TxDOT Guidelines to Assign PMIS Treatment Levels

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16. Abstract

This report has been developed to provide TxDOT with guidelines to assign PMIS treatment levels for asphalt and rigid pavements which include Preventive Maintenance (PM), Light Rehabilitation (LRhb), Medium Rehabilitation (MRhb), and Heavy Rehabilitation (HRhb). The treatment level definitions were presented as well as their respective construction projects and frequency of use by TxDOT. The work treatments were defined with focus on the description, conditions for use, advantages, limitations, and expected performance. A decision-support matrix is also included for asphalt and concrete pavements with the aim of identifying the best treatment, based on the severity of existing distresses, traffic levels, functionality of the road, and extent of surface imperfections. In the case of asphalt pavements, an approach was presented to include available structural indices in the network-level decision making process.

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TxDOT GUIDELINES TO ASSIGN PMIS TREATMENT LEVELS

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INTRODUCTION

This document has been developed to provide TxDOT with guidelines to assign PMIS treatment levels. There are four treatment levels in PMIS: Preventive Maintenance, Light Rehabilitation, Medium Rehabilitation and Heavy Rehabilitation. Work treatment description, conditions for use, limitations, and expected performance are provided for treatments listed under each PMIS treatment level. A decision-support matrix is also included for asphalt and concrete pavements with the aim of identifying the best treatment based on the severity of the existing distresses, traffic level, functionality of the road, and extent of surface imperfections.

PMIS TREATMENT LEVEL DEFINITIONS

Preventive Maintenance (PM) is used to reduce the rate of deterioration and retard failures of pavements still in good condition, extending its service life (see Figure 1). This functional life of the pavement is extended by protecting the pavement structure from water infiltration and repairing any minor surface distresses at an early stage of development. While minor surface defects are temporarily corrected, combining the treatment with activities such as patching may result in a short term ride improvement. Structural capacity is not increased, and low severity non-load related distresses are corrected.

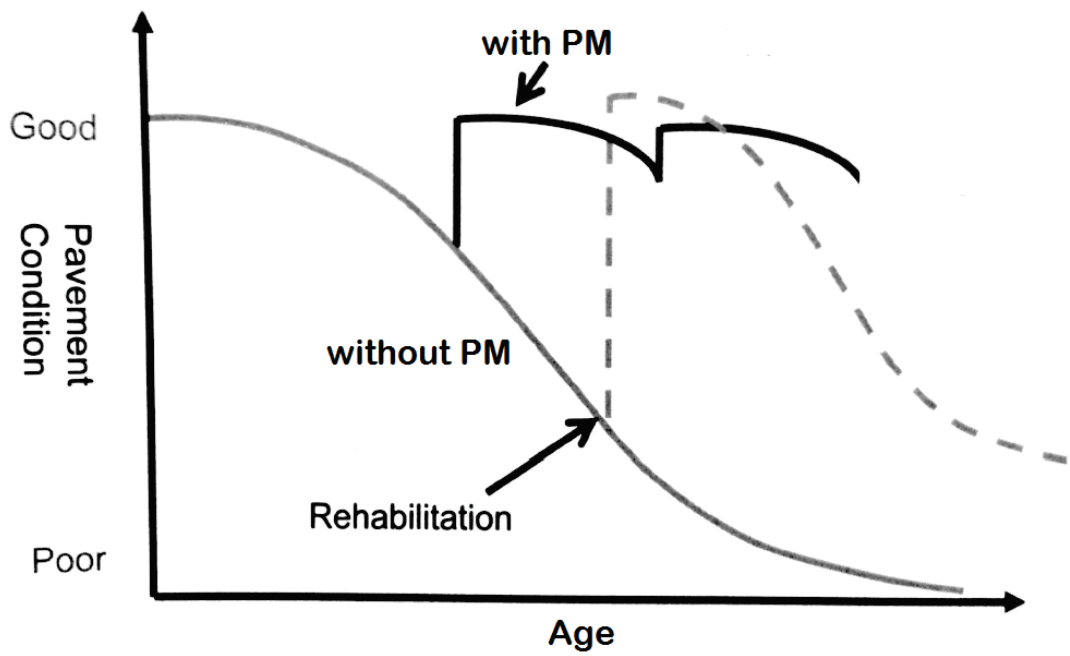

Figure 1. Pavement Condition with and without Preventive Maintenance (68).

Light Rehabilitation is usually composed of non-structural improvements to address surface distresses mainly related to aging and environmental effects. In addition, it restores functional characteristics and protects structural integrity. Structural capacity will not significantly improve, but ride quality improvement is expected.

Medium Rehabilitation is a structural improvement that will extend the service life of an existing pavement and increase its load-carrying capacity. This is usually accomplished by increasing the pavement thickness to carry increased vehicular loading or volume. Treatments under this category also restore functional characteristics improving the ride quality considerably.

Heavy Rehabilitation is the partial or complete removal and replacement of the existing pavement structure to restore functional and structural conditions to at least the original conditions. Good ride quality is restored, and all distresses are removed. Treatments under this category are performed on pavement sections with extensive structural distresses.

Tables 1, 2, and 3 shows the work treatments listed under each PMIS category for asphalt, jointed concrete, and continuously reinforced concrete pavements, respectively.

Table 1. Asphalt Pavement Work Treatments by PMIS Treatment Level.

Treatment Level	TxDOT's Description	Frequency of Use by TxDOT		
		Frequent	Rare	Expanding
Preventive Maintenance	Cape Seal		X	
	Fog Seal	X		
	Microsurfacing		X	
	Seal Coat	X		
	Thin Overlay (2" thick or less)	X		
	Ultra-Thin Friction Course	X		
Light Rehabilitation	Base Repair and Seal	X		
	Cold In-Place Recycling		X	
	Hot In-Place Recycling		X	
	Mill and Inlay; or Mill, Seal, and Thin Overlay	X		
	Overlay Greater than 2" Thick but Less than 3"		X	
Medium Rehabilitation	Base Repair, Spot Seal, Edge Repair, and Overlay	X		
	Level Up and Overlay	X		
	Mill and Overlay	X		
	Mill, Stabilize Base, and Seal		X	
	Overlay Between 3" and 5"		X	
Heavy Rehabilitation	Full Depth Reclamation (Pulverization and Resurfacing)	X		
	Mill, Cement Stabilize Base, and Overlay	X		
	Reconstruction	X		
	Thick Overlay Greater than 5"		X	

Note: "Frequency of use" by TxDOT is included in Tables 1, 2, and 3 based on preliminary feedback from TxDOT.

Table 2. Jointed Concrete Pavement Work Treatments by PMIS Treatment Level.

Treatment Level	TxDOT's Description	Frequency of Use		
		Frequent	Rare	Expanding
Preventive Maintenance	Joint and Crack Sealing	X		
	Diamond Grinding and/or Grooving			X
	Partial Depth Patch			X
	Ultra-Thin Friction Course		X	
Light Rehabilitation	Thin Asphalt Overlay	X		
	Dowel Bar Retrofit and Diamond Grinding		X	
	Full Depth Repair of Concrete	X		
Medium Rehabilitation	Full Depth Repair and Structural Asphalt Overlay and/or Slab Stabilization	X		
	Slab Replacement	X		
Heavy Rehabilitation	Rubblizing and Asphalt Overlay			X
	Unbonded Concrete Overlay			X
	Reconstruction	X		

Table 3. Continuously Reinforced Concrete Pavement Work Treatments by PMIS Treatment Level.

Treatment Level	TxDOT's Description	Frequency of Use		
		Frequent	Rare	Expanding
Preventive Maintenance	Diamond Grinding and/or Grooving			X
	Partial Depth Patch	X		
	Ultra-Thin Friction Course		X	
Light Rehabilitation	Thin Asphalt Overlay	X		
	Full Depth Repair of Concrete	X		
Medium Rehabilitation	Full Depth Repair and Structural Asphalt Overlay and/or Slab Stabilization	X		
	Bonded Concrete Overlay			X
Heavy Rehabilitation	Reconstruction	X		
	Unbonded Concrete Overlay			X

CRITERIA FOR TREATMENT SELECTION

CLIMATIC ZONE

Four climatic zones are defined in Texas:

- Zone 1: Wet-cold climate and poor, very poor, or mixed subgrade.
- Zone 2: Wet-warm climate and poor, very poor, or mixed subgrade.
- Zone 3: Dry-cold climate and good, very good, or mixed subgrade.
- Zone 4: Dry-warm climate and good, very good, or mixed subgrade.

Figure 2 shows the climatic zones, and Table 4 has a list with the counties that fall in each zone.

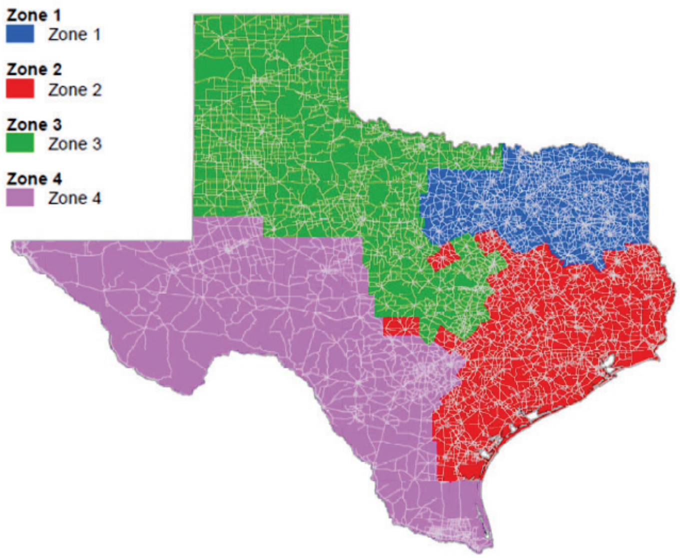

Figure 2. Climatic Zones in Texas.

Table 4. Counties in Climate and Subgrade Zones.

Zone	Counties
Zone 1	1, 19, 32, 34, 37, 43, 57, 60, 61, 71, 73, 75, 81, 92, 93, 103, 108, 112, 113, 117, 120, 127, 130, 139, 155, 172, 175, 182, 183, 184, 190, 194, 199, 201, 212, 213, 220, 225, 230, 234, 249, 250
Zone 2	3, 4, 8, 11, 13, 20, 21, 26, 28, 29, 36, 45, 62, 74, 76, 80, 82, 85, 87, 89, 90, 94, 98, 101, 102, 106, 110, 114, 121, 122, 124, 126, 129, 137, 143, 144, 145, 146, 147, 149, 154, 158, 166, 170, 174, 176, 178, 181, 187, 196, 198, 202, 203, 204, 205, 210, 228, 229, 235, 236, 237, 239, 241
Zone 3	5, 6, 9, 12, 14, 16, 17, 18, 23, 25, 27, 30, 33, 35, 38, 39, 40, 42, 44, 47, 49, 50, 51, 54, 56, 58, 59, 63, 65, 68, 77, 78, 79, 84, 86, 91, 96, 97, 99, 100, 104, 105, 107, 111, 115, 118, 128, 132, 135, 138, 140, 141, 148, 150, 152, 153, 157, 160, 161, 167, 168, 169, 171, 173, 177, 179, 180, 185, 188, 191, 197, 206, 208, 209, 211, 215,217, 219, 221, 223, 224, 227, 242, 243, 244, 246, 251, 252
Zone 4	2, 7, 10, 15, 22, 24, 31, 41, 46, 48, 52, 53, 55, 64, 66, 67, 69, 70, 72, 83, 88, 95, 109, 116, 119, 123, 125, 131, 133, 134, 136, 142, 151, 156, 159, 162, 163, 164, 165, 186, 189, 192, 193, 195, 200, 207, 214, 216, 218, 222, 226, 231, 232, 233, 238, 240, 245, 247, 248, 253, 254

TRAFFIC LEVELS

Table 5 show the traffic level definitions for asphalt, jointed concrete, and continuosly reinforced concrete. The are three levels of traffic defined for asphalt pavements, and two levels defined for jointed and continuosly reinforced concrete.

Table 5. Matrix Traffic Level Definitions.

Pavement	Traffic Level	ADT/Lane
Asphalt	Low	< 1,000
	Medium	1,000 – 5,000
	High	> 5,000
Jointed Concrete	Low	< 7,500
	High	≥ 7,500
Continuously Reinforced Concrete	Low	< 7,500
	High	≥ 7,500

Note: The traffic levels defined in Table 5 are based on the decision tree trigger criteria presented in TxDOT Project 0-6386 "Evaluation and Development of Pavement Scores, Performance Models and Needs Estimates" (20). In this report, asphalt pavements have four ADT traffic levels independent of functional class. ADT 1 and 2 were merged in these guidelines to simplify the definitions. For concrete pavements there are only two traffic levels, low and high, which are dependent on functional classes and there are only low and high levels. We have adopted in these guidelines an ADT/Lane value of 7,500 as a threshold since this value differentiates between high and low for major roads.

DISTRESS EXTENT LEVELS

Table 6 shows the definitions for asphalt distress extent levels. The distress extent levels for raveling and flushing are from the PMIS Rater's Manual (58). For alligator, block, longitudinal, and transverse cracking, the extent levels are based on the asphalt decision tree revised in TxDOT Project 0-6386 (20). As a reference, Table 7 shows the corresponding distress score values for the distress extent ranges defined in Table 6. The distress scores values are for a single distress type.

Table 6. Asphalt Distress Extent Level Definitions.

Distress	Units	Extent Level		
		Low	Medium	High
Alligator Cracking	Percent area	< 15	15 - 50	> 50
Block Cracking	Percent area	< 20	20 - 50	> 50
Longitudinal Cracking	Linear feet per station	< 100	100 - 175	> 175
Transverse Cracking	Number per station	< 6	6 - 10	> 10
Raveling	Percent area	≤ 10	11 - 50	> 50
Flushing	Percent area	≤ 10	11 - 50	> 50

Table 7. Distress Score per Defined Extent Level for Single Distress Type.

Distress	Extent Level		
	Low	Medium	High
Alligator Cracking	100-69	69-55	55-51
Block Cracking	100-70	70-60	60-56
Longitudinal Cracking	100-86	86-70	70-28
Transverse Cracking	100-88	88-76	76-38
Raveling	-	-	-
Flushing	-	-	-

RIDE QUALITY LEVELS

Table 8 describes the ride quality index for each level in terms of IRI (International Roughness Index) in in/mi and the Ride Score Index for asphalt pavements.

Table 8. Asphalt Ride Quality Level Definitions.

Ride Quality Index		Ride Quality Level
Ride Score (RS)	IRI (in/mi)	
< 2.25	> 200	Low
2.25 ≤ RS ≤ 3.0	140 < IRI ≤ 200	Medium
> 3.0	≤ 140	High

NETWORK LEVEL STRUCTURAL CONDITION

The matrices created for asphalt pavements can also incorporate information on the avilable structural characteristics of the flexible pavement. The Structural Condition Index (SCI) created in Project 0-4322 is a FWD-based structural condition estimator (67). Table 9 shows the threshold values per treatment that were created in the implementation of the SCI.

Table 9. Structural Condition Index Treshhold Values.

SCI Scores (SCI*100)	Treatment Level
90–100	Do Nothing
80–89	PM
65–79	LRhb
50–64	MRhb
0–49	HRhb

On the other hand if that index is not available, other indices may be used in a two-step process. The first step would be to find the troubled layer and then use Table 14 to assign the treatment level that best fits. The following tables (10–13) may be used in the first step to find the distressed layer according to the available structural condition data. The main indices used are the Surface Curvature Index (SCI), the Base Curvature Index (BCI), the FWD sensor 7 (W_7), and the subgrade modulus. For table 13, the layer thickness was also incorporated.

Table 10. Structural Condition Indices Based on FWD to Diagnose Possible Distressed Layer.

w7	SCI	Diagnosis
≤1.2	<21	Good Base, Stiff Subgrade
	>20, <40	Marginal Base, Stiff Subgrade
	>39	Thin or Soft base, Stiff Subgrade
1.3–1.9	<21	Good Base, Marginal Subgrades
	>20, <40	Marginal Base, Marginal Subgrade
	>39	Thin or Soft Base, Marginal Subgrade
≥2.0	<21	Good Base, Soft or Wet Subgrade
	>20, <40	Marginal Base, Soft or Wet Subgrade
	>39	Thin or Soft Base, Soft or Wet Subgrade

Table 11. Subgrade Modulus Ranges to Diagnose Subgrade Quality.

Subgrade Modulus, ksi	Diagnosis
Less than 4	Very Poor
4-8	Poor
8-12	Fair
12-16	Good
>16	Very Good

Table 12. Ratio of Base to Subgrade Modulus to Diagnose Base Quality.

Ratio (Ebase/Esubgrade)	Diagnosis
>3	Good Base
2-3	Marginal Base
<2	Poor Base

Table 13. Structural Condition Indices Based on FWD and Layer Thickness to Diagnose Possible Distressed Layer.

Index Parameters	Asphalt Thickness, in.				Diagnosis
	>5	<=5,>=2.5	<2.5,>=1	<1	
SCI	<4	<6	<12	<16	Very Good Asphalt Layer
	4-6	6-10	12-18	16-24	Good Asphalt Layer
	6-8	10-15	18-24	24-32	Fair Asphalt Layer
	8-10	15-20	24-30	32-40	Poor Asphalt Layer
	>10	>20	>30	>40	Very Poor Asphalt Layer
BCI	<2	<3	<4	<8	Very Good Base Layer
	2-3	3-5	4-8	8-12	Good Base Layer
	3-4	5-9	8-12	12-16	Fair Base Layer
	4-5	8-10	12-16	16-20	Poor Base Layer
	>5	>10	>16	>20	Very Poor Base Layer
w7	<1	<1	<1	<1	Very Good Subgrade Layer
	1-1.4	1-1.4	1-1.4	1-1.4	Good Subgrade Layer
	>1.4-1.8	>1.4-1.8	>1.4-1.8	>1.4-1.8	Fair Subgrade Layer
	>1.8-2.2	>1.8-2.2	>1.8-2.2	>1.8-2.2	Poor Subgrade Layer
	>2.2	>2.2	>2.2	>2.2	Very Poor Subgrade Layer

Once the distressed layer has been identified, the second step is to assign the most appropriate treatment level. Table 14 shows the most appropiate layer that each PMIS treatment level addresses. Once the treatment level is assigned the asphalt pavement decision matrix can be used to more directly assign a treatment.

Table 14. Aspahlt Pavement Layer Addressed by PMIS Treatment Levels.

Treatment Level	Pavement Layer		
	HMA	Base/Subbase	Subgrade
PM	●		
LRhb	●	◑	
MRhb	◑	●	
HRhb		◑	●

● = Recommended ◑ = Conditionally Recommended (may depend on other factors)

<u>Note:</u> Although not directly referenced, the following references were used in the description of the treatments for the proposed guidelines: 2, 3, 5, 9-13, 15-18, 21-26, 32, 33, 35, 36, 37, 40, 41, 43-46, 49-52, 54, 55, 57-60, and 67.

INSTRUCTIONS FOR USING THE DECISION SUPPORT MATRIX FOR THE SELECTION OF TREATMENT ALTERNATIVES

The decision support matrix shown in Table 15 is based on predominant distresses present for selecting treatment alternatives. A full-shaded circle means that treatments are definitively recommended options, a half-shaded circle means that the treatment is conditionally recommended because there are other factors involved in the decision, and an empty space means that the treatment is not used for that distress level. The purpose of the matrix is to aid in identifying all possible alternatives based on predominant distressess. The matrix is not intended to replace decision trees used in PMIS. Multiple distresses or a combination of distresses and extent deserves further study.

Example: If there is low extent block cracking (<20 percent by area), the recommended preventive maintenance alternatives are: cape, fog, seal coat, thin overlay, or ultrathin. However, microsurfacing is not recommended for block cracking. If there is high extent block cracking (>50 percent), the same preventive maintenance treatments apply, although thin overlay and ultrathin treatments are now conditionally recommended; light rehabilitation and medium rehabilitation treatments are also possible alternatives, including Hot and Cold Recycling, or a Mill and Overlay. The other treatments in the matrix are either not recommended (Base Repair) or conditionally recommended (Inlay, etc.). The application of light rehabilitation or medium rehabilitation treatments is preferred when there are multiple distress types present or the District wants to upgrade the section.

FLEXIBLE (ASPHALT) PAVEMENT TREATMENTS

Table 15. Decision Support Matrix for the Selection of Treatment Alternatives for Asphalt Pavements.

Level	Treatment	Climatic Zone				Traffic			Predominant Pavement Distress: Rutting				Patching	Failures	Block Cracking			Alligator Cracking			Longitudinal Cracking			Transverse Cracking			Raveling			Flushing			Ride Quality		
		1	2	3	4	L	M	H	Shallow	Deep	Severe	Failure	-	-	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
Preventive Maintenance	Cape Seal	●	●	●	●	●	●	◑	●	●	◑		●	◑	●	●	●	●	●	◑	●	●	●	●	●	●	●	●	●	●	●	●	●	◑	
	Fog Seal	1*	1*	●	●	●	◑	◑					●		●	●	●	●	◑		●	●	●	●	●	●	●	●	●						
	Microsurfacing	●	●	●	●	●	●	●	●	●	◑		●					◑			◑			◑			●	●	●	●	●	●			
	Seal Coat	●	●	2*	2*	●	◑	◑	●	◑			●	◑	●	●	●	●	◑		●	●	●	●	●	●	●	●	●	●	◑	◑		◑	◑
	Thin Overlay 2" Thick or Less	●	●	●	●	◑	●	●	●	●	◑		●	◑	●	●	◑	●	◑		●	●	◑	●	●	◑	●	●	●	●	●	●	●	◑	
	Ultrathin Surface Course	●	●	●	●	◑	●	●	●	◑			●	◑	●	●	◑	●	◑		●	●	◑	●	●	◑	●	●	●	●	●	●	◑		
Light Rehabilitation	Base Repair and Seal	●	●	●	●	●	●	◑		◑	●	●		●				●	●	●														●	◑
	Cold In-Place Recycling	●	●	●	●	◑	●	◑		◑	◑	◑	●	◑		◑	●	●	◑	◑		◑	●		◑	●			●		◑	●	●	●	◑
	Hot In-Place Recycling	●	●	●	●	◑	●	●		◑	◑	◑	●	◑		◑	●	●	◑	◑		◑	●		◑	●			●		◑	●	●	●	◑
	Mill and Inlay; or Mill, Seal and Thin Overlay	●	●	●	●	◑	●	●		◑	●	◑	●	◑			◑	●	●	◑			◑			◑					◑	●	●	●	◑
	Overlay Greater Than 2" Thickness But Less Than 3"	●	●	●	●		●	●		◑	●	◑	◑	◑			◑	●	●	◑			◑			◑					◑	●		●	◑
Medium Rehabilitation	Base Repair, Spot Seal, Edge Repair and Overlay	●	●	●	●	◑	●	●		●	●	◑	◑	●			◑	●	●	◑			◑											●	●
	Level Up and Overlay	●	●	●	●	●	●	●	◑	●	●	◑	◑	●			◑	●	●	◑			◑									●		●	●
	Mill and Overlay	●	●	●	●	●	●	●		◑	●	◑		◑		◑	●		◑	◑			◑								◑	●		●	●
	Mill, Stabilize Base, and Seal	●	●	●	●	●	●	●		◑	●	●							◑	●														●	●
	Overlay Between 3" and 5"	●	●	●	●	●	●	●	●	●	●	●							◑	●														●	●
Heavy Rehabilitation	Full Depth Reclamation (Pulverization and Resurfacing)	●	●	●	●	●	●	●	●	●	●	●							◑	●															3*
	Mill, Cement Stabilize Base, and Overlay	●	●	●	●	●	●	●	●	●	●	●							◑	●															3*
	Reconstruction	●	●	●	●	●	●	●	●	●	●	●							◑	●															3*
	Thick Overlay Greater Than 5"	●	●	●	●	●	●	●	●	●	●	●							◑	●															3*

●= Recommended ◑= Conditionally Recommended (may depend on other factors)

1* - Fog Seal not recommended for Medium and High Traffic sections

2* - Seal Coat not recommended for High Traffic sections

3*- Heavy Rehabilitation to correct poor ride quality (RS< 1.5 or IRI > 270 in/mi) is recommended when such treatment will also correct severe distortion and/or fracture in the existing pavement (such as in areas with expansive soils)

Cape Seal	
Description	The cape seal is an integrated surface treatment system constructed by topping a chip seal with microsurfacing or slurry seal. Slurry seals are constructed of a mixture of slow-setting emulsified asphalt, dense-graded crushed fine aggregate, mineral filler, or other additives and water. The single layer chip seal is applied to the pavement surface in the conventional manner; once the chip seal has been cured for 4 to 10 days, the second treatment is applied (66).
Conditions for Use	• *Main Distresses*: Cape seals are used to address longitudinal, transverse, block cracking, raveling/weathering and low to medium severity bleeding. The treatment is also helpful in sealing low to medium severity fatigue cracks. • *Traffic*: Cape seals are suitable for low and high traffic roads but it is commonly used for the latter. This is as result of the second surfacing locking loose chips in place. Traffic should be kept at slower speeds on high-volume roadways until the seal coat finishes curing and it is covered by the secondary treatment. • *Climate*: Performs well in all climatic regions, except when using microsurfacing. Microsurfacing performs better in warm temperatures with low daily changes. The best time of the year for placing chip seals and microsurfacing as well as the placing temperatures previously described apply. The treatments must be placed in warm weather with low humidity and wind, while rainy cold conditions should be avoided. • *Restrictions:* Pavements structurally deficient or very rough must be avoided. The treatment is not recommended for cracks wider than 0.25 inches and rutting greater than 1 inch (6). The presence of medium to high severity alligator and many potholes in the candidate project is not desirable.
Advantages	• The cape seal provides a dense surface with good skid resistance and a relatively long service life. • The slurry seal cover over the chip seal eliminates the problem with loose aggregates and reduces traffic noise. • Protects against moisture infiltration. • Improves ride quality and reduces minor roughness if the surface is properly prepared. • Less susceptible to snow plows. • Effective in areas where HMA is not available and high resistance to shearing forces is required.
Limitations	• Higher initial cost and limited use in the United States. • If slurry seal is used as the secondary treatment, the long curing time may cause traffic delays. • There is need to establish traffic control twice in a relatively short time period. • Cape seal can accelerate the development of stripping in susceptible HMA pavements. • Few contractors have experience in constructing cape seals as an integrated system and availability may be limited in some areas. • Adds only limited structural capacity.
Expected Performance	The performance of the treatment is expected to last from 7 to 15 years (31).

Fog Seal	
Description	Fog seal is a very light application of slow-setting, water-diluted asphalt emulsion applied directly on the pavement surface with no aggregate. Normally, an asphalt distributor is used to apply the treatment.
Conditions for Use	• *Main Distresses*: The treatment can be used to treat low severity longitudinal, transverse, and block cracking. Furthermore, the treatment will fix low severity raveling and fatigue cracking. • *Traffic*: Roadways treated include very low to high traffic but typically with ADT< 4,000 (1). When the increased ADT or truck percentage levels are encountered the surface wear increases. On high volume roads, skid-resistance may become a factor. • *Climate*: Fog seal performs well in all climatic regions. It is best to place the treatment when temperatures are warm or hot and dry. When placed in cool temperatures, longer curing times are required prior to opening to traffic. • *Restrictions:* Pavements with significant fatigue cracking or severe thermal cracking are not good candidates. The treatment should not be used if medium severity flushing/bleeding is encountered or if rutting is present. In addition, the pavement needs to be sufficiently porous to absorb a substantial amount of the emulsion when placing the fog seal.
Advantages	• Low initial cost. • Provides some pavement edge delineation. • Can be applied to a seal coat that exhibits aggregate shelling. Aggregate shelling happens after the first cold spell after a seal coat. • Reduces asphalt aging, oxidation, hardening and prevents moisture infiltration.
Limitations	• No structural value is added. • The treatment has a short life expectancy. • Stripping is susceptible in asphalt pavements. • Can reduce skid-resistance. • Traffic needs to remain closed for 2 hours due to the slow-setting emulsion (6). • Does not affect the ride quality of a roadway.
Expected Performance	The performance is expected to last 1 to 3 years (31).

Microsurfacing	
Description	Microsurfacing is composed of polymer-modified emulsified asphalt cement, well-graded crushed fine aggregate (top size < 0.5 inches), mineral filler, water, and additives which are then mixed in specialized, compartmented, self-powered trucks (29). Although the components of microsurfacing are very similar to hot mix asphalt, microsurfacing is placed at ambient temperatures which usually does not require compaction, allowing the placement of much thinner layers than can be possible with regular hot mix. Microsurfacing is also more stable than slurry seals and can be placed at thicknesses 3 times the size of the largest aggregate in the mix.
Conditions for Use	• *Main Distresses*: The treatment can be used for low to medium severity transverse, longitudinal, and block cracking. In addition, the treatment will arrest raveling/weathering, low to medium bleeding, shallow rutting, and low severity alligator cracking. • *Traffic*: The treatment has succeeded in both low and high volume roadways. Typically used for ADT > 400 (31). • *Climate*: The treatment is effective in all climates, but it performs better in warm temperatures with low daily changes. Placement in hot weather should be avoided if there is potential for flushing. Construction should not be commenced if freezing temperatures are expected within 24 hours since it can lead to early raveling (31). • *Restrictions:* Pavements with structural failures and high severity thermal cracking should be avoided. In addition, microsurfacing is not effective against unstable rutting or rutting more than 1.5 inches and cracks more than 0.25-inches wide (31). Prior to treatment it may be necessary to perform other activities.
Advantages	• Corrects oxidation of the pavement surface, surface friction and seals the pavement while filling minor surface irregularities. • Opens to traffic after an hour. • Can improve ride quality. • Performs better than seal coat in areas of turning and stopping movements. • The tack coat is usually not required unless the surface is extremely dry or raveled.
Limitations	• Does not address structural capacity. • Microsurfacing can accelerate the development of stripping in susceptible asphalt pavements. • There is potential for early damage in areas of heavy truck turning and down grade locations.
Expected Performance	The performance is expected to be from 3 to 8 years (39).

Seal Coat	
Description	A seal coat or chip seal is a thin surface treatment applied by spraying a layer of asphalt binder (emulsified asphalt, cutback asphalt or asphalt cement) directly to the pavement surface followed by a pneumatically rolled aggregate cover. The rolling of the single-sized (50–70 percent) crushed aggregate is necessary to increase chip retention. The maximum chip size determines the thickness of the seal layer, and it usually ranges from 0.25 inches to 0.375 inches, but larger chips have been successfully implemented on high truck traffic roads (31).
Conditions for Use	• *Main Distresses*: Seal coats have been successful in treating light to moderate non-load related longitudinal, transverse, and block cracking. In addition, the treatment can be used to address light to moderate raveling and flushing. The seal coat may also serve as a temporary solution for light alligator cracking. • *Traffic*: Although seal coats have been used to treat roads with ADT > 10,000, they are typically used when ADT < 1,000 where the chip seal is placed over an aggregate base or ADT < 2,000 when placed over the existing asphalt layer (31). Commonly it is placed on roads with less than 15 percent truck volume or 250 Average Daily Truck Traffic (ADTT) (1). Alternatively, roads up to 45 percent truck volume have been successfully treated in the past (65). • *Climate*: Seal coats perform well in all climatic conditions but special attention should be given during placement. Seal coats should be placed in warm weather with low humidity and wind, while rainy cold conditions should be avoided. The treatment is not recommended after September or when freezing is expected within 48 hours (31). • *Restrictions:* Avoid using seal coats on structurally failed pavements with extensive fatigue cracking, severe longitudinal and transverse cracking or rutting greater than 0.5-inches deep (31). Cracks wider than 0.125 inches should be sealed before the placement of the seal coat (62). The treatment is not recommended for areas of frequent truck turning, braking, accelerating, and snow plowing areas. Attention to traffic noise should be taken when treating high speed roads. If needed the existing pavement must have severe distresses patched.
Advantages	• The treatment creates a waterproof membrane that not only protects the underlying materials from moisture and erosion, thus retaining their strength, but also reduces surface oxidation and bleeding. • Improves surface friction and texture; corrects minor deformations and provides a temporary cover for a base course until the rest of the asphalt course is placed. • Durable, lower initial cost, and widely available.
Limitations	• Prolonged traffic disruption due to the curing of the treatment. • The treatment does not improve ride quality. • Adds no structural capacity. • Chip seals are susceptible to stripping. • Cannot effectively bridge cracks wider than 0.25 inches (53). • Ride quality is mainly determined by the roughness of the underlying layer. • Loose chips not embedded can become windshield hazards.
Expected Performance	The life of the treatment is from 3 to 8 years (65). Chip seals placed over aggregate bases will generally last a shorter time.

Thin Overlay (2 inches thick or less)	
Description	Plant mixed asphalt cement and aggregate applied to the existing surface in thicknesses between 0.75 and 2 inches (53). Stone matrix, dense-graded, and open-graded mixes are used. Tack coat is required before the placement of the thin overlay in order to improve the bond to the existing surface.
Conditions for Use	• *Main Distresses*: Thin overlays are successful in treating low to medium severity transverse, longitudinal, and block cracking. Furthermore, the treatment addresses low to moderate raveling and low alligator cracking. Extensive patching in good condition may also be treated. • *Traffic*: Performance is not affected by ADT or percent trucks. Due to thin overlays not being structural layers, they may experience top down cracking when certain combinations of loadings, environmental conditions, and pavement structures exists. • *Climate*: The treatment performs well in all weather. It is recommended that during placement the air temperature should be above 40 °F (37). Rain should be avoided when placing. • *Restrictions:* Not recommended for pavements with extensive fatigue cracking or structurally failed pavements. Also, pavements that exhibit extensive deterioration or high severity thermal cracking should be avoided. Candidate roads should have a stable pavement with a good base. If severe distresses are present, milling of the asphalt layer should be incorporated. If the surface is not uniform, special consideration to the grinding of the surface before placement should be taken. When rutting is present, separate rut-filling applications are needed.
Advantages	• Enhances ride and surface friction while reducing hydroplaning and tire splash (when using open graded friction course). • The treatment delays serious distresses and extends the life of the pavement. • Provides a protective waterproof membrane and corrects surface irregularities.
Limitations	• Localized pavement failures and deteriorated cracks will quickly reflect through the new surface. • High initial cost and specialty contractors required. • Curb and bridge clearance may be an issue. • Does not add structural capacity.
Expected Performance	The life of the treatment is from 7 to 10 years (39).

Ultra-Thin Friction Course	
Description	An ultra-thin friction course or NovaChip® is a thin layer, typically 0.5 to 0.75 inches of coarse or gap graded aggregate hot mix asphalt concrete (29). The hot mix layer is bound to the surface with a polymer-modified asphalt emulsion specially designed to seal the existing surface. The treatment can be applied to both asphalt and concrete pavements.
Conditions for Use	• *Main Distresses*: The treatment addresses light to moderate longitudinal, transverse, block cracking, and patches. In addition, moderate raveling, low flushing, and bleeding are inhibited. • *Traffic*: Typically used for ADT > 1,000, but very low to high traffic roads are treated (31). The wearing course is capable of withstanding higher ADT volumes than other thin treatments. • *Climate*: Performs well in all climates. When placing, rain should be avoided. The minimum placing air temperature is recommended to be around 60 °F (66). • *Restrictions:* Pavement should be structurally sound with rut depths less than 0.5 inches (31). High severity thermal cracking should not be present. Cracks in the surface greater than 0.25 inches wide should be sealed or repaired before placement of treatment. Bump grinding may be considered before placement if the surface is not uniform. The treatment is not appropriate when there is little remaining life or extensive pavement deterioration.
Advantages	• Increases skid-resistance while reducing tire/road noise and vehicle splash/spray. • Very good ride quality after construction is achieved. • Provides some increase of the structural capacity and retards fatigue cracking. • Can be opened to traffic within minutes. • Provides a durable riding surface. • Typically selected when there are user concerns with speed.
Limitations	• Not suited for rutted pavements. • Requires special paving equipment to place mix and a license to apply it. • Not economical from a mobile asphalt plant production due to the high quality requirements and small ultra-thin wearing course quantities. • Density control is difficult.
Expected Performance	The performance is expected to be from 7 to 10 years (39).

Base Repair and Seal	
Description	The localized base repair entails marking the limits of repair, cutting the pavement, removing the unsuitable base material without disturbing the subgrade, and replacing the base material with suitable material ensuring compaction. The remaining hole is filled with asphalt concrete. The surface is then prepared by spraying a layer of asphalt binder (emulsified asphalt, cutback asphalt, or asphalt cement) followed by a pneumatically rolled aggregate cover. The rolling of the single-sized (50–70 percent) crushed aggregate is necessary to increase chip retention. The maximum chip size determines the thickness of the seal layer, and it usually ranges from 0.25 to 0.375 inches, but larger chips have been successfully implemented on high truck traffic roads (31).
Conditions for Use	• *Main Distresses*: Seal coats have been successful in treating light to moderate non-load related longitudinal, transverse, and block cracking. In addition, the treatment can be used to address light to moderate raveling and flushing. The seal coat may also serve as a temporary solution for light alligator cracking. The base repair will address localized structural distresses such as alligator cracking and rutting. • *Traffic*: Although seal coats have been used to treat roads with ADT > 10,000, they are typically used when ADT < 1,000 where the chip seal is placed over an aggregate base or ADT < 2,000 when placed over the existing asphalt layer (31). Commonly it is placed on roads with less than 15 percent truck volume or 250 ADTT (1). Alternatively, roads up to 45 percent truck volume have been successfully treated in the past (65). • *Climate*: Seal coats perform well in all climatic conditions, but special attention should be given during placement. Seal coats should be placed in warm weather with low humidity and wind, while rainy cold conditions should be avoided. The treatment is not recommended after September or when freezing is expected within 48 hours (31). • *Restrictions:* Avoid pavements with poor subgrade or extensive fatigue cracking, severe longitudinal and transverse cracking, and rutting greater than 0.5 inches deep (31). Cracks wider than 0.125 inches should be sealed before the placement of the seal coat (62). The treatment is not recommended for areas of frequent truck turning, braking, accelerating, and snow plowing areas. Attention to traffic noise should be taken when treating high speed roads. If the structural distresses are widespread, the localized base repair will not be effective.
Advantages	• The treatment creates a waterproof membrane that not only protects the underlying materials from moisture and erosion, thus retaining their strength, but also reduces surface oxidation and bleeding. • Improves surface friction and texture; corrects minor deformations and provides a temporary cover for a base course until the rest of the asphalt course is placed. • Durable, lower initial cost and widely available.
Limitations	• Prolonged traffic disruption due to the curing of the treatment. • The treatment does not improve ride quality. • Adds no structural capacity. • Chip seals are susceptible to stripping. • Cannot effectively bridge cracks wider than 0.25 inches (53). • Ride quality is mainly determined by the roughness of the underlying layer. • Loose chips not embedded can become windshield hazards.
Expected Performance	The base repair ensures that the seal coat does not experience premature failures. The life of the treatment is from 3 to 8 years (39).

Cold In-Place Recycling	
Description	Cold in-place recycling (CIR) is an in-situ process in which a specialized train cold mills 2–4 inches of the existing asphalt pavement (31). The milled asphalt is then crushed, mixed with virgin aggregates and emulsion, and finally re-laid. The treatment is commonly followed by a surface treatment or an overlay.
Conditions for Use	• *Main Distresses*: CIR may treat severe surface distresses that can reach as deep as 4 to 6 inches. Rutting, flushing and raveling are also addressed with the treatment. • *Traffic*: The recycling is mostly performed on very low to medium volume roads. Heavy traffic should be avoided when the treatment is curing. Lower traffic roadways usually follow CIR with a surface treatment, not an asphalt overlay. • *Climate*: The treatment performs well in all climates. Special care should be taken when placing, such as avoiding rain and temperatures below 50 °F (6). At least 2 weeks of good weather are required for the surface to cure (6). • *Restrictions:* Pavements must have a sound base, and failures should be patched prior to the treatment. Candidate pavements must not have extensive severe structural deficiencies or distresses deeper than the recycling depth. If the surfaced has been chip sealed or if there are extensive number of patches, CIR may not be a viable option. The existing asphalt surface should not be milled in 1-1.6 inches, and virgin aggregate must be below 25 percent by weight of RAP (31).
Advantages	• The surface friction, roughness and cross slope are restored. • Corrugations, bumps and bleeding are also fixed by the treatment. • Reflective cracking is mitigated.
Limitations	• Difficult to conduct on steep grades, tightly curved roads, or on roads with many utility adjoining.
Expected Performance	The treatment will last for 12 to 20 years (31).

Hot In-Place Recycling	
Description	Hot in-place recycling (HIR) is an in-situ process in which a specialized train heats the surface 300–350°F, so that 1–2 inches of the AC surface can be scarified and mixed with new asphalt and a rejuvenating agent (29). The mixture can then be applied and compacted with conventional hot mix asphalt paving equipment. When mineral aggregate or new hot mix asphalt is added, it is called the remixing process. The treatment is commonly followed by a surface treatment or an overlay.
Conditions for Use	• *Main Distresses*: HIR is a good treatment for moderate thermal and load-associated cracking, surface rutting, raveling, and flushing. • *Traffic*: HIR is used in very low to high traffic roads. The heat-scarification process must only be performed on low traffic roads. The remixing process can be constructed on pavements with high volume. No surface treatment or overlay is needed when low traffic is experienced. • *Climate*: The treatment performs well in most climates. Cold climates will cause reflective cracks in 1 to 2 years (31). Special care should be taken when placing, such as avoiding rain and temperatures below 50°F (31). • *Restrictions:* Pavements must have a sound base, and failures should be patched prior to the treatment. Candidate pavements must not have extensive severe structural deficiencies like alligator cracking, deep rutting, or distresses deeper than the recycling depth. If the surfaced has been chip sealed, an extensive number of patches are present, or surface delamination is present, HIR may not be a viable option. Virgin aggregate or HMA added must be below 30 percent by weight of RAP (29).
Advantages	• The rideability is improved, and the surface texture is restored. • The roughness is decreased.
Limitations	• Difficult to conduct on steep grades, tightly curved roads, or on roads with many utilities adjoining. • Small projects are not economical.
Expected Performance	The performance is dependent on the process used. If heater-scarification with no surface treatment is used 2–4 years; heater-scarification with surface treatment 6–10 years; remixing process 7–14 years; and remixing process with overlay 6–15 years (31).

Mill and Inlay; or Mill, Seal, and Thin Overlay	
Description	This treatment includes a combination of construction activities. The pavement is first cold milled, which is the removal of part or the entire existing asphalt surface. When necessary, the milled surface is sealed, or prepared, by spraying asphalt binder (emulsion or hot applied asphalt binder) and immediately covering it with a one-sized aggregate layer. Finally, a thin layer of plant mixed asphalt cement (less or equal to 2 inches) and aggregate is applied to the existing surface). The mix can be stone matrix, dense-graded, and open-graded. Tack coat is required before the placement of the thin overlay in order to improve the bond to the existing surface. When the asphalt mix fills the same milled depth it is called an inlay, and if not it is a thin overlay.
Conditions for Use	• *Main Distresses*: Thin overlays are successful in treating low to medium severity transverse, longitudinal and block cracking. Furthermore, the asphalt overlay addresses low to moderate raveling, bleeding, and low alligator cracking. The cold milling allows for more severe surface distresses to be fixed, including stable shallow rutting and deteriorated patches. • *Traffic*: Performance is not affected by ADT or percent trucks. Due to thin overlays not being structural layers, they may experience top down cracking when certain combinations of loadings, environmental conditions, and pavement structures exists. • *Climate*: The treatment performs well in all weather. It is recommended that during placement the air temperature should be above 40°F (37). Rain should be avoided when placing. • *Restrictions:* Not recommended for pavements that are structurally failed. Candidate roads should have a stable pavement with a good base. Severe distresses present will be milled. When deep rutting is present, separate rut-filling applications are needed. Patching of localized severe distresses must be completed prior to the milling. Sealing of the milled surface must be done when there are visible or latent cracks on the milled surface.
Advantages	• The seal additionally waterproofs the structure, seals small cracks, and protects the surface from solar radiation. • Cold milling will restore proper grades and cross-slopes. • Enhances ride and surface friction while reducing hydroplaning and tire splash (when using open graded friction course). • The treatment delays serious distresses and extends the life of the pavement.
Limitations	• Does not add structural capacity. • Curb and bridge clearance may be an issue. • High initial cost and specialty contractors required. • Millings must be disposed or recycled.
Expected Performance	The expected life of the treatment will be 4 to 20 years (65).

Overlay Greater than 2 inches but Less than 3 inches	
Description	Plant mixed asphalt cement and aggregate applied to the existing surface in thicknesses greater than 2 inches and less than 3 inches. Stone matrix, dense-graded, and open-graded mixes are used. Tack coat is required before the placement of the overlay in order to improve the bond to the existing surface.
Conditions for Use	• *Main Distresses*: Asphalt overlays are successful in treating low to medium severity transverse, longitudinal, and block cracking. Furthermore, the treatment addresses moderate raveling and alligator cracking. Extensive patching in good condition and shallow rutting may also be treated. • *Traffic*: Performance is not affected by ADT or percent trucks. If the overlay is being used for added structural capacity, the thickness is dependent on traffic loading. The pavement design method used within a given state transportation agency should be used. • *Climate*: The treatment performs well in all weather. It is recommended that during placement the air temperature should be above 40°F (37). Rain should be avoided when placing. • *Restrictions:* Not recommended for pavements with extensive fatigue cracking or structurally failed pavements. Candidate roads should have a stable pavement with a good base. If severe surface distresses are present, milling of the asphalt layer should be incorporated. If the surface is not uniform, special consideration to the grinding of the surface before placement should be taken. When deep rutting is present, separate rut-filling applications are needed.
Advantages	• Enhances ride and surface friction while reducing hydroplaning and tire splash (when using open graded friction course). • The treatment delays serious distresses and extends the life of the pavement. • Provides a protective waterproof membrane and corrects surface irregularities. • Limited added structural capacity is expected. • Less susceptible to cracking reflection to the asphalt layer.
Limitations	• High initial cost and specialty contractors required. • Curb and bridge clearance may be an issue. • Open friction courses should not be resurfaced.
Expected Performance	The life of the treatment is expected to last from 3 to 17 years (39). TxDOT generally requires for the overlay to last at least 8 years (29).

Base Repair, Spot Seal, Edge Repair and Overlay	
Description	The localized base repair entails marking the limits of repair, cutting the pavement, removing the unsuitable base material without disturbing the subgrade, and replacing the base material with suitable material ensuring compaction. When this same repair is constructed on the edge of the pavement it is called an edge repair. The localized surface is then sealed by spraying asphalt binder (emulsion or hot applied asphalt binder) and immediately covering it with a one-sized aggregate layer Once these maintenance activities have been performed; an overlay layer (>2 inches) of plant mixed asphalt cement and aggregate is applied to the existing surface. The mix can be stone matrix, dense-graded and open-graded. Tack coat is required before the placement of the overlay in order to improve the bond to the existing surface.
Conditions for Use	• *Main Distresses*: The process is successful in treating transverse, longitudinal, and block cracking. Furthermore, the treatment addresses moderate raveling and alligator cracking. Extensive patching in good condition and shallow rutting may also be treated. Localized failed areas such as fatigue cracking accompanied by rutting, may also be fixed. • *Traffic*: Performance is not affected by ADT or percent trucks. If the overlay is being used for added structural capacity, the thickness is dependent on traffic loading. The pavement design method used within a given state transportation agency should be used. • *Climate*: The treatment performs well in all weather. It is recommended that during placement the air temperature should be above 40 °F (37). Rain should be avoided when placing. • *Restrictions:* Not recommended for pavements with extensive fatigue cracking or structurally failed pavements. Candidate roads should have a stable pavement with a good base. If structural distresses are widespread, this combination of treatments may not be cost effective.
Advantages	• Enhances ride and surface friction while reducing hydroplaning and tire splash (when using open graded friction course). • The treatment delays serious distresses and extends the life of the pavement. • Provides a protective waterproof membrane and corrects surface irregularities. • Less susceptible to crack reflecting to the asphalt layer. • Added structural capacity is expected. • Underlying cause of the problem is fixed.
Limitations	• High initial cost and specialty contractors required. • Curb and bridge clearance may be an issue. • Open friction courses should not be resurfaced.
Expected Performance	The base repair, the surface sealing, and the edge repair ensure that the overlay does not experience premature failures. The life of the treatment is from 3 to 17 years (65). TxDOT overlay schedule is typically 8 years (29).

Level Up and Overlay	
Description	The level up patching involves laying down (blade or laydown) a 1 to 1.5-inch asphalt mix layer over existing ruts in the pavement. The size of the patch may be two full-width lanes and 50 feet or more in length (14). There are three types of materials used including hot mix hot-laid asphalt concrete, limestone rock asphalt (LRA), and special reclaimed asphalt pavement mixes. An overlay layer (>2 inches) of plant mixed asphalt cement and aggregate is applied to the existing surface. The mix can be stone matrix, dense-graded, and open-graded. Tack coat is required before the placement of the overlay in order to improve the bond to the existing surface.
Conditions for Use	• *Main Distresses*: Asphalt overlays are successful in treating low to medium severity transverse, longitudinal and block cracking. Furthermore, the treatment addresses moderate raveling and alligator cracking. Extensive patching in good condition and shallow rutting may also be treated. The level up fills deep ruts less than or equal to 1 inch. • *Traffic*: Performance is not affected by ADT or percent trucks. If the overlay is being used for added structural capacity, the thickness is dependent on traffic loading. The pavement design method used within a given state transportation agency should be used. • *Climate*: The treatment performs well in all weather. It is recommended that during placement the air temperature should be above 40°F (37). Rain should be avoided when placing. • *Restrictions:* Not recommended for pavements with extensive fatigue cracking or structurally failed pavements. Candidate roads should have a stable pavement with a good base. If severe surface distresses are present, milling of the asphalt layer should be incorporated. If the surface is not uniform, special consideration to the grinding of the surface before placement should be taken. The overlay should be placed right after the level-up.
Advantages	• Enhances ride and surface friction while reducing hydroplaning and tire splash (when using open graded friction course). • The treatment delays serious distresses and extends the life of the pavement. • Provides a protective waterproof membrane and corrects surface irregularities. • Added structural capacity is expected. • Less susceptible to crack reflecting to the asphalt layer.
Limitations	• High initial cost and specialty contractors required. • Curb and bridge clearance may be an issue. • Open friction courses should not be resurfaced.
Expected Performance	The life of the treatment is expected to last from 3 to 17 years (39). The level-up course will ensure the overlay does not fail prematurely. TxDOT overlay schedule is 8 years (29).

Mill and Overlay	
Description	The pavement is first cold milled, which is the removal of part or the entire existing asphalt surface. An overlay layer (>2 inches) of plant mixed asphalt cement and aggregate is applied to the existing surface. The mix can be stone matrix, dense-graded, and open-graded. Tack coat is required before the placement of the overlay in order to improve the bond to the existing surface.
Conditions for Use	• *Main Distresses*: Asphalt overlays are successful in treating medium to high severity transverse, longitudinal, and block cracking. Furthermore, the treatment addresses moderate raveling and alligator cracking. The cold milling allows for more severe surface distresses to be fixed, including stable shallow rutting and deteriorated patches. • *Traffic*: Performance is not affected by ADT or percent trucks. If the overlay is being used for added structural capacity, the thickness is dependent on traffic loading. The pavement design method used within a given state transportation agency should be used. • *Climate*: The treatment performs well in all weather. It is recommended that during placement the air temperature should be above 40 °F (37). Rain should be avoided when placing. • *Restrictions:* Not recommended for pavements that are structurally failed. Candidate roads should have a stable pavement with a good base. When extensive deep rutting is present, separate rut-filling applications are needed. Patching of localized severe distresses must be completed prior to the milling. If the surface is not uniform, special consideration to the grinding of the surface before placement should be taken.
Advantages	• Enhances ride and surface friction while reducing hydroplaning and tire splash (when using open graded friction course). • The treatment delays serious distresses and extends the life of the pavement. • Provides a protective waterproof membrane and corrects surface irregularities. • Adds structural capacity. • Less susceptible to crack reflecting to the asphalt layer. • Cold milling will restore proper grades and cross-slopes.
Limitations	• High initial cost and specialty contractors required. • Curb and bridge clearance may be an issue. • Open friction courses should not be resurfaced. • Millings must be disposed or recycled.
Expected Performance	The life of the treatment is expected to last from 3 to 17 years (39). The milling will assure the overlay does not fail prematurely. TxDOT overlay schedule is 8 years (29).

Mill, Stabilize Base, and Seal	
Description	The pavement is first cold milled, which is the removal of the entire existing asphalt surface. The soil stabilization is an improvement of pertinent soil properties by the addition of various materials that include cement, lime, fly ash, and even geosynthetics. The surface is then prepared by spraying a layer of asphalt binder (emulsified asphalt, cutback asphalt, or asphalt cement) followed by a pneumatically rolled aggregate cover. The rolling of the single-sized (50–70 percent) crushed aggregate is necessary to increase chip retention. The maximum chip size determines the thickness of the seal layer, and it usually ranges from 0.25 to 0.375 inches, but larger chips have been successfully implemented on high truck traffic roads (31).
Conditions for Use	• *Main Distresses*: The cold milling allows for severe to moderate surface load and thermal induced distresses to be fixed. Rutting and deteriorated patches will also be treated. • *Traffic*: Very low to high traffic volume roadways can be treated. The base thickness will depend on traffic loading. If using lime, restrict to lower trafficked roads. • *Climate*: Care should be taken when using cement to stabilize the base in frost-heavy areas. Construction must not be done during heavy rain, heavy snow, or when the surface is frozen. Warm temperatures are required for the stabilization reaction to happen. Placement of the seal should be when air temperature is above 40 F (37). • *Restrictions:* The subgrade must have sufficient support or differential movement may reflect cracking. The seal coat is not recommended for areas of frequent truck turning, braking, accelerating, and snow plowing areas. Attention to traffic noise should be taken when treating high speed roads.
Advantages	• The seal additionally waterproofs the membrane that not only protects the underlying material from moisture but also reduces oxidation and bleeding. • Cold milling will restore proper grades and cross-slopes. • Restores surface friction, ride and texture. • The treatment delays serious distresses and extends the life of the pavement. • Lime can expedite the project when wet layers are present. • Cement can be used to stabilize any soil except highly organic soils. • Reduces swell/ shrink potential of clayey soils. • Increase base soil strength and stiffness. • Adds structural capacity.
Limitations	• Millings must be disposed or recycled. • Susceptible to development of block cracking or severe longitudinal cracking.
Expected Performance	Assuming that the roadway has a proper structural design, the life expectancy of subgrade or base materials is more than 20 years (31).

Overlay Between 3 and 5 inches	
Description	Plant mixed asphalt cement and aggregate applied to the existing surface in thicknesses greater than 3 inches and less than 5 inches. Stone matrix, dense-graded and open-graded mixes are used. Tack coat is required before the placement of the overlay in order to improve the bond to the existing surface.
Conditions for Use	• *Main Distresses*: Asphalt overlays are successful in treating medium to high severity transverse, longitudinal and block cracking. Furthermore, the treatment addresses moderate raveling and alligator cracking. Extensive patching in good condition and rutting may also be treated. • *Traffic*: Performance is not affected by ADT or percent trucks. The overlay thickness is dependent on traffic loading. The pavement design method used within a given state transportation agency should be used. • *Climate*: The treatment performs well in all weather. It is recommended that during placement the air temperature should be above 40°F (37). Rain should be avoided when placing. • *Restrictions:* Not recommended for pavements that are structurally failed. Candidate roads should have a stable pavement with a good base. If severe surface distresses are present, milling of the asphalt layer should be incorporated. If the surface is not uniform, special consideration to the grinding of the surface before placement should be taken. When deep rutting is present, separate rut-filling applications may be needed.
Advantages	• Enhances ride and surface friction while reducing hydroplaning and tire splash (when using open graded friction course). • The treatment delays serious distresses and extends the life of the pavement. • Provides a protective waterproof membrane and corrects surface irregularities. • Added structural capacity is expected. • Less susceptible to cracking reflection to the asphalt layer.
Limitations	• High initial cost. • Curb and bridge clearance may be an issue. • Open friction courses should not be resurfaced.
Expected Performance	The life of the treatment is expected to last from 6 to 17 years (39). TxDOT overlay schedule is 8 years (29).

Full Depth Reclamation (Pulverization and Resurfacing)	
Description	Full depth reclamation (FDR) is the uniform pulverization of the full thickness of the asphalt pavement and a predetermined portion of the base (less or equal to 12 inches). The material is then blended with stabilization materials that include cement, lime, fly ash, and asphalt emulsions. The new base is then compacted and resurfaced.
Conditions for Use	• *Main Distresses*: FDR eliminates all existing distress. • *Traffic*: Very low to high traffic volume roadways can be treated. The base thickness will depend on the traffic loading. If using lime, restrict to lower trafficked roads. • *Climate*: Care should be taken when using cement to stabilize the mix in frost heave areas. Asphalt as the stabilization agent is not attractive for areas of high humidity (>80) or high rainfall (47). Construction must not be done during heavy rain, heavy snow or when the surface is frozen. Warm temperatures are required for the stabilization reaction to occur. • *Restrictions:* If the depth of the desired stabilization is greater than the depth of the existing materials above the subgrade or if the resulting material blend is of poor quality, additional aggregates, RAP, or crushed PCC may be added. Cutting into the subgrade should be avoided since it may introduce excessive fines to the blend. This will result in moisture susceptibility of the recycled layer. When using cement as the stabilization agent, excessive strength should be avoided. Areas which have localized severe alligator cracking or structural rutting may need a full depth patch.
Advantages	• 24–72 hours of curing needed to open to traffic (47). • Restores surface friction, ride, and texture. • Adds structural capacity. • Reduces the risk of reflective cracking significantly. • Limes can expedite the project when wet layer are present. • Increase base soil strength, and stiffness. • Cement can stabilize any soil except highly organic soils. • Recycles in-situ materials. • Waterproofs fine-grained subgrade soils.
Limitations	• Increased stiffness can cause shrinkage cracking. • Chemical stabilization may need as much as a week before the surfacing (47). • Asphalt emulsions have not shown satisfactory performance. • No truck traffic allowed until riding surface is placed.
Expected Performance	The life of the treatment is expected to last with surface treatment 7 to 10 years, with asphalt overlay 15 to 20 years (31).

Mill, Cement Stabilize Base and Overlay	
Description	The pavement is first cold milled, which is the removal of the entire existing asphalt surface. The soil stabilization is an improvement of pertinent soil properties by the addition of various materials that in this case cement. An overlay layer (>2 inches) of plant mixed asphalt cement and aggregate is applied to the existing surface. The mix can be stone matrix, dense-graded, and open-graded. Tack coat is required before the placement of the overlay in order to improve the bond to the existing surface.
Conditions for Use	• *Main Distresses*: The cold milling allows for moderate to severe surface load and thermal induced distresses to be fixed. Rutting and deteriorated patches will also be treated. • *Traffic*: Very low to high traffic volume roadways can be treated. The base thickness and overlay will depend on traffic loading. The pavement design method used within a given state transportation agency should be used. • *Climate*: Care should be taken when using cement to stabilize the base in frost-heavy areas. Construction must not be done during heavy rain, heavy snow, or when the surface is frozen. Stabilization should be complete at least 1 month before first freeze (47). It is recommended that during the overlay placement the air temperature should be above 40°F (37). Rain should be avoided when placing. • *Restrictions:* The subgrade must have sufficient support; if not differential movement may reflect cracking. Cutting into the subgrade should be avoided since it may introduce excessive fines to the blend. This will result in moisture susceptibility of the recycled layer. Excessive strength should be avoided. Areas which have severe alligator cracking or severe structural rutting may need a full depth patch. Typically 3 to 9 percent of cement is needed and 300 to 400 psi 7-day unconfined compressive strength is recommended (48). The base must contain high quality materials or less than 25 percent passing the No. 200 sieve, and the plasticity index must be below 12 (56).
Advantages	• Cold milling will restore proper grades and cross-slopes. • Restores surface friction, ride, and texture. • The treatment delays serious distresses and extends the life of the pavement. • Cement can be used to stabilize any soil except highly organic soils. • Increase base soil strength, and stiffness. • Adds structural capacity. • The overlay provides a protective water proof membrane.
Limitations	• Millings must be disposed or recycled. • Susceptible to development of block cracking or severe longitudinal cracking. • Curb and bridge clearance may be an issue.
Expected Performance	Assuming that the roadway has a proper structural design, the life expectancy of subgrade, or base materials is more than 20 years and can be greater than 45 years (31).

Reconstruction	
Description:	Reconstruction is the total replacement of the flexible pavement structure to at least the original structural and functional characteristics.
Conditions for Use	• *Main Distresses*: Reconstructing the pavement will reset any surface distress, load transfer issue, or any base or subbase problem. • *Traffic*: The traffic will impact the subbase, subgrade, and asphalt thickness. The pavement design method used within a given state transportation agency should be used. • *Climate*: When constructing, common asphalt concrete placing standards should be met. • *Restrictions:* Candidate projects should have no redeemable pavement life, need changes to roadway geometrics, or need major subgrade corrections. Usually performed when there are high distress levels or overlays are no longer effective. In some instances, the pavement will be reconstructed due to planning, development, level of service upgrade, and utility reconstruction.
Advantages	• Restores structural and functional characteristics to at least the original conditions. • Persistent frost heave areas or pavements over organic soils can only be fixed through reconstruction.
Limitations	• Side slopes must be modified. • Most expensive activity.
Expected Performance	Pavement design depends on the percent of trucks and ADT; the design life for a flexible pavement can be 30 or 20 years. The perpetual pavement can last for at least a period of 30 years if properly maintained (29).

Thick Overlay Greater than 5 Inches	
Description	Plant mixed asphalt cement and aggregate applied to the existing surface in thicknesses greater than 5 inches. Stone matrix, dense-graded, and open-graded mixes are used. Tack coat is required before the placement of the overlay in order to improve the bond to the existing surface.
Conditions for Use	• *Main Distresses*: Asphalt overlays are successful in treating medium to high severity transverse, longitudinal. and block cracking. Furthermore, the treatment addresses moderate raveling and alligator cracking. Extensive patching in good condition and rutting may also be treated. • *Traffic*: Performance is not affected by ADT or percent trucks. The overlay thickness is dependent on traffic loading. The pavement design method used within a given state transportation agency should be used. • *Climate*: The treatment performs well in all weather. It is recommended that during placement the air temperature should be above 40 °F (37). Rain should be avoided when placing. • *Restrictions:* Not recommended for pavements that are structurally failed. Candidate roads should have a stable pavement with a good base. If severe surface distresses are present, milling of the asphalt layer should be incorporated. If the surface is not uniform, special consideration to the grinding of the surface before placement should be taken. Severe localized distresses will require full depth patching.
Advantages	• Enhances surface friction while reducing hydroplaning and tire splash (when using open graded friction course). • The treatment delays serious distresses and extends the life of the pavement. • Provides a protective waterproof membrane and corrects surface irregularities. • Added large structural capacity is expected. • Susceptibility to reflection cracking is highly reduced. • Highly increases ride smoothness.
Limitations	• Not cost effective if pre-repair activities are included. • Curb and bridge clearance are an issue. • Open friction courses should not be resurfaced. • May only mask severe distresses. • Does not address sub-surface distresses.
Expected Performance	The life of the treatment is expected to last more than 17 to 30 years (39).

JOINTED CONCRETE PAVEMENT (JCP) TREATMENTS

Table 16. Decision Support Matrix for the Selection of Treatment Alternatives for Jointed Concrete Pavements.

Level	Treatment	Climatic Zone				Traffic		Pavement Condition Variable												
								Failed Joints and Cracks		Predominat Failures							Shattered Slabs	Longitudinal Cracking	Concrete Patches	Ride Quality
		1	2	3	4	Low	High	Spalled Joints	Transverse Cracking	Corner Breaks	Punchouts	Asphalt Patches	Failed Concrete Patches	D-Cracking	Severe Spalls	Popouts				
Preventive Maintenance	Joint and Crack Sealing	●	●	●	●	●	●	●	●						◑			●		
	Diamond Grinding and/or Grooving	●	●	●	●	●	●							◑	◑	◑			◑	●
	Partial Depth Patch	●	●	●	●	●	●	●	●				●	●	●	●				◑
	Ultra-Thin Friction Course	●	●	●	●	◑	●	●	●		◑	◑			●	◑			●	◑
Light Rehabilitation	Thin Asphalt Overlay	●	●	●	●	◑	●	●	●		◑	◑		◑	●	◑			●	◑
	Dowel Bar Retrofit and Diamond Grinding	●	●	●	●	●	●											●		●
	Full Depth Repair of Concrete	●	●	●	●	●	●		◑	●	●	●	●	◑	◑	◑	●	◑		◑
Medium Rehabilitation	Full Depth Repair, Structural Asphalt Overlay and/or Slab Stabilization	●	●	●	●	●	●			◑	◑			◑	◑		◑	◑		●
	Slab Replacement	●	●	●	●	●	●			◑	●	◑	◑	●		●	●	●		◑
Heavy Rehabilitation	Rubblizing and Asphalt Overlay	●	●	●	●	●	●	◑	◑	●	●		◑	●	●	●	●	●		●
	Unbonded Concrete Overlay	●	●	●	●	●	●	◑	◑	◑	◑	◑	◑	◑	◑	◑	◑	●		◑
	Reconstruction	●	●	●	●	●	●			●	●	●	●	●	●	●	●	●		●

● = Recommended ◑ = Conditionally Recommended (may depend on other factors)

<table>
<tr><th colspan="2">Joint and Crack Sealing</th></tr>
<tr><td>Description</td><td>Crack sealing is an operation which involves thorough crack preparation by sawing or routing, then extensively cleaning the crack, followed by placing high quality bituminous or silicone material over the crack. Joint resealing follows the same procedure except the existing sealant must be removed before the thorough joint preparation (routing or sawing and cleaning) and the seal installation. The seal material can be cold- or hot- applied thermosetting.</td></tr>
<tr><td>Conditions for Use</td><td>• Main Distresses: Crack sealing is effective at sealing low to medium severity transverse or longitudinal cracks where the width is less than or equal to 0.5 inches (6). Full-depth working transverse cracks typically experience the same range of movement as transverse joints, therefore these cracks should be sealed as well. Resealing joints and cracks is recommended when sealants are damaged over more than 20 percent along the joint or crack (27).
• Traffic: The behavior of joint and crack sealing is not affected by different ADT levels or percent trucks. Higher traffic will require durable sealants and/or more frequent replacement.
• Climate: The treatment performs well in all climatic conditions. Placing in a moist environment will inhibit bonding of the crack sealer. Sealant is best applied when temperatures are moderately cool as in spring or fall. Colder climates require lower modulus sealants than hot climates. Transverse and longitudinal sealing should be specified in freeze-thaw areas, where anti-icing or de-icing treatments can fill unsealed joints with incompressible materials. The air temperature must be at least 40°F during placement (8).
• Restrictions: Concrete pavements that exhibit structural deterioration and which have cracks showing other significant distresses like faulting or spalling are not good candidates. Do not use crack sealing where there are unpatched full-depth blowups, rocking slabs, settlement, and pumping of water or fines. The pavement must have a sound base with good cross section and good lateral support. Joints wider than 0.75 inches should not be considered for treatment (53).</td></tr>
<tr><td>Advantages</td><td>• The treatment prevents faulting, pumping, spalling, and blowups.
• Prevents water and incompressible materials from entering the pavement structure.
• Sealed cracks deteriorate less and contribute less to the overall deterioration of the pavement.
• Beneficial on structurally failing pavement to prolong the time until rehabilitation.
• Experienced and reliable technique.</td></tr>
<tr><td>Limitations</td><td>• Sealing process can increase roughness if placed in an over-band configuration.
• No structural improvement and adversely affects skid resistance.
• Poor appearance and visibility.
• If road is opened to traffic immediately after, the sealant must be protected against pick-up by tires.
• Hot-applied sealants should be allowed to cure 3 to 4 months before being covered with an overlay.
• It is important for the sealant tot be allowed to cure before opening to traffic.</td></tr>
<tr><td>Expected Performance</td><td>Sealant performance is dependent on material type, placement geometry, application quality, and environmental conditions. Hot-poured asphalt sealant lasts approximately 2 to 3 years. In the case of silicone sealant, the treatment can last 10 to 15 years (4).</td></tr>
</table>

Diamond Grinding and/or Grooving	
Description	Diamond grinding is the removal of the top 0.1–0.25 inch layer of concrete pavement with special equipment fitted with closely spaced diamond-studded saw blades (29). Diamond grooving is the cutting of narrow grooves longitudinally, or sometimes transversely, that cover the full width of the concrete pavement lane. Both treatments are usually used in conjunction, but in some situations only a sole technique may be required.
Conditions for Use	• *Main Distresses*: Diamond grinding addresses joint faulting between 0.12 and 0.5 inches and patching unevenness (19). Patches more than 10 per mile and faulting more than 0.25 inches will trigger diamond grinding (27). • *Traffic*: There are no traffic limitations, but the following considerations should be taken. If faulting is addressed and the distress mechanism is not, faulting can reoccur due to continued truck loading. If polishing is being addressed, heavy traffic volume may cause the problem to reoccur. Diamond grinding projects have shown truck percentages ranging from 5.4 percent to 25 percent (65). • *Climate*: The weather has no effect on the treatment performance. If the treatment is used in cold climates, studded tire or chain surface wear may become an important factor. • *Restrictions:* Candidate pavements should have sound functional and structural characteristics. The treatment is not appropriate when signs of structural failures such as severe faulting and corner breaks are present. Not recommended for pavements with significant slab cracking, >10 percent of the slab, or material problems (19). Material problems include D-cracking and alkali-silica reactivity (ASR). When grinding exposes soft coarse aggregates known to polish quickly, grooving should be used in conjunction. Load transfer efficiency must be > 70 percent or deflection basin area > 25 in. (27).*
Advantages	• Restores smooth-riding surface and increases skid-resistance. • Reduces pavement noise and restores surface texture. • When grooving is included, it increases safety by preventing hydroplaning and wet weather accidents. • Reduces pumping at the joints or cracks. • Does not affect overhead clearances underneath bridges. • It has a negligible effect on structural capacity.
Limitations	• Does not address pavement distress mechanism. • Softer coarse aggregates that are exposed by grinding may polish. • Small vehicles and motorcycles may encounter small lateral movements or "wiggle". • Byproduct slurry must be disposed of in a safe environmentally friendly manner.
Expected Performance	The treatment performance is expected to last 8-12 years (27).

*** Defined as** $$\boldsymbol{Basin\ Area} = \frac{\boldsymbol{6(d_0+2d_1+2d_2+d_3)}}{\boldsymbol{d_0}}$$

d_0 = Surface deflection at the test load center

d_1 = Surface deflection at 12 inches from the test load center

d_2 = Surface deflection at 24 inches from the test load center

d_3 = Surface deflection at 36 inches from the test load center

Partial Depth Patch	
Description	Partial depth patching is the removal of small shallow deteriorated areas by milling, chipping, and sawing of unsound concrete and replacement with suitable materials. The filler can be rapid-setting concrete, conventional PCC, bituminous materials, and proprietary materials. Its selection is based on curing time, climatic conditions, materials costs, and desired life. This work also includes removal and replacement of asphalt concrete patches from spalled or damaged areas. When the area is less than 6 inches in length and 1.5 inches in width, this treatment is referred to as joint spalling repairs (42).
Conditions for Use	• *Main Distresses*: This treatment repairs localized distresses within the upper third to upper half slab thickness. The distresses addressed include joints and cracks with low severity deterioration, including shallow spalling with a depth < 4 inches, scaling, and deterioration of existing repairs or of areas adjacent to the repairs (29). Surface popouts and potholes may also be fixed with a partial depth patch. Two-inch wide spalls that are more than 10 percent of the crack or joint will trigger the treatment (27). • *Traffic*: The treatment is effective at all traffic levels. If using concrete as the filler material, open to traffic when the flexural strength reaches 3,000 psi (28). • *Climate*: Performs well in all climatic regions, but manufacturer's recommendations on use of the respective filler material should be followed. The partial depth patch should not be placed on frozen existing concrete pavements or under rainy conditions. Conventional PCC and most repair materials should not be placed below 40°F (8). Curing of PCC under cool weather may be too slow to allow timely opening to traffic. • *Restrictions:* Pavements with structural deficiencies or working cracks caused by shrinkage, fatigue, and/or foundation movement are not good candidates. Spalls with exposed load transfer devices like corroded dowel bars, spalls caused by D-cracking and Alkali-Silica Reactivity (ASR), and spalls that extend 6–10 inches from the joint should be avoided (8). Partial depth repairs must have a minimum dimension of 4 inches by 12 inches and 1 to 3 inches in depth (28).
Advantages	• Deters further deterioration, restores structural integrity, and improves rideability. • Relieves temporary roughness caused by material problems such as D-cracking or alkali-silica reactivity ARS. • Surface texture is restored.
Limitations	• Byproduct slurry must be disposed of in a safe environmentally friendly manner. • If bituminous filler is used, the treatment is only temporary. • Cracks found through the full slab thickness may require full-depth repair.
Expected Performance	The performance is based on the installation quality control and can be expected to last 3 to10 years (27).

Ultra-Thin Friction Course	
Description	In addition to treating HMA pavements, ultra-thin friction course have been used on PCC pavements. An ultra-thin friction course, or NovaChip®, is a thin layer, typically 0.5 to 0.75 inches of course or gap graded aggregate hot mix asphalt concrete (29). The hot mix layer is bound to the surface with a polymer-modified asphalt emulsion specially designed to seal the existing surface. The treatment can be applied to both asphalt and concrete pavements.
Conditions for Use	• *Main Distresses*: The NovaChip® also has the capability to treat low severity corner breaks, longitudinal and transvers cracking, low material related distress (D-cracking-ASR), and moderate spalling. • *Traffic*: Although it can be used in any traffic level, it is predominantly used in high ADT and truck volume roadways. • *Climate*: Performs well in all climatic regions. Should be placed above 45°F or according to the type of asphalt binder used (7). When placing, rain should be avoided. • *Restrictions:* Not recommended where extensive structural distresses exist and extensive material related distresses such as D-cracking and ASR are present. Will not treat blowups, pumping or faulted joints. Prior to placement of the treatment, cracks greater than 0.25 inches wide should be sealed, bump and grinding should be implemented as needed, and severe stresses should be patched (7). Over-banding methods of crack sealing are not recommended; strips left behind can reflect through the finished pavement.
Advantages	• Improves splash/spray characteristics, skid-resistance, and tire noise. • Can be opened to traffic within 15 minutes (7). • It restores low severity roughness and improves ride quality. • Retards reflective cracking. • The treatment seals most minor cracks that are < 0.25 inches wide (29).
Limitations	• Requires special paving equipment to place the mix. • Does not add structural capacity. • Variable width shoulders with a cross slope or grade break in excess of 3 percent may not be feasible to treat (7).
Expected Performance	Estimated treatment performance is 6 to 10 years (7).

<table>
<tr><th colspan="2">Thin Asphalt Overlay</th></tr>
<tr><td>Description</td><td>Plant mixed asphalt cement and aggregate applied to the existing surface in thicknesses of 2 inches or less (29). Stone matrix, dense-graded, and open-graded mixes are used. Tack coat is required before the placement of the thin overlay in order to improve the bond to the existing surface.</td></tr>
<tr><td>Conditions for Use</td><td>• Main Distresses: Thin overlays address faulting, spalling, and longitudinal cracking. Patches per mile greater than 10 or faulting greater than 0.25 inches, and stable bump or settlement, trigger the thin overlay recommendation (27).
• Traffic: Performance is not affected by ADT or percent trucks. Due to thin overlays not being structural layers, they experience bottom up reflective cracking with certain combinations of loadings, environmental conditions and rigid joint location.
• Climate: The treatment performs well in all climatic regions, but a better performance is achieved in dry weather, with no large drops in temperature. In colder climates, special attention must be paid to resistance to thermal cracking as well as debonding because of snow plow use. It is recommended that during placement, the air temperature should be above 40°F (37).
• Restrictions: Rigid pavement must be in relative good condition with only minor structural deficiencies. If structural distresses are present, they must be repaired prior to placement of the HMA overlay. The distresses that should be avoided or pre-fixed are punchouts, shattered slabs, D-cracking, deteriorated patches, and corner breaks. Pavements with rocking slabs or a load transfer efficiency below 70 percent are not suitable for repair with an overlay (27). The use of thicker HMA overlays, the use of geotextiles, or the sawing and sealing of joints are some options to counter the cracks from reflecting through to the asphalt layer.</td></tr>
<tr><td>Advantages</td><td>• Increases the fatigue life of the slab by reducing curl stresses.
• Restore the functional capacity.
• Improves rideability and skid-resistance.
• Good alternative for diamond grinding when hard aggregates are encountered.
• Reduces wearing effect of wheel loads on the rigid surface.</td></tr>
<tr><td>Limitations</td><td>• Using geotextiles or sawing and sealing the joints may make the treatment too expensive.
• It is inevitable that contraction joints will reflect through the new HMA overlay.
• It does not increase the structural capacity.
• The overlay is susceptible to transverse reflective cracking and faster deterioration if asphalt patches are used as pre-repair.</td></tr>
<tr><td>Expected Performance</td><td>The expected performance is 5 to 15 years (27). Sawing and sealing the joints after an overlay have been shown to increase the life of the overlay by 4 years (30).</td></tr>
</table>

Dowel Bar Retrofit (DBR) and Diamond Grinding	
Description	DBR is a technique to link the concrete slabs together in order for the load to be distributed evenly across the joint. This is done by cutting slots with a diamond saw over the joints and existing transverse cracks. Dowel bars are set into the slots at a mid-slab depth. The slots are then backfilled with cementing grout, Portland cement concrete, and rapid-setting proprietary materials. Diamond grinding is performed after and is the removal of the top 0.1–0.25 inch layer of a concrete pavement with special equipment fitted with closely spaced diamond-studded saw blades (29).
Conditions for Use	• *Main Distresses*: The combination of treatments addresses faulting, pumping, patching unevenness, and crack or joint deterioration. Diamond grinding can treat faulting less than or equal to 0.5 inches while the dowel bar retrofit will fix the root cause of the distress (19). • *Traffic*: There are no traffic restrictions. The higher the ADT and percent trucks, the greater the potential need for DBR. • *Climate*: Used in all climatic regions. • *Restrictions:* Good candidate pavements should not show D-cracking, reactive aggregate distresses, fatigue cracking, joint deterioration due to poor concrete durability, and structural failures like severe faulting and corner breaks. The number of slab panels cracked should be <10 percent (19). The pavement should have a basin area less than 25 inches or load transfer efficiency equal or less than 70 percent (27)*. Also, the pavement must have less than 10 percent of joints spalled more than 2 inches wide (27). Diamond grinding should be completed within 30 days of placing the patching material (42).
Advantages	• Restores surface smoothness and corrects differential deflections. • Alleviates the potential for pumping, faulting and corner breaks. • Restores load transfer capability. • Reduces pavement noise.
Limitations	• Byproduct slurry must be disposed of in a safe environmentally friendly manner. • Softer coarse aggregates that are exposed by grinding may polish.
Expected Performance	The treatment is expected to last 10 to 15 years (42).

* Defined as $$\boldsymbol{Basin\ Area} = \frac{\mathbf{6}(\boldsymbol{d_0}+\mathbf{2}\boldsymbol{d_1}+\mathbf{2}\boldsymbol{d_2}+\boldsymbol{d_3})}{\boldsymbol{d_0}}$$

d_0 = Surface deflection at the test load center

d_1 = Surface deflection at 12 inches from the test load center

d_2 = Surface deflection at 24 inches from the test load center

d_3 = Surface deflection at 36 inches from the test load center

Full Depth Repair of Concrete	
Description	Full depth repair is a method which involves making lane width, full depth saw cuts to remove deteriorated concrete down to the base. Then, the base is repaired as needed, load transfer devices are installed and the excavated area is refilled with new concrete.
Conditions for Use	• *Main Distresses*: Full depth repair of rigid pavements is used to repair deficiencies deeper than 1/3 the slab thickness. The main distresses addressed include longitudinal cracking, pumping, transverse cracking, low severity D-cracking, blowups, punchouts, and deep joint spalling (>1/3 slab thickness) (29). Spalls with exposed reinforcing steel and cracks through the full thickness of the slab usually require this treatment. FDR is also considered when corner breaks are more than 10 percent of the slab, if the slab is shattered or if there are soft subgrade materials. Existing repairs may also be treated as long as it is limited to the upper 1/3 of the slab (8). Transverse and longitudinal joint separations can also be repaired. • *Traffic*: Open to traffic when test beam modulus of rupture of 300 psi or greater is attained (8). • *Climate*: Performs well in all climatic regions but manufacturer's recommendations on the use of the respective filler material should be followed. The full depth patch should not be placed on frozen existing concrete pavements or under rainy conditions. Conventional PCC and most repair materials should not be placed below 40°F (8). Curing of PCC under cool weather may be too slow to allow timely opening to traffic. • *Restrictions:* If the deterioration is widespread or if the pavement is structurally deficient, it may be more cost effective to overlay or reconstruct. There should not be damage surrounding the repaired area, since it will lead to failure. Pavements with severe material problems (D-cracking, ASR) or where predominant base course or subgrade problems exist, as indicated by differential settlement or load-deflections, should be avoided. Large number of closely spaced joints in a pavement is not desirable since it will cause large number of closely spaced concrete patches. If the patch is 3 feet or less from a transverse joint, the patch should be extended to the existing transverse joint (37). Local extensive structural distresses will warrant subbase or base repair. The minimum area to be repaired should be at least 6 feet long and at least half a full lane width (29).
Advantages	• Restores rideability, structural integrity, and load transfer at joints and cracks.
Limitations	• Longer lane closure than other treatments.
Expected Performance	The treatment has performed for 10 to 15 years (19).

Full Depth Repair and Structural Asphalt Overlay and/or Slab Stabilization	
Description	Plant mixed asphalt cement and aggregate is applied to the existing surface in thicknesses commonly equal or greater than 6 inches or greater (29). Stone matrix, dense-graded, and open-graded mixes are used. Slab Stabilization or undersealing is a pavement technique where flowable material is injected beneath the slab, base or subbase in order to fill voids. Filler can be grout, asphalt cement, and polyurethane. The purpose is not to lift the slab. Before the overlay the pavement's full depth distresses are repaired. Refer to the FDR description for full details.
Conditions for Use	• *Main Distresses*: The treatment method can repair failed joint seals, medium to high severity slab cracking, transverse and/or longitudinal joint separations, high severity joint spalling, scaling, and transverse joint faulting. The asphalt overlay can also address a substantial amount of patches, more than 3 reflection failures per mile, or more than 10 percent of joints that have corner breaks (27). The slab should be stabilized if 20 percent of the inspected section cracks and joints are voided according to GPR analysis. Also, unstable bump or settlement may require stabilization. Refer to the FDR description for details on main distresses. • *Traffic*: Overlays on JCP had ADT ranges from low to very high and truck percentage from 5 percent to 31 percent (65). The pavement design method used within a given state transportation agency should be used. The performance of undersealing is not affected by different levels of ADT or percent trucks. Refer to the FDR description for details on traffic. • *Climate*: The treatment performs well in all climatic regions but a better performance is achieved in dry weather, with no large drops in temperature. In colder climates, special attention must be paid to resistance to thermal cracking as well as debonding because of snow plow use. It is recommended that during placement the air temperature should be above 40°F (37). Undersealing should be placed in warm dry weather. Refer to the FDR description for details on climate. • *Restrictions:* Candidate pavements should not be close to its end of life. Full depth repairs prevent premature failures of the overlay. If structural repairs before the overlay cover 20 percent to 30 percent of the surface area, another cost effective treatment should be implemented (37).Undersealing is not apt for correcting depressions, stop erosion, widespread pumping and highly plastic-fine-grained subgrade soils. In addition, open-graded subbases should not be undersealed. Slabs with poor load transfer and rocking will reflect cracks quickly through the HMA. The use of thicker HMA overlays, the use of geotextiles, or the sawing and sealing of joints are some options to counter the cracks from reflecting through to the asphalt layer. The added structural capacity is dependent on asphalt overlay thickness.
Advantages	• Can be done one lane at a time resulting in overnight lane closures not being required. • The ride, friction, cross-slope characteristics, and skid-resistance are restored. • Increases the fatigue life of the slab by reducing curl stresses, which translates into reduced punchouts. • Undersealing will reduce reflective cracking in HMA overlays. • The common rehabilitation technique increases the structural capacity. • Reduces wearing effect of wheel loads on the rigid surface. • Undersealing reduces the progression of pumping, faulting, and slab cracking.

Full Depth Repair and Structural Asphalt Overlay and/or Slab Stabilization (Continued)	
Limitations	• Using geotextiles or sawing and sealing the joints may make the treatment too expensive. • It is inevitable that contraction joints will reflect through the new HMA overlay in time. • If the slab is stabilized when not needed, it will impair pavement performance. • The overlay may create vertical clearance problems. • Undersealing only restores slab support. • Performance of undersealing is highly dependent on contractor.
Expected Performance	The expected performance of the overlay is 5 to 15 years (27). The performance of undersealing is extremely variable. Sawing and sealing the joints after the overlay have been shown to increase the life by 4 years (30). The life of FDR is 10 to 15 years (19).

Slab Replacement	
Description	The treatment is a selective slab replacement by removing the deteriorated concrete down to the base, repairing the base, installing load transfer devices, and refilling the excavated area with new concrete. Slab replacing may include replacing underlying layers.
Conditions for Use	• *Main Distresses*: The replacing of slabs should be done if D-cracking, blowups, punchouts, extensive severe cracking, severe joint spalling, and deteriorated joints or existing repairs are encountered. • *Traffic*: There are no traffic restrictions for this treatment. To minimize the traffic impact, rapid strength concrete can be used. • *Climate*: Performs well in all climatic regions. When placing concrete the air temperature must have a minimum of 40°F (42). The pouring of the concrete must not be done when rain is imminent. • *Restrictions:* Candidate projects must have a total length of replacement of less than 100 feet. If more than 10 percent of the slabs in a given lane need replacement, this treatment will not be cost effective (4). Grinding, if needed, should be performed on the whole lane within the project. Pavements which have extensive and severe distresses or need added structural integrity may proceed with an asphalt concrete overlay. Failing to repair underlying base layers when needed will result in premature failure. The premature failure translates into higher maintenance costs and negative impacts on traffic.
Advantages	• Improves rideability. • Pavement may be restored to original condition.
Limitations	• Slab replacements with asphalt concrete are short term solutions.
Expected Performance	The performance is expected to last 10 years (42). If an asphalt overlay is included, a "rule-of-thumb" is that 1 inch of overlay adds one extra year (29).

Rubblizing and Asphalt Overlay	
Description	Rubblization is the process of fracturing, with resonating beam equipment, an existing rigid pavement into pieces, ideally into 1 to 3-inch chunks at the top and into 3 to 6-inch chunks towards the bottom (31). The crushing also debonds any reinforcing steel, creating a very high quality aggregate base material. This material is then overlaid with 6 inches or greater of hot mix asphalt concrete (29).
Conditions for Use	• *Main Distresses*: The main triggers are moderate to severely cracked (longitudinal and transverse) or broken panels, severe spalled joints, severe joint faulting, and severe scaling. The asphalt overlay can also address a substantial amount of patches, more than 3 reflection failures per mile, or more than 10 percent of joints that have corner breaks (27). The treatment can also fix severe structural deficiencies, infrequent settlement, heaves, and blowups. • *Traffic*: Very low to very high traffic pavements have been treated. The overlay thickness will be designed based on traffic loading. The pavement design method used within a given state transportation agency should be used. • *Climate*: The treatment performs well in all climatic regions but a better performance is achieved in dry weather, with no large drops in temperature. In colder climates, special attention must be paid to resistance to thermal cracking as well as debonding because of snow plow use. During construction, avoid heavy rain or snow events and when the ground is frozen. Overlay placement should be done when the air temperature is higher than 45°F (37). • *Restrictions:* The candidate projects must have adequate drainage, adequate subgrade support, and adequate stiffness of pavement layers beneath the concrete. This support is necessary during the rubblizing process. The strength of the base will be dependent on the efficiency of the breaking process.
Advantages	• The rubblizing process does not damage utilities, provides sound base for overlay, results in lower variability of fractured slab modulus and is the most economical. • The treatment provides a maintainable surface, extends the service life, increases structural capacity and prevents reflective cracking. • Can be constructed on a single lane, eliminating the need to divert traffic. • Restores ride, friction and cross-slope. • Spall repair and full depth repair are not necessary
Limitations	• It is not a rigid pavement anymore. • Rubblizing technology is limited and specialized contractors are limited. • Traffic can't be maintained on rubblized surface until asphalt concrete course is placed. • The asphalt concrete overlay design is more complex.
Expected Performance	The performance is expected to last from 15 to 20 years (31).

Unbonded Concrete Overlay	
Description:	Unbonded concrete overlay is an overlay pavement system consisting of a concrete overlay, 5 inches or greater, over the existing rigid layer, with an interlayer (at least 1 inch) between them to break the bond (29). Bituminous mixtures provide the best material for the interlayer because of the lower modulus. The concrete overlay should follow the placement, design, and finishing requirements for new construction. This includes texturing, joint placement (dowel bars and tie bars), joint sealing, and pavement sealing.
Conditions for Use	• *Main Distresses*: The treatment is successful when the existing pavement is in poor condition. Severe material related distresses and D-cracking are also addressed. Faulting of 0.375 inches or less, rocking of the slabs and/or lack of support by the existing pavement can be fixed with the unbonded overlay (34). • *Traffic*: The traffic becomes an important factor when designing the thickness of the concrete overlay. The pavement design method used within a given state transportation agency should be used. • *Climate*: The treatment performs well in all climatic regions. When placing, common construction standards should be met. • *Restrictions:* Candidate projects should have shattered slabs, failed patches, settlements, and slab pumping removed or repaired. Some districts repair spalling before treatment, but it is not necessary.
Advantages	• The Bituminous interlayer reduces curling and warping stresses in the overlaid slab and also prevents existing distresses to reflect through to the concrete overlay. • The existing concrete pavement takes the role of a stabilized subbase like cement treated base. • Restores or enhances structural capacity. • Improves surface friction, noise, and rideability. • Saturated subgrade and poor soils may also benefit.
Limitations	• Due to the added thickness, vertical clearance may be an issue. • Side slopes must be modified.
Expected Performance	Depending on the thickness of the overlay, the treatment may last for 20 to 40 years (4).

Reconstruction	
Description:	Reconstruction is the total replacement of the rigid pavement structure to at least the original structural and functional characteristics.
Conditions for Use	• *Main Distresses*: Reconstructing the pavement will reset any surface distress, load transfer issue, or any base or subbase problem. • *Traffic*: The traffic will impact the slab thickness design. The pavement design method used within a given state transportation agency should be used. • *Climate*: The reconstructed pavement is designed with environmental conditions in mind. When constructing, common concrete placing standards should be met. • *Restrictions:* Candidate projects should have no redeemable pavement life, need changes to roadway geometrics or need major subgrade corrections. Usually performed when there are high distress levels or overlays are no longer effective. In some instances, the pavement will be reconstructed due to planning, development and utility reconstruction.
Advantages	• Restores structural and functional characteristics to at least the original conditions.
Limitations	• Side slopes must be modified. • Most expensive activity.
Expected Performance	The rigid pavement is designed to last for at least a period of 30 years (29).

CONTINUOUSLY REINFORCED CONCRETE (CRCP) TREATMENTS

Table 17. Decision Support Matrix for the Selection of Treatments for Continuously Reinforced Concrete Pavements.

Level	Treatment	Climatic zone				Traffic		Pavement Condition Variable				
		1	2	3	4	Low	High	Spalled Cracks	Punchouts	Asphalt Patches	Concrete Patches	Ride quality
Preventive Maintenance	Diamond Grinding and/or Grooving	●	●	●	●	◑	●	●			◑	●
	Partial Depth Patch	●	●	●	●	●	●	●			◑	
	Ultra-Thin Friction Course	●	●	●	●	●	●	●			●	
Light Rehabilitation	Thin Asphalt Overlay	●	●	●	●	●	●	●		◑	●	
	Full Depth Repair of Concrete	●	●	●	●	●	●		●	●	●	
Medium Rehabilitation	Full Depth Repair and Structural Asphalt Overlay and/or Slab Stabilization	●	●	●	●	●	●		●	●	●	●
	Bonded Concrete Overlay	●	●	●	●	●	●		●	●	●	◑
Heavy Rehabilitation	Reconstruction	●	●	●	●	●	●		●	●	●	●
	Unbonded Concrete Overlay	●	●	●	●	●	●		●	●	●	◑

● = Recommended ◑ = Conditionally Recommended (may depend on other factors)

Diamond Grinding and/or Diamond Grooving	
Description	Diamond grinding is the removal of the top 0.1 to 0.25-inch layer of a concrete pavement with special equipment fitted with closely spaced diamond-studded saw blades (29). Diamond grooving is the cutting of narrow grooves longitudinally, or sometimes transversely, that cover the full width of the concrete pavement lane. Both treatments are usually used in conjunction but in some situations only a sole technique may be required.
Conditions for Use	• *Main Distresses*: Patches more than 10 per mile and faulting more than 0.25 inches will trigger diamond grinding (27). • *Traffic*: There are no traffic limitations but the next considerations should be taken. If faulting is addressed and the distress mechanism is not, faulting can reoccur due to continued truck loading. If polishing is being addressed, heavy traffic volume may cause the problem to reoccur. Heavy traffic volume will wear the treatment out. Diamond grinding projects have shown truck percentages ranging from 5.4 percent to 25 percent (65). • *Climate*: The weather has no effect on the treatment performance. If the treatment is used in cold climates, studded tire or chain surface wear may become an important factor. • *Restrictions:* Candidate pavements should have sound functional and structural characteristics. The treatment is not appropriate when signs of structural failures such as severe faulting and punchouts are present. Not recommended for pavements with significant slab cracking, material-related deficiencies or soft coarse aggregates known to polish quickly. Load transfer efficiency must be > 70 percent or deflection basin area > 25 inches (27) *.
Advantages	• Restores smooth-riding surface and increases skid-resistance. • Reduces pavement noise and restores surface texture. • Reduces pumping at the joints or cracks. • When grooving is included, it increases safety by preventing hydroplaning and wet weather accidents. • Does not affect overhead clearances underneath bridges. • It has a negligible effect on structural capacity.
Limitations	• Does not address pavement distress mechanism. • Softer coarse aggregates that are exposed by grinding may polish. • Small vehicles and motorcycles may encounter small lateral movements or "wiggle". • Byproduct slurry must be disposed of in a safe environmentally friendly manner.
Expected Performance	The treatment performance is expected to last 8-12 years (27).

* Defined as $$\boldsymbol{Basin\ Area} = \frac{\boldsymbol{6(d_0+2d_1+2d_2+d_3)}}{\boldsymbol{d_0}}$$

d_0 = Surface deflection at the test load center

d_1 = Surface deflection at 12 inches from the test load center

d_2 = Surface deflection at 24 inches from the test load center

d_3 = Surface deflection at 36 inches from the test load center

Partial Depth Patch	
Description	Partial depth patching is the removal of small shallow deteriorated areas by milling, chipping, and sawing of unsound concrete and replacement with suitable materials. The filler can be rapid-setting concrete, conventional PCC, bituminous materials, and proprietary materials. Its selection is based on curing time, climatic conditions, materials costs, and desired life. This work also includes removal and replacement of asphalt concrete patches from spalled or damaged areas. When the area is less than 6 inches in length and 1.5 inches in width, this treatment is referred to as joint spalling repairs (42).
Conditions for Use	• *Main Distresses*: This treatment repairs localized distresses within the upper third to upper half slab thickness. The distresses addressed include 2-inch wide spalls greater than 10 percent of the crack, scaling and deterioration of existing repairs of areas adjacent to the repairs (27). Surface popouts and potholes may also be fixed with a partial depth patch. • *Traffic*: The treatment is effective at all traffic levels. If using concrete as the filler material, open to traffic when the flexural strength reaches 3,000 psi (28). • *Climate*: Performs well in all climatic regions but manufacturer's recommendations on use of the respective filler material, should be followed. The partial depth patch should not be placed on frozen existing concrete pavements or under rainy conditions. Conventional PCC and most repair materials should not be placed below 40°F (8). Curing of PCC under cool weather may be too slow to allow timely opening to traffic. • *Restrictions:* Pavements with structural deficiencies, fatigue and/or foundation movement are not good candidates. Spalls with exposed reinforcing steel or spalls caused by D-cracking and Alkali-Silica Reactivity (ASR) should be avoided. Partial depth repairs must have a minimum dimension of 4 inches by 12 inches and 1 inch to 3 inches in depth (28).
Advantages	• Deters further deterioration, restores structural integrity, and improves rideability. • Relieves temporary roughness caused by material problems such as D-cracking or Alkali-Silica Reactivity ARS. • Surface texture is restored.
Limitations	• Byproduct slurry must be disposed of in a safe environmentally friendly manner. • If bituminous filler is used, the treatment is only temporary. • Cracks found through the full slab thickness may require full-depth repair.
Expected Performance	The performance is based on the installation quality control and can be expected to last 3 to 10 years (27).

Ultra-Thin Friction Course	
Description	In addition to treating HMA pavements, ultra-thin friction course have been used on PCC pavements. An ultra-thin friction course, or NovaChip®, is a thin layer, typically 0.5 to 0.75 inches of course or gap graded aggregate hot mix asphalt concrete (29). The hot mix layer is bound to the surface with a polymer-modified asphalt emulsion specially designed to seal the existing surface. The treatment can be applied to both asphalt and concrete pavements.
Conditions for Use	• *Main Distresses*: The NovaChip® also has the capability to treat low severity cracking, low material related distress (D-cracking ARS), and moderate spalling. • *Traffic*: Although it can be used in any traffic level, it is predominantly used in high ADT and truck volume roadways. • *Climate*: Performs well in all climatic regions. Should be placed above 45°F or according to the type of asphalt binder used (7). When placing, rain should be avoided. • *Restrictions:* Not recommended where structural distresses exist and extensive material related distresses such as D-cracking and ASR are present. Prior to placement of the treatment cracks greater than 0.25 inches wide should be sealed, bump and grinding should be implemented as needed and severe distresses should be patched (7). Over-banding methods of crack sealing are not recommended; strips left behind can reflect through the finished pavement. CRC pavements must not have cracks filled or transverse cracks sealed.
Advantages	• Improves splash/spray characteristics, skid-resistance, and tire noise. • Can be opened to traffic within 15 minutes (7). • It restores low severity roughness and improves ride quality. • Retards reflective cracking. • The treatment seals most minor cracks that are <0.25 inches wide (29).
Limitations	• Requires special paving equipment to place the mix. • Does not add structural capacity.
Expected Performance	Estimated treatment performance is 6 to 10 years (7).

Thin Asphalt Overlay	
Description	Plant mixed asphalt cement and aggregate applied to the existing surface in thicknesses of 2 inches or less (29). Stone matrix, dense-graded and open-graded mixes are used. Tack coat is required before the placement of the thin overlay in order to improve the bond to the existing surface.
Conditions for Use	• *Main Distresses*: Thin overlays address faulting, spalling, and longitudinal cracking. Patches per mile greater than 10 or faulting greater than 0.25 inches, and stable bump or settlement, trigger the thin overlay recommendation (27). • *Traffic*: Performance is not affected by ADT or percent trucks. Due to thin overlays not being structural layers, they experience bottom up reflective cracking with certain combinations of loadings, environmental conditions, and rigid joint location. • *Climate*: The treatment performs well in all climatic regions but a better performance is achieved in dry weather, with no large drops in temperature. In colder climates, special attention must be paid to resistance to thermal cracking as well as deboning because of snow plow use. It is recommended that during placement the air temperature should be above 40°F (37). • *Restrictions:* Rigid pavement must be in relative good condition with only minor structural deficiencies. If structural distresses are present, they must be repaired prior to placing of the HMA overlay. The distresses that should be avoided or pre-fixed are punchouts, D-cracking, and deteriorated patches. Pavements with rocking slabs or a load transfer efficiency below 70 percent are not suitable for repair with an overlay (27).
Advantages	• Increases the fatigue life of the slab by reducing curl stresses. • Restore the functional capacity. • Improves rideability and ski-resistance. • Good alternative for diamond grinding when hard aggregates are encountered. • Reduces wearing effect of wheel loads on the rigid surface.
Limitations	• It is inevitable that contraction joints will reflect through the new HMA overlay. • It does not increase the structural capacity. • The overlay is susceptible to transverse reflective cracking and faster deterioration if asphalt patches are used as pre-repair.
Expected Performance	The expected performance is 5 to 15 years (27).

Full Depth Repair of Concrete	
Description	Full depth repair is a method which involves making lane width, full depth saw cuts to remove deteriorated concrete down to the base. Then the base is repaired as needed, load transfer devices are installed, and the excavated area is refilled with new concrete. In CRC pavements, special considerations must be taken during construction. An additional area must be removed at the end of the patch for splicing the longitudinal steel reinforcement; the new longitudinal reinforcement should match the existing size and spacing; and transverse reinforcement should be included at a spacing of 1 foot center to center (37).
Conditions for Use	• *Main Distresses*: Full depth repair of rigid pavements is used to repair deficiencies deeper than 1/3 the slab thickness. The main distresses addressed include high severity D-cracking, transverse and longitudinal cracking, punchouts, and deep spalling; from less than 0.5 inches to as deep as half the slab thickness (29). Spalls with exposed reinforcing steel and cracks through the full thickness of the slab usually require this treatment. FDR is triggered when punchouts are greater than 10 percent of the slab, if there is a broken cluster area, or if there are soft subgrade materials. Existing repairs may also be treated as long as it's limited to the upper 1/3 of the slab (8). • *Traffic*: Open to traffic when test beam modulus of rupture of 300 psi or greater is attained (8). • *Climate*: Performs well in all climatic regions but manufacture's recommendations on the use of the respective filler material used, should be followed. The full depth patch should not be placed on frozen existing concrete pavements or under rainy conditions. Conventional PCC and most repair materials should not be placed below 40°F (8). Curing of PCC under cool weather may be too slow to allow timely opening to traffic. • *Restrictions:* If the deterioration is widespread or if the pavement is structurally deficient, it may be more cost effective to overlay or reconstruct. There should not be damage surrounding the repaired area, since it will lead to failure. Pavements where predominant base course or subgrade problems exist, as indicated by differential settlement or load-deflections, should be avoided. Large number of closely spaced joints in a pavement is not desirable since it will cause large number of closely spaced concrete patches. The area to be repaired must be a minimum of 3 feet beyond the end of a longitudinal crack extending from a broken area (37). Local extensive structural distresses will warrant subbase or base repair. The minimum area to be repaired should be at least 6 feet long and at least half a full lane width (29).
Advantages	• Restore rideability structural integrity and load transfer at joints and cracks.
Limitations	• Longer lane closure than other treatments.
Expected Performance	The treatment has performed for 10 to 15 years (19).

Full Depth Repair and Structural Asphalt Overlay and/or Slab Stabilization	
Description	Plant mixed asphalt cement and aggregate is applied to the existing surface in thicknesses commonly between 4 to 6 inches or greater (61). Stone matrix, dense-graded, and open-graded mixes are used. Slab stabilization or undersealing is a pavement technique where flowable material is injected beneath the slab, base, or subbase in order to fill voids. Filler can be grout, asphalt cement and polyurethane. The purpose is not to lift the slab. Before the overlay the pavement's full depth distresses are repaired. Refer to the FDR description for full details.
Conditions for Use	• *Main Distresses*: The treatment method can repair failed joint seals, medium to high severity slab cracking, longitudinal joint separations, high severity joint spalling, and scaling. The asphalt overlay can also address more than 10 patches per mile or faulting greater than 0.25 inches, and stable bump or settlement (27). The slab should be stabilized if 20 percent of the inspected section cracks and joints are voided according to GPR analysis. Also, unstable bump or settlement may require stabilization. Refer to the FDR description for details on main distresses. • *Traffic*: Overlays can be used on low to very high ADT and truck percentage roadways. The pavement design method used within a given state transportation agency should be used. The performance of undersealing is not affected by different levels of ADT or percent trucks. Refer to the FDR description for details on traffic. • *Climate*: The treatment performs well in all climatic regions but a better performance is achieved in dry weather, with no large drops in temperature. In colder climates, special attention must be paid to resistance to thermal cracking as well as debonding because of snow plow use. It is recommended that during placement the air temperature should be above 40°F (37). Undersealing should be placed in warm dry weather. Refer to the FDR description for details on climate. • *Restrictions:* Candidate pavements should not be close to its end of life. Full depth repairs prevent premature failures of the overlay. If structural repairs before the overlay cover 20 percent to 30 percent of the surface area, another cost effective treatment should be implemented (37).Undersealing is not apt for correcting depressions, stop erosion, widespread pumping and highly plastic-fine-grained subgrade soils. In addition, open-graded subbases should not be undersealed. Slabs with poor load transfer and rocking will reflect cracks quickly through the HMA. The added structural capacity is dependent on the asphalt overlay thickness.
Advantages	• Can be done one lane at a time resulting in overnight lane closures not being required. • The ride, friction, cross-slope characteristics, and skid-resistance are restored. • Increases the fatigue life of the slab by reducing curl stresses, which translates into reduced punchouts. • Undersealing will reduce reflective cracking in HMA overlays. • The common rehabilitation technique increases the structural capacity. • Reduces wearing effect of wheel loads on the rigid surface. • Undersealing reduces the progression of pumping, faulting, and slab cracking.
Limitations	• It is inevitable that any joints will reflect through the new HMA overlay in time. • If the slab is stabilized when not needed, it will impair pavement performance. • The overlay may create vertical clearance problems. • Undersealing only restores slab support. • Performance of undersealing is highly dependent on contractor.
Expected Performance	The expected performance of the overlay is 5 to 15 years (27). The performance of undersealing is extremely variable. The combination of treatments should extend the treatment's life closer to 15 years.

Bonded Concrete Overlay	
Description	In bonded concrete overlays a new concrete layer, 2 to 8 inches thick, is applied to the existing surface (29). The basic assumption of this treatment is that the different concrete layers are behaving as a monolithic layer. Therefore, full bond between the new and old concrete must be ensured.
Conditions for Use	• *Main Distresses*: The treatment addresses light cracking, shallow spalling, and covers patches in place. • *Traffic*: The thickness of the overlay is a function of existing structural capacity and the necessary structural capacity to fulfill traffic demands. The pavement design method used within a given state transportation agency should be used. • *Climate*: Special attention should be given to adverse environmental conditions during paving. Hot-dry climates and high velocity wind pose the most problematic setting for the overlay placement because these conditions favor the loss of moisture from fresh concrete. • *Restrictions:* The perfect candidate pavement will have a sound structural condition but be structurally sufficient. Structural distresses should be avoided. If deep spalling, delamination, D-cracking, punchouts, drainage problems, and deteriorated patches are present they must be repaired beforehand. If the treatment is being used to restore functional characteristics, a concrete overlay of 2 inches should be used. When overlay thickness is more than 40 percent, longitudinal steel is needed (29). AC patches must be removed and replaced with PCC.
Advantages	• Reduces the wheel load stresses, extending the pavement life. • Improves friction, noise and rideability; while eliminating scaling. • Construction is time consuming and costly. • Less susceptible than asphalt overlay to rutting. • The use of cement type III allows for the road to be opened to traffic within 6 to 24 hours (29).
Limitations	• If extensive structural repairs are needed, the overlay becomes too expensive. • Texas has had problems with bonded concrete overlays due to debonding.
Expected Performance	The performance of the treatment is based on thickness but it has been shown to add 20 years to the life of pavements (29).

Reconstruction	
Description	Reconstruction is the total replacement of the rigid pavement structure to at least the original structural and functional characteristics.
Conditions for Use	• *Main Distresses*: Reconstructing the pavement will reset any surface distress, load transfer issue, or any base or subbase problem. • *Traffic*: The traffic will impact the slab thickness design. The pavement design method used within a given state transportation agency should be used. • *Climate*: The reconstructed pavement is designed with environmental conditions in mind. When constructing, common concrete placing standards should be met. • *Restrictions:* Candidate projects should have no redeemable pavement life, need changes to roadway geometrics, or need major subgrade corrections. Usually performed when there are high distress levels or overlays are no longer effective. In some instances, the pavement will be reconstructed due to planning, development, and utility reconstruction.
Advantages	• Restores structural and functional characteristics to at least the original conditions.
Limitations	• Side slopes must be modified. • Most expensive activity.
Expected Performance	The pavement is designed to last for at least a period of 30 years (29).

Unbonded Concrete Overlay	
Description	Unbonded concrete overlay is an overlay pavement system consisting of a concrete overlay, 5 inches or greater, over the existing rigid layer, with an interlayer (at least 1 inch) between them to break the bond (29). Bituminous mixtures provide the best material for the interlayer because of the lower modulus. The concrete overlay should follow the placement, design, and finishing requirements for new construction. This includes texturing, joint placement (tie bars), joint sealing, and pavement sealing.
Conditions for Use	• *Main Distresses*: The treatment is successful when the existing pavement is in poor condition. Severe material related distresses and D-cracking are also addressed. Faulting of 0.375 inches or less, rocking of the slabs and/or lack of support by the existing pavement can be fixed with the unbonded overlay (34). • *Traffic*: The traffic becomes an important factor when designing the thickness of the concrete overlay. The pavement design method used within a given state transportation agency should be used. • *Climate*: The treatment performs well in all climatic regions. When placing, common construction standards should be met. • *Restrictions:* Candidate projects should have failed patches, settlements, pumping and punchouts removed or repaired. Some districts repair spalling before treatment, but it is not necessary.
Advantages	• Bituminous interlayer reduces curling and warping stresses in the overlaid slab and also prevents existing distresses to reflect through to the concrete overlay. • The existing concrete pavement takes the role of a stabilized subbase like cement treated base. • Restores or enhances structural capacity. • Improves surface friction, noise, and rideability. • Saturated subgrade and poor soils may also benefit.
Limitations	• Due to the added thickness, vertical clearance may be an issue. • Side slopes must be modified.
Expected Performance	Depending on the thickness of the overlay the treatment may last for 20 to 40 years (4).

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