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Pavement Repairs in Preparation for a Preventative Maintenance Contract

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16. Abstract

The synthesis study focused on pavement preparatory work performed before preventive maintenance (PM) surfacing contracts with the goal of answering, "What work needs to be performed to the roadway before a new surface is placed?" Preparatory work performed by in-house maintenance forces or maintenance contracts may include crack sealing, fog seal, repairs, milling, and level-up and should be performed well in advance of the PM contract. Both flexible and rigid pavements may require work in advance of a PM contract. Seal coats or thin overlays are typical PM surfacing projects. The synthesis investigated best practices, factors that affect materials selected, factors that affect repair decisions, timing of preparatory work, and the effects of the repair procedures and materials on the life of the new surface based on the preparatory work performed.

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PAVEMENT REPAIRS IN PREPARATION FOR A PREVENTIVE MAINTENANCE CONTRACT

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DISCLAIMER

This research was sponsored by the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The engineer (researcher) in charge of the project was Darlene C. Goehl, P.E. #80195.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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CHAPTER 1: INTRODUCTION

In this synthesis study, the research team investigated preparing pavements for a future preventive maintenance (PM) project by reviewing the current state-of-the-practice and emerging research. A survey was developed and distributed to the Texas Department of Transportation (TxDOT) personnel through the web-based software, Qualtrics. The factors evaluated were policies, procedures, methods, timing, materials, equipment resources, budgets, and the maintenance crew's knowledge, skills, and abilities. Both rigid and flexible pavements were included, with the focus on flexible pavements and seal coat PM contracts. The Atlanta and Bryan districts provided information about best practices used within the districts to help determine repair areas.

It is important when preparing a roadway for a PM treatment to understand the benefits the treatment is providing. However, it is more important to understand what it does not provide so that the preparation addresses those areas. For example, the benefits and challenges for a seal coat PM treatment are shown in Table 1.

Table 1. Seal Coat [1].

Benefits	Challenges
Seals an existing bituminous surface against the intrusion of air and water.	Seal coat has little or no structural strength.
Enriches an existing dry or raveled surface.	Ride quality is not improved.
Arrests the deterioration of a surface showing signs of distress.	Mimics the surface shape, therefore surface geometry cannot be improved.
Provides a skid-resistant surface.	
Provides the desired surface texture.	
Improves light-reflecting characteristics where these are required (by use of light-colored stone).	
Enables paved shoulders or other geometric features to be demarcated by providing a different texture or color.	
Provides a uniform-appearing surface.	

This report documents the information found in the literature review and survey.

CHAPTER 2:
SURVEY RESULTS

An electronic survey link was sent to all TxDOT districts. Eighteen people representing 17 (i.e., 68 percent) districts responded. The responding districts are shown in Figure 1 and highlighted in blue. The survey consisted of 24 questions. This chapter contains a summary of the key points from the survey. Please refer to Appendix A for the full survey and results.

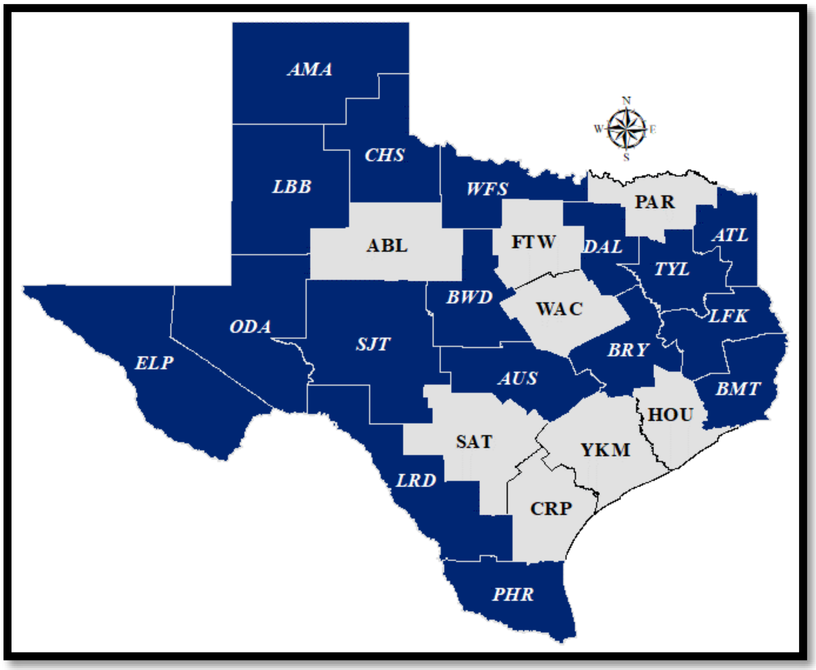

Figure 1. Responding Districts (Dark Blue and Name in Italics).

All districts described their PM process. The PM program is a collaborative effort between several offices, typically maintenance, area office, and district staff, including the pavement engineer. Typically, the pavement condition data in the pavement management information system (PMIS) or pavement analyst (PA) system along with a visual inspection, time of last surface maps, and funding considerations are used to aid in the selection of projects.

Skid number, condition score, and distress score are the most used PMIS/PA data. Failures and rutting are the most common distresses used for flexible pavement. All concrete pavement data is used, with the worst conditions such as punchouts, failures, and shattered slabs being used by most.

The main preventive maintenance treatments for flexible pavements are seal coats and thin overlays. The least used are micro-surfacing and slurry seals. Concrete pavements do not have a main type or routine PM treatment; diamond grinding and thin hot mix overlays are sometimes used as PM treatments.

The maintenance supervisor and area engineer typically determine the in-house repairs based on visual observations and experience. There is not a formal method to evaluate how these repairs perform other than a visual observation usually performed before the PM project. The size of the repair is determined by visual observations.

The timeframe for receiving the roadway list is good at an average of 17.5 months ahead of time. The average time to work on repairs is 8.4 months with a need for more time (i.e., 5.2 months on average) to complete the repairs. Fog seal is not commonly used on repairs that have not had adequate cure time.

The type of problem found influences the repair strategy the most, followed by budget and timeframe for the repair work. The main repair strategies typically used for flexible pavements are base repair and level-up. Crack seal is also routinely used. For concrete pavement, most of the repairs are contracted and not performed in-house. The main concrete repairs are full depth patches, partial depth patches, and spall repair.

The most common contracted work is crack seal and concrete repairs. All districts indicated they owned equipment for blade laid level-up. In general, most districts do not contract for equipment with an operator. Crack seal was the only treatment that the districts did not own all the equipment needed.

All materials typically used for repairs are available through a requisition. Cement is the most common in-stock material. One district indicated that concrete was difficult to get.

The concerns with the PM program are as follows:

- Balancing the needs with budget.
- Fleet (equipment), including operators.
- Preparatory work is performed correctly for adequate structure and good ride.
- Time to perform repairs.
- Material availability.
- Material cost.

CHAPTER 3: LITERATURE REVIEW

An extensive literature review was conducted. Over 300 reports and websites were reviewed. References from Australia and New Zealand contained the most detailed information concerning preparing a pavement before placing a seal coat. This chapter contains the key findings from the literature review and summarizes the topics of pavement management, PM treatments, and maintenance repairs.

PAVEMENT MANAGEMENT

Most pavement management systems, including TxDOT's, have criteria that estimate when maintenance, preventive maintenance, and rehabilitation are needed. Table 2 is a summary of criteria from TxDOT's *Maintenance Management Manual*. Ride quality is quantified by a serviceability index (SI). The SI-equivalent international roughness index (IRI) was estimated by the research team and added to the table.

Table 2. TxDOT Pavement Maintenance Level of Service [2].

	Condition	Desirable Level	Acceptable Level	Tolerable Level
Distress	**ADT Level**	**Maintain as Follows:**	**Maintain as Follows:**	**Maintain as Follows:**
Rutting	0–500	< 1/2" and 50% per wheelpath (WP)	< 1" and 50% per WP	< 3" and 25% per WP
Rutting	501–10,000	< 1/2" and 50% WP	< 1" and 50% WP	< 3" and 25% per WP
Rutting	10,001 and up	< 1/2" and 25% per WP	< 1" and 25% per WP	< 1" and 50% per WP
Alligator Cracking	n/a	Maintain with no visible cracks	Maintain with visible cracks < 10% per WP	Maintain with visible cracks < 50% per WP
Ride Quality	0–500	> 2.5 SI (178 IRI)	> 2.0 SI (221 IRI)	> 1.5 SI (270 IRI)
Ride Quality	501–10,000	> 3.0 SI (141 IRI)	> 2.5 SI (178 IRI)	> 2.0 SI (221 IRI)
Ride Quality	10,001 and up	> 3.5 SI (109 IRI)	> 3.0 SI (141 IRI)	> 2.5 SI (178 IRI)

The design life of the pavement, along with the timing for different levels of treatment, affects the condition and life cycles of the pavement. Figure 2 is an example of a pavement condition deterioration curve with typical locations of maintenance treatments.

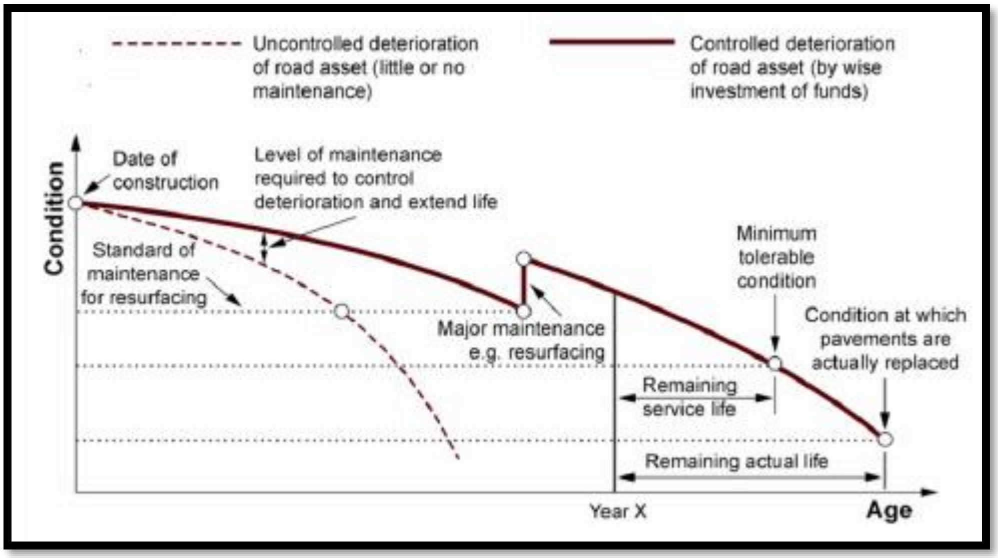

Figure 2. Pavement Deterioration with Time [3].

PM TREATMENTS

The typical PM treatments found in the literature are shown in Table 3, along with the expected treatment life. The focus of this project is preparing a pavement for a seal coat. The project survey indicated that the timeframe to complete repairs before the PM project ranged from 0 to 24 months with an average of 8.4 months. On average, those responding to the survey would have liked an additional 5 months to prepare roadways. The cure time considered the best for repairs was 9.3 months and ranged from 3 to 12 months. This project's survey did not ask the expected life of a seal coat, however, in TxDOT research project 0-7106's survey, the expected life for a seal coat was 6.4 years.

Table 3. Treatment Life.

Treatment	Expected Life (Years)
Fog Seal	3.5 [4]; 2 to 4 [5]
Crack Seal	Not found in literature.
Seal Coat (Small Aggregate)	5 [4]; 5 to 7 (Aggr. 5mm to 7mm) [5, 6]
Seal Coat (Large Aggregate)	8 to 15 (Aggr. > 10 mm) [6]
Double Seal	8 to 15 [6]
Slurry Seal	5 [4]; 5 to 10 [6]; 5 to 8 [5]
Scrub Seal	6 to 7 [5]
Microsurfacing	6 [4]; 5 to 10 [6]; 6 to 10 [5]
High Friction Surface Treatment	
Open Graded Mix	10 to 15 (modified binder) [6]
Thin Open Graded	8 to 12 (modified binder) [6]
Dense Graded Mix	8 to 20 [6]
Thin Overlay	7 [4]

Stone Mastic Asphalt or Coarse Gap-Graded Asphalt	10 to 20 [6]
Fine Gap-Graded Asphalt	15 to 25 [6]
Cape Seal	8 to 15 [6]
Dowel Bar Retrofit	10 to 22 [7]
Cross Stitch	10 to 20 [7]
Diamond Grinding	15 to 20 [7]
Concrete Partial Depth Repair/Spall Repair	10 to 20 [7]
Concrete Full Depth Repair	15 to > 20 [7]
Concrete	30 to 40 [6]

REPAIRS FOR PM TREATMENT

When performing a repair for a seal coat PM treatment it is important to ensure that a uniform texture is achieved over the width of the area to be sealed. Significant changes in surface condition, such as nonuniform over area being sealed, can lead to rock loss or flushing due to constructability issues when placing the new seal coat. The typical repairs performed before the PM treatment are shown in Table 4. 1In the bandaging technique the hot binder is poured on to the cleaned pavement and then spread with a metal tool to make a ‘bandage’ 2–3 mm thick and 75–100 mm wide [8].

Table 5 has the cure time before the PM treatment is placed for maintenance repairs.

Table 4. Typical Repairs.

Method	Description	Treatment
Crack Repair	< 1/8" wide (< 1 mm wide affects less than 5% of the pavement [8])	Seal coat (strip/spot locations).
	1/8" to 1/5" (1 to 5 mm wide [8])	Use polymer or rubber modified binder seal coat. Bandaging[1] or a strain alleviating membrane (SAM) seal is used [8].
	> 1/8" [1] (3 mm or wider [8])	Fill with special filling materials before the polymer modified bitumen membrane is applied [8].
	5 to 15 mm-wide cracks [8]	Bandaging is advisable on surfaces that are laid hot. If the surface is laid cold, or laid on a cold surface, ‘crack filling’ is used [8].
Rutting		Pavement full depth repair or other repairs to strengthen pavement. Filling ruts with hot mix, slurry, or dry chipping a rutted area before chip sealing.
	up to 1 1/2" deep	Hot mix or slurry/microsurface applied with rut box.
Potholes/Failures		• Structural repair with surface texture of repairs must match the texture of the adjacent surface as closely as possible [8].

Method	Description	Treatment
		• Base Repair: ○ Full depth hot mix or limestone rock asphalt (LRA). ○ Full depth repair with stabilizer (full depth reclamation [FDR]). ○ Remove and replace with base. • Localized asphaltic concrete patch/overlay. • Concrete repair: Spall. • Concrete repair: Partial depth repair. • Concrete repair: Full depth repair.
Rough Surface	Small area	• Remove and replace (ex. washboarding). • Diamond grinding.
	Large areas	Mill or overlay (level-up).
Surface Texture	Chip Loss 1) Intermittent chip loss and/or the height difference between this area and adjacent seal is minimal 1/5" (< 5 mm) [8]. 2) Height difference is obvious [8].	1) Removal of excess or free binder (high pressure water treatment) from the stripped areas is recommended [8]. 2) Repair will be required. Re-spraying of binder and rolling in new chip. The replacement chip size is carefully selected to ensure that the post-repair surface texture and level closely match the surrounding seal [8].
	Flushing [9].	• High pressure water treatments. • Apply aggregate ○ Blotter material (coarse sand/stone screenings). ○ Layer of small size (grade 5) aggregate. ○ Layer of larger (grade 4 or 3) size aggregate. • Sandwich seal. • Apply lime water. • Apply water. • Remove and replace bleeding pavement surface.
	Uneven Texture—significantly different to most of the existing seal	Filling existing deep-texture areas or reinstating texture with a texturizing seal, which is a localized, situation-specific chip seal [8].
Permeable Surface		Sealing off the top of the porous layer to prevent the binder from the reseal from being drawn down into it. • One treatment option involves spraying the permeable surface area with an emulsion binder (as a light application only), and then spreading

Method	Description	Treatment
		a fine chip, grit or coarse sand over the sprayed surface area. • Another option is a two-coat final surfacing using an emulsion binder (without the need for a preseal Grade 6 coat) [8]. • Fog seal.
Concrete Joints		• Joint and crack sealing. • Spall repair. • Joint repair ○ Dowel bar retrofit. ○ Stitching.

[1]*In the bandaging technique the hot binder is poured on to the cleaned pavement and then spread with a metal tool to make a 'bandage' 2–3 mm thick and 75–100 mm wide* [8].

Table 5. Timing before Reseal.

Repair Type	Maintenance Treatment	Minimum Time before Sealing
Crack Sealing Using:	Emulsion	2 months [8, 10, 11]
	Cutback products	6 months [8, 10, 11]
	Hot bituminous products	2 months [8, 10, 11]; 1 year [12]
Patching and Edge Breaks:	Premixed/cold mix asphalt made with cutback bitumen	6 Months [11]; > 9 months [8]
	Premixed/cold mixed asphalt made with bitumen emulsion	4 months [11]; > 9 months [8]
	Premixed/cold mix asphalt made with fluxed bitumen	> 9 months [8]
	Cold mix	6 months [13]
	Hot mix asphalt	2 months [11]; > 9 months [8]
	Microsurfacing	3 months [11]; > 9 months [8]
Reseals Using:	Cutback bitumen and grit	6 months [11]
	Emulsion and grit	1 months [11]
Structural Repairs	Cold in-place asphalt recycling	Moisture content ≤ 2% of total material weight [12]
	Flexible base repair	Moisture content < 2% of optimum [14]
Other:	Treatment of flushed areas by asphalt patching or using solvents	2 months [11]; 2 to 6 months [8]
	Maintenance of shoulders and longitudinal drains	2 weeks [8, 10, 11]
	Line marking before resealing	3 to 6 months [11]
	High pressure water retexturing	2–6 months [11]; 6 weeks [8]
	Concrete joint sealing	Manufacturer's recommendation [12]

BEST PRACTICES—FLEXIBLE PAVEMENTS

It is important that repairs be performed in a manner that provides the best chance of the PM treatment achieving its design life and maintaining the pavement's level of service. One of the most important considerations, when the PM treatment is a seal coat, is that the pavement surface texture, hardness, and absorption properties are uniform and as close as possible to the unrepaired existing pavement. This is needed since the adjustments to the application rates of a seal coat are dependent on the surface characteristics.

To have a successful seal coat, a uniform surface, both transverse and longitudinally, is needed. Longitudinal adjustments can be made during the placement of the seal coat. However, to adjust the rate being applied by the asphalt distributor, the distributor needs at least 50 feet of travel for the rate change to occur. This means that the minimum rate adjustment longitudinally is greater than 100 feet.

Transverse variation is much more difficult and cannot be adjusted while in motion unless a multi-spray bar distributor is used. Even with multiple spray bars, there are limitations to the transverse patterns available. Generally, transverse changes are made by adjusting nozzle sizes in a set pattern: smaller size over the wheelpaths, and larger size over outside the wheelpaths. Refer to Figure 3, which shows an area that was sealed and is now bleeding above a hot mix level-up adjacent to an existing seal coat.

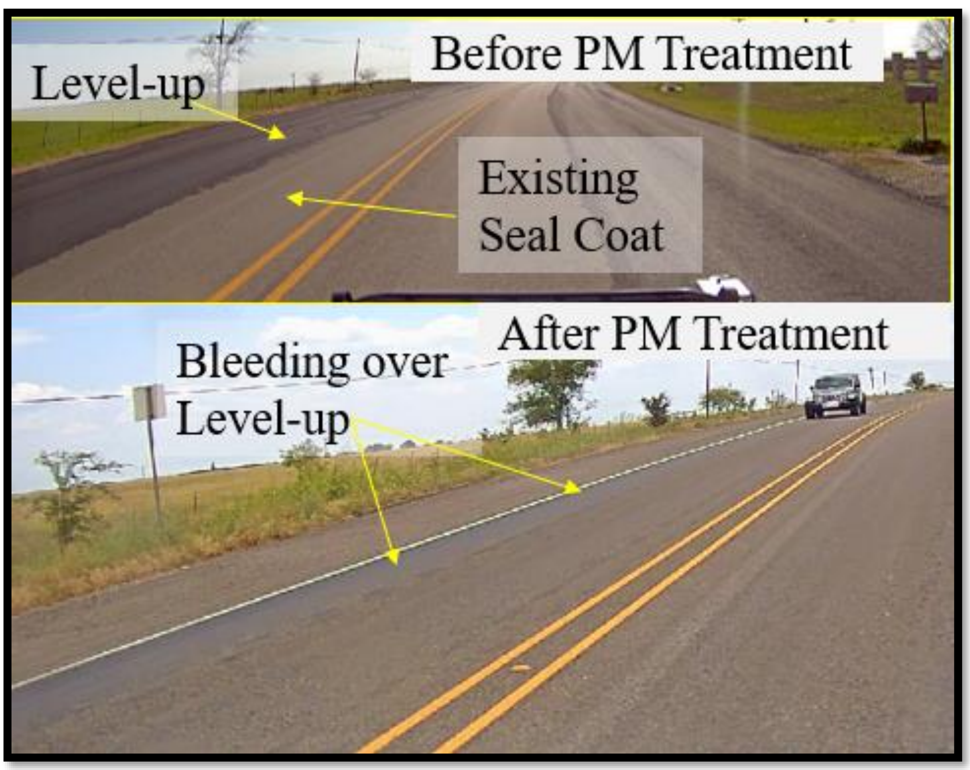

Figure 3. Texture Effects on PM Treatment.

The Bryan and Atlanta districts provided case studies on how to use existing information to help determine repairs. Specifically, the Bryan District is using the IRI data in the software Grind Diagnostics (developed by the Texas A&M Transportation Institute) to help identify locations and limits of milling and level-up.

The Austroads publications contained some of the most comprehensive information concerning preparing a roadway for a reseal. Table 6 is a summary of the discussions for the repairs from the *Guide to Pavement Technology Part 7: Pavement Maintenance*. It also includes information from other sources that are referenced. Chang et al., [15] contained summaries for different treatment types along with their advantages and limitations. This information is included in the treatment discussions. Table 7 has commonly used materials for repairs.

Table 6. Best Practices for Flexible Pavement Repairs.

Type	Flexible Pavement
Pothole General	1. Square the hole, trim edges vertical, and remove loose material prior to reinstatement. 2. If base is used in the repair, seal the surface. a. Compact in layers < 100 mm thick (compact to dry side if sealing immediately or soon after). 3. If asphalt is used in repair, thoroughly compact asphalt. a. Where available, hot mix asphalt is preferable to cold mix asphalt. b. If cold mix asphalt is used, add grit to the patch to prevent traffic pick-up, then seal the surface after curing. i. Avoid cold mix on heavy traffic roads if sealing within 2 months. ii. Cold mix is ok if it cures greater than 6 months before sealing.
Edge Repairs	1. Remove loose material (use a stringline). 2. Use a vertical edge, not rounded. 3. Hot or cold mix asphalt is used. Gritting may be needed on cold mix. 4. Ensure that the cause of the edge break is fixed.
Stripping/ Raveling	1. Small areas of stripping or raveling may be treated by application of seal coat or fog seal. 2. Large areas of stripping or raveling are generally beyond the scope of routine maintenance.
Flushing/ Bleeding	Try one of the following: 1. Apply water. 2. Apply lime water. 3. Apply blotter material (i.e., coarse sand, stone screenings, grade 5 aggregate). 4. Apply layer of larger (grade 4 or 3) size aggregate. 5. Dry matting/sandwich seal (refer to Table 9). 6. High pressure water treatments. 7. Remove and replace bleeding pavement surface.
Cracking	1. Investigate the crack pattern to determine the cause.

Type	Flexible Pavement
	2. Clean and fill with bitumen binder.
Shape Correction: Shoving	1. Usually shallow (seal coat problem) and not structural. 2. If stable condition it may be practicable to fill the depressions with hot or cold mix asphalt. 3. If it remains unstable it will be necessary to remove the unsound material and replace it with a stable hot or cold mix asphalt.
Shape Correction: Rutting	1. Any faulty pavement or subgrade material must be replaced by suitable material. 2. Large depressions may require full depth repairs or patched with hot mix asphalt.
Pavement Cleaning	1. Pavement cleaning may include pavement sweeping, undertaken using hand-held brooms, bobcat mounted broom or vacuum suction broom, 2. Removal of dead animals and removal of vegetation such as grass or moss.

Table 7. Materials Used for Repairs.

Repair	Material Use	Commonly Used Material in Texas
Level-up	Bond coat or Tack coat	Emulsions: SS-1, SS-1H, CSS-1H Level-up: Dense Graded Hot Mix (Items 340, 341 or 344), Limestone Rock Asphalt (LRA, Item 330), or Hot-Mix Cold-Laid (Item 334)
Seal Coat	Seal patches and cracks	Emulsions: HFRS-2P, CHFRS-2P, CRS-2P; Cutback: RC250 Aggregate: Type B, D or L, Grades 3, 4 or 5
Cold Mix[1]	Patching and level-up	Emulsion: AES 300, CSS-1H, CSS-1S, CMS-2S
Fog Seal	Patches, raveling, cracking	Emulsions: SS-1, SS-1H, CSS-1H, CSS-1
Prime Coat	Patches	Emulsions: AE-P, Cutback: RC250
FDR	Patch	Emulsions: CSS-1H, CSS-1 Chemical Stabilizers: Lime, Cement
Base Repair	Base remove and replace	Flexible Base Dense Graded Hot Mix (Items 340, 341 or 344) LRA Cement Treated Base

[1]*Cold mix is a mixture of binder and aggregate that is combined through a pugmill or asphalt plant and typically stored in a stockpile for use as temporary patching, leveling, and cold paving material* [5].

Crack Seal

Crack sealing is the placement of adhesive material into and/or over working cracks (i.e., those that open and close with temperature changes, such as transverse thermal and reflective cracks, diagonal cracks, and certain longitudinal reflective cracks) at the pavement surface to prevent the infiltration of moisture into the pavement structure. Cracks should be prepared by cleaning with air blasting or other acceptable method. When required, cracks should be routed or sawed to provide a reservoir over the crack.

Crack seal is suitable for low and high traffic roads. Slow moving traffic can pick up fresh crack sealant. It performs well in all climatic regions; however, the right materials should be selected for the expected temperatures. Sealing should be done in the coldest months of the year while the cracks are at their widest opening to give time for the crack sealant to age/cure prior to hot weather.

Some advantages of using this type of treatment are as follows:

- Least expensive preventive maintenance treatment.
- Effective at keeping water out of the pavement structure.
- May slow progression of load-related cracking.

Some weaknesses of using this type of treatment are as follows:

- Excessive cracking may be better addressed by the use of a “blanket” treatment such as a seal coat.
- Extensive crack sealing may require a blotting sand to maintain the pavements skid resistance. A blotting stone can also alleviate “tracking” of the fresh sealant.
- Excessive crack seal can negatively affect ride quality if too much material is used.

Fog Seal

Fog seal is a light application of emulsion sprayed on the roadway surface. It is used to enhance aggregate retention and seal hairline cracks. Life extensions of 2–4 years are typical [5]. Figure 4 is an example of a fog seal being placed on a maintenance level-up patch.

Figure 4. Fog Seal.

Research has shown that there are several uses for a fog seal, and it can be used to prevent raveling, improve appearance of pavement, reduce permeability of surface, protect binder from oxidation, and rejuvenate binder. Fog seal is a very light application of slow-setting, water-diluted asphalt emulsion applied directly on the pavement surface with no aggregate.

When preparing a pavement for a seal coat, it is important to provide a uniform surface. The fog seal helps ensure that the area to be sealed has uniform properties related to absorption. As mentioned, fog seals can reduce permeability of the surface which will directly affect the proposed binder rate of the seal coat. Table 8 shows commonly used materials and rates for fog seal.

Table 8. Fog Seal [16].

Material	Dilution Ratio Emulsion:Water	Application Rates (gal/sy)	Cure Time and Open To Traffic
CSS-1H	40% : 60%	0.08 to 0.10	Cure time depends on weather. Cool weather—approximately one hour, hot and humid—up to three hours. Open to traffic when it is cured and not tacky so that it will not "pick-up."
	50% : 50%	0.08 to 0.10	
	30% : 70%	0.15 to 0.17 or 0.12 to 0.15	

The typical equipment needed when performing the fog seal operation are an asphalt distributor and traffic control devices. Roadways treated include very low to high traffic but typically with an average daily traffic (ADT) < 4,000 [17]. When increased ADT or truck percentage levels are encountered the surface wear increases. In high volume roads, skid-resistance may become a factor.

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.

Some advantages of a fog seal are as follows:

- 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 following seal coat placement.
- Reduces asphalt aging, oxidation, and hardening and prevents moisture infiltration.

Some weaknesses of using this type of treatment are as follows:

- No structural value is added, therefore pavements with significant fatigue cracking or severe thermal cracking are not good candidates.
- The treatment has a short life expectancy.
- Can reduce skid-resistance. The pavement needs to be sufficiently porous to absorb a substantial amount of the emulsion when placing the fog seal.
- Traffic needs to remain closed until fog seal is cured.
- Does not affect the ride quality of a roadway.
- The treatment should not be used if medium severity flushing/bleeding is encountered or if rutting is present.

Seal Coat

Seal coats are used in many repair methods and on the existing pavement. A seal coat or chip seal is a thin surface treatment applied by spraying a layer of asphalt binder (e.g., 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 usually ranges from 1/4 inch to 1/2 inch. Table 9 contains descriptions of the several variations of seal coats.

Table 9. Seal Coat.

Name	Description	Figure
Primer Seal	A primer seal is the application of a suitable primer binder and fine cover aggregate to a prepared pavement. It is used as	Figure 5

Name	Description	Figure
	a temporary treatment prior to applying the next bituminous surfacing [18].	
Single Seal Coat	A single layer of binder, covered by a single layer of aggregate.	Figure 6
Dry Matting or Sandwich Seal	A single layer of aggregate spread over the existing surface (or infill of the stripped areas of a partially stripped seal), followed by a single application of binder and a further application of aggregate, generally a small-sized aggregate to lock the first aggregate application in place [19].	
Racked-in Seal or Scatter Seal	A single-layer seal coat with a smaller aggregate "scattered" on top to provide a temporary mechanical interlock between the larger particles.	Figure 7
Double Seal Coat	Two single-layer seal coats with the second layer placed soon after the first. Generally, the bottom layer has a larger aggregate than the top layer.	Figure 6
Cape Seal	Single seal coat followed by a microsurface.	
Inverted Seal	A double seal coat with the bottom layer having a smaller aggregate than the top layer.	Figure 7
Strain Alleviating Membrane Interlayer (SAMI)	A single seal coat with a heavily modified binder. SAM is the surface seal coat, and SAMI is an interlayer.	
Fiber Reinforced Seal (FRS)	An FRS uses a polymer modified emulsion and chopped glass fiber as reinforcement. The process is as follows: 1) Use a purpose-built sprayer or sprayer attachment that, in a single pass: a) Sprays binder onto the pavement. b) Cuts the required amount of fiberglass to length, generally 60 mm, and blows this onto the first layer of binder. c) Sprays a second layer of binder over the cut fibers. 2) The bitumen and fiber layers are immediately covered with an aggregate that is locked into place using an aggregate scatter coat.	
Geotextile Reinforced Seal (GRS)	Place a bond coat, then the GRS, and then place a single seal coat when used as an underseal or double seal coat when used as a wearing course.	
Scrub Seal	A surface treatment designed as a mass crack sealer with frictional properties of a chip seal. Used on roadways with	Figure 8

Name	Description	Figure
	high-density, top-down cracking as a wearing course or interlayer [5].	

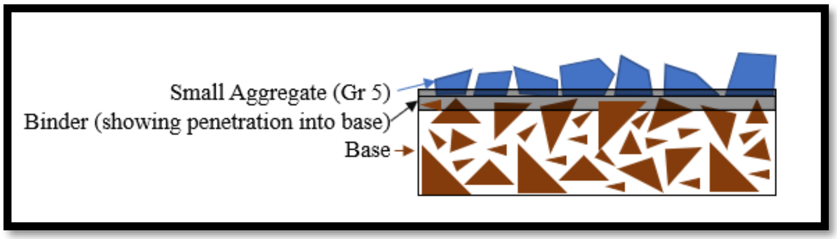

Figure 5. Primer Seal.

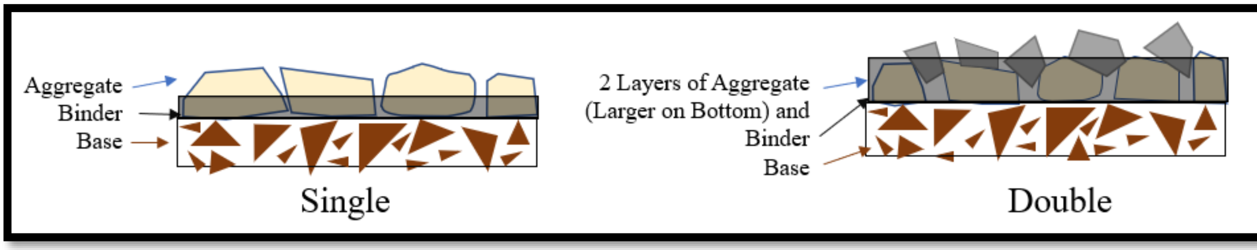

Figure 6. Single and Double Seal Coat.

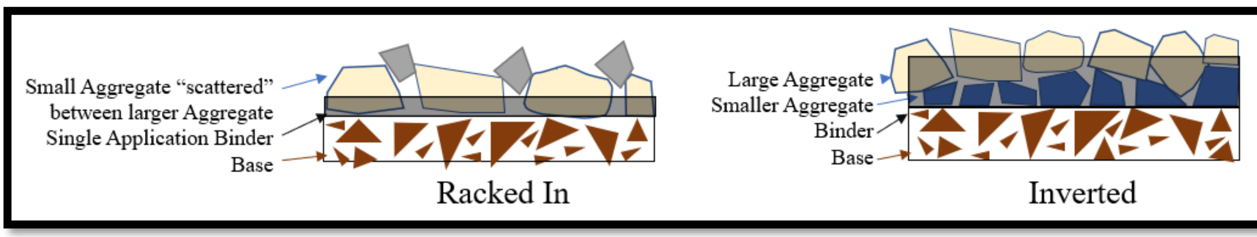

Figure 7. Racked In and Inverted Seal Coat.

Figure 8. Scrub Seal.

Although seal coats have been used to treat roads with an annual average daily traffic (AADT) > 10,000, they are typically used when AADT < 10,000. Seal coats perform well in all climatic conditions. Best practice is to place seal coats in warm weather with low humidity and wind, while rainy cold conditions should be avoided. The treatment is not recommended when freezing is expected within 48 hours.

Some advantages of seal coats are as follows:

- 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.

Some weaknesses of using this type of treatment are as follows:

- The treatment does not improve ride quality. Ride quality is mainly determined by the roughness of the underlying layer.
- Adds no structural capacity.
- Loose chips not embedded can become windshield hazards.
- Traffic noise is louder than with other types of surfaces.

- The treatment is not recommended for structurally failed pavements with extensive fatigue cracking, severe longitudinal and transverse cracking, or rutting greater than 0.5 inch deep.
- The treatment is not recommended for areas of frequent truck turning, braking, accelerating, and snow plowing areas.
- Use transverse variable asphalt shot rates where wheel paths are already bleeding.

Microsurfacing

Microsurfacing is a surface treatment/wearing course that addresses loss of friction, oxidation rutting, and minor reprofiling [5]. Microsurfacing is composed of polymer-modified emulsified asphalt cement, well-graded crushed fine aggregate (top size < 1/2 inch), mineral filler, water, and additives, which are then mixed in specialized, compartmented, self-powered trucks [15]. Although the components of microsurfacing are very similar to hot mix asphalt, microsurfacing is placed at ambient temperatures which usually do 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 three times the size of the largest aggregate in the mix. Figure 9 shows the microsurfacing placement equipment.

Figure 9. Microsurfacing.

Microsurfacing is suitable for all traffic levels. It is effective in all climates, but it performs better in warm temperatures with low daily fluctuations. 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 [20].

Some advantages of seal coats are as follows:

- Corrects oxidation of the pavement surface and 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 (i.e., high shear environments).
- A tack coat is usually not required unless the surface is extremely dry or raveled.

Some weaknesses of using this type of treatment are as follows:

- Does not address structural capacity.
- There is potential for early damage in areas of heavy truck turning and down grade locations (insufficient cure time).
- Pavements with structural failures and high severity thermal cracking are not good candidates. In addition, microsurfacing is not effective against unstable rutting or rutting more than 1.5 inches and cracks more than 0.25 inches wide[20]. Prior to treatment it may be necessary to perform other remedial activities.

Spot Base Repair with Seal Coat Surface

There are several types of material used for full depth base repairs. Those typically used are hot mixed asphaltic concrete, flexible base, and stabilized base. 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 surface is then prepared by spraying a layer of asphalt binder (e.g., emulsified asphalt, cutback asphalt, or asphalt cement) followed by a pneumatically rolled aggregate cover. Figure 10 shows the seal coat placement equipment.

Figure 10. Seal Coat.

The typical equipment needed to perform the base repair operation are as follows:

- Traffic control devices.
- Broom.
- Haul trucks.
- Milling machine or excavator.
- Asphalt distributor.
- Chip spreader or tailgate spreader.
- Steel wheel and pneumatic rollers.
- Water truck (water for rollers).
- Blade.
- Stabilization.
    - Pulverizing mixer (reclaimer).
    - Water truck.
    - Additive spreader.
    - Padfoot roller.
    - Pneumatic roller.
    - Flat wheel roller.
- Full depth asphalt.
    - Blade.
    - Laydown machine.

  - Vibratory steel wheel roller.
  - Pneumatic roller.

The advantages for this type of repair are as follows:

- The seal coat surfacing 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.

Some weaknesses of using this type of treatment are as follows:

- Prolonged traffic disruption due to the curing of the treatment.
- Adds no structural capacity, however, it restores structure.
- The treatment does not improve ride quality.
- If the structural distresses are widespread, the localized base repair will not be effective.

Mill and Inlay

This treatment includes a combination of construction activities. The pavement is first cold milled, which is the partial or entire removal of the existing asphalt surface. When necessary, the milled surface is sealed, or prepared, by spraying asphalt binder (i.e., 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 than 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, if not it is a thin overlay.

Performance is not affected by AADT 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. The treatment performs well in all weather. Rain should be avoided when placing.

The advantages for this type of repair are as follows:

- 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.

Some weaknesses of using this type of treatment are as follows:

- Does not add structural capacity.
- Curb and bridge clearance may be an issue.
- High initial cost and specialty contractors required.
- Millings must be disposed of or recycled.
- Not recommended for pavements that have 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.

Level-up

A level-up is used to improve surface geometry irregularities, friction properties, and ride quality. Several types of material can be used such as a dense graded asphaltic concrete (both hot and cold mixed), LRA, and rejuvenated rap. In general, an asphaltic concrete material is used for level-up. The typical equipment needed to perform the level-up operation are as follows:

- Traffic control devices.
- Milling machine.
- Broom.
- Haul trucks.
- Asphalt distributor.
- Blade or paver (lay-down machine).
- Steel wheel and pneumatic rollers.
- Water truck (water for rollers).

Dessouky et al., described the best practice for constructing a level-up in the following ten steps:

Step 1: Ensure proper traffic control at both ends of the project site is set up.
Step 2: Mill the upper 1/2 to 1 inch to remove the distressed material.
Step 3: Remove the vegetation along the shoulder and scrape pavement markers by blading.
Step 4: Clean the pavement surface from debris and dirt using a broom.
Step 5: Distribute tack coat using asphalt distributor over the existing surface.
Step 6: Monitor transport and placement of patching mix.
Step 7: Pave the patching mix.

Step 8: Compact with rollers.
Step 9: Perform a visual inspection and ride test [21].

This type of repair can perform in all traffic and climate conditions. Thin lift mixes cool very rapidly which can adversely affect the time available to properly compact, especially in cooler weather. Rain should be avoided when placing.

Some advantages of this treatment are as follows:

- Enhances ride and surface friction.
- The treatment delays serious distresses and extends the life of the pavement.
- Provides a protective waterproof membrane and corrects surface irregularities.

Some weaknesses of using this type of treatment are as follows:

- High initial cost and specialty contractors required.
- Curb and bridge clearance may be an issue.
- Localized pavement failures and deteriorated cracks will quickly reflect through the new surface. If severe distresses are present, milling of the asphalt layer should be incorporated.
- If the surface is not uniform, special consideration to the planning of the surface before placement should be taken.
- When rutting is present, milling or separate rut-filling applications are needed.
- Does not add structural capacity. Not recommended for pavements with extensive fatigue cracking or structurally failed pavements. 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.
- Pavements that exhibit extensive deterioration or high severity thermal cracking should be avoided.
- Candidate roads should have a stable pavement with a good base.

High Pressure Water Retexturing

High pressure water retexturing (HPWR) is a process that uses ultra-high pressure water (i.e., 32,000 to 36,000 psi) to remove excess surface asphalt, which increases the texture of the pavement surface. Refer to Figure 11 for an example of the texture change after the HPWR treatment. This type of repair can perform well in all traffic and climate conditions. The HPWR water cutting process is most efficient at lower pavement temperatures when the binder is stiff, and water cutting is not effective when pavement surface temperatures exceed 110°F and the binder gets soft and sticky [22]. While the HPWR is effective in all climates, the work must be performed above freezing and when the pavement surface temperature is below an upper limit of

100°F. Freezing temperatures will cause water in the UHP pump and piping systems to freeze, rendering the UHP water cutting unit ineffective.

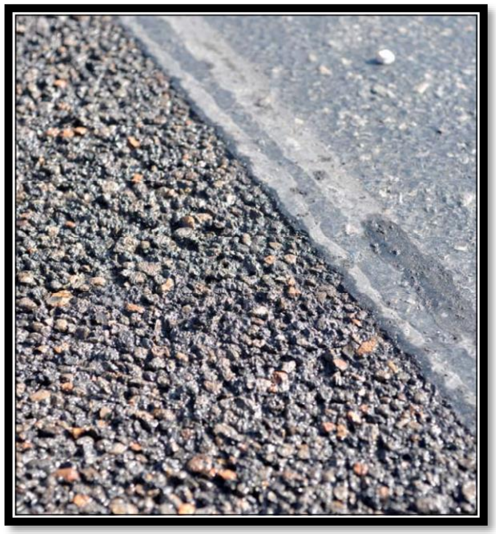

Figure 11. HPWR.

Some advantages of this treatment are as follows:

- Improves pavement friction.
- Is cost effective treatment for bleeding pavements.

Some weaknesses of using this type of treatment are as follows:

- Does not provide structural improvement.
- Cannot be performed during freezing weather.
- Disposal of asphalt material may be a concern.
- A practical upper limit on pavement surface temperature for UHP water cutting, which nominally, is 100°F [22].
- A practical lower limit on ambient air temperature is 32°F.
- Generally, a wheelpath is 3 feet wide, however most of the cutting equipment is less than 3 feet in width.

BEST PRACTICES—RIGID PAVEMENTS

The focus of this project is for seal coat PM preparation. PM projects with thin overlays are typically used for rigid pavements. The common repairs are shown in Table 10.

Table 10. Best Practices for Rigid Pavement.

Type	Rigid Pavement
General	Common rigid pavements are jointed unreinforced plain concrete pavement, jointed reinforced concrete pavements, or continuously reinforced concrete pavements (CRCP).
Defects	Common problems that are in general beyond the scope of routine maintenance include: • Subsidence of all or part of a slab. • Shearing or bending of dowels at construction or expansion joints following differential settlement of slabs. • Open joints that allow the ingress of surface water. • Pumping or flexing of the slab under traffic causing the ejection of liquid mud from the subgrade. • Spalling or cracking of the slab ends and corners due to impact from traffic. • Cracking of the slab allowing ingress of water and settlement to give an uneven surface. • Development of a slippery surface.
Spalling	Cold or hot mix asphalt is most often used for this purpose.
Permanent Repairs	Common permanent repairs include the following: • Maintenance of joints. • Crack sealing. • Cross stitching. • Spall repairs. • Slab replacements. • Joint repairs. • Treatment of slippery or worn surfaces. • Pumping. • Slab jacking (or mud jacking).

Joint and Crack Seal

Crack sealing is an operation that 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 thorough joint preparation (i.e., routing or sawing and cleaning) and the seal installation. The seal material can be cold- or hot-applied thermosetting.

The behavior of joint and crack sealing is not affected by traffic levels, however, higher traffic will require durable sealants and/or more frequent replacement. The treatment performs well in all climatic conditions. Placing in a moist environment will inhibit the bonding of the crack sealer. Sealant is best applied when temperatures are moderately cool, such 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. Do not place sealant when the concrete pavement is below 55°F or above 90°F [14].

Some advantages of this treatment are as follows:

- The treatment mitigates 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.

Some weaknesses of using this type of treatment are as follows:

- Sealing process can increase roughness if placed in an over-band configuration.
- No structural improvement and adversely affects skid resistance.
- Degrades appearance (especially meandering cracks sealed with bituminous sealant).
- 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 three to four months before being covered with an overlay.
- It is important for the sealant to be allowed to cure before opening to traffic.
- Concrete pavements that exhibit structural deterioration and have cracks/joints 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 a good cross section and good lateral support.
- Joints wider than 0.75 inch should not be considered for treatment [23].

Diamond Grinding

Diamond grinding 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 [24]. 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. Diamond grinding should be completed within 30 days of placing the patching material [25].

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. The weather has no effect on the treatment performance.

Some advantages of this treatment are as follows:

- 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.

Some weaknesses of using this type of treatment are as follows:

- 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.
- 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 [26]. Basin area is defined by Equation 1.

Equation 1. Basin Area

$$\text{Basin Area} = (6 \text{ x } (d_0 + 2d_1 + 2d_2 + d_3)) / d_0$$

Spall Repair

TxDOT's *Concrete Repair Manual* breaks the spalls into three categories of severity, minor, intermediate, or major, as shown below:

- Minor Spalls
    - Damage is less than 1 inch deep and it covers an area less than 12 square inches. However, if the majority (i.e., more than 50 percent) of a reinforcing bar or strand circumference is exposed due to inadequate cover then the spall would be classified as intermediate even if it is less than 1 inch deep.

    - The inspector may elect to designate repairs that cover areas larger than 12 square inches as minor depending on the location and extent of the damage.
    - A deeper spall (2 inches maximum) can be categorized as minor as long as it does not progress beyond the outer layer of reinforcement.
    - The best repair method for minor spalls is typically neat epoxy or epoxy mortar.
- Intermediate Spall:
    - The damage exposes a majority (i.e., more than 50 percent) of the outer cage of reinforcing bar or strand circumference, or the damage is greater than 2 inches deep.
    - The maximum depth of an intermediate spall is 6 inches.
    - No significant stresses are likely to develop in or immediately around the repair material due to service loads.
    - Proprietary, bagged concrete repair materials are typically used to repair intermediate spalls.
- Major Spall:
    - Damage extends well beyond the outer layer of reinforcement.
    - Significant stresses are likely to develop in or immediately around the repair material due to service loads.
    - Major spalls typically involve deep repairs to members in which capacity has been reduced as a result of damage and deterioration. The repair is meant to restore capacity of the damaged member. The best option in such applications is to use batched concrete with properties similar to the parent material.

Some advantages of this treatment are as follows:

- Improves pavement ride quality.
- Repairs structural damage.
- For minor spalls, the epoxy provides an excellent waterproof barrier and can significantly slow down the rate of corrosion if properly applied.

Some weaknesses of using this type of treatment are as follows:

- May not bond well to future overlays.
- Different appearance compared to the surrounding pavement.

Joint Repair

Dowel bar retrofit is a technique to link the concrete slabs together in order for the load to be transferred evenly across the joint. This is done by cutting slots with a diamond saw over the joints and existing working transverse cracks; retrofit is typically done only in the wheel paths. 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.

Stitching is a technique to link concrete across longitudinal joints and cracks.

There are no traffic restrictions, and the techniques can be used in all climatic regions.

Some advantages of this treatment are as follows:

- Restores surface smoothness and corrects differential deflections.
- Alleviates the potential for pumping, faulting, and corner breaks.
- Restores load transfer capability.
- Reduces pavement noise.

Some weaknesses of using this type of treatment are as follows:

- 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 [27].
- The pavement should have an falling weight deflectometer (FWD) basin area less than 25 inches or a load transfer efficiency equal or less than 70 percent [26]. Also, the pavement must have less than 10 percent of joints spalled more than 2 inches wide [26]. Patch with asphaltic concrete.

Partial Depth Patch

Partial depth patching is the removal of small shallow deteriorated areas by milling, chipping, and sawing of unsound concrete and the replacement with suitable materials. The filler can be rapid-setting concrete, conventional concrete, bituminous materials, and proprietary materials. The filler 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 [25].

The treatment is effective at all traffic levels. It performs well in all climatic regions. The partial depth patch should not be placed on frozen existing concrete pavements or under rainy conditions. Curing of concrete under cool weather may be too slow to allow for timely opening to traffic. TxDOT specifications state, “Do not place concrete when the ambient temperature in the shade is below 40°F and falling unless approved. Concrete may be placed when the ambient temperature in the shade is above 35°F and rising or above 40°F” [14]. Place concrete that is between 40°F and 95°F.

TxDOT specifications also state, “Provide Class HES concrete in accordance with Item 421, ‘Hydraulic Cement Concrete,’ and designed to attain a minimum average flexural strength of 255 psi or a minimum average compressive strength of 1,800 psi within the timeframe designated for opening to traffic if it is less than 72 hr after concrete placement. Otherwise, provide Class S conforming to Item 421, 'Hydraulic Cement Concrete' or Class P concrete conforming to Item 360, 'Concrete Pavement'" [14].

Some advantages of this treatment are as follows:

- Deters further deterioration, restores structural integrity, and improves rideability.
- Relieves temporary roughness caused by material problems such as D-cracking or alkali-silica reactivity (ASR).
- Surface texture is restored.

Some weaknesses of using this type of treatment are as follows:

- 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 ASR should be avoided.
- If bituminous filler is used, the treatment is only temporary.
- Cracks found through the full slab thickness may require full-depth repair.

Full Depth Patch

Full depth patching includes patching and slab replacement. This treatment is done 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 replacement may include replacing underlying layers.

There are no traffic restrictions for this treatment. To minimize the traffic impact, rapid strength concrete can be used. This treatment performs well in all climatic regions. TxDOT specifications state, "Do not place concrete when the ambient temperature in the shade is below 40°F and falling unless approved. Concrete may be placed when the ambient temperature in the shade is above 35°F and rising or above 40°F" [14]. Place concrete that is between 40°F and 95°F. TxDOT specifications also state, "Provide Class HES concrete designed to attain a minimum average flexural strength of 255 psi or a minimum average compressive strength of 1,800 psi within the designated timeframe if the timeframe designated for opening to traffic is less than 72 hr after concrete placement. Otherwise, provide Class P concrete conforming to Item 360, 'Concrete Pavement'" [14].

Some advantages of this treatment are as follows:

- Improves rideability.
- Pavement may be restored to original condition.

Some weaknesses of using this type of treatment are as follows:

- Slab replacements using asphalt concrete are short term solutions.
- Candidate projects should 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 [28].
- Full depth patches should not be used on pavements that have extensive and severe distresses, or need added structural integrity, following the slab replacement.
- Failing to repair underlying base layers when needed will result in a subsequent premature failure. The premature failure translates into higher maintenance costs and negative impacts on traffic.
- Grinding may be needed to improve ride quality.

Slab Stabilization

Slab stabilization or undersealing is a pavement rehabilitation technique where flowable material is injected beneath the slab, base, or subbase in order to fill voids. Filler can be grout, asphalt cement, or polyurethane. The purpose is not to lift the slab, but to displace water, fill any voids, and eliminate faulting. There are no traffic restrictions, and the techniques can be used in all climatic regions.

Some advantages of this treatment are as follows:

- Increases the structural capacity.
- Improves ride quality.
- Undersealing reduces the progression of pumping, faulting, and slab cracking.

Some weaknesses of using this type of treatment are as follows:

- If the slab is stabilized when not needed, it will impair pavement performance.
- Undersealing only restores slab support.
- Performance of undersealing is highly dependent on contractor.

CHAPTER 4:
CONCLUSIONS AND RECOMMENDATIONS

SURVEY AND LITERATURE REVIEW

The survey showed that there are several best practices occurring throughout Texas, however there are still concerns with the preparatory work being performed.

While there is a significant amount of research concerning individual treatments, there is not a lot of information specific to maintenance repairs in preparation for a PM treatment. The New Zealand and Australia literature provided the most details concerning preparing a roadway for a seal coat. It is emphasized in the literature that to have a successful seal coat, a uniform surface, both transverse and longitudinally, is needed.

The typical treatments and conditions that are used was summarized from the literature. Table 11 is a summary of flexible pavement treatments, and Table 12 is a summary of rigid pavements; both tables include a description of the condition that the treatment may be suitable to use.

Table 11. Recommended Flexible Pavement Treatments.

Condition		Treatment[1]						
Description	Criteria	Fog Seal	Crack Seal	Strip/ Spot Seal Coat	Base Repair and Seal	Mill and Inlay	Level-up	HPWR
Life (yrs)	n/a	3.5		5 to 10	5 to 10	7	7	> 2
Cure Time before PM	n/a	n/a	1 yr	2 wks	2 wks[2]	2 mo	2 mo	6 wks
Traffic (AADT)	< 1,000	R	R	R	R	C	R	n/a
	1,000 to 5,000	C	R	R	R	R	R	n/a
	> 5,000	C	R	C	R	R	R	n/a
Skid Value (SN)	17 to 30	n/a	n/a	n/a	n/a	R	R	C
	< 17	n/a	n/a	n/a	n/a	R	R	C
Ride Quality	≤ 140	n/a	n/a	n/a	n/a	R	n/a	n/a
	140 to 200	n/a	n/a	n/a	R	R	R	n/a
	> 200	n/a	n/a	n/a	C	C	R	n/a
Rutting (in)	0.25 to 0.49	n/a	n/a	R	n/a	n/a	C	n/a
	0.5 to 0.9	n/a	n/a	C	C	C	R	n/a
	1.0 to 1.9	n/a	n/a	n/a	R	R	R	n/a
	> 2	n/a	n/a	n/a	R	C	C	n/a
Alligator Cracking (%)	< 15	R	n/a	R	R	R	R	n/a
	15.1 to 50	C	n/a	C	R	R	R	n/a
	> 50	n/a	n/a	n/a	R	C	C	n/a
Other Cracking:	Longitudinal	R	R	R	n/a	C	C	n/a
	Transverse	R	R	R	n/a	C	n/a	n/a
	Block	R	R	R	n/a	C	C	n/a

Patching	n/a	**R**	n/a	**R**	n/a	**R**	**C**	n/a
Failures	n/a	n/a	n/a	**C**	**R**	**C**	**R**	n/a
Raveling	n/a	**R**	n/a	**R**	n/a	n/a	n/a	n/a
Flushing	n/a	n/a	n/a	**C**	n/a	**R**	**R**	**R**

*1. **R** is the recommended treatment, **C** is a conditionally recommended treatment since other factors may influence the treatment strategies and n/a is not a recommended treatment.*
2. When flexible base is used, it should be cured to < 2 percent of optimum moisture content before strip seal is placed to cover base repair.

Table 12. Recommended Rigid Pavement Treatments.

Conditions		Treatment[1]							
Description	**Criteria**	**Joint and Crack Seal**	**Diamond Grinding**	**Spall Repair**	**Joint Repair[2]**	**Patch w/Asphaltic Concrete**	**Partial Depth Patch**	**Full Depth Patch**	**Slab Stabilization**
Life (yrs)	n/a	2–3	8–12	5–10	10–15	5–15	3–10	10–15	5–15
Traffic	all	**R**	**R**	**R**	**R**	**R**	**R**	**R**	n/a
n/a Skid Value (SN)	17 to 30	n/a	**R**	n/a	n/a	n/a	n/a	n/a	n/a
	< 17	n/a	**R**	n/a	n/a	n/a	n/a	n/a	n/a
Ride Quality	≤ 140	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	140 to 200	n/a	**R**	n/a	**R**	**R**	**C**	n/a	**R**
	> 200	n/a	**C**	n/a	**C**	**C**	**C**	n/a	**C**
Spalling	n/a	**R**	**R**	**R**	**R**	**R**	**R**	n/a	n/a
Cracking:	Transverse	**R**	n/a	**R**	**R**	**R**	**R**	**C**	**C**
	D-Cracking	n/a	**C**	n/a	n/a	**C**	**R**	**C**	**C**
	Longitudinal	n/a	n/a	n/a	n/a	**C**	n/a	**C**	**C**
Patch—Asph	n/a	n/a	n/a	n/a	n/a	**C**	n/a	**R**	**R**
Patch—Conc	n/a	n/a	**R**	n/a	n/a	**R**	**R**	**R**	**R**
Failures[3]	n/a	n/a	n/a	n/a	n/a	**C**	**R**	**R**	**C**
Failed Joint	n/a	**R**	n/a	n/a	**R**	n/a	n/a	**R**	**R**

*1. **R** is the recommended treatment, **C** is a conditionally recommended treatment since other factors may influence the treatment strategies and n/a is not a recommended treatment.*
2. Several types of joint repair such as dowel bar retrofit and stitching.
3. Failures include shattered slabs and punchouts.

FUTURE RESEARCH RECOMMENDATIONS

The survey respondents identified the following as areas that more information is needed and could be addressed through future research:

- Budget.
  - Balancing the needs with available funds.
  - Material availability and cost.

    - Equipment availability and cost.
- Equipment.
    - In-house equipment including operators and level of skills using equipment.
    - Availability of rental equipment.
- Repairs.
    - Repairs performed correctly for adequate structure and good ride.
    - Adequate lead time to perform repairs and allow them to cure.
    - Best practices for each type of repair.

In addition to researching the areas specifically identified, the survey responses indicated that additional information is needed to help define the limits of repairs and a repair evaluation procedure. Based on the survey and literature review, there are several areas that future research could provide additional information specific to performing maintenance repairs in preparation for a PM treatment. These areas of future research include:

- Develop general information and best practices information booklets, similar to the Austroad's "Pavement Work Tips" series.
    - Document the best practices for each type of repair.
    - Show how to best perform the repair with the PM treatment in mind.
    - Determine cure times before PM treatment is placed.
    - Document the key components needed to perform the repairs.
        - Equipment: a specific area of interest was compaction equipment. Additional information is needed to help identify the appropriate types and sizes of compaction equipment.
        - Materials.
        - Skills and training for employees.
- Develop a procedure to determine limits of repairs.
    - Determining the limits of the repair is currently performed based on a visual inspection. A process should be developed to determine the repair size for the different types of repairs that is less subjective than a visual estimate. This could also be included in the best practices booklets, since different conditions may require different evaluation tools and techniques.
        - Improve the Grind Diagnostics program so that it can identify ride improvement limits.
        - Evaluation process should include different procedures based on the conditions being repaired.
- Develop a repair evaluation procedure.
    - Currently there is no formal process to evaluate how well a repair is made, how it performs, or how it effects the PM treatment.
    - Develop a procedure to evaluate repair performance.

    - Develop a risk-based evaluation procedure.
    - Is the repair performed to a level so that the PM treatment can be placed and perform for its expected life?
    - Is the repair cured adequately so that it does not adversely affect the PM treatment?
- Develop a procedure to document performance of the repair.
    - Over time, climate, and traffic conditions.
    - Effects on PM treatment (good and bad).
- Develop training workshops.
    - How to evaluate a pavement for PM work.
    - How to evaluate a completed repair.
    - How to evaluate performance of the repair and PM treatment.

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APPENDIX A

Question 1. Which of the following preventive maintenance (PM) treatments are typically used in your district for FLEXIBLE PAVEMENT?

- ☐ Seal Coat
- ☐ Scrub Seal
- ☐ Micro-surfacing
- ☐ Slurry Seal
- ☐ Thin Hot Mix Overlay
- ☐ High Friction Surface Treatment
- ☐ Other, please describe

The treatments and responses are shown in Figure 12, with the percentage and count of response shown under each heading. The other treatment was not described.

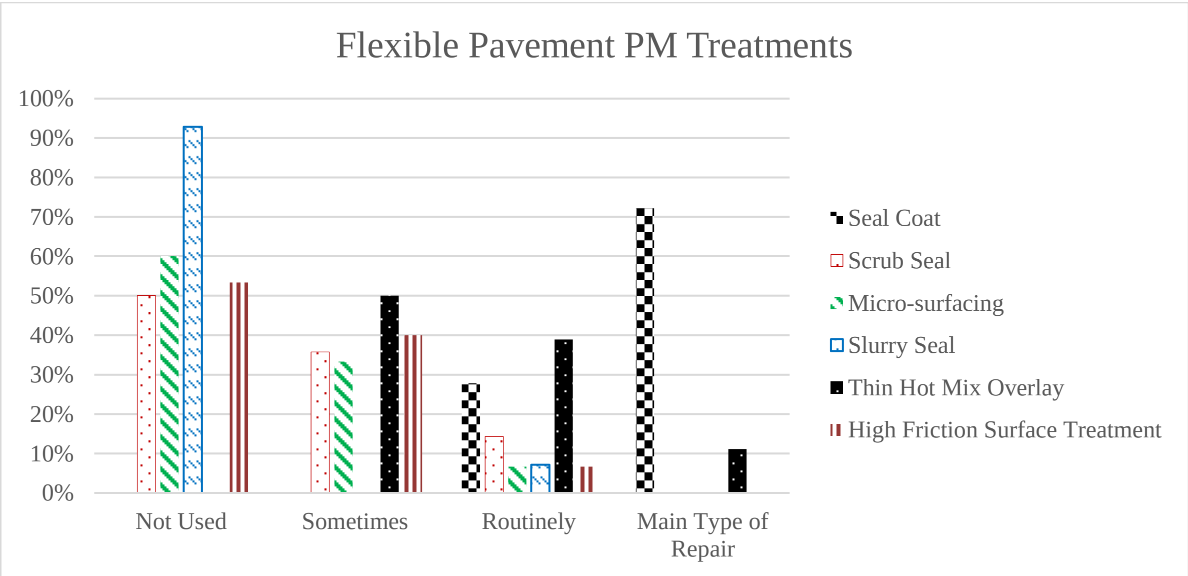

Figure 12. Q1—PM Treatments.

Question 2. Which of the following PM treatments are typically used in your district for CONCRETE PAVEMENT?

- ☐ Thin Hot Mix Overlay
- ☐ Texturing: shotblasting
- ☐ Texturing: sandblasting
- ☐ Texturing: cold milling and shotblasting
- ☐ Diamond Grinding
- ☐ Other, please describe

The treatments and responses are shown in Figure 13. The other treatment was not described.

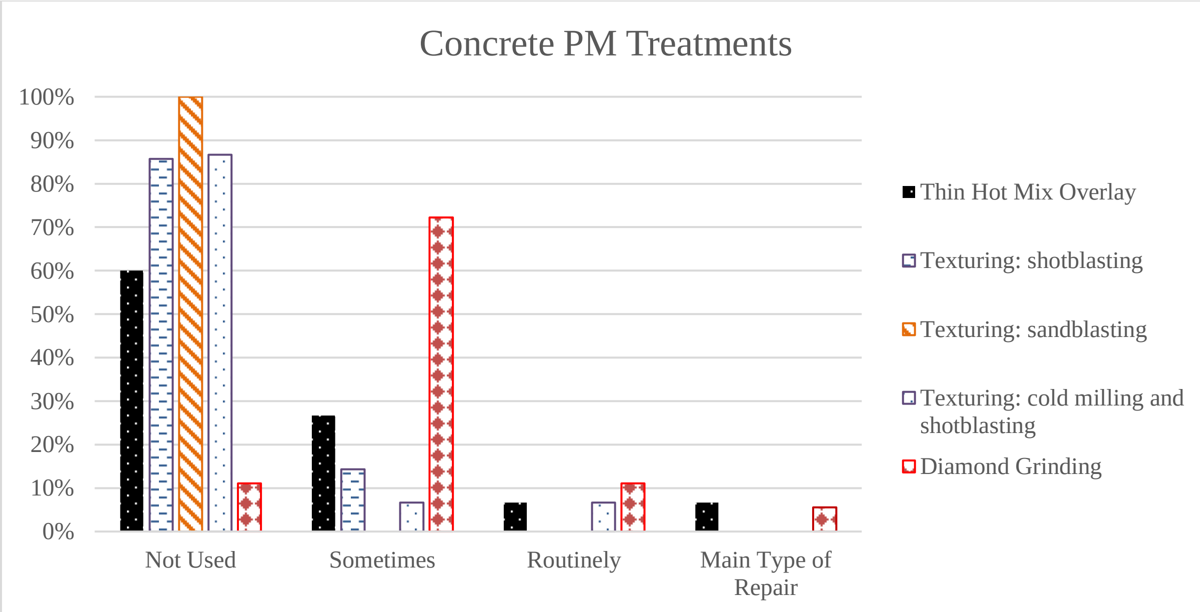

Figure 13. Q3—Concrete PM Treatments.

Question 3. When selecting a section of roadway for a PM project, which general process do you use? Please describe your process, resources used (ex. date of last surface map) and any software, etc. that you have developed within your district. Note: Maintenance offices may have a different process than District Staff."

The responses are shown in Table 13.

Table 13. Q3 PM Process.

	Responses
1	-Road condition scores -Time to last treatment -Visual Inspections -Available funding -Maintenance Section input -Roadway Drives -How does road condition compare against entire network. -Use of Pavement Analyst -Time frame to design projects -Overlaps with upcoming projects (STIP)
2	The Bryan district has the maintenance supervisors turn in their top 3–5 roadways in their county to the AE for review. The AE rides these roadways and ranks them for the area office priority. These are all submitted to the pavement engineer. The DOM, DOT, DOC, DTPD, deputy DE, design engineer, and pavement engineer ride these roadways as a group and rank them on a 1–10 scale with 1 being the worst. The same group host a couple of meetings to look at budget, PA, and PMIS maps to determine the order the projects will let. The district tries to optimize their budget during this process. We also try to stay on a 7-year seal cycle.
3	Our main PM work is seal coat which begins with the date of last surface map to help develop/look at a seal coat cycle. 7 year > 3,000 ADT 8 year > 2,000 ADT 9 year > 1,000 ADT 10 year < 1,000 ADT This is the basis that we are using for a seal coat cycle. Once the roadways are identified based on last surface and ADT, they are evaluated to determine if they are good seal coat candidates. This could be based on current roadway conditions, amount of resources available and needed to prep, urban corridor, high traffic, etc. There is also roadway segments that may be evaluated as out of cycle. This could be based on need to preserve due to development or increase in heavy traffic, large maintenance work completed and need to be

	Responses
	preserved, or need to hold a road segment together until rehab project can be funded. Some other resources used are the PMIS maps.
4	We usually check the overall PMIS score for the roadways for each counties, surface age of the roadways, skid score, and visual observation by the Area Office maintenance inspectors and any other special concern or requirement identified to include the roadway in the PM project. We use PA, Pathways, TSD-Traffic Speed Deflectometer, FWD etc. and internal discussion with each county (Area Office), raters go and figured rutting and cracking etc. to prioritized the PM projects.
5	Project Visit organized by Director of Maintenance that includes District Engineer, Deputy District Engineer, Director of Construction, Director of Traffic Operations, Lab/Pavement Engineer, Area Engineer. Projects are selected based on conditions. When needed FWD/GPR are obtained to determine proper treatment. Also included in the selection is the last surface time, traffic, etc. Maintenance supervisors have input during the entire process.
6	We have an established process for our four YR PMP process that involves Maintenance Sections, Area Offices, District Maintenance, and District Leadership. It is a collaborative effort to identify and address our critical roadway sections. We utilize an excel based program/spreadsheet to evaluate PMIS/PA data that helps identify and rank critical sections. We utilize this ranking as a starting point and verify the critical sections with the Area Offices and Maintenance Sections. This is done by visiting the Maintenance Sections and driving candidate roadway locations to validate the findings and rankings. These ranked sections are then evaluated across the District for final selection by District Maintenance to push forward for development & letting through our four YR plan. We utilize the PA program and data associated with the program to help map conditions scores, skids scores, and any other valuable information. This information is then overlaid with planned work via CAT 1 funds and in house or contract maintenance work (023 and 045 funds) to ensure we do not have any overlaps and needed work in advance of a PM project is done timely.
7	BMT evaluates condition and distress scores (PMIS), rutting, current surface age map, CRIS crash data, skid values, and surface type to create a prioritized list of proposed roadways to be driven, scored, and selected by district directors and the DE for an eventual contracted PM project. Initial list for consideration is submitted by the Area Engineers, but the Director of Maintenance and staff measure these submittals against all BMT district data.
8	Area Offices submit candidate projects to the district using visual inspection, ADT, existing surface age, skid data and PMIS data as criteria. AE's and district staff evaluate the list of candidate projects to rank at the district level. projects are driven and data such as PMIS is used to determine highest ranking projects. If PMIS data indicates a need that is not submitted as a project, that segment is driven and discussed with AE to determine why it wasn't submitted.
9	Our recipe of success starts with our tried and true methods outlined in our District's Pavement Design Guide. SJT has one of the state's smallest CAT 1 allocations and Maintenance budgets, we have to very selective about what we build and how to afford it. TxDOT had a formula in the past that would inversely fund districts based on their pavement scores. So, we historically got less money because we had very good pavement scores. After funding, our next ingredient is the Data that drives the process. This data includes PMIS and skid scores, crash data and section wish lists. This data is analyzed, evaluated and prioritized. Some of that data is exported into maps like our "Not Good or Better Maps." We also review skid maps and KA heat maps. Our last ingredient is our Day Rides aka Boots on the Ground. This is where we to ride the roads and visually evaluate them as well as meet with the section leaders to discuss their one year and four year plans as well as getting their two worst roads.

	Responses
10	We use PMIS, PA, surface age map and generally look for 7–9 years from seal coat to seal coat. On previous overlays we look for around five years before a seal coat. We also include input from AEs and maintenance supervisors. All this info is put together and discussed in a group setting to come up with the four year plan.
11	We perform periodic visual assessments of the pavement conditions and types of distress, visit with the maintenance supervisors on concerns and in-house repairs performed, review most recent PMIS data, use skid data, wet weather crash report, surface age map, seal coat history, and other such documents.
12	We keep a spreadsheet database that tracks the roadway segments by their last surfacing date. We generate maps from this spreadsheet. We select roadways primarily on a seven year sealcoat cycle with some roadways being extended to 8–9 years depending on their condition and funding constraints. We utilize PA to further evaluate PM candidate roadways along with field observations to determine if a roadway has deteriorated beyond a point where PM is the correct operation. These roadways are moved into rehab and reconstruction type projects.
13	We selected by cycle and need. We will use condition maps, skid maps, and surface age maps to determine need. Also, will evaluate the roads in person.
14	PMIS information along with site visits and field evaluations helps our district in the selection process. Within the condition scores, the ride score or distress criteria is reviewed to determine the which is the controlling factor. Verification in the field is reviewed as not all scores appear to be accurate. If distress is the controlling factor then what is the issue is determined and verified in the field as well. Skid scores can also help by providing possible areas to address for the sections. Rides are conducted to visually view the issues by multiple staff members before selection
15	consider age of surface, current PMIS score, skid, rutting, visual inspection and rating during van ride with district staff, pathweb
16	Skid data. PMIS. Surface age map. Drive the roads.
17	we get recommendations from the section supervisor and their area engineer. They rank them according to priority. PMIS and Skid numbers are used to help determine problem areas. ADT and truck traffic are also considered. All roads are ridden by select district staff and this group determines which projects the district will do.

Question 4. Do you use the following PMIS/PA data to help identify PM projects?

- ☐ Skid
- ☐ IRI
- ☐ Ride Score
- ☐ Distress Score
- ☐ Condition Score

The responses are summarized in Figure 14.

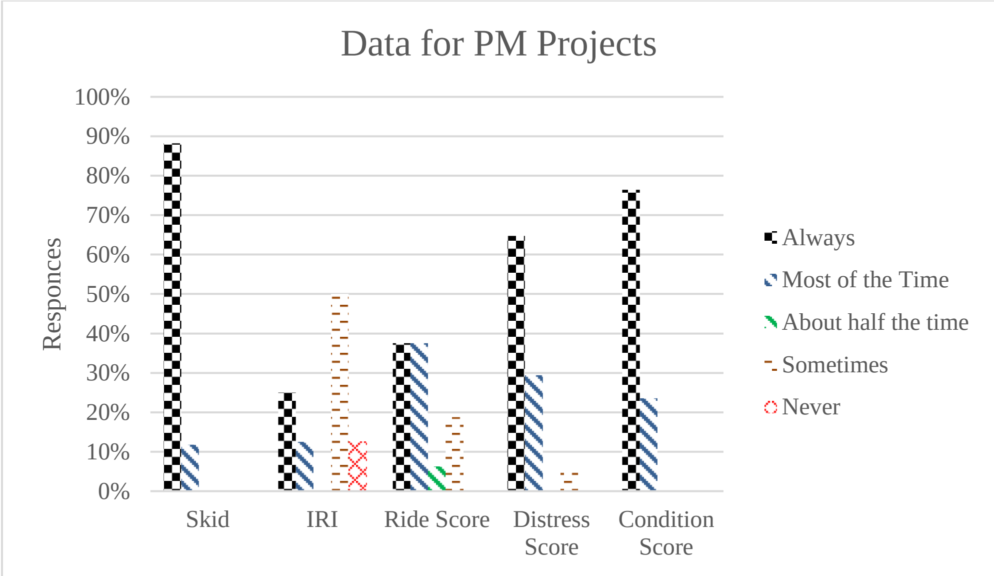

Figure 14. Q4—PMIS/PA Data for PM Projects.

Question 5. Do you use the following, FLEXIBLE PAVEMENT, PMIS data to help identify PM projects?

- ☐ Rutting
- ☐ Patching
- ☐ Failures
- ☐ Block Cracking
- ☐ Alligator Cracking
- ☐ Longitudinal Cracking
- ☐ Transverse Cracking
- ☐ Raveling
- ☐ Flushing

The responses are summarized in Figure 15, with the percentage shown under each heading.

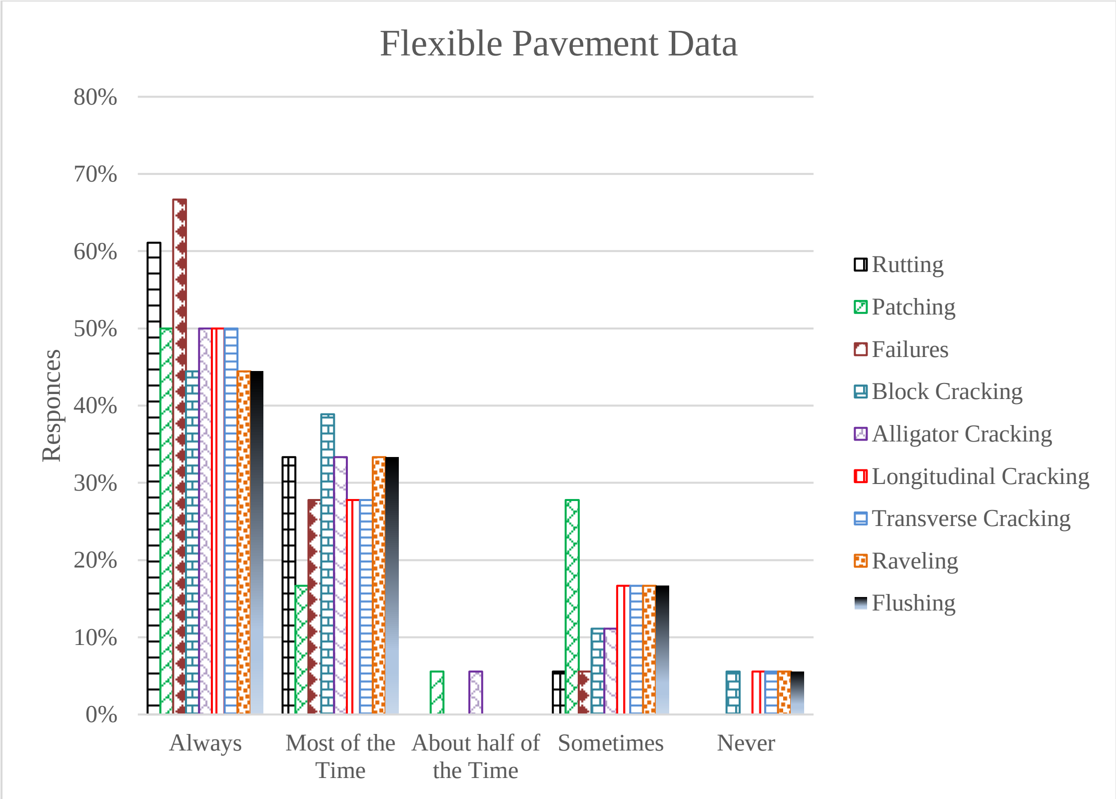

Figure 15. Q5—PMIS/PA Data Flexible Pavement.

Question 6. Do you use the following, CONTINUOUSLY REINFORCED CONCRETE PAVEMENT (CRCP), PMIS data to help identify PM projects?

- ☐ Spalled Cracks
- ☐ Punchouts
- ☐ Asphalt Patches
- ☐ Concrete Patches
- ☐ Average Crack Spacing

The responses are summarized in Figure 16.

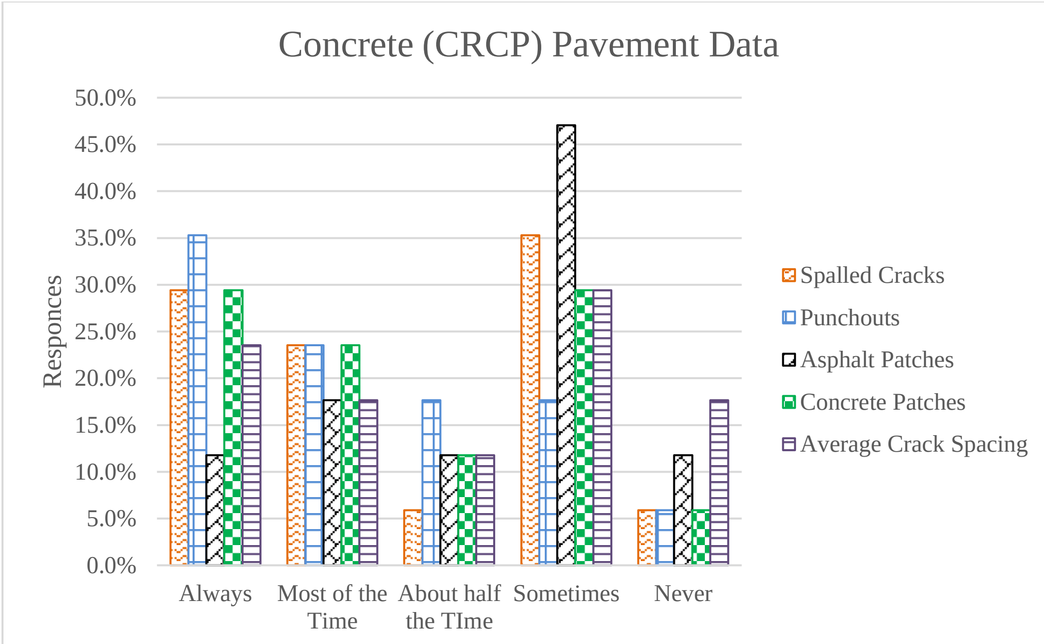

Figure 16. Q6—PMIS/PA Data CRCP.

Question 7. Do you use the following, JOINTED CONCRETE PAVEMENT, PMIS data to help identify PM projects?

- ☐ Failed joints and cracks
- ☐ Failures
- ☐ Shattered slabs
- ☐ Slabs with longitudinal cracks
- ☐ Concrete patches
- ☐ Apparent joint spacing

The responses are summarized in Figure 17.

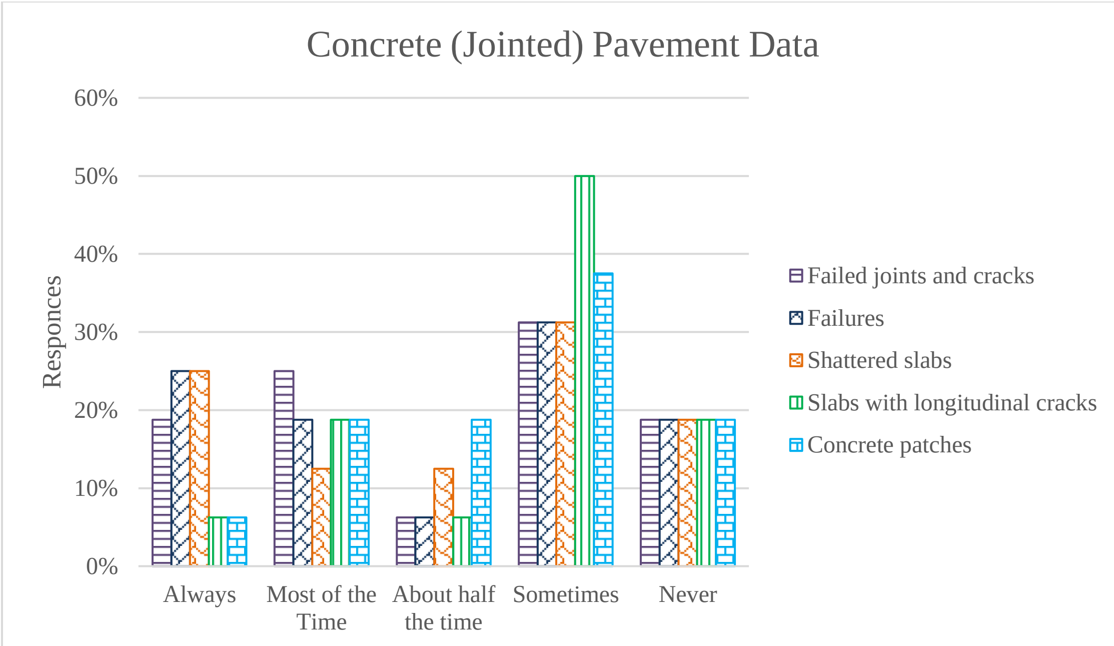

Figure 17. Q7—PMIS/PA Data JCP.

Question 8. Do you consider the timeframe since last surface to help identify PM projects?

The timeframe is important for identifying PM projects; 78 percent said yes, 17 percent said sometimes, and 5 percent do not consider the timeframe. The following are the comments when sometimes was indicated:

- *With the usage of TOM we have seen an increase in the longevity of the PM projects. We have also moved to a needs based program versus a cycle based program.*
- *It is a factor in the ranking but not the sole factor.*
- *Typically, age is not considered. We try to repair what needs repair. If old surface on low adt, resurfacing may not be a priority.*

Question 9. Who determines the type of in-house repair prior to the PM project?

- ☐ Maintenance Supervisor
- ☐ Area Engineer
- ☐ Pavement Engineer
- ☐ Laboratory Engineer
- ☐ Maintenance Engineer
- ☐ Design Engineer
- ☐ Construction Engineer
- ☐ Other, please describe

The responses are summarized in Figure 18.

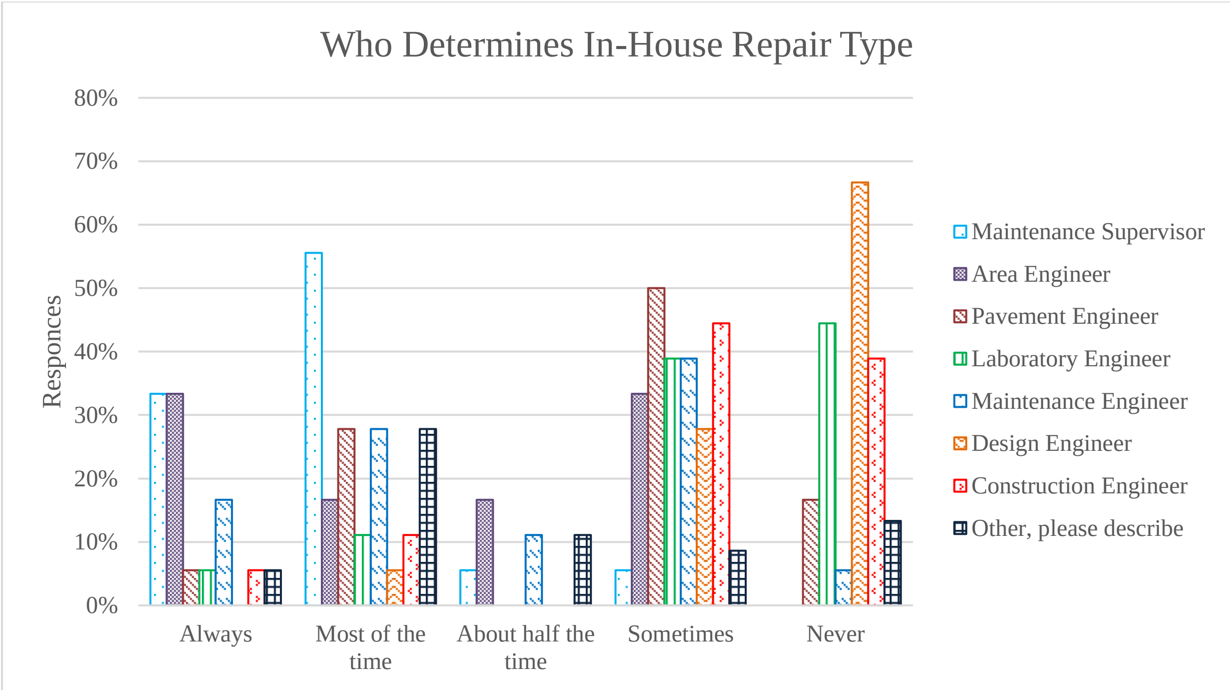

Figure 18. Q9—Who Determines In-House Repair.

Question 10. What factors influence the type of repairs that are performed prior to the PM project?

- Visual Observation and experience
- Perform testing such as GPR, FWD, coring, etc.
- Materials on hand or readily available
- Equipment availability
- Skill of Crew to perform the repair
- Timeframe (some repairs are faster to complete than others)
- Budget

The responses are summarized in Figure 19.

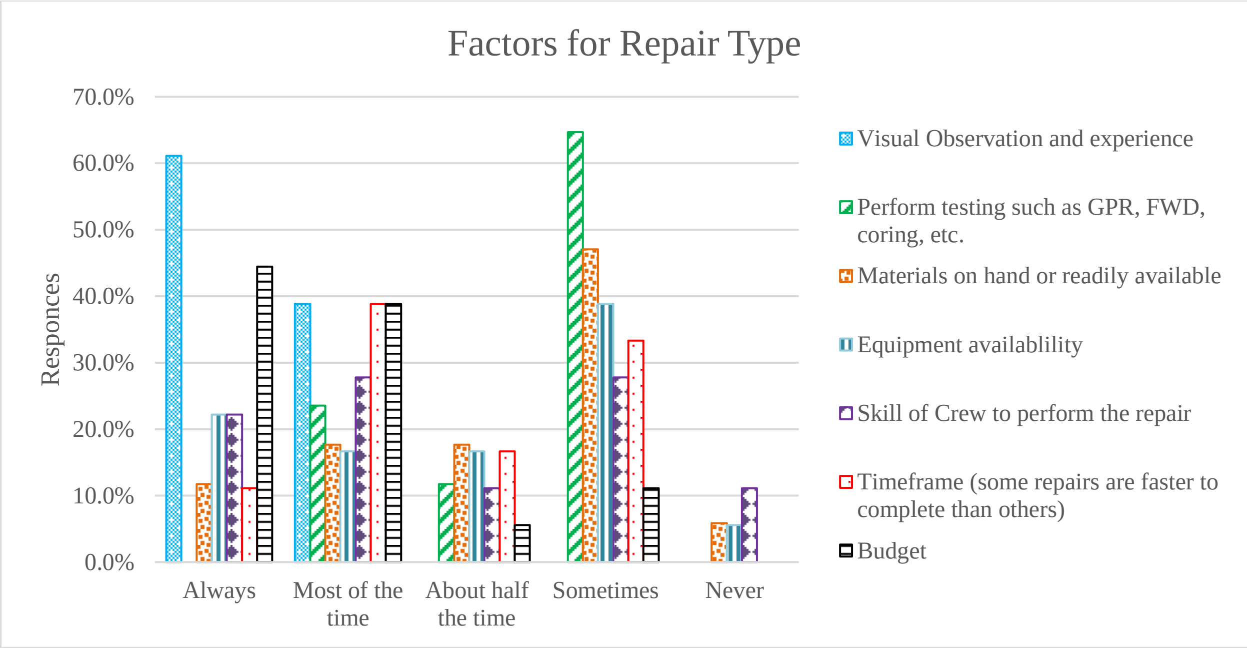

Figure 19. Q10—Factors for Repair Types.

Question 11. How do you evaluate how well the repairs worked? Select all that apply.

- ☐ Next year's PMIS data
- ☐ Visual observation including ride quality before PM contract
- ☐ Visual observation including ride quality after PM contract
- ☐ Preparatory work is not evaluated
- ☐ Formal evaluation process, please describe

The results are summarized in the chart in Figure 20.

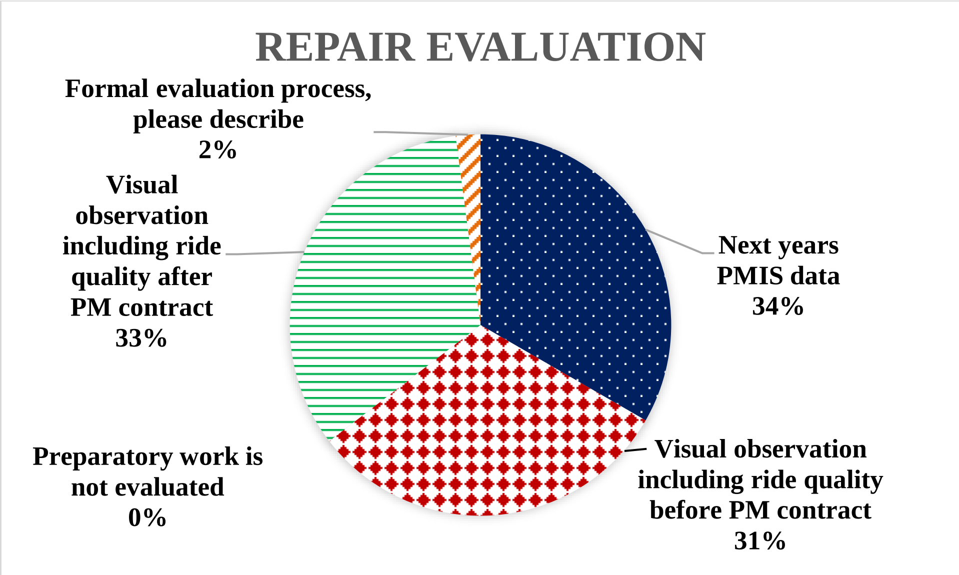

Figure 20. Q11—Repair Evaluation.

Question 12. What is the timeframe that you receive a list of roads to prepare for a PM project?

The timeframe ranges from 12 to 24 months with an average of 17.5 months.

Question 13. How far in advance, on average, of the PM project do you complete the repairs?

The timeframe ranges from 0 to 24 months with an average of 8.4 months.

Question 14. Would you like more time to prepare the roads, if so approximately how much? Select 0 if, in general, you have enough lead time to prepare the roadways.

The timeframe ranges from 0 to 12 months with an average of 5.2 months.

Question 15. What do you consider the best timeframe for repairs to cure in advance of the PM project being constructed?

The timeframe ranges from 3 to 12 months with an average of 9.3 months.

The timeframes for questions 12 through 15 are shown in Figure 21.

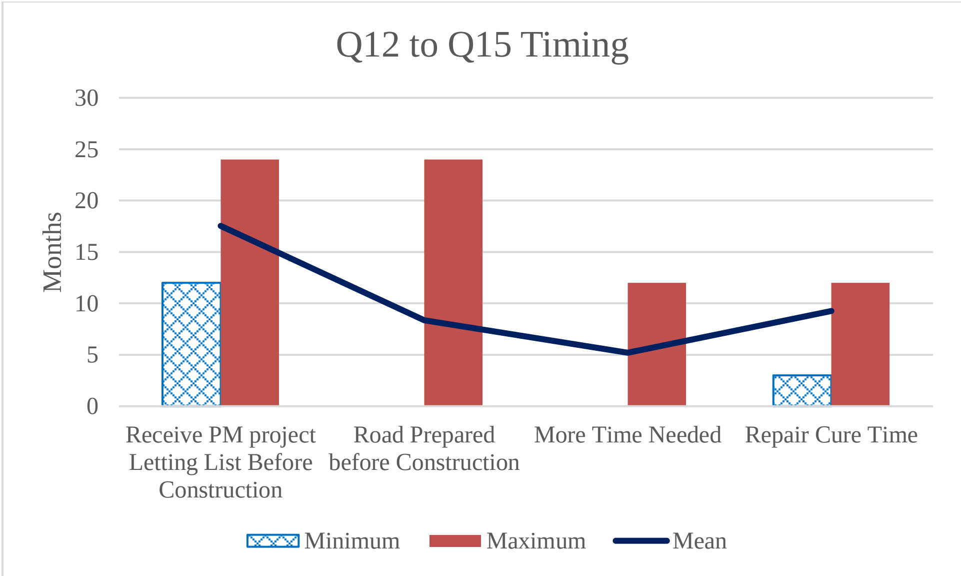

Figure 21. Q12–Q15 Timeframe.

Question 16. If there is not enough time for repairs to cure in advance of the PM project being constructed, do you fog seal the repair?

Refer to Figure 22 for a summary of the responses.

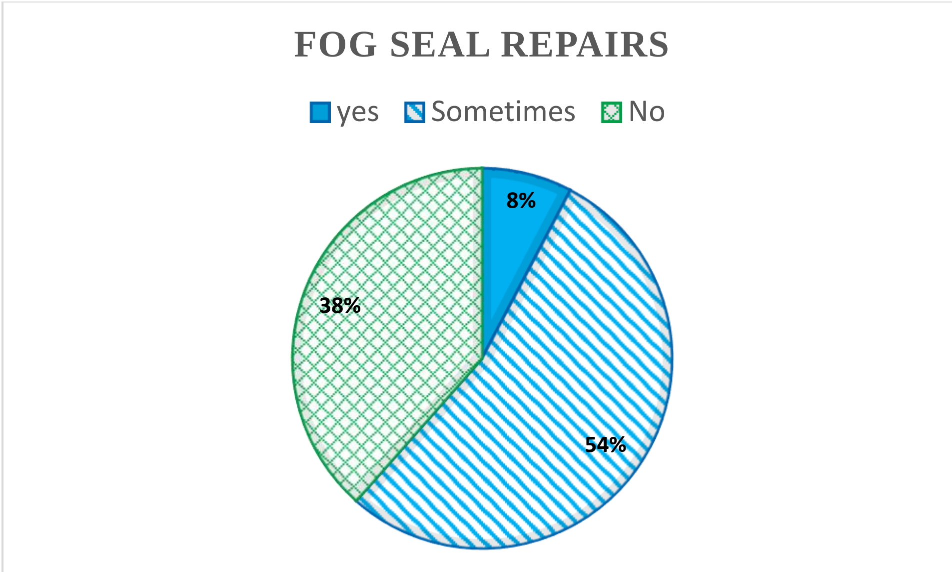

Figure 22. Q16—Fog Seal.

Question 17. Please rank the following influences on the repair strategy used, with 1 being most important.

- Type of problem ex. poor ride, pothole, cracking, etc.
- Budget
- Timeframe to perform repairs before PM project.
- Equipment
- Crew's knowledge and skills to perform repair
- Material availability
- Speed of performing repair

The results of the ranking are shown in Figure 23.

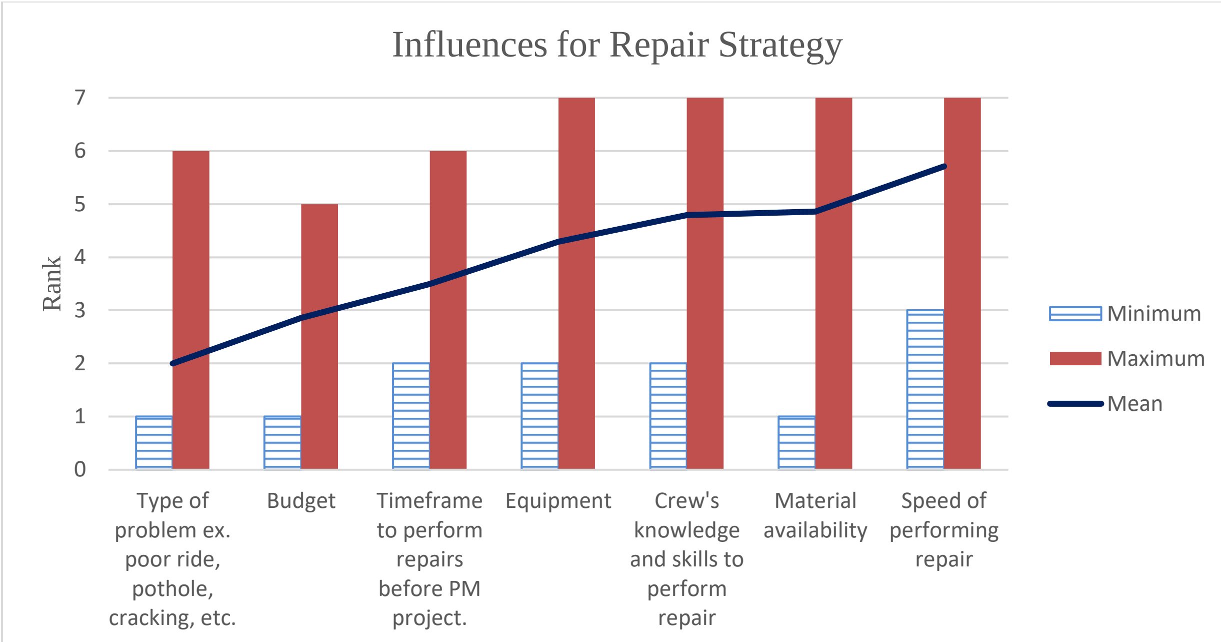

Figure 23. Q17—Ranking.

Question 18. Which of the following FLEXIBLE PAVEMENT preparatory work types are typically used in your section? Also note if your personnel need additional training to perform the repairs.

- ☐ Crack sealing:
- ☐ Seal Coats (strip/spot):
- ☐ Base Repair: Full Depth Repair with stabilizer like cement
- ☐ Base Repair: Remove and replace with base
- ☐ Base Repair: Full Depth Hot Mix
- ☐ Base Repair: Full Depth LRA
- ☐ Base Repair: Full Depth other asphaltic material
- ☐ Level-up: Hot Mix
- ☐ Level-up: LRA
- ☐ Level-up: Rejuvenated RAP
- ☐ Level-up: other asphaltic material
- ☐ Milling:
- ☐ Micro-milling:
- ☐ Fog Seal
- ☐ Other, please describe

Refer to Figure 24 for a summary of the responses.

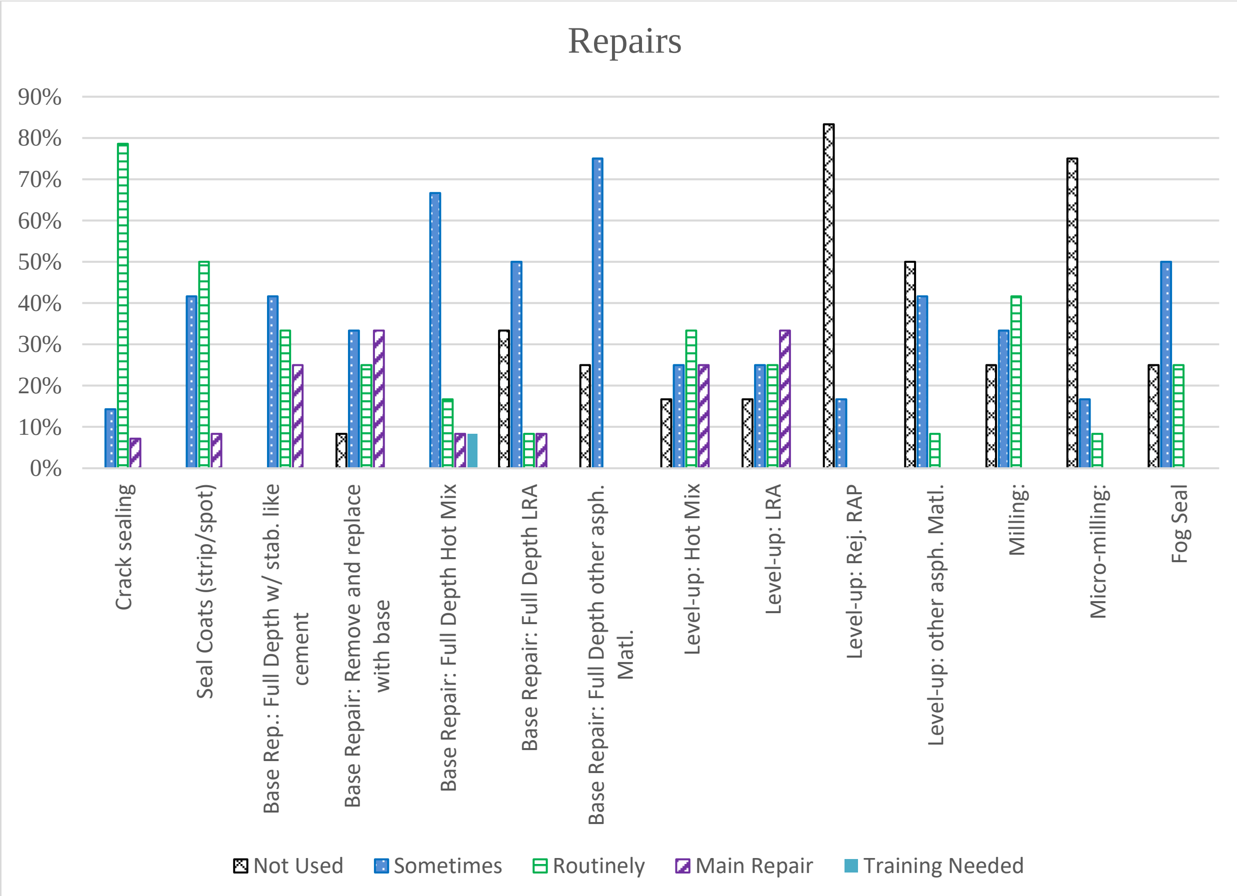

Figure 24. Q18—Repairs.

Question 19. Which of the following Concrete PAVEMENT preparatory work types are typically used in your section?

- ☐ Concrete repair: Spall
- ☐ Concrete repair: Partial depth repair
- ☐ Concrete repair: Full depth repair
- ☐ Joint repair
- ☐ Joint Sealing
- ☐ cross-stitching,
- ☐ slot-stitching
- ☐ U-bar stitching
- ☐ Dowel Bar Retrofit
- ☐ Diamond Grinding
- ☐ Crack sealing

Refer to Figure 25 for a summary of the responses.

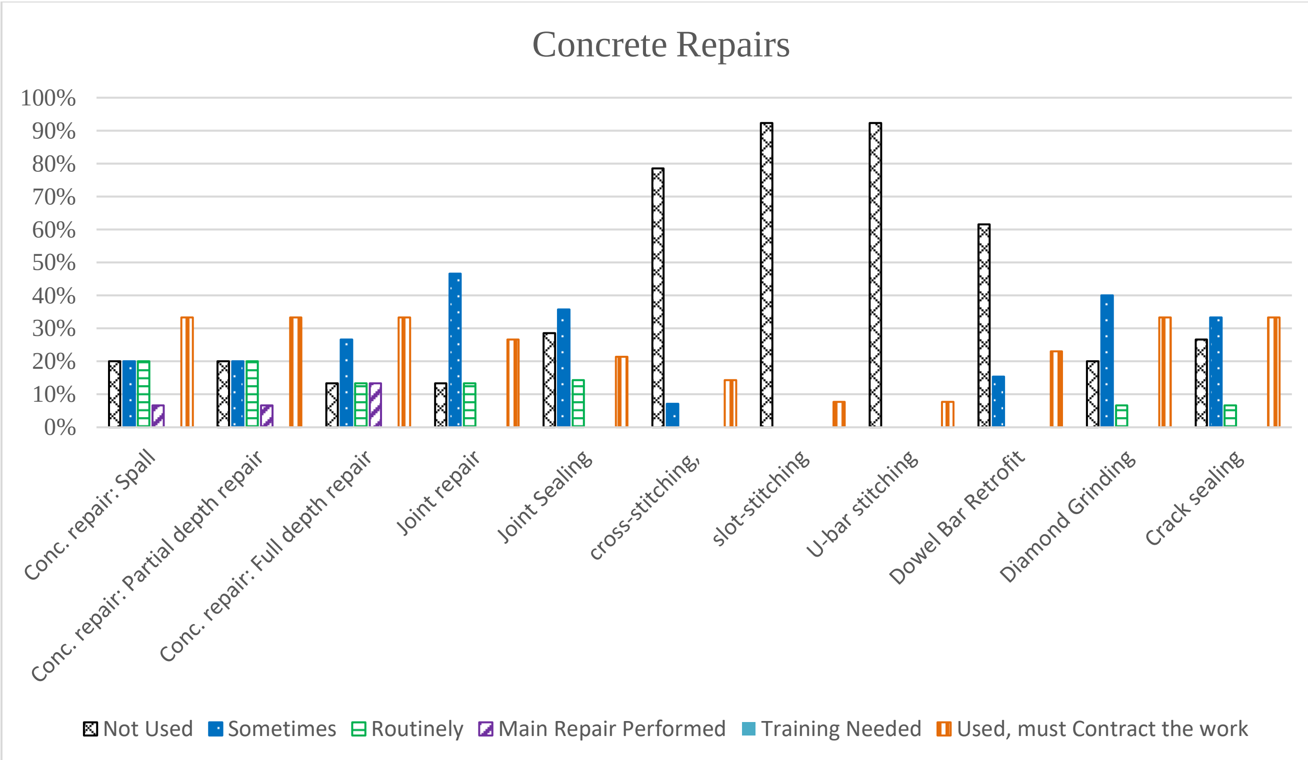

Figure 25. Q19—Concrete Repairs.

Question 20. For the Repairs listed, note if your section/district has the equipment needed to perform the work.

- ☐ Base repair with new base
- ☐ Base repair with stabilizer (i.e. cement, lime, etc.)
- ☐ Crack Seal
- ☐ Fog Seal
- ☐ Spot/Strip Seal Coat
- ☐ Level-up: blade Laid
- ☐ Level-up: Laydown machine
- ☐ Full Depth HMA patch
- ☐ Thin Overlay - Blade Laid
- ☐ Thin Overlay: Laydown machine
- ☐ Edge repair
- ☐ Milling
- ☐ Concrete Spall Repair
- ☐ Partial Depth Concrete Patch
- ☐ Pull Depth Concrete Patch
- ☐ Joint Repair

Refer to Figure 26 for a summary of the responses.

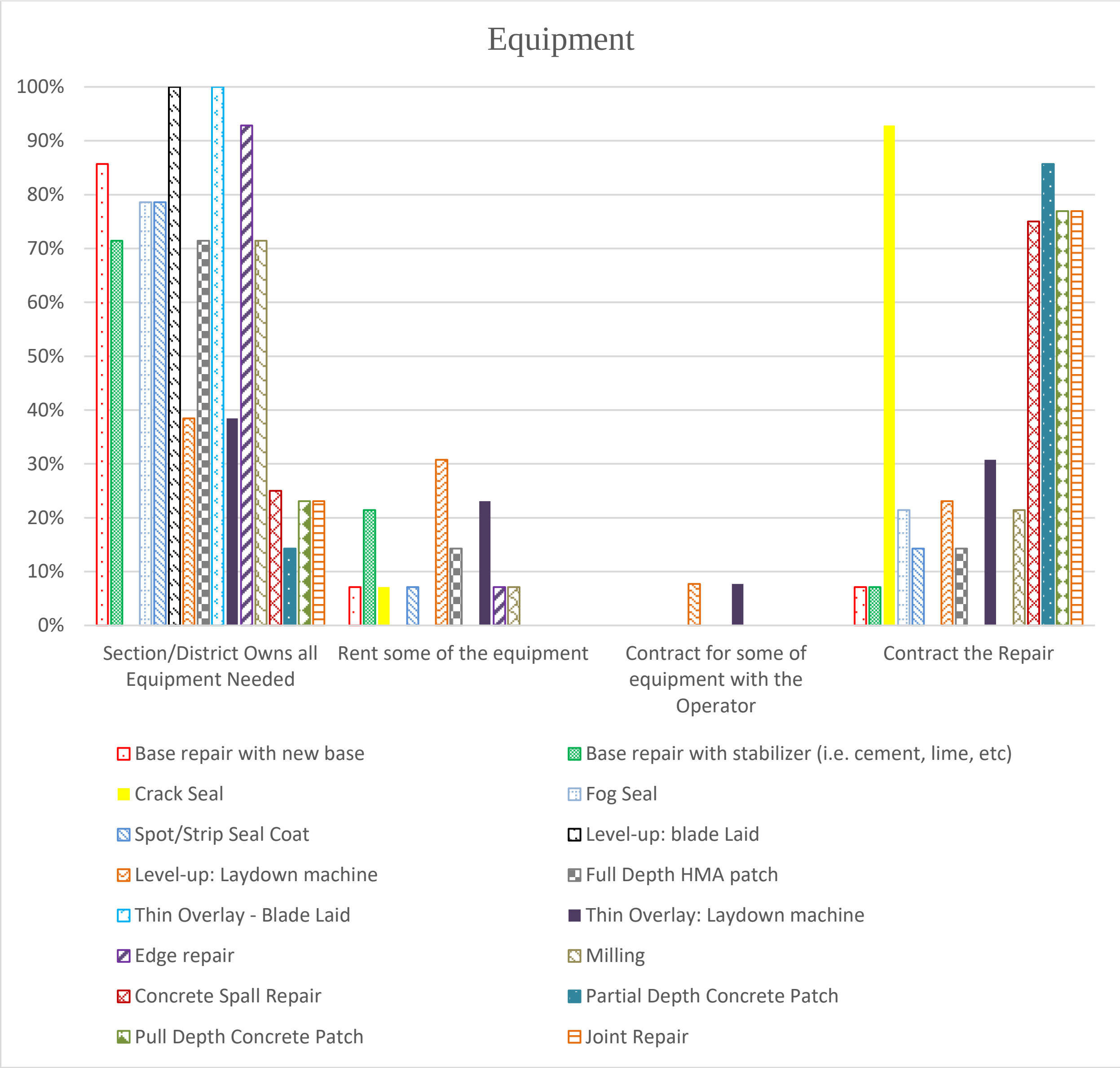

Figure 26. Q20—Equipment.

Question 21. For the repair materials listed, note if your section/district has the access to the material needed to perform the work.

- ☐ Crack Seal
- ☐ Flexible base
- ☐ Cement
- ☐ Fog Seal
- ☐ Seal Coat Binder
- ☐ Seal Coat Aggregate
- ☐ Hot Mix
- ☐ Hot Mix Cold Laid

- LRA
- Rejuvenated RAP
- Concrete
- Spall Repair
- Rebar/Dowel Bars
- Other, please describe

Refer to Figure 27 for a summary of the responses.

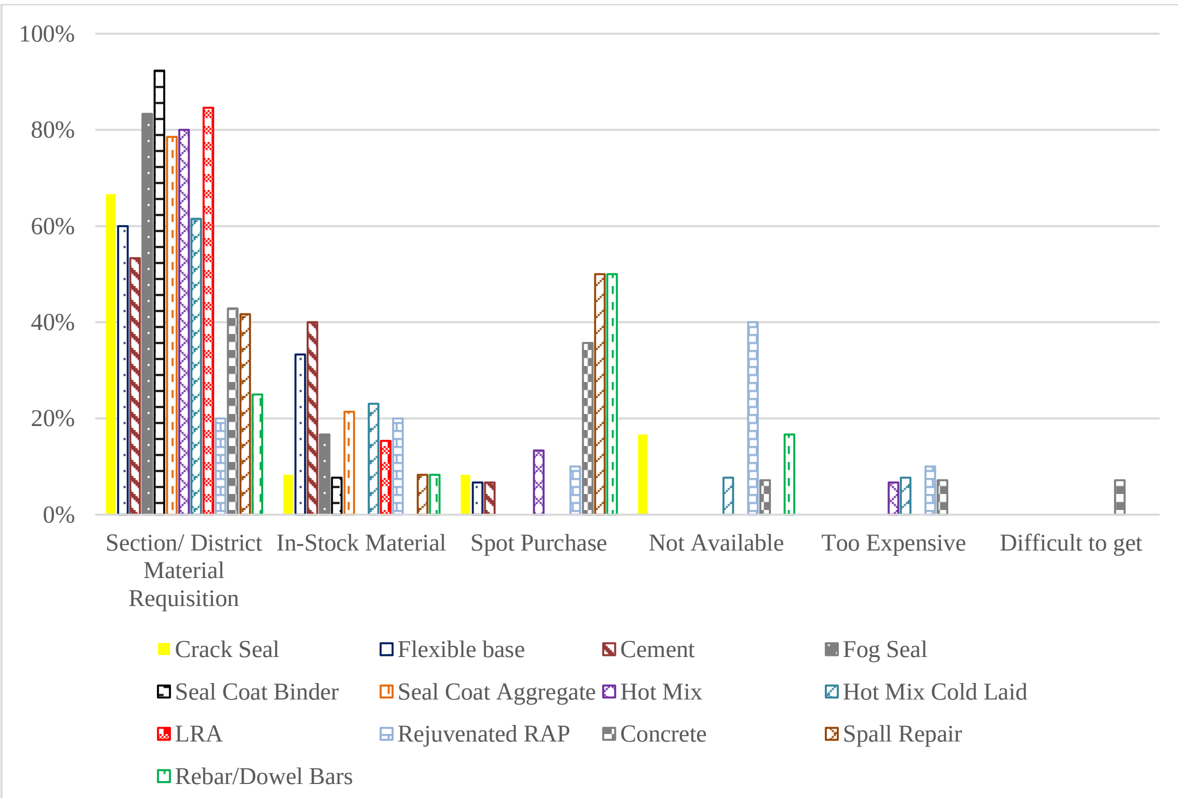

Figure 27. Q22—Materials

Question 23. How do you determine the size of the repair (length, width and depth)? Review the factors on the left then select the typical reason.

- Fix only the visually distressed area.
- Equipment size
- Material Availability
- Time to perform the repair
- Cost of Repair
- Effect of size on performance of the PM treatment.
- Longitudinal construction joint location
- Other, please describe

Figure 28 is a summary of the factors effecting the repair size.

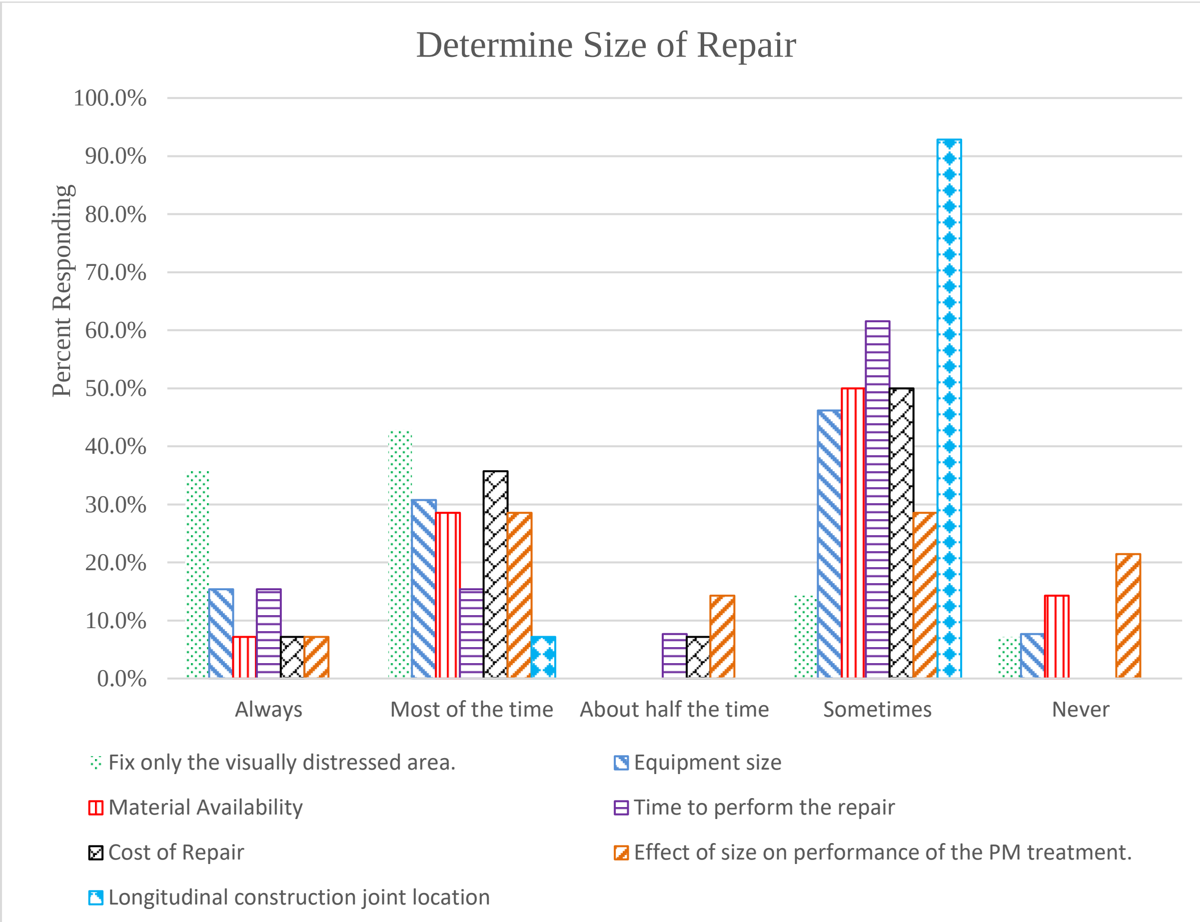

Figure 28. Q23 – Size of Repair.

Question 24. Please describe your concerns with preparing roads for PM projects.

Refer to Table 14 for a summary of the concerns.

Table 14. Q24 PM Concerns.

Number	Comments
1.	In general, my concerns are usually finding the balance between the roadway needs and the overall budget. Other than those items we have a well-established program to address our roadway prep for upcoming PM projects.
2.	Crack seal is a contracted process. My understanding is that maintenance sections are allowed to use a pull-pot to perform this process in-house. Here in BMT, our fleet is a serious problem. As an example, most sections don't have a functioning distributor. If they do, its typically far undersized for the minimum scope of work or is so unreliable that we can't plan to tackle projects of any magnitude. Skid steers are also a challenge. Very little in-house repairs are handled by local FOD and,

	when equipment goes in for work, it is often out of service for very long periods of time. I'm currently starting a conversation with FOD to address these issues.
3.	Enough time, equipment and operators, material availability cost
4.	The prep work is performed correctly and will result in a roadway that is structurally adequate and rides good.