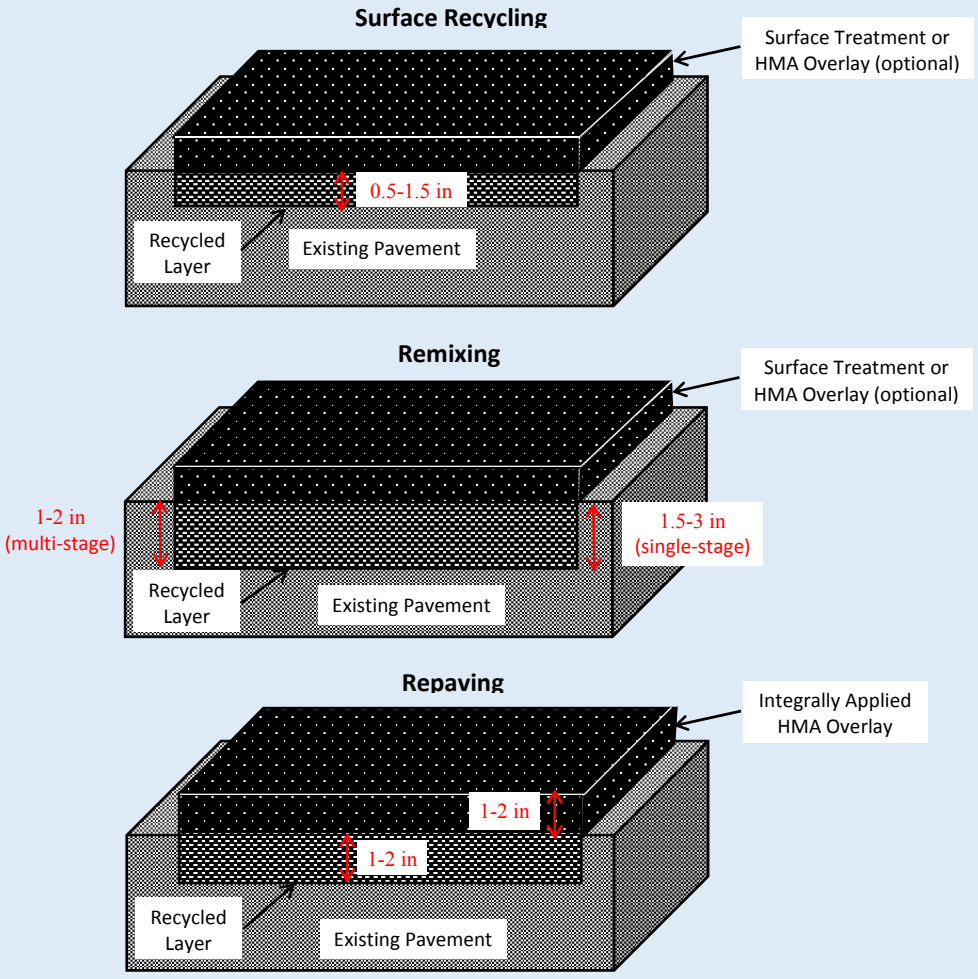
ULTRA-THIN BONDED WEARING COURSE	
Treatment Description	***Ultra-Thin Bonded Wearing Course (UTBWC)—***Also known as an ultra-thin friction course, an ultra-thin bonded wearing course may be used as an alternative treatment to chip seals, micro surfacing, or thin HMA overlays. This consists of a gap-graded, polymer-modified HMA layer (typically between 0.375 and 0.75 in. thick) placed on a tack coat (heavy, polymer-modified emulsified asphalt). It is effective at treating minor surface distresses and increasing surface friction. UTBWC was originally developed as a proprietary product called NovaChip®, but since the patent expired, several State transportation departments have developed their own specification for this treatment (Merritt et al. 2015). **Ultra-Thin Bonded Wearing Course** 
Performance Objectives	***Seal/Waterproof Pavement—***Prevent or slow the infiltration of moisture into the pavement surface. ***Rejuvenate Surface/Inhibit Oxidation—***Protect pavement surface from further oxidation. ***Reduce/Eliminate or Stabilize Surface Defects—***Eliminate raveling/weathering and mitigate other surface defects, such as surface cracks and bleeding. ***Improve Texture for Friction—***Improve micro-texture and macro-texture to correspondingly increase friction. ***Improve Profile (Surface Drainage and Ride)—***Correct minor surface profile irregularities and correspondingly improve (to some extent) lateral surface drainage and ride quality. ***Improve Texture for Pavement/Tire Noise—***Improve micro-texture and macro-texture to correspondingly reduce noise. ***Improve Texture for Splash/Spray and Hydroplaning Concerns—***Improve macro-texture to correspondingly reduce splash/spray generation and/or vehicle hydroplaning potential.

HOT IN-PLACE RECYCLING

Treatment Description

Hot In-Place Recycling (HIR)—As a preservation treatment, hot in-place recycling (HIR) corrects surface distresses within the top 2 in. of an existing HMA pavement by softening the surface material with heat, mechanically loosening/scarifying it and mixing it with recycling agent, aggregate, rejuvenators, and/or virgin asphalt. HIR consists of three different techniques:

- **Surface Recycling**—pavement surface (typically top 0.5 to 1.5 in.) is heated, loosened/scarified, combined with new asphalt, and re-laid for the purpose of minor mix improvement/modification. In single-pass surface recycling (low-volume roads), the recycled mix is re-laid and serves as the final wearing surface. In double-pass surface recycling (moderate- to high-volume roads), an HMA overlay or a surface treatment is applied over the recycled surface.
- **Remixing**—pavement is heated, loosened/scarified, combined with virgin aggregate and new asphalt (and/or new HMA), and re-laid for significant mix improvement/ modification and/or modest pavement strengthening. In single-stage recycling, the treatment depth is generally between 1.0 and 2.0 in. In multi-stage recycling, the treatment depth is typically between 1.5 and 3.0 in., and is carried out in two to four sequential layers. The recycled mix can serve as the final wearing surface (low-volume roads) or can serve as a base for an HMA overlay or surface treatment (moderate to high volume roads).
- **Repaving**—pavement surface is heated, loosened/scarified, combined with new asphalt, and re-laid in tandem with an HMA overlay for the purposes of pavement strengthening and restoration of surface profile and/or friction. In the single-pass method, the hot recycled mix is screeded, a new HMA mix is place on top of the uncompacted recycled layer, and the two layers are compacted as one thick, thermally bonded lift. In the multiple-pass method, the hot recycled mix is screeded, new HMA mix is placed on the uncompacted recycled layer using a separate paving machine, and the two layers are compacted as one thick, thermally bonded lift. Repaving is surface recycling with an integrally applied thermally bonded overlay.



Performance Objectives

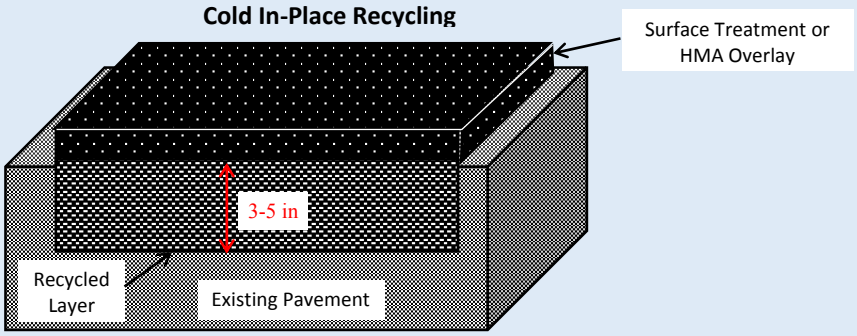
Rejuvenate Surface/Inhibit Oxidation—Enrich or remove/replace the hardened/oxidized existing surface.
Reduce/Eliminate or Stabilize Surface Defects—Eliminate raveling/weathering and eliminate or mitigate other surface defects, such as surface cracks and bleeding.
Improve Texture for Friction—Improve micro-texture and macro-texture to correspondingly increase friction.
Improve Profile (Surface Drainage and Ride)—Correct surface profile irregularities (including stable rutting) and correspondingly improve lateral surface drainage and ride quality.

COLD IN-PLACE RECYCLING

Treatment Description

Cold In-Place Recycling (CIR)—A process that consists of milling and sizing reclaimed asphalt pavement (RAP) and mixing in-place the RAP with recycling additive and new aggregate (either in the milling machine's cutting chamber or in a mix paver) to produce a recycled cold mix, which is then re-laid and compacted as a new base course.

As a preservation treatment, CIR is primarily used to restore profile/cross-slope and/or mitigate surface and other upper layer distresses. Its depth of application in a preservation capacity is limited to 3 to 4 in. For moderate- to high-volume roadways, the CIR recycled layer is accompanied by an HMA overlay or surface treatment.



Performance Objectives

Rejuvenate Surface/Inhibit Oxidation—Enrich or remove/replace the hardened/oxidized existing surface.

Reduce/Eliminate or Stabilize Surface Defects—Eliminate raveling/weathering and eliminate or mitigate other surface defects, such as surface cracks and bleeding.

Improve Texture for Friction—Improve micro-texture and macro-texture to correspondingly increase friction.

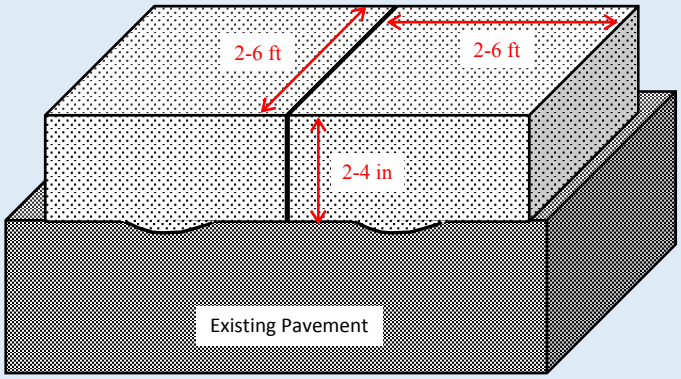
Improve Profile (Surface Drainage and Ride)—Correct surface profile irregularities (including stable rutting) and correspondingly improve lateral surface drainage and ride quality.

ULTRA-THIN PCC OVERLAY

Treatment Description

***Ultra-Thin PCC Overlay*—**Involves the placement of a thin (2 to 4 in.) PCC layer, with slab dimensions between 2 and 6 ft., over an existing AC-surfaced pavement. The primary purpose of an ultra-thin PCC overlay is to eliminate surface distresses (e.g., raveling and cracking), correct various forms of deformation (e.g., corrugations and rutting), and improve friction and smoothness (Smith et al. 2014).

Ultra-Thin PCC Overlay



Performance Objectives

***Reduce/Eliminate or Stabilize Surface Defects*—**Eliminate raveling/weathering and mitigate other surface defects, such as surface cracks and bleeding.

***Improve Texture for Friction*—**Improve micro-texture and macro-texture to correspondingly increase friction.

***Improve Profile (Surface Drainage and Ride)*—**Correct surface profile irregularities (including stable rutting) and correspondingly improve lateral surface drainage and ride quality.

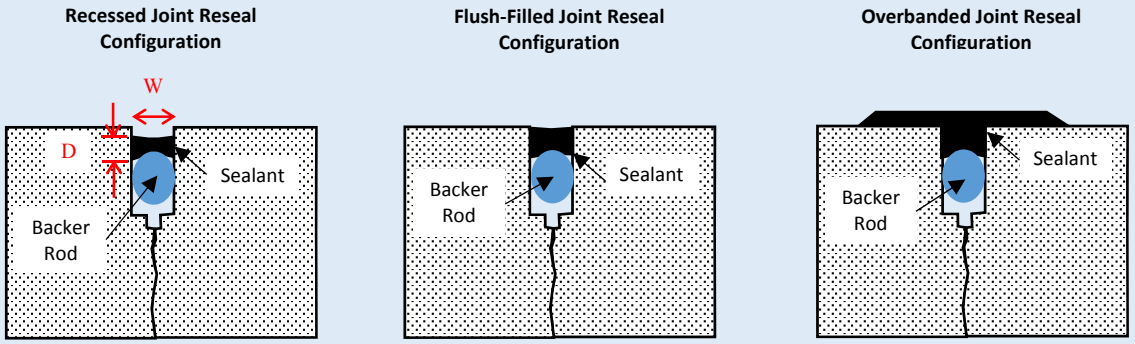
JOINT RESEALING AND CRACK SEALING

Treatment Description

***Joint Resealing and Crack Sealing*—**Joint resealing and crack sealing of PCC pavements prevents moisture and incompressible materials from infiltrating the pavement structure. This helps to slow or minimize the development of moisture-related distresses (such as pumping or faulting) and to prevent the occurrence of spalling, blowups, and other pressure-related distresses that might be caused by incompressible materials collecting in the joints (Smith et al. 2014).

Joint resealing consists of removing existing deteriorated transverse and/or longitudinal joint sealant (if present), refacing and pressure-cleaning the joint sidewalls, and installing new sealant material. The three primary configurations for joint resealing are shown below. Liquid sealants generally require the installation of backer rod to (a) prevent the sealant from seeping down into the joint and (b) provide a shape factor (i.e., ratio of sealant width [W] to sealant depth [D]) that minimizes the stresses that develop within the sealant and along the sealant/pavement interface (Smith et al. 2014). Typical shape factors are 1:1 for polymerized/rubberized asphalt sealants and polysulfide/polyurethane sealants and 2:1 for silicone sealants. The overbanded configuration is perceived to perform better because of the additional bonding area, but is subject to traffic wear on high-trafficked pavements or damage by snowplow blades, and can negatively affect ride quality (Smith et al. 2014).

Crack sealing consists of sawing, power cleaning, and sealing cracks (typically transverse, longitudinal, and corner-break cracks wider than 0.125 in.) in concrete pavement using high-quality sealant materials. It is primarily intended to slow the rate of deterioration by preventing the intrusion of incompressible materials and reducing the infiltration of water into the crack.



Performance Objectives

***Seal/Waterproof Pavement*—**Prevent or slow the infiltration of moisture into the pavement surface.

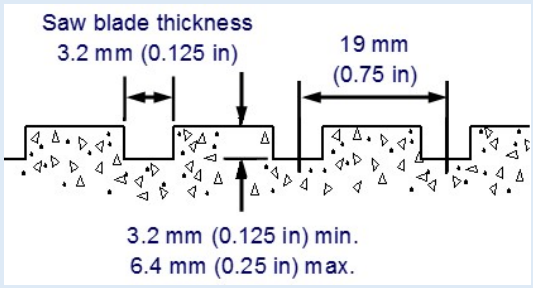
***Prevent Intrusion of Incompressibles*—**Prevent sand, dirt, pebbles, and other small particles from penetrating into the crack/joint and resulting in spalling when slabs expand in high temperatures.

DIAMOND GROOVING

Treatment Description

***Diamond Grooving*—**Consists of cutting narrow, discrete grooves into the pavement surface, which helps to reduce hydroplaning, vehicle splash and spray, and wet-weather crashes. The grooves may be created in the pavement either longitudinally (in the direction of traffic) or transversely. Longitudinal grooving is more commonly done on in-service roadways because it is less intrusive to adjacent traffic lane operations; transverse grooving provides a more direct drainage route and contributes to braking forces, but may also contribute to noise emissions. Typical groove dimensions are shown in the figure below (Smith et al. 2014).

Diamond Grooving Dimensions



Performance Objectives

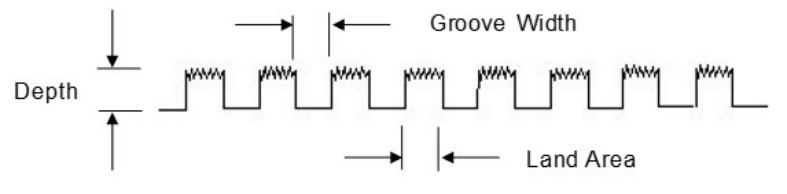
***Improve Texture for Friction*—**Improve macro-texture to correspondingly increase friction.
***Improve Texture for Pavement/Tire Noise*—**Improve micro-texture and/or macro-texture to correspondingly reduce noise.
***Improve Texture for Splash/Spray and Hydroplaning Concerns*—**Improve macro-texture to correspondingly reduce splash/spray generation and/or vehicle hydroplaning potential.

DIAMOND GRINDING

Treatment Description

***Diamond Grinding*—**Consists of removing a thin layer of concrete (usually between 0.12 and 0.25 in.) from the pavement surface, using special equipment fitted with a series of closely spaced, diamond-tipped saw blades that form longitudinal grooves/channels in the pavement surface. Diamond grinding removes joint faulting and other surface irregularities, thereby restoring a smooth-riding surface while also increasing surface friction and reducing noise emissions. Typical groove dimensions are shown in the figure and table below (Smith et al. 2014).

Diamond Grinding Dimensions



	Range	Hard Aggregate	Soft Aggregate
Groove Width, in.	0.09-0.15	0.09-0.15	0.09-0.15
Land Area, in.	0.07-0.13	0.07-0.11	0.09-0.13
Depth, in.	0.04-0.12	0.04-0.12	0.04-0.12
No. of Blades, per ft.	50-60	53-60	50-54

Performance Objectives

***Improve Texture for Friction*—**Improve micro-texture and macro-texture to correspondingly increase friction.

***Improve Profile (Surface Drainage and Ride)*—**Correct surface profile irregularities, such as faulted joints/cracks and curled/warped slabs, and correspondingly improve ride quality and lateral and longitudinal surface drainage.

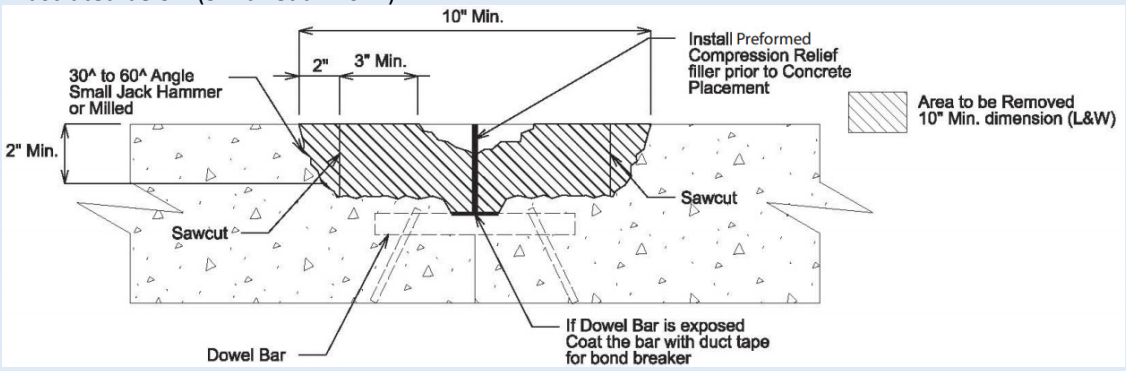
***Improve Texture for Pavement/Tire Noise*—**Improve micro-texture and/or macro-texture to correspondingly reduce noise.

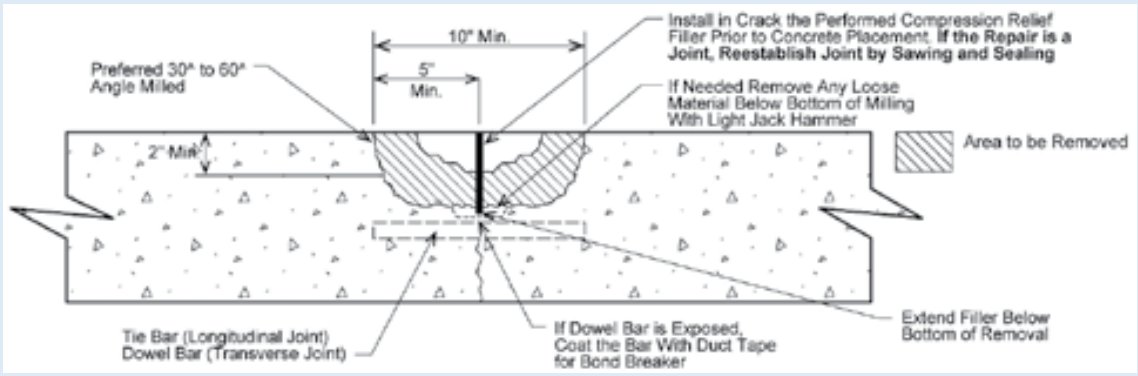
***Improve Texture for Splash/Spray and Hydroplaning Concerns*—**Improve macro-texture to correspondingly reduce splash/spray generation and/or vehicle hydroplaning potential.

PARTIAL-DEPTH AND FULL-DEPTH REPAIR

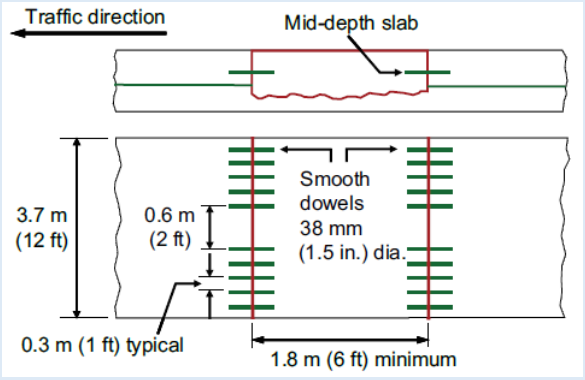
Treatment Description

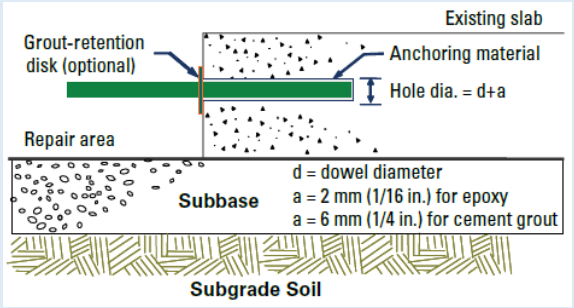
Partial-Depth Repair (PDR)—Form of patching that addresses small, shallow areas of deteriorated PCC. These deteriorated areas are removed and replaced with an approved repair material, thereby restoring or maintaining the serviceability of the pavement. Partial-depth repairs should be used to correct joint spalling and other surface distresses that are limited to the upper third of the slab. Typical partial-depth repair details are illustrated below (Smith et al. 2014).





Full-Depth Repair (FDR)—Cast-in-place or precast concrete repairs that extend through the full thickness of the existing slab, requiring full-depth removal and replacement of full lane-width areas. Full-depth repairs are effective at correcting slab distresses that extend beyond one-third the pavement depth, such as longitudinal and transverse cracking, corner breaks, and deep joint spalling. Typical full-depth repair details are illustrated below (Smith et al. 2014)





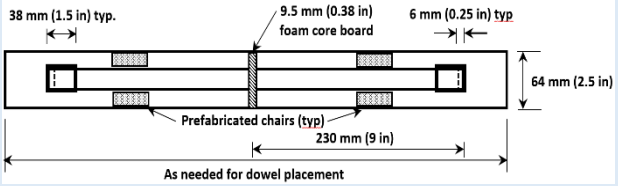
Performance Objectives

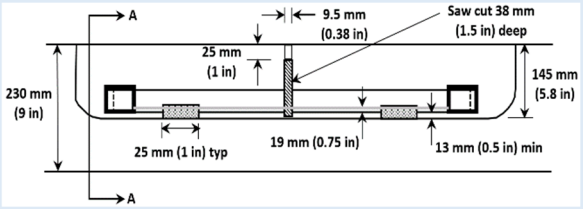
Seal/Waterproof Pavement—Prevent or slow the infiltration of moisture into the pavement surface.
Prevent Intrusion of Incompressibles—Prevent sand, dirt, pebbles, and other small particles from penetrating into the crack/joint and resulting in spalling when slabs expand in high temperatures.
Improve Profile (Surface Drainage and Ride)—Correct surface profile irregularities, such as faulted joints/cracks and curled/warped slabs, and correspondingly improve ride quality and lateral and longitudinal surface drainage.

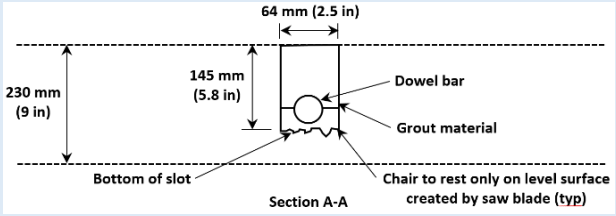
DOWEL BAR RETROFIT AND CROSS-STITCHING

Treatment Description

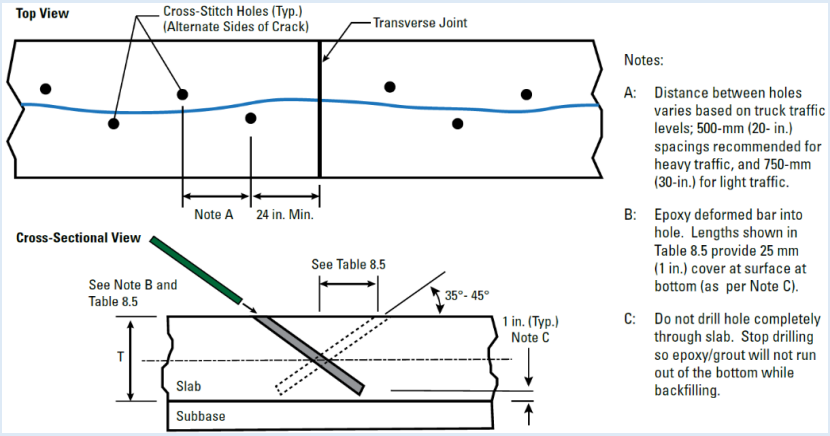
Dowel Bar Retrofit (DBR)—Consists of placing mechanical load transfer devices (i.e., dowel bars) across joints or cracks in an existing jointed PCC pavement. The process entails cutting slots (3 to 4 per wheelpath) across a joint or crack, removing the concrete within the slots, inserting the dowel bars into the slots, and placing and consolidating patching material around the bars in the slots. The dowel bars increase the load transfer capacity of the joint or crack, thereby reducing deflections and decreasing the potential for the development of pumping, faulting, and corner breaks. Poor load transfer at existing joints or cracks may result from an un-doweled jointing situation (in which excessive joint or crack openings leads to reduced aggregate interlock), corrosion of existing load transfer devices, and poor pavement drainage resulting in loss of underlying support (Smith et al. 2014). Typical DBR details are illustrated below (Smith et al. 2014).







Cross-Stitching—Repair technique for longitudinal cracks/joints in which deformed tie bars are inserted and grouted into angled (35° typically) drilled holes across the crack/joint. The purpose of cross-stitching is to maintain aggregate interlock and provide added reinforcement and strength to minimize vertical and horizontal movement or widening at the crack/joint (Smith et al. 2014). Typical cross-stitching details are presented below (Smith et al. 2014).



Angle	Slab Thickness, mm (in)							
	200 (8)	225 (9)	250 (10)	275 (11)	300 (12)	325 (13)	350 (14)	375 (15)
Distance from Crack to Hole, mm (in)								
35°	145 (5.75)	165 (6.50)	180 (7.25)	195 (7.75)	210 (8.50)	—	—	—
40°	—	—	—	165 (6.50)	180 (7.25)	195 (7.75)	205 (8.25)	—
45°	—	—	—	—	150 (6.00)	165 (6.50)	175 (7.00)	190 (7.50)
Length of Bar, mm (in)								
35°	240 (9.50)	275 (11.00)	315 (12.50)	365 (14.50)	400 (16.00)	—	—	—
40°	—	—	—	315 (12.50)	350 (14.00)	400 (16.00)	465 (18.50)	—
45°	—	—	—	—	300 (12.00)	350 (14.00)	415 (16.50)	450 (18.00)
Diameter of Bar, mm (in)								
	19 (0.75)	19 (0.75)	19 (0.75)	19 (0.75)	19 (0.75)	25 (1.0)	25 (1.0)	25 (1.0)

Performance Objectives

Improve Profile (Surface Drainage and Ride)—Increase load transfer efficiency and reduce potential for crack/joint faulting and growth, and correspondingly improve long-term ride quality and (to some extent) lateral and longitudinal surface drainage.