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Develop Best Practices for Flexible Pavement Repairs

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16. Abstract

Texas plans to invest over $18 trillion in preventive maintenance (PM) and rehabilitation between FY 2026 and 2035, allocating one-third specifically to PM. This significant investment must be protected through ongoing enhancements to techniques that extend the life of PM treatments, especially seal coats, which make up the bulk of Texas's PM efforts. This study focused on identifying best practices for pre-PM flexible pavement repairs to ensure durability and cost-effectiveness. The research included a review of existing literature, analysis of Texas Department of Transportation (TxDOT) Pavement Management Information System (PMIS) data from 2019–2023, and TxDOT district surveys to identify types of asphalt pavement distress, repair methods, constraints, and performance trends. Results show that repair decisions mainly rely on visual inspections and PMIS scores, with little use of nondestructive testing. Factors such as repair type (e.g., crack sealing, level-up, and base repair), material availability, variations in curing time, and budget play key roles in determining outcomes. Advanced tools—such as Grind Diagnostic, falling weight deflectometer, dynamic cone penetrometer, and ground penetrating radar—were examined to help define repair scopes and improve structural assessments. The study created a standardized decision framework and repair guidelines that support better preparatory work, extend PM lifespan, and reduce lifecycle costs. Implementing these best practices across the state will improve system reliability, lower the risk of early failures, and strengthen TxDOT's ability to achieve performance goals.

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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 views 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 researcher in charge of the project was Tito Nyamuhokya.

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

BACKGROUND

Texas faces significant challenges in maintaining its extensive roadway network. Since 2001, the Texas Department of Transportation (TxDOT) has aimed to keep at least 90 percent of the system in good or better condition. Figure 1 illustrates the percentage of roads rated "good" or better alongside maintenance expenditures from fiscal year (FY) 2008 to FY 2023 (TxDOT 2021b).

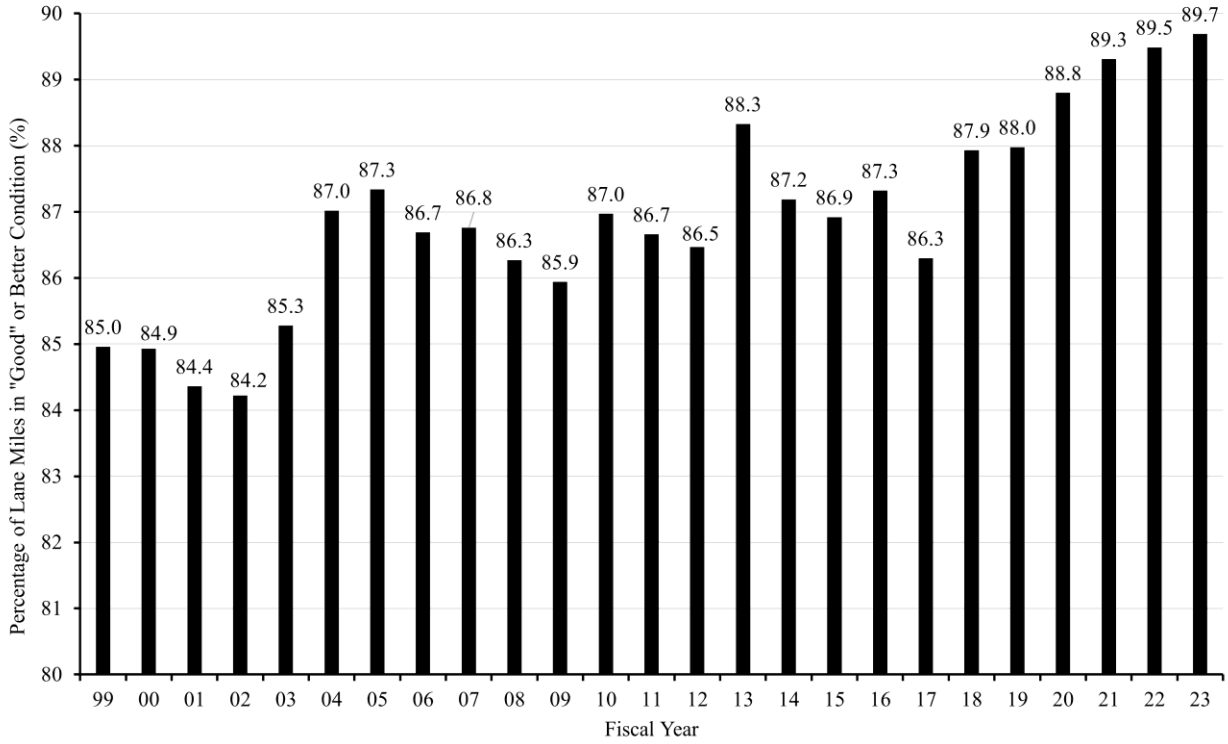


Figure 1. Statewide Percentage "Good" or Better and Maintenance Expenditure in FY 2008–2023.

TxDOT has numerous sections of roadway with preventive maintenance (PM) type of work contracted annually and requires some in-house preparatory work to prepare the pavement for the PM treatment (Serigos et al. 2017). The critical question is: **What preparatory work should be performed before applying a new surface treatment?**

LITERATURE REVIEW

PM is a proactive strategy designed to address potential issues before they occur, thereby extending pavement life and improving serviceability. Without maintenance, pavement conditions decline progressively due to traffic and environmental factors, accelerating over time until serviceability thresholds are reached. PM treatments applied while pavements are still in

good condition slow deterioration and prolong service life. This strategic approach goes beyond immediate concerns; it involves implementing measures specifically aimed at preventing future distress within pavements (Figure 2). PM treatments are strategically applied when the pavement surface is still in good condition. This proactive approach aims to prevent accelerated damage, effectively extending the pavement's service life.

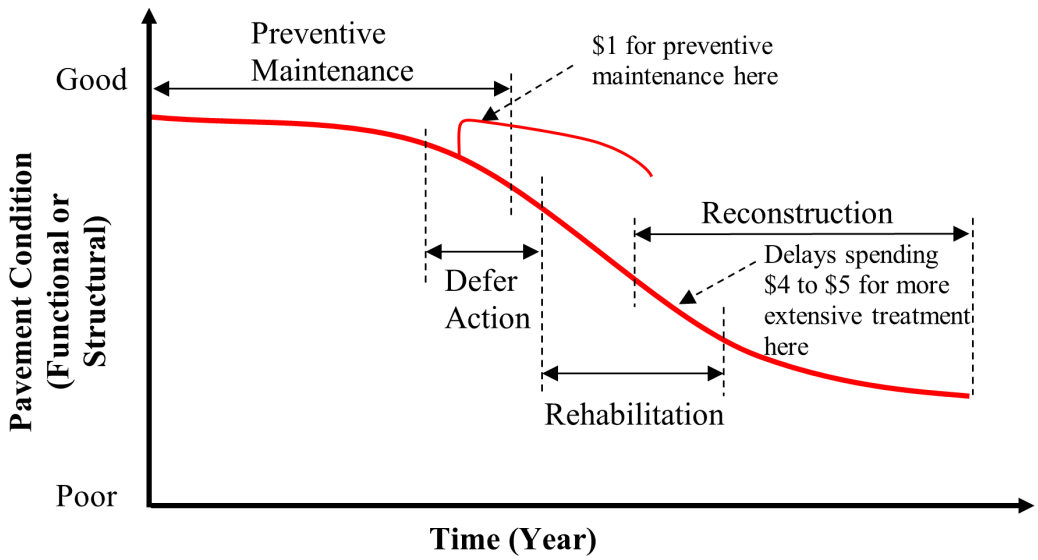


Figure 2. Theoretical Pavement Performance Curve for Different Maintenance and Rehabilitation Strategies.

Maintenance Treatment Categories

TxDOT uses four categories of treatments, with **PM** and **light rehabilitation (LR)** being the most relevant to this research:

- **PM:** Applied to pavements in good condition to slow deterioration and extend service life. PM protects the pavement structure from water infiltration and corrects minor surface defects. While structural capacity is not increased, low-severity, non-load-related distresses are addressed, and short-term ride quality may improve.
- **LR:** Focuses on non-structural improvements to address surface distress caused by aging and environmental effects. LR restores functional characteristics and protects structural integrity but does not significantly increase structural capacity.
- **Medium Rehabilitation (MR):** Provides structural improvements by increasing pavement thickness to enhance load-carrying capacity and extend service life. MR also restores functional characteristics and improves ride quality considerably.

- **Heavy Rehabilitation (HR):** Involves partial or complete removal and replacement of the pavement structure to restore both functional and structural conditions. HR is applied to sections with extensive structural distress.

Proper maintenance ensures repairs are made at the right time and on the right project. This principle aligns with the Federal Highway Administration's (FHWA's) Everyday Counts initiative, which emphasizes timely pavement preservation using quality materials and practices.

Performance Monitoring

TxDOT monitors both flexible and rigid pavements for ride quality using the International Roughness Index (IRI) and visual ratings for distress. *The Pavement Management Information System (PMIS) Rater's Manual* (TxDOT 2016) defines distress types and scoring methods. Combining distress and ride scores provides an overall condition score for each roadway section. TxDOT employs automated and semi-automated data collection methods using 3D laser technology and high-resolution cameras. Figure 3 and Figure 4 show examples of the ride quality and visual distress, respectively.

Figure 3. Ride Quality.

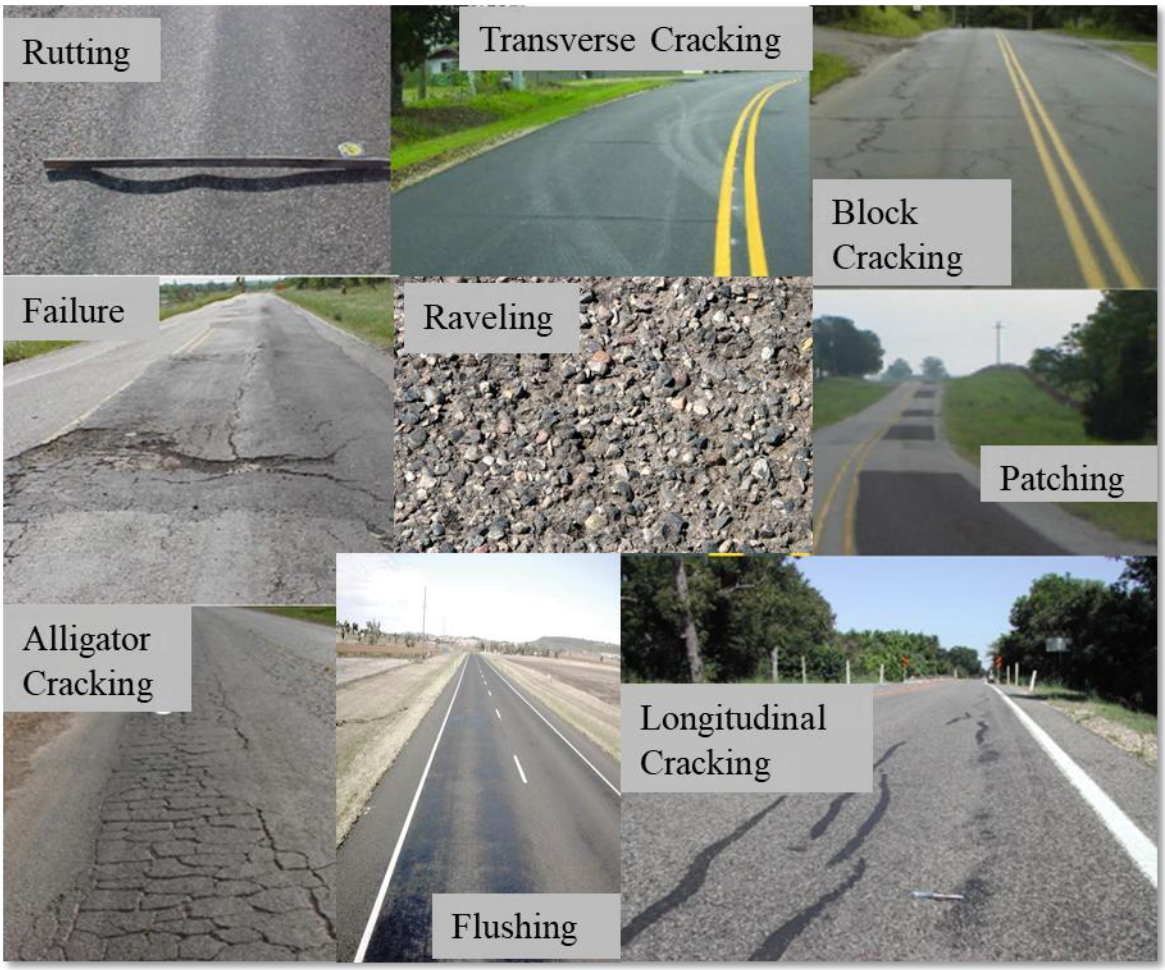


Figure 4. Flexible Pavement Distresses.

Common PM Repairs

Table 1 summarizes PM activities related to flexible pavement. While all these maintenance categories can be carried out either in-house or through contractual arrangements, there is a preference for outsourcing most preventive and major maintenance tasks.

Table 1. Summary of PM Activities Related to Flexible Pavement.

Type of Work	Preventive Maintenance (PM)
Travel Way	Pavement-related work performed to prevent major deterioration of the pavement. Work would typically include, but not be limited to, milling or bituminous level-ups to restore rideability, light overlays (overlays not exceeding a depth of 2 inches), seal coats, crack sealing, and micro-surfacing. Preparatory work such as milling, repairs, or level-ups may also be performed.
Shoulder and Side Approaches	All shoulder work to prevent major pavement deterioration, including milling or bituminous level-ups to restore cross section, light overlays (overlays not to exceed an average depth of 2 inches), seal coats, crack sealing, and micro-surfacing. Shoulder repair and widening not to exceed 26-foot full roadway width (TxDOT 2023)

Multiple repairs may be combined before applying a seal coat PM treatment (Figure 5).

Figure 5. Example Preparatory Work.

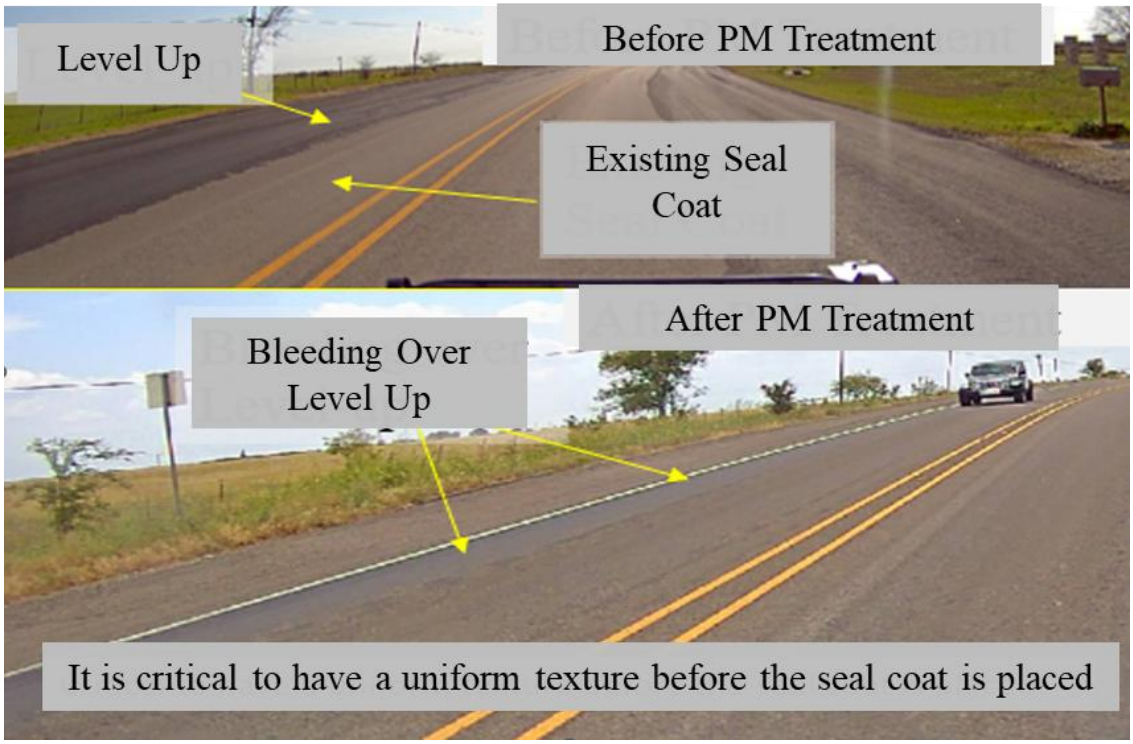


Figure 6. Repair Effect on Seal Coat.

Maintenance Data in TxDOT

PMIS: Stores ride quality and distress ratings for the entire state-maintained highway network. PMIS generates three scores:

- **Condition Score:** Combines ride and distress (range: 1–100).
- **Distress Score:** Reflects distress severity (range: 1–100).
- **Ride Score:** Indicates smoothness (range: 0.1–5.0).

Texas Maintenance Assessment Program (TxMAP): Launched in 1999, TxMAP documents, assesses, and rates maintenance performance for roughly 4,000 one-mile roadway segments each year. Evaluations include 5 percent of non-interstate highway system centerline miles and 10 percent of interstate system centerline miles in Texas. Ratings are on a 1–5 scale, with 5 representing the best. A zero rating indicates the element is not applicable. The annual TxMAP report provides the administration with insights into district maintenance performance and the overall condition of the highway system. The data aid in budget planning and legislative compliance (Graff 2012; TxDOT 2023). Figure 7 illustrates an example of a TxDOT maintenance condition assessment inspection report. The form covers three aspects (Pavement, Traffic Operations, Roadside). However, in this report, the Figure 7 only shows the pavement maintenance conditions.

Texas Maintenance Condition Assessment Inspection Form

DISTRICT		INSPECTOR	
COUNTY		ACCOMPANIED BY	
HIGHWAY		INSPECTED ON	
BEGIN RM	BEGIN DISP	ASSESSMENT #	
END RM	END DISP	INSPECTION #	
DIRECTION	__ NB __ SB __ EB __ WB	COMMENT	
PAVEMENT	__ JCP __ Hot Mix __ Seal __CRCP __Plant Mix __Micro Mixed Surface		

Pavement	Circle One	Circle One	COMMENTS
Main Lane - Rutting	**1 / 2 / 3 / 4 / 5 / 0**	>1" | 1/2" to 1" | 1/4" to 1/2" | <1/4" | Deep	
Main Lane - Cracking	**1 / 2 / 3 / 4 / 5 / 0**	Block | Longitudinal Crack | Transverse Crack | Wide | Long/Trans	
Main Lane - Failures	**1 / 2 / 3 / 4 / 5 / 0**	Base Failures | Depressions | Open BF | Rough Patches | Spalling | Potholes| Surface Failures| Punch Out	
Main Lane - Ride	**1 / 2 / 3 / 4 / 5 / 0**	Failures | Joints | Patches | Rough | Settlement | Cracks | Depressions	
Edges	**1 / 2 / 3 / 4 / 5 / 0**	Broken | Drop-Offs | Broken/Drop-Offs | Curb and Gutter	
Shoulders	**1 / 2 / 3 / 4 / 5 / 0**	Cracks | Failures	

Figure 7. Example of Inspection Report.

SUMMARY

Chapter 1 emphasizes the importance of preventive maintenance and preparatory repairs in meeting TxDOT's performance goals. It details treatment categories, monitoring systems, and common repair practices while stressing the need for standardized decision-making supported by PMIS data and emerging tools.

CHAPTER 2. IDENTIFYING MAIN FLEXIBLE PAVEMENT REPAIRS

OVERVIEW

This chapter presents the analysis of TxDOT's PMIS data and findings from district surveys to identify common flexible pavement repairs performed before PM projects. The goal is to understand current practices and constraints influencing repair strategies.

The Texas A&M Transportation Institute (TTI) research team collected and analyzed PMIS data from TxDOT districts. The dataset initially spanned 2014–2023; however, errors in early years (2014–2018) raised concerns about accuracy. The source of the error was mostly from rutting, where the observed values were way beyond the typical value. Consequently, the analysis focused on data from 2019–2023. The dataset included:

- Pavement location and responsible district.
- Roadway section details (start and end points).
- Pavement condition scores.
- Distress and ride quality ratings.

In addition, the team developed a fact-based questionnaire, distributed through TxDOT district offices, to capture field practices and decision criteria related to:

- Pavement evaluation and project selection.
- Repair strategy and limit determination.
- Evaluation of PM project performance.

ANALYSIS OF MAINTENANCE PMIS DATA

The PMIS analysis assessed distress and condition scores for 0.5-mile asphalt pavement sections across all districts. For this research, the team focused exclusively on scores from asphalt concrete pavements. Scores were grouped into five categories: **very good, good, fair, poor,** and **very poor**. The summary of the score analysis is presented in Table 2, Table 3, Table 4, and Table 5.

Table 2. Summary of Distress and Condition of Texas Asphalt Pavement (District 1 to 7).

	Distress Score Range	Number of Sections in the Range	Percentage of Sections	Condition Score Range	Number of Sections in the Range	Percentage of Sections	Category
01–PARIS	90–100	24511	65.0	90–100	22410	59.6	very good
	80–89	7120	18.9	70–89	10317	27.5	good
	70–79	3192	8.5	50–69	2775	7.4	fair
	60–69	1291	3.4	35–49	977	2.6	poor
	1–59	1611	4.3	1–34	1101	2.9	very poor
02–FORT WORTH	90–100	28806	69.5	90–100	26036	63.1	very good
	80–89	5833	14.1	70–89	9265	22.5	good
	70–79	2977	7.2	50–69	3441	8.3	fair
	60–69	1616	3.9	35–49	1252	3.0	poor
	1–59	2228	5.4	1–34	1259	3.1	very poor
03–WICHITA FALLS	90–100	25239	76.8	90–100	24315	74.2	very good
	80–89	4208	12.8	70–89	5982	18.3	good
	70–79	1668	5.1	50–69	1545	4.7	fair
	60–69	879	2.7	35–49	392	1.2	poor
	1–59	849	2.6	1–34	521	1.6	very poor
04–AMARILLO	90–100	32470	68.6	90–100	30501	64.7	very good
	80–89	6998	14.8	70–89	10736	22.8	good
	70–79	3516	7.4	50–69	3910	8.3	fair
	60–69	2028	4.3	35–49	1045	2.2	poor
	1–59	2298	4.9	1–34	952	2.0	very poor
05–LUBBOCK	90–100	40856	67.2	90–100	39667	65.5	very good
	80–89	10330	17.0	70–89	14713	24.3	good
	70–79	4395	7.2	50–69	4246	7.0	fair
	60–69	2355	3.9	35–49	1131	1.9	poor
	1–59	2832	4.7	1–34	835	1.4	very poor
06–ODESSA	90–100	25176	61.5	90–100	24261	59.5	very good
	80–89	6864	16.8	70–89	9961	24.4	good
	70–79	3493	8.5	50–69	3488	8.6	fair
	60–69	1847	4.5	35–49	1444	3.5	poor
	1–59	3545	8.7	1–34	1612	4.0	very poor
07–SAN ANGELO	90–100	23407	63.4	90–100	22738	61.7	very good
	80–89	8299	22.5	70–89	11348	30.8	good
	70–79	3045	8.3	50–69	1969	5.3	fair
	60–69	1102	3.0	35–49	446	1.2	poor
	1–59	1044	2.8	1–34	342	0.9	very poor

Table 3. Summary of Distress and Condition of Texas Asphalt Pavement (District 8 to 13).

	Distress Score Range	Number of Sections in the Range	Percentage of Sections	Condition Score Range	Number of Sections in the Range	Percentage of Sections	Category
08–ABILENE	90–100	29681	69.5	90–100	27828	65.3	very good
	80–89	7739	18.1	70–89	10573	24.8	good
	70–79	2627	6.2	50–69	2602	6.1	fair
	60–69	1280	3.0	35–49	784	1.8	poor
	1–59	1384	3.2	1–34	803	1.9	very poor
09–WACO	90–100	26881	68.3	90–100	25614	65.3	very good
	80–89	6854	17.4	70–89	9859	25.1	good
	70–79	3100	7.9	50–69	2225	5.7	fair
	60–69	1157	2.9	35–49	682	1.7	poor
	1–59	1382	3.5	1–34	864	2.2	very poor
10–TYLER	90–100	28332	66.5	90–100	26883	63.3	very good
	80–89	7285	17.1	70–89	10647	25.1	good
	70–79	3546	8.3	50–69	3185	7.5	fair
	60–69	1625	3.8	35–49	890	2.1	poor
	1–59	1837	4.3	1–34	883	2.1	very poor
11–LUFKIN	90–100	26193	82.4	90–100	24964	78.9	very good
	80–89	3340	10.5	70–89	4701	14.9	good
	70–79	1271	4.0	50–69	1077	3.4	fair
	60–69	518	1.6	35–49	361	1.1	poor
	1–59	472	1.5	1–34	543	1.7	very poor
12–HOUSTON	90–100	33615	77.5	90–100	29037	67.3	very good
	80–89	3375	7.8	70–89	6769	15.7	good
	70–79	2293	5.3	50–69	3251	7.5	fair
	60–69	1233	2.8	35–49	1631	3.8	poor
	1–59	2866	6.6	1–34	2431	5.6	very poor
13–YOAKUM	90–100	28394	68.3	90–100	27237	65.7	very good
	80–89	8105	19.5	70–89	10678	25.8	good
	70–79	2774	6.7	50–69	2158	5.2	fair
	60–69	1207	2.9	35–49	556	1.3	poor
	1–59	1081	2.6	1–34	798	1.9	very poor

Table 4. Summary of Distress and Condition of Texas Asphalt Pavement (District 14 to 19).

	Distress Score Range	Number of Sections in the Range	Percentage of Sections	Condition Score Range	Number of Sections in the Range	Percentage of Sections	Category
14–AUSTIN	90–100	31343	76.7	90–100	29691	72.9	very good
	80–89	5270	12.9	70–89	7818	19.2	good
	70–79	2287	5.6	50–69	2038	5.0	fair
	60–69	988	2.4	35–49	533	1.3	poor
	1–59	978	2.4	1–34	657	1.6	very poor
15–SAN ANTONIO	90–100	30165	58.9	90–100	27089	53.2	very good
	80–89	10800	21.1	70–89	15055	29.5	good
	70–79	4903	9.6	50–69	5264	10.3	fair
	60–69	2413	4.7	35–49	1773	3.5	poor
	1–59	2942	5.7	1–34	1775	3.5	very poor
16–CORPUS CHRISTI	90–100	25608	72.6	90–100	23859	67.9	very good
	80–89	4865	13.8	70–89	6719	19.1	good
	70–79	1890	5.4	50–69	2270	6.5	fair
	60–69	1115	3.2	35–49	824	2.3	poor
	1–59	1804	5.1	1–34	1462	4.2	very poor
17–BRYAN	90–100	25833	70.3	90–100	23620	64.4	very good
	80–89	6828	18.6	70–89	9461	25.8	good
	70–79	2525	6.9	50–69	2237	6.1	fair
	60–69	834	2.3	35–49	643	1.8	poor
	1–59	735	2.0	1–34	695	1.9	very poor
18–DALLAS	90–100	35129	73.3	90–100	29470	61.9	very good
	80–89	5051	10.5	70–89	8302	17.4	good
	70–79	2405	5.0	50–69	4029	8.5	fair
	60–69	1438	3.0	35–49	2039	4.3	poor
	1–59	3878	8.1	1–34	3768	7.9	very poor
19–ATLANTA	90–100	23911	78.1	90–100	23043	75.4	very good
	80–89	3969	13.0	70–89	5433	17.8	good
	70–79	1392	4.5	50–69	1146	3.8	fair
	60–69	550	1.8	35–49	395	1.3	poor
	1–59	791	2.6	1–34	524	1.7	very poor

Table 5. Summary of Distress and Condition of Texas Asphalt Pavement (District 20 to 25).

	Distress Score Range	Number of Sections in the Range	Percentage of Sections	Condition Score Range	Number of Sections in the Range	Percentage of Sections	Category
20–BEAUMONT	90–100	21778	78.5	90–100	20436	73.8	very good
	80–89	3262	11.8	70–89	4730	17.1	good
	70–79	1173	4.2	50–69	1161	4.2	fair
	60–69	512	1.8	35–49	478	1.7	poor
	1–59	1022	3.7	1–34	881	3.2	very poor
21–PHARR	90–100	19975	70.4	90–100	18970	67.1	very good
	80–89	4416	15.6	70–89	6150	21.8	good
	70–79	1750	6.2	50–69	1891	6.7	fair
	60–69	978	3.4	35–49	620	2.2	poor
	1–59	1253	4.4	1–34	632	2.2	very poor
22- LAREDO	90–100	15902	62.8	90–100	14945	59.2	very good
	80–89	4951	19.6	70–89	7067	28.0	good
	70–79	2149	8.5	50–69	1953	7.7	fair
	60–69	1014	4.0	35–49	586	2.3	poor
	1–59	1307	5.2	1–34	703	2.8	very poor
23–BROWNWOOD	90–100	18605	64.1	90–100	17711	61.2	very good
	80–89	6502	22.4	70–89	9024	31.2	good
	70–79	2397	8.3	50–69	1542	5.3	fair
	60–69	805	2.8	35–49	325	1.1	poor
	1–59	695	2.4	1–34	333	1.2	very poor
24–EL PASO	90–100	17093	73.6	90–100	15209	65.8	very good
	80–89	3200	13.8	70–89	4515	19.5	good
	70–79	1265	5.4	50–69	1848	8.0	fair
	60–69	724	3.1	35–49	703	3.0	poor
	1–59	942	4.1	1–34	840	3.6	very poor
25–CHILDRESS	90–100	24373	86.5	90–100	23747	84.4	very good
	80–89	2261	8.0	70–89	3125	11.1	good
	70–79	720	2.6	50–69	694	2.5	fair
	60–69	343	1.2	35–49	225	0.8	poor
	1–59	487	1.7	1–34	335	1.2	very poor

PMIS Data Analysis

Followings are the key observations from the PIMS data analysis.

- Rural districts such as **Childress, Lufkin, and Atlanta** maintain a high percentage of sections with high distress scores (> 90), likely due to lower traffic volumes and smaller networks (Figure 8).
- Large metropolitan districts such as **San Antonio, Dallas, Houston, and Fort Worth** show higher percentages of sections with relatively poor pavement conditions, primarily due to heavy traffic and complex maintenance demands (Figure 9).
- **Odessa**, a smaller district with significant oil and gas traffic and limited asphalt plants, also exhibits a higher percentage of sections with poor conditions (Figure 9).

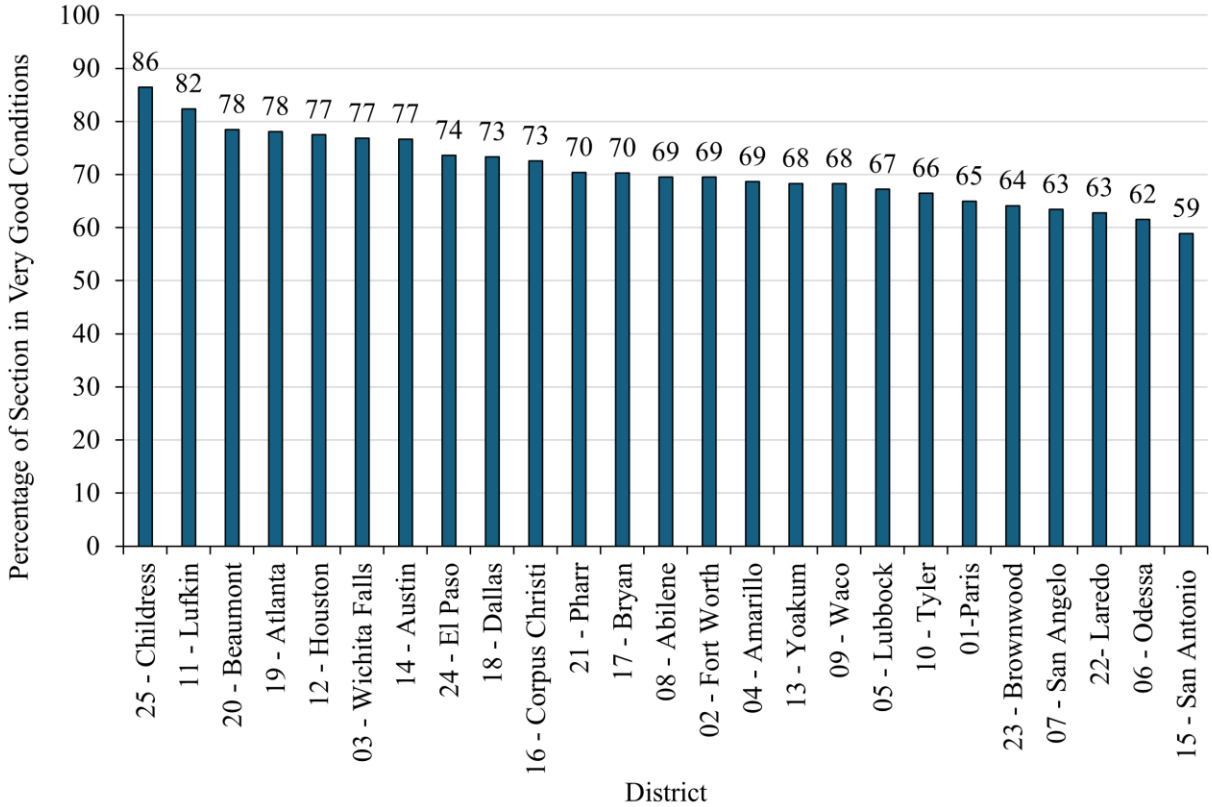


Figure 8. Percentage of Section (0.5 mile) with Very Good Distress Score.

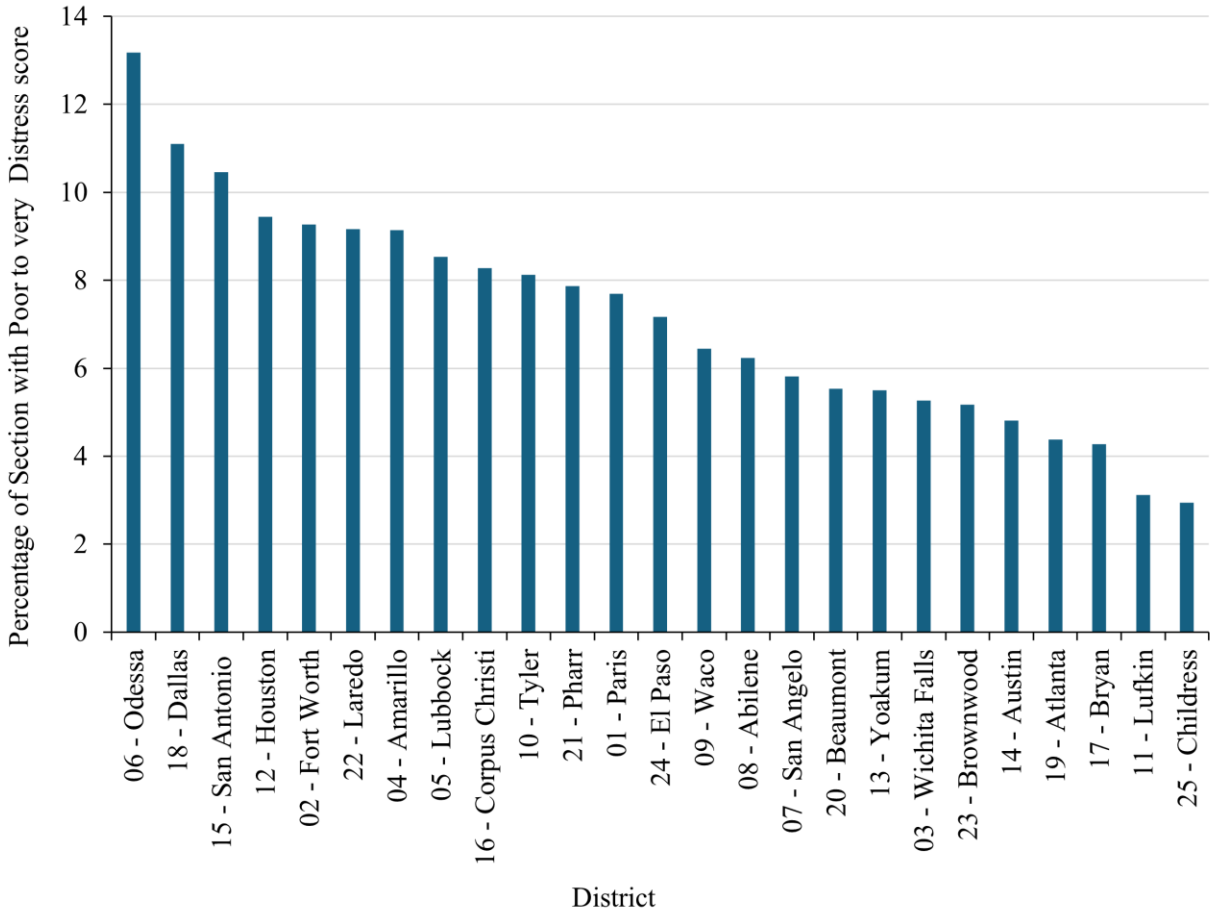


Figure 9. Percentage of Section (0.5 mile) with Poor Distress Score.

The Texas PMIS Annual Report 2020–23 echoes a similar finding, this time using the condition score (distress and ride scores) (TxDOT 2023). Figure 10 shows that rural districts, such as Childress, Lufkin, Atlanta, and others, have high condition scores. In contrast, Odessa and large metro districts (i.e., Houston, Dallas, etc.) have relatively lower scores. However, on average, all districts have good condition scores (Figure 10).

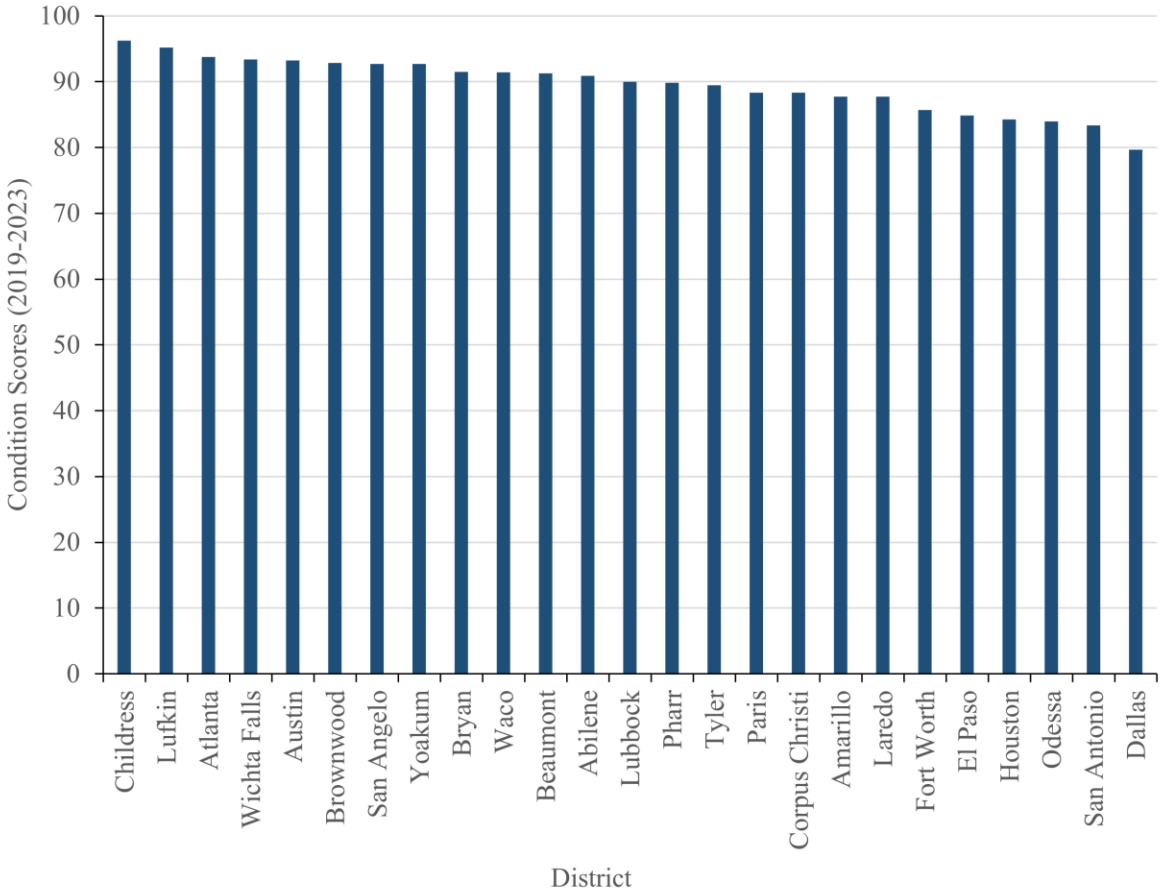


Figure 10. TxDOT District Ranking According to Condition Scores 2019–2023.

Trend Analysis

To evaluate maintenance trends, the research team developed customized code to extract and plot distress scores annually, since the volume of data required automated processing. The core of the computing code is shown in Figure 11. This approach allowed identification of sections that improved or deteriorated significantly after repairs. Sections with scores above 98 (very good; relatively new) and below 70 (poor; need maintenance) were prioritized for further evaluation. Figure 12 to Figure 18 show examples from Lufkin and Odessa, highlighting contrasting outcomes:

- Some repaired sections remained in good condition for years. For example, Figure 12 and Figure 13 show a distress score trend for Lufkin, one of the districts with the most sections with good scores. Once repaired, most of the sections in this district stayed in good shape for a relatively long period.
- Some sections failed within a year, raising questions about repair practices and material performance. For example, Figure 14, Figure 15, and Figure 16 show sections from Odessa with a relatively high proportion of poor-scoring sections.

```
# Plot bar graphs for each unique combination of County, ID, and District

for group key, group data in grouped data. items():

    county, id_, district = group key # Extract County, ID, and district from
group key

    years = sorted (group data. keys ()) # Sort years


    # Prepare data for bar groups

    Num sections = max(len(scores) for scores in group data. values ())

    section_data = np.full((num_sections, len(years)), np.nan)  # Initialize
with NaNs

    for i, year in enumerate(years):

        scores = group_data.get(year, [])  # Get scores for the year, default
to empty list

        for j, score in enumerate(scores):

            section_data[j, i] = score  # Assign the score


    # Check if any section meets the criteria for plotting

    sections_to_plot = []

    for j in range(num_sections):

        scores = section_data[j, :]

        if len(scores) > 1:

            for i in range(len(scores)-1):

                earlier_score = scores[i]

                later_score = scores[i+1]

                if earlier_score is not None and later_score is not None:

                    if earlier_score > 98 and later_score < 71:

                            sections_to_plot.append(j)

                            break # Once the section meets the
criteria, no need to check further years
```

Figure 11. Computing Code to Extract and Plot Graphs of the Distress Scores.

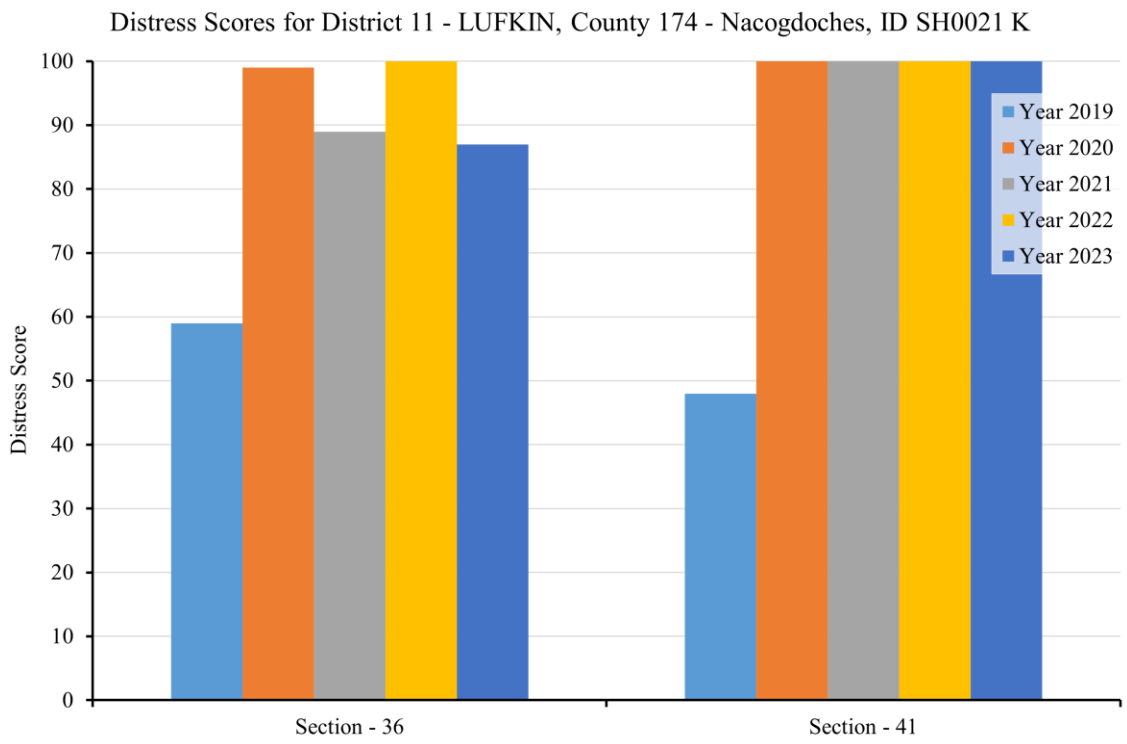


Figure 12. Sample of the Well-Fixed Sections in Lufkin.

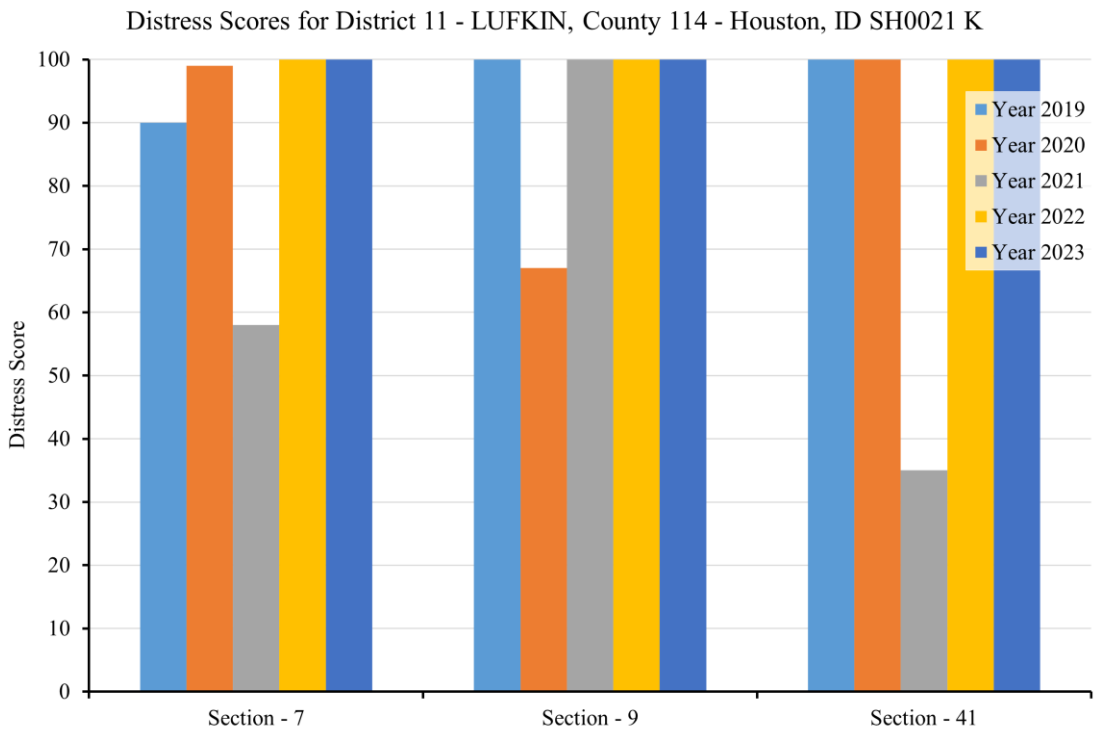


Figure 13. Sample of the Well-Fixed Sections in Lufkin: Fixed and Remain in Good Condition.

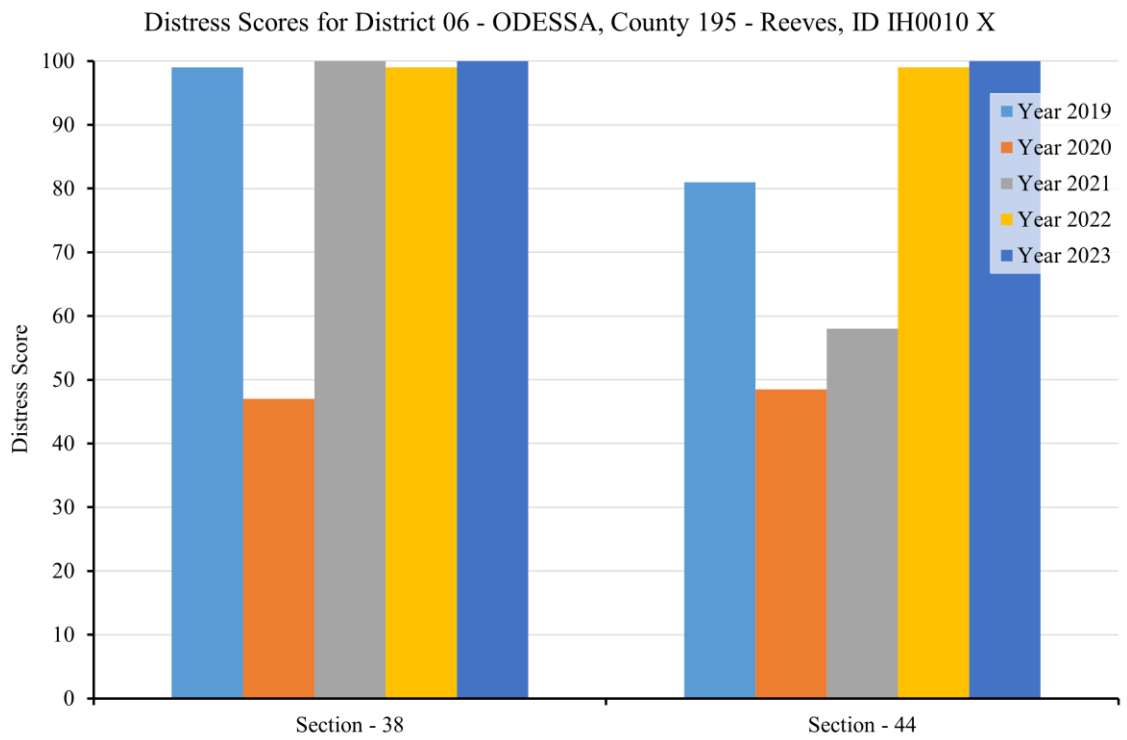


Figure 14. Sample of Well-Fixed Sections in Odessa: Fixed and Remain in Good Condition.

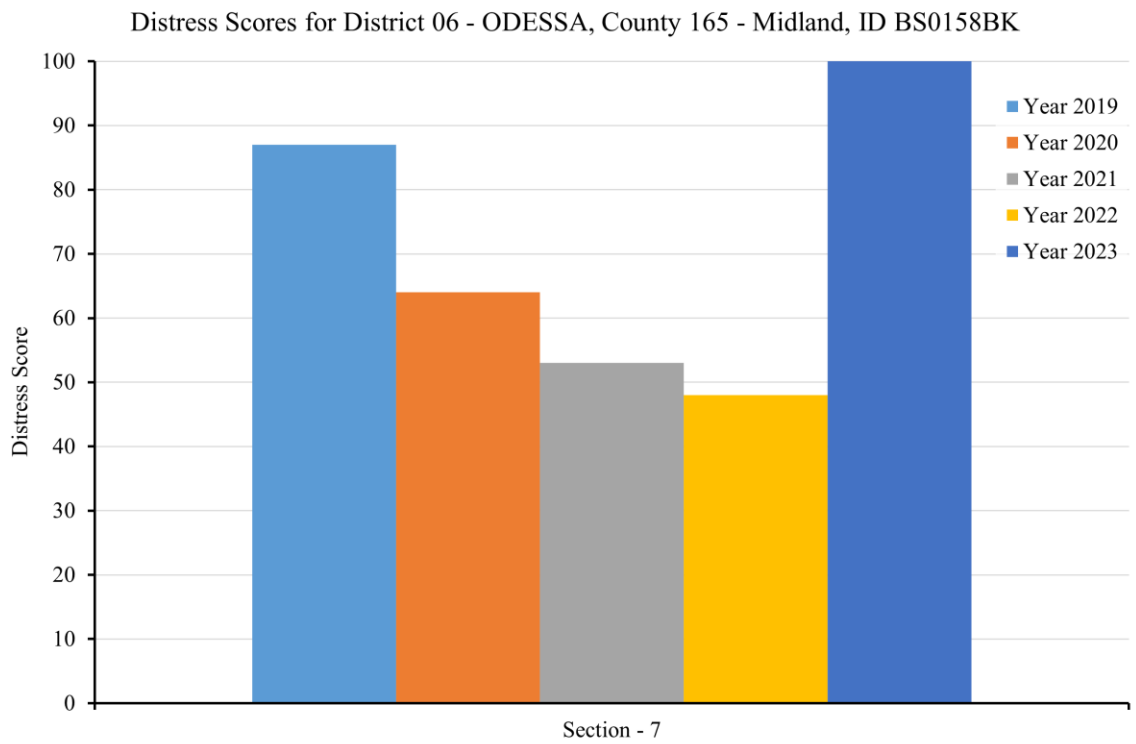


Figure 15. Sample of a Section in Odessa: Left to Deteriorate for Years Before Fixed 2023.

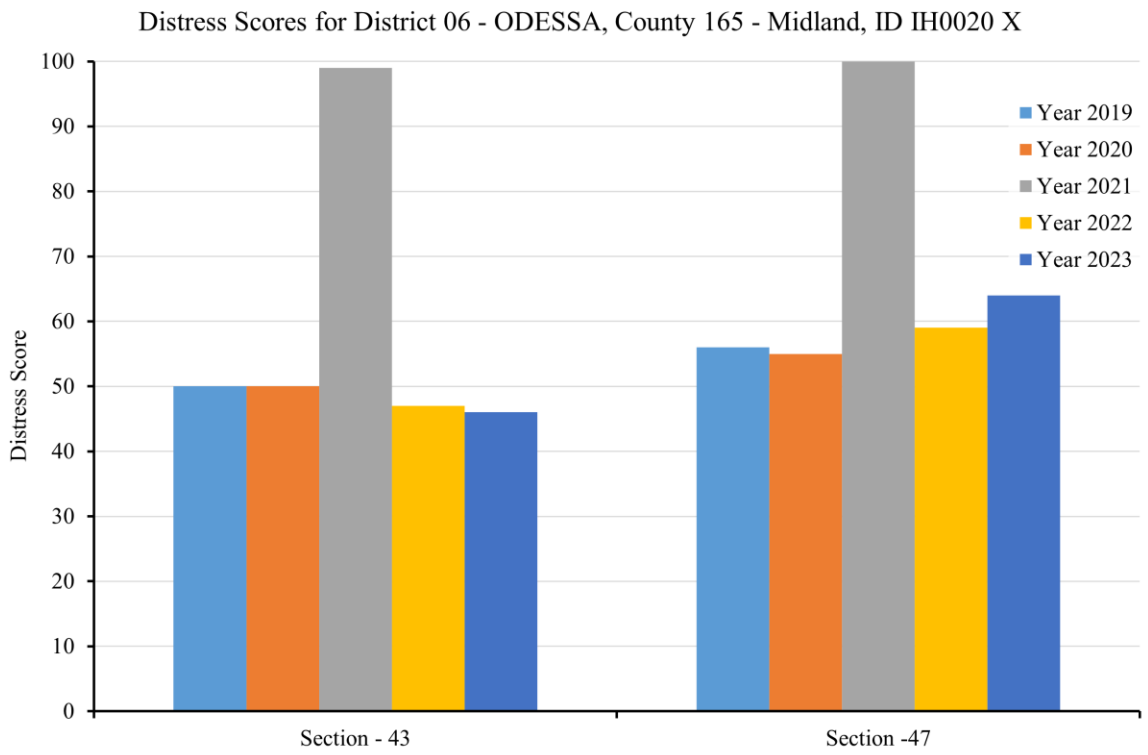


Figure 16. Sample of Poor Sections in Odessa Fixed and Failed.

SURVEY

An online survey was distributed to TxDOT districts to gather insights on maintenance practices and decision-making for preparatory repairs before PM. The survey targeted maintenance supervisors, pavement engineers, and other relevant personnel. The research team received 25 responses from 21 districts. Four districts—Houston, Laredo, Paris, and Corpus Christi—did not respond to the survey. Figure 17 shows participating districts, and Table 6 lists respondent locations and work areas.

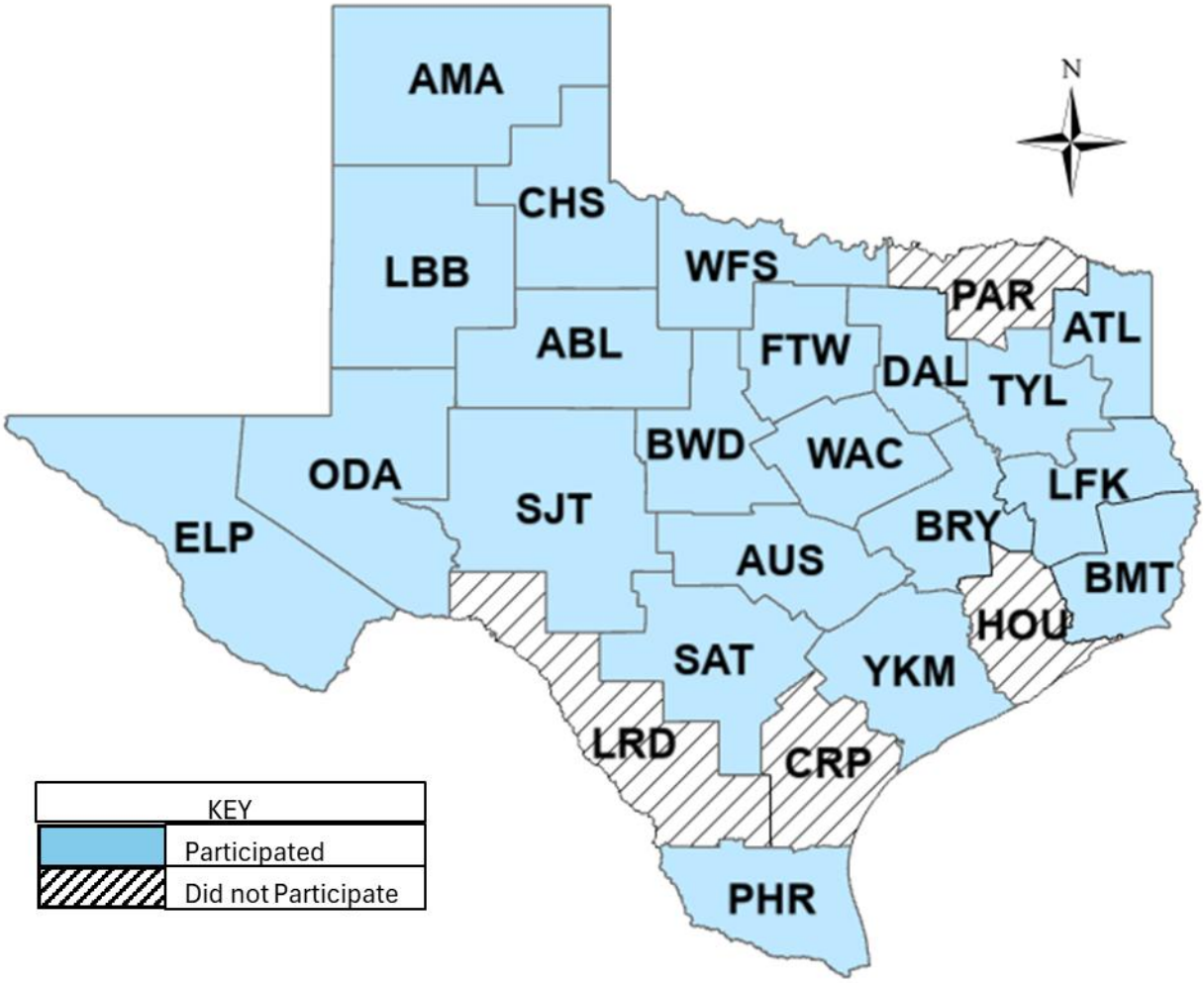


Figure 17. Responses to the Survey from Districts in Texas.

Table 6. Location of the Survey Respondents.

Work Area (e.g., Maintenance or Area Office)	Office Location (City or County)	District or Division
Maintenance	Waco, TX	Waco
District Operations	Odessa, TX	Odessa District
District Maintenance	Brownwood, TX	Brownwood
Pavement and Materials	San Angelo, TX	San Angelo
District Office	Fort Worth, TX	Fort Worth
Lubbock District	Lubbock, TX	Lubbock
Bryan District Lab	Bryan, TX	Bryan District
District Laboratory–District Construction	Pharr, TX	Pharr
Maintenance	Tyler, TX	Tyler District
El Paso District Office	El Paso, TX	El Paso
District Office	Yoakum, TX	Yoakum
District Office	Wichita Falls, TX	Wichita Falls
Maintenance	Austin, TX	Austin
Amarillo District	Amarillo, TX	Amarillo
District Maintenance	Abilene, TX	Abilene
District Maintenance	Atlanta, TX	Atlanta
District Maintenance	Beaumont, TX	Beaumont-20
Administration	Austin, TX	Austin
Maintenance	Lufkin, TX	District
District	Dallas, TX	Dallas
Maintenance	San Antonio, TX	San Antonio
District Office	Abilene, TX	Abelene
Maintenance, Traffic, Construction	Childress, TX	Childress

The survey primarily used a matrix format of questions, as shown in an example in Figure 18, to identify the current state of practice within TxDOT regarding the importance of different variables. The whole questionnaire, detailed responses, and analysis are attached in the appendix.

Q15 When considering how to repair a problem (the problem is listed on the left), do you consider how it will affect the new seal coat construction? For example, will I lose rock over the patch if I only level up the outside part of a lane?

	Always (1)	Most of the Time (2)	About half of the Time (3)	Sometimes (4)	Never (5)
Rutting (1)	○	○	○	○	○
Patching (2)	○	○	○	○	○
Failures (3)	○	○	○	○	○
Block Cracking (4)	○	○	○	○	○
Alligator Cracking (5)	○	○	○	○	○
Longitudinal Cracking (6)	○	○	○	○	○
Transverse Cracking (7)	○	○	○	○	○
Raveling (8)	○	○	○	○	○
Flushing (9)	○	○	○	○	○

Figure 18. A Sample of the Questionnaire.

The following summarizes the findings from the survey of maintenance and pavement personnel regarding preparatory repairs and practices used before PM projects. The extended responses can be found in the appendix. Key findings from the survey include:

- **Decision authority:** Maintenance supervisors make most repair decisions (43 percent) with input from pavement engineers for structural issues.
    - **Implication:** Decision-making is primarily decentralized to maintenance supervisors, with technical input from pavement engineering staff as needed.
- **PMIS data usage:** PMIS skid and distress scores are the most frequently used indicators for planning repairs (60 percent). Ride score and IRI were also reported as inputs to planning decisions.

- **Implication:** Safety and surface condition metrics (skid and distress) are dominant triggers for pre-PM repair planning, with ride quality indicators supplementing decisions.

- **Influence of flexible pavement distress on planning repairs:** Reported use of flexible pavement PMIS distress data was relatively even, with method selections ranging from 9 percent to 16 percent.
  - **Implication:** No single flexible pavement metric overwhelmingly dominates; districts apply a balanced set of indicators.

- **Factors influencing pre-PM repair type:** Visual observation and experience dominate decision-making (56 percent), followed by budget constraints (15 percent).
  - **Implication:** Field judgment is the primary driver, followed by available funding. Funding could also be a reason for less consideration to testing (e.g., ground-penetrating radar [GPR], falling weight deflectometer [FWD], etc.)

- **Factors influencing whether the repair is in-house or contracted:** Crew skill was the primary factor influencing this decision (38 percent), followed by budget (25 percent).
  - **Implication:** Internal capabilities and budget availability largely determine delivery mode (in-house vs. contracted).

- **Most common flexible pavement preparatory work types:** Level-up (hot mix), milling, and crack sealing are the most frequent preparatory repairs. Base repairs (to fix structural failures) and fog seals (to fix minor cracks, surface raveling, etc.) are used selectively. About 80 percent of responses indicate fog seal is typically applied to repairs when the cure time is limited before PM.
  - **Implication:** The respondents emphasize correcting the profile, sealing cracks, and applying structural patches before PM. This could also mean distress corresponding to the most mentioned repairs occurs frequently.

- **Material availability:** Seal coat aggregate and asphalt binder are universally available, while rejuvenated reclaimed asphalt pavement (RAP), lime rock asphalt, and specialty materials often face supply gaps.
  - **Implication:** Although seal coat inputs are easily accessible, supply gaps in several specialty materials affect the selection and timing of repairs.

- **Determination of repair size (i.e., length, width, and depth):** The primary approach is to fix visually distressed areas directly (**40 percent** of all selected approaches), with

limited iterative sizing analyses. Other considerations include the cost of repairs and the effect of size on PM performance.

  - **Implication:** Crews depend on practical, in-field sizing, whereas formal optimization is less frequently used.

- **Consideration of effects of pavement distress on new seal coat:** In general practice, the effects of distress are considered to a certain level. The survey indicates the most frequently considered distress interactions are rutting (14 percent) and failure (17 percent). Notable exception: One respondent never considered block cracking effects.

  - **Implication:** Interaction between repairs and the upcoming seal coat is acknowledged.

- **Cure Time:** Reported cure windows range from 0–18 months, depending on material type and climate. The respondent reported the following time frames to cure different materials.

  - Crack sealing: 0–18 months.
  - Patching materials: 4–18 months.
  - Hot mix asphalt (HMA): 1–18 months.
  - Spot surface repairs (seal coat/micro-surfacing): Minimum 0–4 months; practical upper bound ~18 months.
  - Structural repairs: 0–18 months.

  - **Implication:** Reported cure windows are broad and climate-dependent.

- **Post-construction evaluation:** The repair effectiveness is primarily assessed through visual inspection and next-year PMIS data; nondestructive testing (NDT) is rarely used.

  - **Implication:** Post-construction evaluation combines qualitative field assessment with subsequent PMIS indicators. There is a gap in utilizing non-destructive equipment to evaluate repair effectiveness.

- **Other challenges raised by respondents:** Respondents cited the following factors as sources of not achieving good quality and long-lived PM.

  - **Flushing:** Excessive flushing is prevalent; prevention during seal coat construction is preferred over reactive mitigation.
  - **Seal coat buildup:** Failures associated with cumulative seal coat lifts; many roads have at least two layers.
  - **External shocks:** Hurricanes/heavy rain can deplete budgets, materials, and personnel, limiting preparation time.

- **Emergency repairs:** Managed differently due to lack of preparation; explicit guidance is essential.
- **Truck traffic:** High volumes may require advanced materials not stocked by maintenance sections; temporary fixes are often used for rapid response.
- **Funding alignment:** Repair work related to PM (Category 1 or contracted) is generally included within the PM project.

SUMMARY

Chapter 2 analyzes PMIS data and survey responses to identify standard repair practices, decision factors, and constraints. The findings underscore the need for standardized decision frameworks, improved material access, and integration of NDT to enhance repair effectiveness and PM performance.

CHAPTER 3. PLANNING TOOLS AND PROCEDURES TO DETERMINE REPAIR AND LIMITS

OVERVIEW

This chapter outlines the planning, tools, and procedures used to determine the types of flexible pavement repairs and limits before PM treatments. It addresses essential aspects of repair planning, pavement evaluation, and other influencing factors such as traffic, weather, and drainage conditions. The goal is to ensure that repairs are properly scoped, executed, and cured to maximize PM performance and minimize premature failures.

REPAIR PLANNING

PMIS Data

As noted in the literature review, PMIS is a vital database that collects and maintains distress and condition scores for Texas pavements. Analyzing these data enables TxDOT to identify roads that need repair and develop suitable strategies. Some districts use GIS (or TxDOT's internal dashboard) to overlay pavement condition and distress scores on maps for visualization and to prioritize repairs. Others analyze PMIS data with Microsoft Excel, but the process can be overwhelming because the data are collected every 0.5 mile. To enhance the effectiveness of PMIS data, the research team has developed an algorithm that uses PMIS scores to assist districts in reviewing their data and prioritizing repair projects. The algorithm evaluates the performance of different pavement sections within counties. For example, the Brownwood District used the algorithm to review PMIS data across all counties by plotting and comparing 2024 and 2025 inputs; sections with a difference of 10 or more in condition or distress scores prompted further review (Figure 19). If no treatment or repair was performed on a section that showed a significant change over consecutive years, personnel were dispatched to verify the actual conditions or determine whether it was a data-collection error.

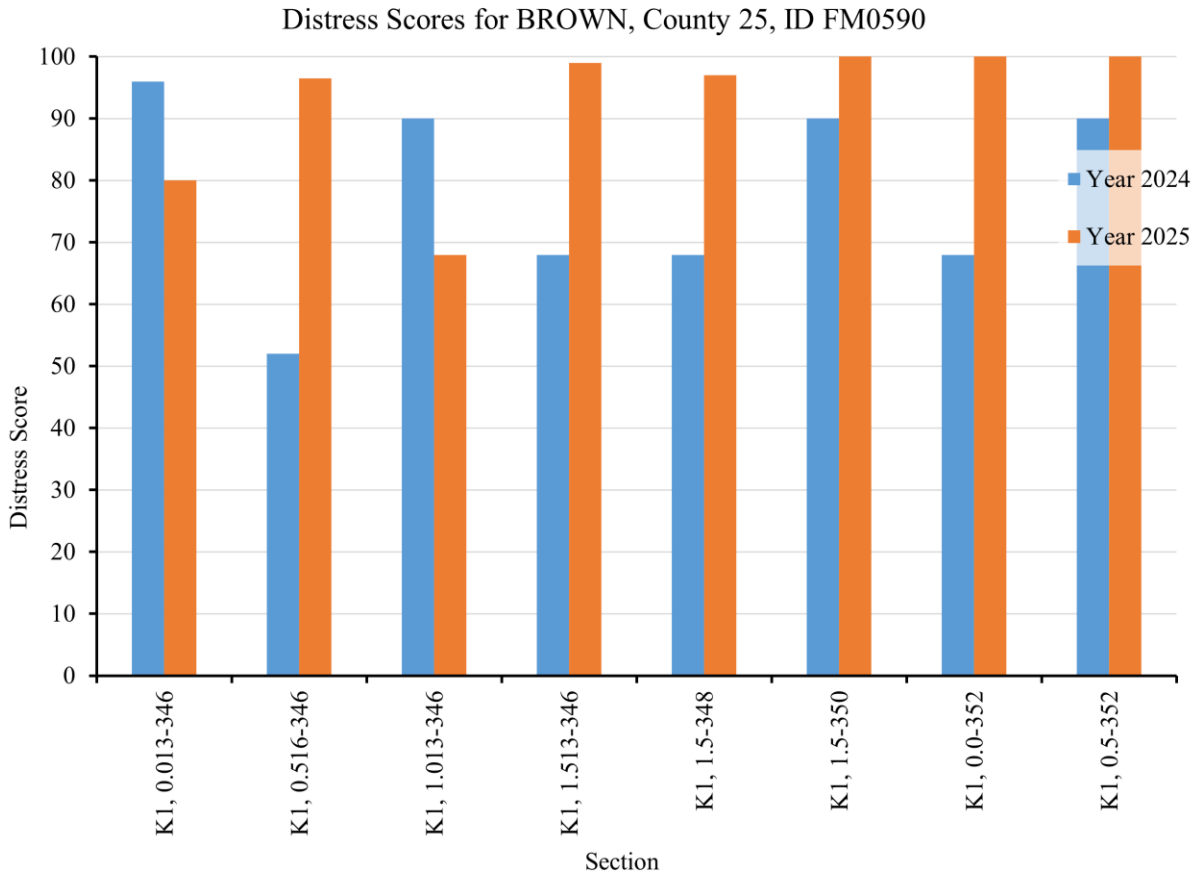


Figure 19. Distress Score for FM 0590 Brown County in Brownwood.

Grind Diagnostic

The Grind Diagnostic software is another tool used for planning repairs and preventive maintenance. It was developed by TTI and uses algorithms to analyze Profiler data to identify milling limits and level-ups (rut sections). Using its algorithm, Grind Diagnostic groups defects along both wheel paths to calculate a defect correction index (DCI), which indicates when correction is needed for localized roughness that affects ride quality. A DCI value above 0.7 suggests that defects should be corrected. Additionally, Grind Diagnostic can identify specific defect types within the correction group and match them with appropriate repair options. (Fernando et al. 2019). For example, if "bump" is the only defect, the software will suggest "grind only" as the best option. Conversely, if the defect type is "dip and bump," the optimal repair choice will be "mill and fill." Similarly, the software will recommend "spot overlay" as the best fix for a "dip." Additionally, the software can project the amount of materials needed and the total cost, which is crucial for budgeting.

Table 7 shows a demo summary of the repair options and their price. Grind Diagnostic includes a mapping utility to output maps of the results from the DCI (Figure 20) and cost analyses. The map more effectively communicates the locations of defects and whether corrections are

necessary based on the DCI threshold. Meanwhile, the research team is collaborating with the Bryan District to develop a case study that demonstrates the application of Grind Diagnostic software. Additionally, the team is closely assessing projects from other districts, including El Paso, San Angelo, San Antonio, Corpus Christi, Austin, and Abilene, to evaluate the effectiveness of the software.

Table 7. Grind Diagnostic Demo Display Summary.

	TxDOT Perspective				Contractor Perspective	
Repair Treatment	**Area (SY)**	**HMA (ton)**	**Total Cost**	**Cost per Repair**	**Contractor Cost Perspective**	**Cost per Repair**
Option 1: Grind Only	403	NA	$7,135.68	$285.43	$36,411.52	$1,456.46
Option 2: Mill and Fill	1089	90	$8,003.70	$2,000.92	$47,024.99	$11,756.25
Option 3: Overlay/Level Up	5632	465	$1,813.90	$7,953.48	$90,712.48	$22,678.12
Option 4: Spot Overlay	1160	96	$6,551.32	$1,637.83	$27,526.09	$6,881.52

Note: NA = not applicable.

Figure 20. DCI Analysis Map.

Traffic Volume and Weight

Traffic volume is a crucial metric for planning effective repair strategies. It is well known that high traffic volume, especially when combined with heavy vehicle weights exceeding a road's design capacity, can cause significant pavement damage. This damage often leads to deterioration in ride quality and worsens existing road conditions, resulting in issues like rutting, cracking, and uneven surfaces. In Texas, traffic data can be accessed from the TxDOT statewide planning map (https://www.txdot.gov/apps/statewide_mapping/statewideplanningmap.html). If excessive weight is suspected and supporting data are unavailable, a portable weigh-in-motion system can be used to gather traffic data over several days (at least seven days). This system allows for vehicle weight collection while in motion and can be quickly transported to different sites. Roads with high traffic volumes (usually average daily traffic above 10,000) may require extensive repairs to handle the current traffic levels.

Pavement Age

Old pavements are vulnerable to repeated failures, including structural failures, which may require expensive and comprehensive repairs. A combination of GPR and FWD data may be used to determine whether the pavement is still structurally sound.

Pavement Repair History

Another factor that influences the selection of the best repair strategy is its performance history. It is essential to document which strategy did not work during previous efforts and, more importantly, to identify the alternatives. This information is critical for future repairs and must be documented in the district pavement standard operating procedures (SOP).

Weather Conditions and Drainage

Local weather conditions (i.e., temperature, precipitation, humidity, etc.) and pavement drainage are among the key factors influencing the selection of the most effective strategy for repairing pavement. For example, Texas's high temperatures can cause asphalt to soften and expand, leading to deformation under traffic loads and reduced repair effectiveness. In this scenario, a repair strategy should consider using asphalt designed to withstand high temperatures and working early in the morning or late evening to avoid the extreme heat that can compromise compaction efforts and the quality of the repairs. Moisture and water from rain and humidity, combined with poor pavement drainage, can also damage or exacerbate existing damage, making repairs more difficult and expensive. Thus, ensuring an adequate drainage system to prevent water accumulation on the pavement is essential. Weather and climate information can be found on the National Oceanic and Atmospheric Administration website (https://www.noaa.gov/weather). Likewise, drainage issues can be identified through visual inspection or feedback from maintenance personnel.

Seasonal weather patterns may also affect the severity of the deteriorations and can lead to issues like longitudinal cracking and loss of ride quality. For example, during high rainfall seasons subgrade containing clay with high plasticity index (PI) will swell leading loss of ride quality and conversely during low rainfall seasons the high PI clays will shrink and crack. Another example, during low rainfall season the presence of vegetations (e.g., trees) will draw water from clay resulting in crack patterns that mimic the shape of the dripline of the tree.

Visual Inspection

Visual inspection aims to identify major distresses such as alligator cracking, longitudinal and transverse cracking, potholes, rutting, raveling, shoving, and other signs of deterioration (see Table 8). During this process, the inspector will detail the severity of distress using an acceptable TxDOT scale (e.g., low, moderate, and high) (Miller and Bellinger 2014). The inspector can also identify locations that require extensive investigation using specialized equipment (e.g., NDT, coring, etc.). The visual inspection may involve marking the boundaries of the area to be repaired. To ensure proper repair, the limits are typically extended into a structurally sound section of the pavement, usually a minimum of 12 inches. Additionally, TxDOT construction specifications for HMA require that the longitudinal joints be offset on successive courses by at least 6 inches and that the longitudinal joint on the surface course coincide within 6 inches of the lane lines, avoiding placement in the wheel path (WP). The Table 9 contains the typical WP locations based on the lane width. WPs are assumed to be 3 feet wide in all lanes. **The measurements shown are from the left edge of the lane across to the right edge of the lane**.

Table 8. Typical Distresses for Asphalt Pavements.

Item #	Distress	Measurement
1	Potholes	Square yard
2	Raveling	Square yard
3	Rutting	Square yard
4	Alligator or Fatigue Cracking	Square yard
5	Longitudinal and Transverse Cracking	Linear feet
6	Depression	Square yard
7	Stripping	Square yard
8	Edge Failure	Square yard
9	Shoving	Square yard
10	Block Cracking	Square yard
11	Patching	Square yard

Table 9. Typical Wheel Path Locations.

Lane Width (ft)	Left Outside Width (ft)	Left WP Width (ft)	Between WP Width (ft)	Right WP Width (ft)	Right Outside Width (ft)
9.00	0.00	3.00	2.00	3.00	1.00
10.00	1.00	3.00	2.00	3.00	1.00
11.00	1.33	3.00	2.00	3.00	1.66
12.00	1.66	3.00	2.70	3.00	1.77
13.00	2.30	3.00	2.70	3.00	2.00

PAVEMENT EVALUATION TOOLS

Pavement inspection and evaluation for repairs involves a detailed assessment of a road surface to identify existing damage, determine the severity of distress, and analyze the underlying causes to recommend the most suitable repair strategies, including the type of repair needed and the extent of work required based on the identified issues. The assessment is typically carried out using visual surveys; however, NDT tools and core sampling can reveal the extent of damage at depths that visual inspection cannot reach.

Pavement evaluation tools are available to measure a pavement's functional and structural properties. Structural properties include pavement and subgrade stiffness, pavement layer thicknesses, pavement layer condition, and load transfer (for concrete pavement). Functional properties include roughness, rut depth, geometry, skid resistance, and noise. The following are the NDT tools available to TxDOT for pavement assessment.

FWD and Dynamic Cone Penetrometer (DCP). If structural deficiencies are suspected, the FWD should be used. The FWD uses the deflection of pavement (due to dropping a weight onto a pavement surface) to determine the pavement's structural integrity. The FWD measures the stiffness of pavement layers. Figure 21 shows a road project with a significant variation in strength (Liu and Scullion 2001). Another piece of equipment that can measure stiffness is the DCP. DCP tests often complement the FWD to verify the base/subbase and subgrade moduli. The DCP uses the penetration depth per blow to assess the in-situ strength of undisturbed soil or compacted materials. Figure 22 shows a typical DCP test and its results.

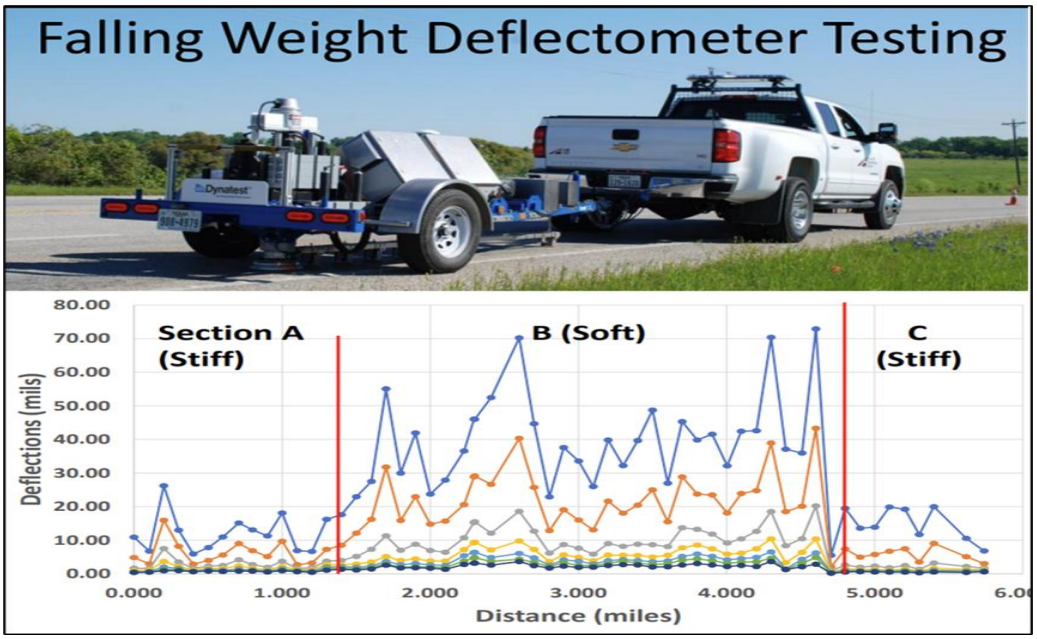


Figure 21. FWD Testing.

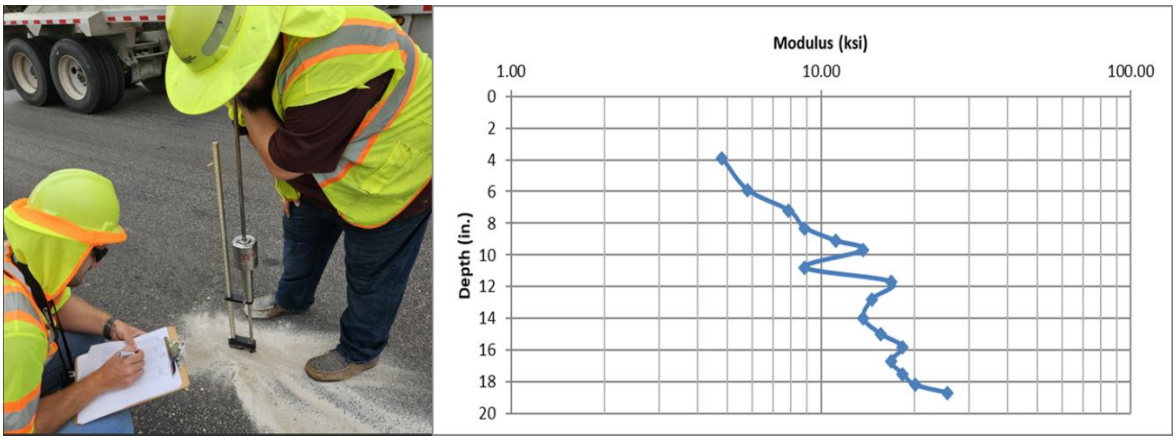


Figure 22. DCP Testing.

GPR. The GPR is used to identify pavement layer thicknesses, potential areas of deterioration, and the limits of the defects. The GPR can estimate the density within HMA layers and identify existing moisture and defects in HMA, such as stripping and segregation. A data-integrating analysis software, PaveCheck, is used to communicate the GPR data to users. The software integrates a video with a color plot of the waveforms. Through GPR data, engineers can identify poor sections along the road and deploy FWD tests and coring at specific points (Figure 23) (De Carteret 2009).

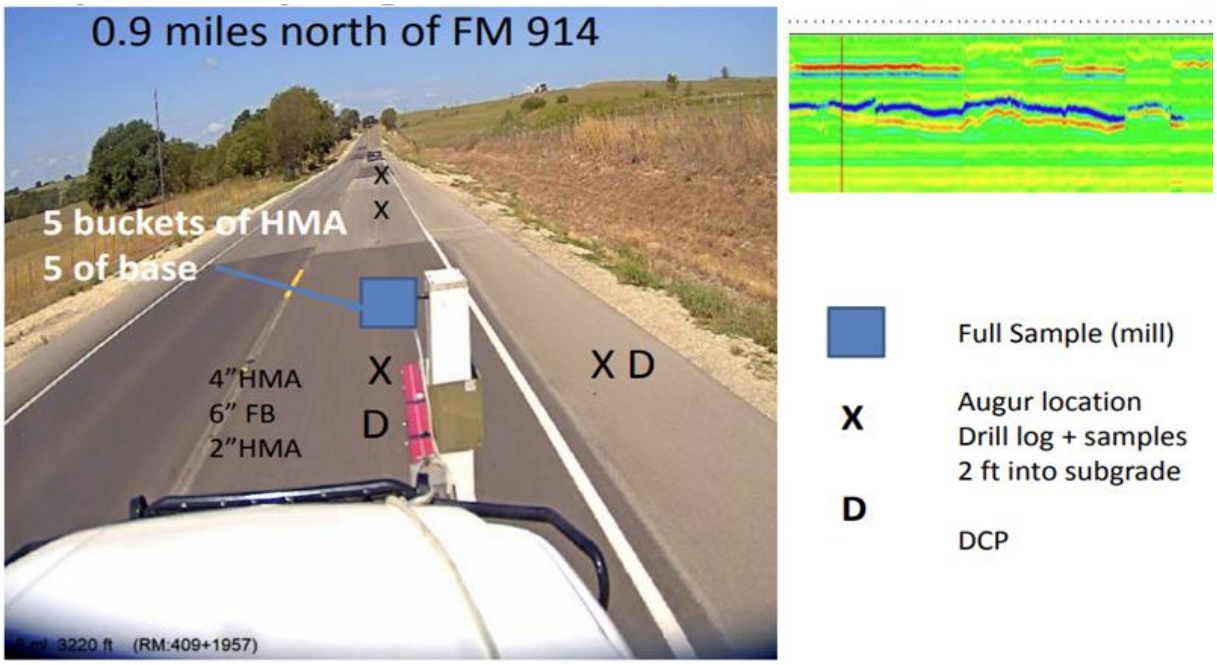
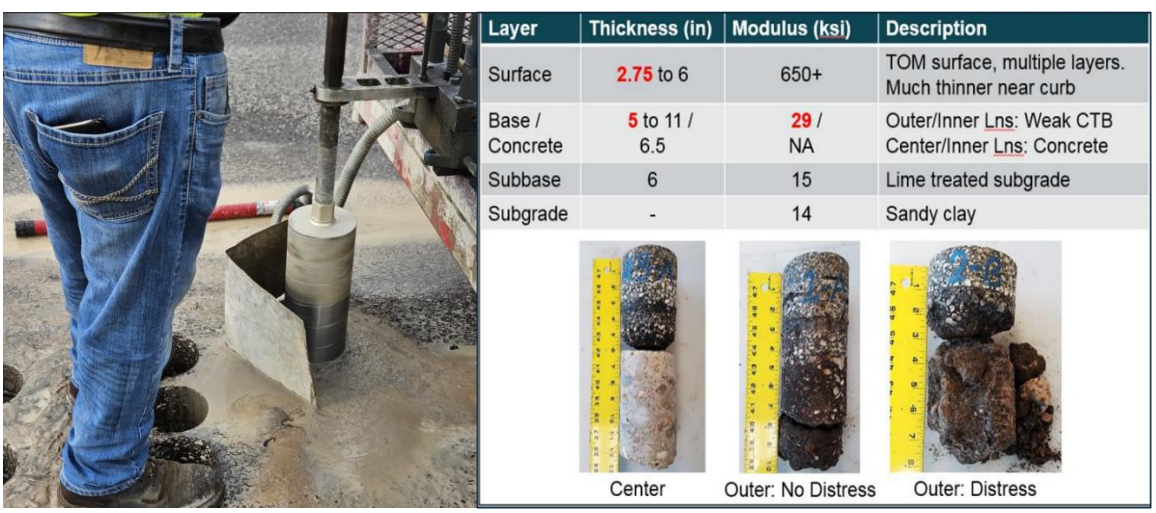


Figure 23. GPR.

Coring. The pavement and subgrade sampling coring device is typically mounted to the back of a truck to gain support and perform heavy-duty coring. Pavement cores are typically extracted to assess the extent of damage or verify NDT findings (e.g., GPR). Core inspection can identify the extent and size of cracks, as well as determine the composition of the pavement layers and materials. Figure 24 shows the coring process and reported examples from previous projects (Goehl et al. 2021).



Layer	Thickness (in)	Modulus (ksi)	Description
Surface	2.75 to 6	650+	TOM surface, multiple layers. Much thinner near curb
Base / Concrete	5 to 11 / 6.5	29 / NA	Outer/Inner Lns: Weak CTB Center/Inner Lns: Concrete
Subbase	6	15	Lime treated subgrade
Subgrade	-	14	Sandy clay

Figure 24. Coring Process and Report.

Inertial Profiler. The inertia profiler can be used to determine the pavement's functional properties. It measures the longitudinal and transverse roughness statistics at highway speeds. The measurements are taken in real time and quantified into two indices: the serviceability index

(SI) and the IRI. This equipment can also identify locations of localized roughness, bumps, and dips. The SI is an input into the flexible pavement design software FPS-23. The inertial profiler is shown in Figure 25.

Figure 25. Inertial Profiler.

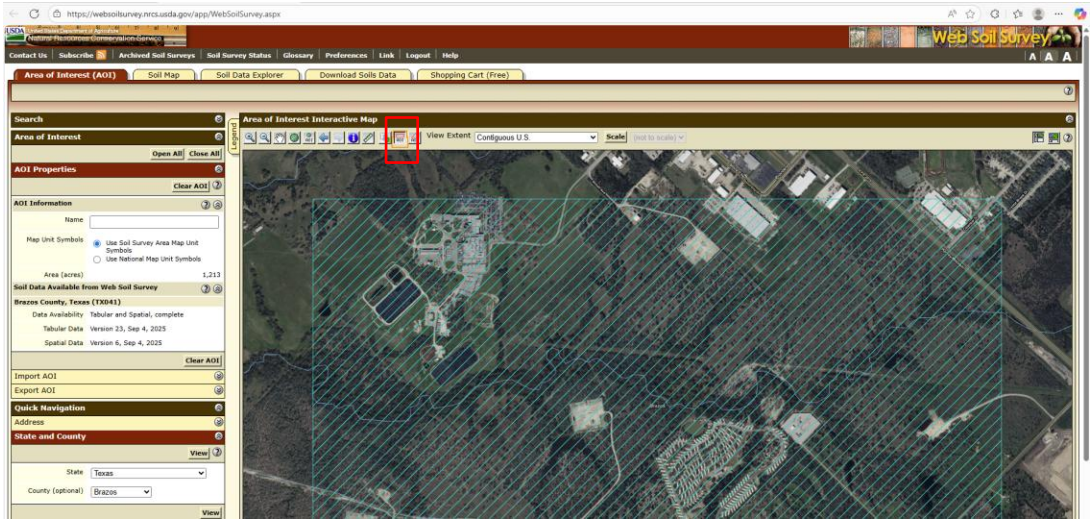
U.S. Department of Agriculture (USDA) Web Soil Survey (WSS). This free online tool provides information about soils in the United States. The USDA Natural Resources Conservation Service (USDA 2025) controls information and access to the website. Pavement engineers can incorporate the soil characteristics from this site into their construction plans or identify potential areas of concern. Engineers can make timely decisions to assist with field sampling locations due to the availability of data and the ease of analysis. The engineers can deduce soil chemical and physical properties, underground water levels, and other properties. The steps for gathering data using WSS are as follows:

1. Go to https://websoilsurvey.nrcs.usda.gov
2. Click Start WSS

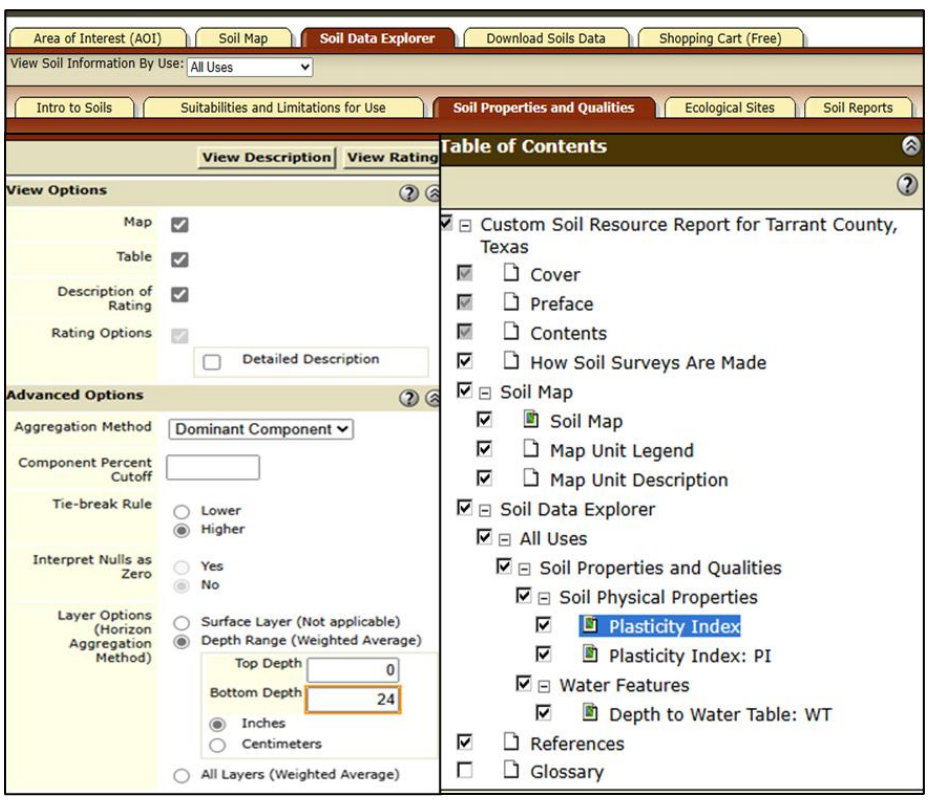
3. Establish area of interest (AOI)

    1. Use any listed method (e.g., address, latitude, longitude, etc.)

2. Use the AOI rectangle or polygon tool to draw the AOI



4. Go to Soil map to see the types and locations of soils within the established POI
5. Go to Soil Data Explorer, then Soil Properties and Qualities



1. Plasticity Index (Physical Properties)

   i. Set depths
   ii. Select view rating
   iii. Add to shopping cart

2. Gypsum (Sulfate chemical properties)

    i. Set depths
    ii. Select view rating
    iii. Add to shopping cart

3. Water Tables (Water features)

    i. Select view rating
    ii. Add to shopping cart

4. Organic material (physical properties)

    i. Set depths
    ii. Select view rating
    iii. Add to shopping cart

6. Go to the shopping cart and check out the report

    1. Choose Download Later
    2. Enter your email address for the download

PAVEMENT EVALUATION PROCEDURES

After describing the repair plans and the tools needed for pavement evaluation, this section covers point-by-point details of the field-testing plans and sampling materials for further lab evaluation. It is important to review all existing data before determining new data requirements. As-built plans, specifications, and estimates (PS&E), Pavement Analyst (PA)/PMIS data, soil reports, and pavement design reports are among the most common sources of information. WSS serves as a reliable source for soil properties.

Testing Plan

This is a phased plan and will be dynamic and change as information is gathered and analyzed.

Phase 1. Background and Non-Destructive Testing

1. Collect and assess background information, including but not limited to the current typical section, proposed typical section, and WSS subgrade information.
2. It is advised to conduct a GPR with a high-definition video survey of the pavement; however, this is not necessary for the design method.

    a. Determine locations and limits of the survey.

b. Locations should include travel lanes, turn lanes, shoulders, medians, and non-standard areas such as crossing longitudinal joints, etc.

3. Using the information from Step 1 and Step 2, create a plan for FWD testing and other NDT.

    a. A minimum of 30 drops per consistent pavement structure, with a maximum spacing of 0.1 miles between drops. If there is variation in the pavement structure, additional FWD drops may be required.
    b. At intersections or other small projects, all lanes may need testing to collect a minimum of 30 drops within the project limits.

4. Assess if additional testing systems are necessary.

    a. Identify the locations and limits for each testing method. The locations should encompass the typical area to be tested, including travel lanes, turn lanes, shoulders, medians, and non-standard collection points (e.g., across joints).

Phase 2. Field Sampling and Testing

1. Using Phase 1 information, determine a field sampling and testing plan for pavement and soils.

    a. Depending on the type and variability of the material, the locations and number of soil samples may differ from those for pavement.
    b. Review the pavement and subgrade sampling and testing plan, including traffic control, and assist with organizing and providing traffic control.

        i. In general, sampling locations should be in an accessible area.
        ii. When determining the locations, always avoid overhead power lines and underground utilities. If possible, avoid steep slopes and standing or flowing water.
        iii. Deviations within a 50 ft radius of the designated locations are generally not excessive; however, make sure to note adjustments in the logs, including sufficient information to describe the adjustment and its reasoning.

    c. Follow Tex-100-E, "Surveying and Sampling Soils for Highways," and Tex-141-E, "Manual Procedure for Description Identification of Soils," for field sampling and logging information.

2. Perform additional non-destructive testing that may require traffic control as appropriate for the survey objective and include with the sampling plan:

a. Ground-coupled GPR, antenna frequency range 200 MHz to 2.5 GHz.
b. DCP.

3. In general, obtain the quantity of material shown in Table 10 for laboratory testing of subgrade or base. Additional material may be needed.
   a. In Table 10, the container described as a "bag" is a plastic sample bag that holds up to 15 pounds of material and is typically 10.5 inches by 18 inches in size.
   b. In Table 10, the container described as a "bucket" is a 5-gallon plastic bucket that holds up to 45 pounds of material, or a 14-inch by 25-inch canvas sample sack may be used.
   c. While collecting the samples from the field, in situ moisture within the sample should be protected.

Table 10. Material Sampling Quantities.

Test Method	Title	Sample Container	Quantity
Tex-103-E	Moisture Content	Bag	1
Tex-104-E[1]	Liquid Limits	Bag	1
Tex-105-E[1]	Plastic Limit	Bag	1
Tex-106-E[1]	Plasticity Index	Bag	1
Tex-107-E[1]	Bar Linear Shrinkage	Bag	1
Tex-110-E	Particle Size Analysis	Bucket	1
Tex-113-E	Moisture-Density Relationship for Base	Bucket	3
Tex-114-E	Moisture-Density Relationship for Subgrade, Embankment Soils, and Backfill	Bucket	3[2]
Tex-116-E	Ball Mill Method	Bucket	1
Tex-117-E Base	Triaxial Compression—Base	Bucket	4[3]
Tex-117-E Soils	Triaxial Compression—Disturbed Soils	Bucket	5[3]
Part I of Tex-120-E, Tex-121-E, Tex-122-E, Tex127-E, or Tex-134-E	Laboratory Mix Design for Treatment	Bucket	9[4]
Part I of Tex-120-E, Tex-121-E, or Tex127-E	Stabilizer: Lime, Cement, or Fly-Ash	Bucket	1/2
Tex-122-E	Stabilizer: Emulsion	Bucket[6]	1
Tex-134-E	Stabilizer: Foamed Asphalt	Bucket[7]	2
Tex-128-E	Determining Soil pH	Bucket	1/2[8]
Tex-129-E	Resistivity of Soil	Bucket	1[8]
Tex-145-E	Sulfate Content—Colorimetric Method	Bag	1[9]
Tex-146-E	Conductivity Test for Field Detection of Sulfates	Bag	1
Tex-148-E	Soil Organic Content Using UV-Vis Method	Bag	1

[1]Tex-104-E (or Tex-107-E), Tex-105-E, and Tex-106-E are performed as one test. The one bag is enough for all methods—you do not need a bag for each method.

[2]If material has 100 percent passing the 3/8 inch sieve, only one bucket is needed.
[3]Do not forget to sample for moisture-density curve (additional three buckets).
[4]When existing surfacing is greater than 2 inches thick, separate RAP from base material. Obtain a representative portion of RAP and base for a minimum of nine buckets. (Example 4-inch hot mix + 6-inch base, use 3 1/2 buckets for RAP and 5 1/2 buckets for base).
[5]Lime, cement, or fly ash (minimum of 25 pounds). Lime and fly ash samples need to be stored in airtight containers. Make sure the lid is secured tightly.
[6]Emulsion (minimum of 3 gallons).
[7]Asphalt such as PG64-22 for foamed asphalt (minimum of 10 gallons).
[8]Only one bucket is needed when Tex-128-E and 129-E are performed at the same time.
[9]If performed in field, minimum sample size is 300 grams.

Phase 2a. Pavement Sampling

Determine the number of locations, depth, and quantity of material to be obtained. Consider the following when developing the field plan:

1. Review potential pavement design strategies or a combination of strategies.
    a. Refer to TxDOT's *Treatment Guidelines for Soils and Base in Pavement Structures* found at http://ftp.dot.state.tx.us/pub/txdot/mtd/treatment-guidelines.pdf.
2. Determine the location of testing. Designate enough locations to establish typical pavement conditions, significant pavement changes, and potential problem areas. Also, consider testing locations needed for the various design strategies.
    a. Review the existing and proposed geometric design and the number of proposed roadbeds.
        i. Review existing and proposed typical sections.
        ii. Review existing and proposed vertical and horizontal alignments.
    b. Determine the complexity of the existing pavement structure.
        i. Review existing data (e.g., as-built PS&E, PA data, design, construction and maintenance records, and pavement design reports).
        ii. Analyze NDT such as GPR, FWD, Total Pavement Acceptance Device, light detection and ranging (LiDAR), electrical resistivity tomography, and inertial profiler.
        iii. Determine variability of:
            (a) Layer thickness.
            (b) Material changes by layer and along the project.
            (c) Condition of existing materials (i.e., presence and extent of defects).

3. Obtain samples of each layer of material within the pavement structure to the top of the subgrade (refer to Phase 2b for subgrade sampling), including treated subgrade at each location.
4. Log each pavement layer, recording the layer thickness and visual condition. Take photos of the materials.
5. Along with the field sampling, include spot-specific testing such as DCP.

Phase 2b. Subgrade Sampling

Determine the number of locations, depth, and quantity of material required for soil exploration. Consider the following when developing the field plan:

1. Location of testing: Designate enough locations to establish the subgrade's typical condition and identify potential problem areas. Consider the following when determining locations:

    a. Complexity of geological conditions.

        i. Review existing data such as WSS.
        ii. Review existing TxDOT as-built project soil reports.

    b. Whether testing has already been conducted.

2. Depth of testing (reference the appropriate test procedure) based on the criteria being evaluated.

    a. Tex-124-E, "Determining Potential Vertical Rise": Sample a soil column a minimum of 15 feet deep as measured from the top of the proposed untreated natural subgrade elevation unless the TxDOT district-specific SOP revises the depth of soil column. When the SOP revises the depth of the soil column, use the district-specific requirement.
    b. Pavement design information: Sample a soil column at least 2 feet deep from the top of the proposed subgrade. If an embankment is needed to meet the profile, measure from the top of the existing soil. When excavation is necessary, sample and test the material for suitability as an embankment. Review potential laboratory testing requirements and gather enough material to perform these tests.

3. Log samples and take them to the laboratory for further testing.

Phase 3. Laboratory Testing

1. Develop material logs: Use information from Phase 2 and perform laboratory testing to describe the engineering properties of the subgrade and pavement.

2. Design testing: Perform testing required for the proposed pavement design strategies.

Documentation

Document the testing plan, including the following:

- Resources and references used to develop the testing plan.
- Location of tests.
- Type of test.
- Date of testing.
- Name of person(s) that performed the test.
- Quantity of material sampled.
- Material logs.
- Testing data.
- Testing results (data analysis).
- Recommendations.

OTHER CONSIDERATIONS FOR PLANNING REPAIR

Projected Adverse Effects of Repairs on Seal Coat

If the repairs are not performed correctly, they can damage the PM. For example:

Bleeding/Flushing: If the patches are not properly cured or the seal coat asphalt rates are not adjusted, the patches can absorb the seal coat asphalt, leading to rock loss, bleeding, and flushing. Specifically, large level-up sections or big patches may complicate seal coat application due to an increased risk of bleeding or flushing (Goehl et al. 2022; Gransberg and Pidwerbesky 2007). Special operations, such as ultra-high-pressure (UHP) water retexturing, can remove excess binders before applying the seal coat (Figure 26). In a pilot study at the TTI RELLIS campus, researchers demonstrated that hydroblasting can remove excess asphalt from pavements (Estakhri 2010). The study was based on TxDOT Research Project 0-5230 (Lawson et al. 2007). Alternatively, the seal coat binder spray nozzle can be adjusted during operation. However, a practical challenge is that the distributor will travel over 50 feet in the section before adjusting the rate. In other words, the spray rate does not change immediately after a switch flip.

PM Surface Unstable Due to Excessive Repatching/Resurfacing: Excessive layers tend to destabilize the pavement. Some survey respondents (Chapter 3) indicated that this issue exists in certain PM projects. However, a recent project, TxDOT 0-7106, conducted by TTI on behalf of TxDOT, demonstrated that a ball penetration test (used in New Zealand and South Africa) can be employed to assess whether stability issues are present and if adjustments are needed during the seal coating process (Goehl et al. 2025). Figure 27 shows the typical requirement for adjusting the seal coat based on the ball penetration test (Goehl et al. 2025).

Surface Irregularities: Poorly leveled patches can result in bumps or dips. These irregularities impair the uniform application of the seal coat, leading to premature wear and decreased ride score.

Inconsistent Seal Coat Bonding: The seal coat may not adhere properly if the repair materials (especially cold mix) are not fully cured or compacted. This can lead to the seal coat peeling off in the patched areas.

Material Incompatibility: Certain patching materials (e.g., oil-rich cold mixes) may be incompatible with the seal coat emulsion, potentially leading to bleeding, tracking, or seal coat failure in those areas.

Moisture Entrapment: If repairs trap moisture or are done in damp conditions, applying a seal coat too soon can seal in moisture, leading to stripping, blistering, or early deterioration.

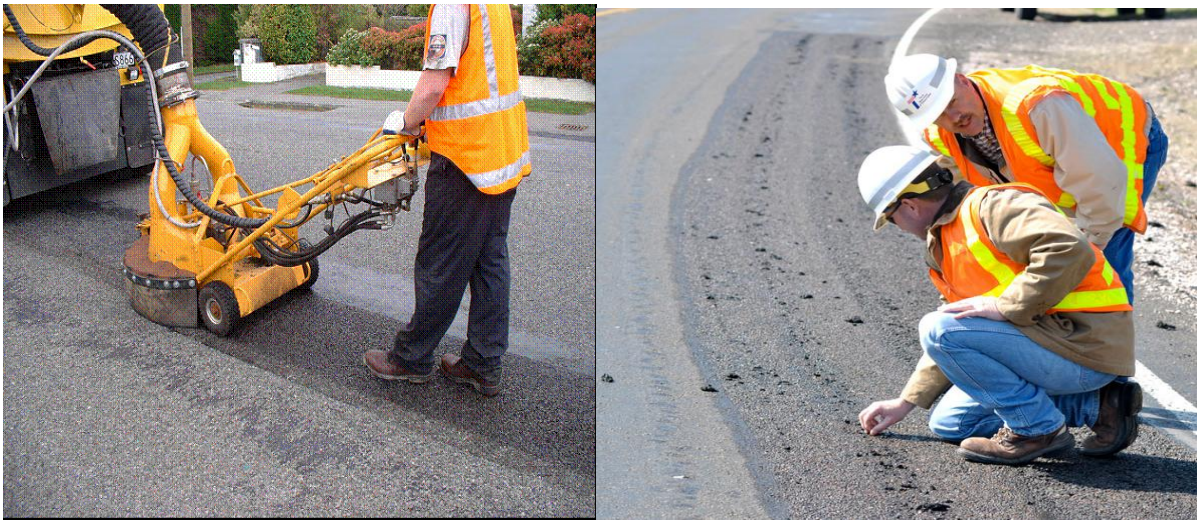


Figure 26. Hydro-Blasting Equipment.

Ball Penetration Test Result	Corresponding Action
< = 0.039 inches (1 mm)	0.039 inches (1 mm) adjustment to mat thickness for application rate on new seal coat.
> 0.039 inches (2 mm) to 0.118 inches (3 mm)	No adjustment.
0.118 inches (3mm) to 0.157 inches (4 mm)	-0.039 inches (-1 mm) adjustment to mat thickness for application rate on new seal coat.
> 0.197 inches (5 mm)	Repair pavement instead of seal coat.

Figure 27. Ball Penetration Test.

Regarding materials, relatively softer binders, such as RC 250, should be avoided in repairs under seal coat operations. Since the seal coat is applied at a higher temperature (350 °C), it may soften the repair binder and, through capillary action, absorb part of it.

Best Practices to Minimize Adverse Effects

Based on the district survey responses, the literature, and the evaluation conducted in this study, the research team suggests the following practices to minimize the adverse effects of repair on PM.

- Allow sufficient curing time for patches before sealing.
- Make sure to use compatible materials for repairs.
- Ensure surfaces are level and compacted.
- Thoroughly clean and dry the surface before applying the seal coat.
- Consider applying a fog seal or tack coat over patches to enhance bonding. For additional information, refer to the seal coat design method.
- Consider using the Ball Penetration Test to assess the stability of the layers.
- Consider using UHP to remove excess binder on bleeding patches or to level up sections.

Contractor Versus In-House Repair

Depending on the availability of maintenance crew personnel, the extent of the repair, and the budget, pavement repairs can be handled by an in-house crew or a contractor. According to the TxDOT district survey conducted under Task 3, in-house crews are excellent at spot repairs, level-up, and spot seals. Similarly, contractors can effectively handle longer and higher-volume spot repairs and roadway rehabilitation.

SUMMARY

This chapter provides a comprehensive framework for planning and executing flexible pavement repairs before PM. It covers data-driven decision-making using PMIS and diagnostic tools, factors influencing repair strategies (e.g., traffic, age, and weather), inspection and evaluation methods, and phased testing plans. Adequate curing, proper preparation, and strategic contractor engagement are critical for successful outcomes.

CHAPTER 4. REPAIR METHOD, CONSTRUCTION TIMING, AND CURING WINDOW

OVERVIEW

This chapter outlines asphalt pavement repair techniques, from preventive measures such as crack sealing and fog sealing to structural solutions including overlays, base repairs, and FDR. It also highlights the importance of proper construction timing to ensure material performance and durability.

ASPHALT PAVEMENT REPAIR METHODS

Crack Seal

Crack sealing is a PM method that involves filling cracks with adhesive materials to prevent water intrusion and slow crack growth. The process begins with cleaning the cracks using air blasting or a hot air lance, and when needed, routing them to create a reservoir for the sealant. It is suitable for cracks wider than 1/8 inch and works well in all climates, especially when done during colder months to allow proper curing. Crack sealing is cost-effective and prolongs pavement life, but excessive use can hurt ride quality and may not be suitable for pavements with severe cracking (TxDOT 2024a; b).

Fog Seal

Fog seal involves lightly spraying diluted asphalt emulsion directly onto the pavement surface without using aggregate. It is typically applied with an asphalt distributor and effectively treats minor cracks, slight raveling, and early fatigue cracking. Fog seal slows oxidation and hardening of the asphalt, helping to prevent moisture infiltration. While it is inexpensive and easy to apply, it does not increase structural capacity and may decrease skid resistance if overused. Its lifespan is relatively short, usually lasting one to three years (Maher et al. 2005; TxDOT 2024a; b).

Seal Coat (Chip Seal)

A seal coat involves spraying asphalt binder followed by spreading and rolling aggregate to form a protective surface layer. This treatment effectively addresses light to moderate cracking, raveling, and flushing, and creates a waterproof membrane that shields underlying layers from moisture damage. Seal coats are commonly used on low- to moderate-traffic roads and perform well in warm, dry conditions. Although cost-effective and durable, it does not enhance pavement structural capacity and may pose hazards from loose aggregate (SDDOT 2010; Wu et al. 2010).

Scrub Seal

The scrub seal is similar to a chip seal but uses a broom to scrub polymer-modified asphalt into surface cracks before applying aggregate. This method is suitable for pavements with numerous

fine cracks but no structural failure. It improves surface texture and seals cracks effectively, though it does not address potholes or severe rutting. Scrub seals are quick to apply and allow traffic to resume within an hour, with a typical lifespan of six to seven years when properly applied (PPRA 2025; TxDOT 2021a).

Level-Up and Overlay

Level-up patching involves applying a thin asphalt layer over ruts or depressions to restore the profile and cross-slope. It is often combined with an overlay for extra structural strength. This technique works well for shallow rutting, minor dips, and edge drop-offs. While it enhances ride quality and helps extend pavement life, it does not address deep structural failures. The performance lasts from 1 to 3 years when used alone, and up to 17 years when combined with an overlay (ODOT 2011; TxDOT 2021a, 2024a; b).

Mill and Overlay

This method involves milling away part of the existing asphalt surface and then applying a new overlay. It proves effective for medium- to high-severity cracking, raveling, and rutting, restoring ride quality and increasing structural capacity. Although highly effective, it requires specialized equipment and comes with a higher initial cost. The lifespan typically ranges from 3 to 17 years, depending on design and traffic conditions (ODOT 2011; TxDOT 2021a, 2024a; b).

Base Repair and Seal

Base repair involves removing failed base material, replacing it with suitable material, and restoring the surface with asphalt before applying a seal coat. This method addresses localized structural failures such as alligator cracking and rutting. It is durable and enhances structural integrity, but it is not suitable for widespread failure. The treatment generally lasts three to eight years (Maher et al. 2005; ODOT 2011; Wu et al. 2010).

Spot Seal Repair

Spot seal repair involves applying localized treatments such as seal coat, fog seal, or slurry seal to repaired areas to fix minor cracking, oxidation, and raveling. It improves waterproofing and extends pavement life but does not offer structural improvements. Its expected performance lasts from three to seven years. The process includes cleaning the surface (Fernando et al. 2019; TxDOT 2024a; b).

Edge Repair

Edge repair restores deteriorated pavement edges by replacing damaged base and asphalt layers. It is suitable for edge cracking, shoulder drop-offs, and lateral support loss. While it enhances safety and prepares the pavement for PM, it can be costly and ineffective if the subgrade is

unstable. Life expectancy ranges from 2 to 5 years without PM to 17 years with PM. (ODOT 2011; TxDOT 2024a; b; Wu et al. 2010).

FDR

FDR pulverizes the entire asphalt layer and part of the base, mixing them with stabilizers to form a new base. It eliminates all existing distress and is ideal for severe, widespread failures. This method recycles materials and restores structural capacity but requires careful design and curing time. Its expected lifespan is 7 to 10 years with surface treatment and up to 20 years with an overlay (Maher et al. 2005; Scullion et al. 2003). Its use as a pre-PM is limited due to cost.

Mill and Cement-Stabilized Base

This method combines milling of the asphalt surface with cement stabilization of the base, followed by an overlay. It is suitable for severe surface and base failures and provides long-term durability. Although highly effective, it is sensitive to moisture and needs proper curing. The expected lifespan is 20 to 30 years (Maher et al. 2005; Scullion et al. 2003; Sebesta 2002; TxDOT 2024a; b).

UHP Water Cutting Treatment

UHP water cutting uses high-pressure jets to remove excess asphalt binder and restore surface texture. It is ideal for flushed pavements and polished surfaces, offering a quick, nonintrusive solution. However, it is temporary and not suitable for deep structural issues. Performance typically lasts one to three years (TxDOT 2024a; b; Waters 2004).

Pothole Repair Methods

Pothole repairs include four approaches: throw-and-roll for quick, temporary fixes that last weeks to months; semi-permanent repair for greater durability (6 to 12 months); spray injection for efficient repairs lasting one to two years; and full-depth patching for permanent structural restoration, which can last 3 to 10 years. Materials that may be used for repairs include LRA, hot-mix cold-lay asphalt concrete, dense-graded HMA, asphaltic concrete patching materials (stockpiled or bagged), and rapid-curing asphalt concrete patching materials (TxDOT 2024a; b). Regarding pre-PM repairs, only permanent pothole repairs are used under PM (Dailey et al. 2017).

CONSTRUCTION TIMING AND CURING WINDOW

To ensure durability, performance, and cost-effectiveness, repairs should be made within a specific window, as discussed in the following sections.

Seasonal Timing

Spring and early fall are ideal for repairs due to moderate temperatures and lower precipitation. Extreme cold or heat should be avoided, since they affect compaction and binder performance; too cold temperatures cause the asphalt to cool too quickly, reducing compaction quality. Likewise, too hot temperatures can lead to over-compaction or bleeding.

Note: It would be a good idea to check local area/district-specific weather data, as the weather in the south could be different than districts in the north in Texas.

Daily Timing

Work should start early in the day to allow for curing before traffic resumes. Late-day paving is discouraged, especially in cooler months. Most asphaltic materials do not cure properly overnight.

Weather Conditions

Repairs must be done on dry surfaces, with no rain forecast within 24 hours, to prevent bonding issues and premature failures caused by moisture accumulation.

Materials-Specific Timing (Repair Time Before PM Treatment)

Repair materials need time to cure before applying PM treatment (e.g., seal coat). A general rule of thumb is to apply 6–12 months after repair. The window could vary depending on the repair material, climate, and traffic conditions. Table 11 shows the typical curing time (Austroads 2021; FHWA 2025; Lawson et al. 2007; NZ Transport Agency 2005; TxDOT 2014).

Table 11. Typical Curing Time Before Sealing.

Repair Type	Maintenance Treatment	Minimum Desirable Time Before Sealing
Crack Sealing	Emulsion	2 months (Austroads 2021; NZ Transport Agency 2005)
	Cutback products	6 months (Austroads 2021; NZ Transport Agency 2005)
	Hot bituminous products	1 year (FHWA 2025; TXAPA 2025)
Patching and Edge Breaks	Premixed/cold-mixed asphalt made with emulsion	4 months (NZ Transport Agency 2005); > 9 months (Austroads 2021)
	Premixed/cold-mixed asphalt made with cutback asphalt	6 months (NZ Transport Agency 2005); > 9 months (Austroads 2021)
	Premixed/cold-mixed asphalt made with fluxing material (LRA)	> 9 months (Austroads 2021)
	Cold mix	6 months (De Carteret 2009)
	HMA	2 months (NZ Transport Agency 2005); > 9 months (Austroads 2021); 4 months (TXAPA 2025)
	Microsurfacing	3 months (NZ Transport Agency 2005); > 9 months (Austroads 2021)
Reseals	Cutback bitumen and Grade 5 aggregates	6 months (NZ Transport Agency 2005)
	Emulsion and Grade 5 aggregates	1 month (NZ Transport Agency 2005)
Fog Seal	Base material: Slow-setting emulsions	3 months (TXAPA 2025)
Structural Repair	Cold in-place asphalt recycling	Moisture content < 2% of total material weight (De Carteret 2009); 9 months (TXAPA 2025)
	Flexible base repair	Moisture content < 2% of optimum (TxDOT 2024a); 6 months (TXAPA 2025)
Other	Treatment of flushed areas by asphalt patching or solvent use	2 months (NZ Transport Agency 2005); 2 to 6 months (Austroads 2021)
	Maintenance of the shoulders and longitudinal drain	2 weeks (Austroads 2021; NZ Transport Agency 2005)
	Line marking before resealing	3 to 6 months (NZ Transport Agency 2005)
	UHP water retexturing	2 to 6 months (NZ Transport Agency 2005); 6 weeks (Austroads 2021)

SUMMARY

This chapter outlines a spectrum of asphalt pavement repair strategies, ranging from PM techniques such as crack sealing and fog sealing to structural solutions like overlays, base repairs, and FDR. The chapter emphasizes the importance of timing and curing in ensuring the durability and performance of asphalt pavement repairs before applying PM treatments such as seal coats.

CHAPTER 5. DATA SYNTHESIS AND BEST REPAIR GUIDELINES

This chapter summarizes the work presented in this report and translates it into user-friendly guidelines. These guidelines are documented separately in a file titled "A Guide for Asphalt Pavement Repair Before Preventive Maintenance." The guide will be one of the most useful tools for engineers and maintenance supervisors to select repair options for asphalt pavement before PM. It covers pavement repair evaluation tools, testing plans, best practices, repair procedures and safety protocols, construction and material curing timing, and how repairs impact PM. However, this chapter focuses only on the key aspects of asphalt pavement repair before PM. It includes the process of choosing optimal repair options (workflow), the advantages and disadvantages of different repair methods, damage (distress) versus repair options, recommended materials for various repairs, and suggested equipment for each repair method.

WORKFLOW

Best practices for asphalt pavement repair prior to PM include thorough planning, identifying the types of distress (structural or functional), determining the source and mechanism of failure, and preparing the repair area before applying the correct material. Recognizing distress can start with data from a PMIS to find areas with poor ratings, followed by visual inspections and NDT to assess potential structural damage. Usually, structural damage extends more than 2 inches deep into the pavement, endangering its integrity. If the maintenance supervisor cannot identify the cause of recurring damage, they should consult the district pavement engineer. The pavement engineer can assist with NDT tools to locate the problem source.

The flowchart shown in Figure 28 outlines the steps for effective asphalt pavement repair strategies before PM.

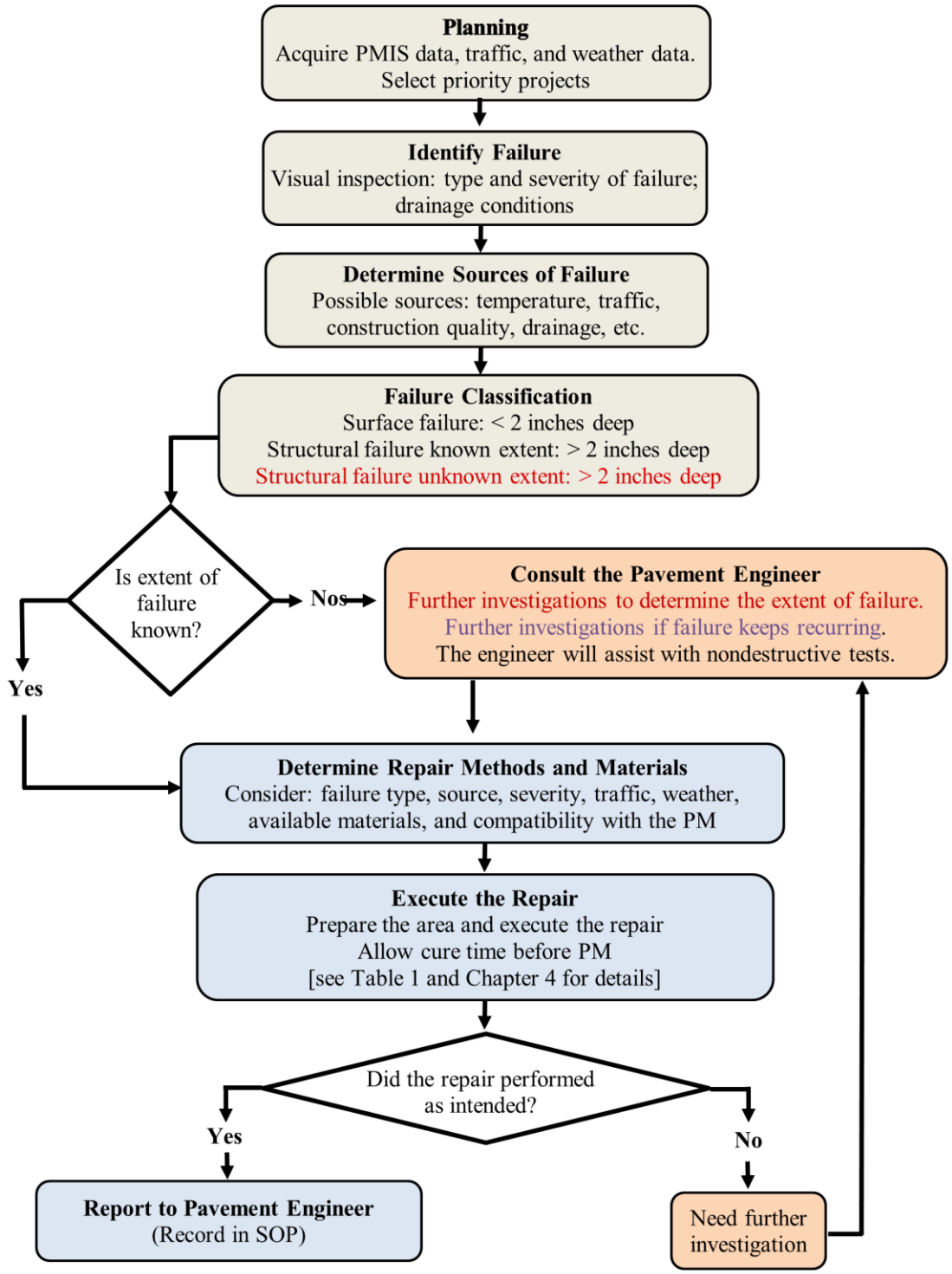


Figure 28. Decision Flowchart Before PM.

REPAIR METHODS, BENEFITS, AND DRAWBACKS

For TxDOT engineers and maintenance supervisors, it is crucial to understand the benefits and limitations of repair techniques to improve performance and resource efficiency. Proper repairs

can extend pavement lifespan, boost ride quality, and reduce lifecycle expenses, while poor or incorrect methods may cause early failures and increased maintenance costs. Table 12 outlines the advantages and disadvantages of asphalt pavement repair before PM (Asres et al. 2021; FHWA 2014; Pavement Interactive 2025; Peshkin et al. 2004; PMS 2025; PPRA 2025; RDC 2021; TXAPA 2025; TxDOT 2011, 2016, 2024a; b).

Table 12. Benefits and Drawbacks of Asphalt Pavement Repairs.

Repair Method	Benefits	Drawbacks
Crack Seal	Cost-effective, prevents water infiltration, and slows the progression of load-related cracking.	It requires frequent reapplication and is less effective on high-severity distress. Excessive crack seals can negatively affect ride quality.
Fog Seal	Inexpensive, seals minor cracks, reduces asphalt aging, oxidation, and hardening, and prevents moisture infiltration.	Less effective on high-severity distresses; when applied heavily, it can reduce skid.
Scrub seal	Cost-effective, can be applied quickly, and seals cracks better than the traditional chip seal.	Not ideal for high-volume or high-speed roads, it cannot fix structural problems, and requires dry, warm conditions for proper curing.
Micro-surfacing	Restores surface texture, improves skid resistance, and extends pavement life.	Higher initial cost, requires skilled labor, may not be effective for other repairs, including fixing structural issues
Seal Coat	Cost-effective, protects pavement from oxidation, improves appearance and texture.	It requires frequent reapplication and is less effective in high-severity distresses. Loose aggregate can become a windshield hazard. Also, the seal coat repair is typically noisy relative to traditional asphalt.
Level Up and (Overlay or Seal Coat)	Improves ride quality, extends pavement life, and is cost-effective.	Does not fix deep structural issues, and it requires skilled labor. Level-up may complicate the uniform application of asphalt binder when PM is the seal coat.
Mill and Overlay	Restores ride quality, extends pavement life, and recycles existing materials.	Higher initial cost, requires skilled labor, and may not address deep structural issues.
Base Repair and Seal	Addresses structural issues, extends pavement life, and improves load-bearing capacity.	Expensive; requires traffic detours, skilled labor, and equipment.
Spot Seal	Targets localized distress, is cost-effective, and has a quick application.	Temporary solution, requires frequent reapplication, and is not effective on high-severity distresses.
Edge Repair and Overlay	Improves edge stability, extends pavement life, and is cost-effective.	Does not fix deep structural issues, and it requires skilled labor.
Full-Depth Reclamation	Renews pavement structure, long service life, and allows design upgrades.	Most expensive, significant traffic disruption, and requires extensive planning and resources.
Cement Stabilized Base	Improves load-bearing capacity, extends pavement life, and addresses structural issues.	Higher initial cost, requires skilled labor.

Repair Method	Benefits	Drawbacks
Ultra High-Pressure Water Retexturing	Restores surface texture, improves skid resistance, and has quick application.	Temporary solution and requires frequent reapplication.
Pothole: Throw-and-Roll	Fast and inexpensive fix of a pothole, requires minimal equipment, and can be done at any time of the year.	Temporary solution with a very short life span. Poor preparation and thus poor bonding. Unstable and cannot be under the PM surface (i.e., seal coat).
Pothole: Spray Injection	The material is self-compacting and can be applied quickly.	Requires specialized equipment and skilled labor. Less effective in wet or cold conditions. Relatively more expensive than Throw-and-Roll.
Pothole: Semi-Permanent Repair	Good bonding with the existing pavement.	Requires dry conditions and takes more time and traffic control.
Full-Depth Patching	Addresses structural issues and is therefore durable and permanent.	It is expensive, time-consuming, and requires traffic control.

DISTRESS (FAILURE) VERSUS REPAIR OPTIONS

Table 13 shows different distress types along with possible repair options. The table includes visual illustrations of failure mechanisms to demonstrate how the distress appears. This information was gathered from several reference documents (Ahmad and Khawaja 2018; Caltrans 2003; Canestrari and Ingrassia 2020; Dong et al. 2013; INDOT 2023; Miller and Bellinger 2014; Pavement Interactive 2025; PMS 2025; RDC 2021; Renolith 2023; TxDOT 2021a; b).

Table 13. Failure Mechanism, Source, and Repair Alternative.

Failure Mechanism	Source	Repair Alternative
 Block cracking	This is due to the temperature changes that cause the pavement to expand and contract. It is most likely limited to the surface layer (> 2 inches deep) and forms as interconnected rectangular pieces (varying in size from 1 foot by 1 foot up to 10 feet by 10 feet). It occurs over a large portion of the pavement area, and its severity can be low, medium, or high based on the crack width.	Low severity cracks (< 1/2 inch wide and infrequent cracks): "Crack Seal" or "Seal Coat." High severity cracks (> 1/2 inch wide and numerous cracks): "Level Up and Overlay."
 Fatigue (or alligator) cracking)	This occurs due to repeated traffic loading on the pavement surface at the wheel path (excessive deflection) and may cause pavement structure failure. This type of cracking initiates at the bottom of the HMA layer, where the tensile stress and strain are highest due to traffic loading. Inadequate pavement thickness and weakening of the subgrade due to the ingress of excessive moisture can cause fatigue cracking.	Small, localized fatigue cracking (few connecting cracks): Remove the cracked pavement area and do "Base Repair, Spot Seal, Edge Repair, and Overlay." Large fatigue-cracked areas (severely spalled interconnected cracks): "Full Depth Reclamation (Pulverization and Resurfacing)."
 Longitudinal cracking	It may be caused by poor joint construction, thermal expansion and contraction of the asphalt material, or differential movement of pavement layers due to moisture change or traffic loading. This type of cracking (at least 1/8 inch in size) is approximately parallel to the pavement's centerline.	Low severity cracks (< 1/2 inch): "Crack Seal" or "Seal Coat." High-severity cracks (>1/2 inch): Replace cracked pavement and do "Level Up and Overlay."
 Transverse cracking	Cracks are predominantly perpendicular to the pavement centerline (or traffic flow) and are typically caused by temperature fluctuations. Transverse cracking (at least 1/8 inch in size) may also reflect cracks from underlying layers.	Low-severity cracks (< 1/2 inch): "Crack Seal." High-severity cracks (< 1/2 inch): Replace cracked pavement and do "Level Up and Overlay."

Failure Mechanism	Source	Repair Alternative
 Potholes	Water, poor drainage, traffic loading, and a weak layer(s) could cause potholes. Extreme cases of other failures, such as raveling, cracking, etc., could also cause potholes. Potholes may extend down to the base course.	Low and moderate-severity (< 2 inch depth): Repair the surface of pavement ("Spray injection or Semi-Permanent Repair"). High-severity (> 2 inch): "Full Depth Patching"
 Excessive patching	Occurs when significant repaving of the pavement layer fails. It may be caused by excessive distress and delamination. High-severity distress shows faulting or settlement beyond 1/4 inch.	Remove the existing patch and then do "Base Repair, Spot Seal, Edge Repair, and Overlay."
 Bleeding/flushing	Excess binder or low air void in asphalt mixes could be the source. Also, the loss of aggregates (exposing the asphalt to the surface) or over-compaction could be the source. This type of failure mechanism is limited to the asphalt surface.	Low to moderate bleeding: "Seal Coat." Moderate to severe bleeding: "Use the ultra-high-pressure water jets to remove excess asphalt binder and improve pavement surface texture."
 Shoving	Shoving can be caused by the failure of the subgrade soil, unstable mix design, poor bond between the different layers of the pavement section, vehicle braking or turning, inadequate compaction, lack of edge support, inadequate pavement thickness, etc.	Moderate to high severity: do "Mill and Overlay." Severe shoving with structural failure: "Perform full-depth patching/repair."
 Depression	Depression is a localized pavement surface settlement compared to the surrounding pavement. It can be caused by a volume change of the subgrade material, settlement of foundation soil, or during construction, which results in pavement surface roughness.	Saw cut and replace the affected pavement area. Then do "Base Repair, Spot Seal, Edge Repair, and Overlay."

Failure Mechanism	Source	Repair Alternative
Rutting	Rutting is a type of surface depression in the wheel path. It is caused by deformation in any pavement layer under traffic loads. The load impact becomes more significant when the mix design, drainage, or construction practices (such as compaction) are poor. Shallow rutting is defined as less than 1/2 inch deep, while deep rutting is measured as greater than 1/2 inch.	Deep Rutting (> 1/2 inch): If rutting occurs in the lower HMA layer, do "Base Repair and Seal." If rutting is at the base layer, do "Full Depth Reclamation." Shallow Rutting (1/4 to 1/2 inch): Do "Mill and Overlay" or "Spot Seal Coat." Another option is micro surfacing.
Raveling	The dislodging of aggregate particles and loss of asphalt binder causes this type of distress. Raveling indicates potential mixture-related issues.	For a small area of raveling: "Seal Coat" and "Fog Seal." Severe raveling: "Mill the surface, if necessary, then place a thin HMA overlay."
Top-down cracking	The top-down cracking begins at the surface of the pavement. It tends to be longitudinal, often within or near vehicles' wheel paths. The crack may be caused by heavy vehicles, thermal stress (high surface temperature), and hardening of the asphalt binder due to age (making it susceptible to cracking under stress).	Low severity cracks: "Crack Seal." Medium severity cracks: Replace the pavement layers slightly deeper than the top-down cracks, then "Mill and Overlay." High severity cracks: "Full Depth Reclamation (Pulverization and Resurfacing)."

RECOMMENDED MATERIALS FOR REPAIR

This section provides a recommended list of common materials used for preparatory repairs to asphalt pavements before PM, aligned with specific methods. Table 14 offers a reference linking each material to its appropriate application, supporting informed decision-making in PM planning. Due to factors such as the unavailability of local materials, other potential materials not listed in this table may also be used, provided they meet the requirements and are approved by TxDOT. In Table 14 "R" is the recommended/allowable material for the repair method, and "NA" is not usually needed for the repair method.

Table 14. Recommended Materials for Repair.

Materials	ITEM or DMS	Crack Seal	Fog Seal	Scrub seal	Micro-surfacing	Seal Coat or spot seal	Level Up or Overlay	Base Repair	Edge Repair[1]	Full-Depth Patching[1]	Pothole Repair[1]
ITEM or Special Specification		712	315	SS 3005	350	316	341, 344	351	See Note 1	See Note 1	See Note 1
Cold-Applied Sealant	300	**R**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hot-Applied Sealants	300	**R**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Asphalt Cement	300	NA	NA	NA	NA	**R**	**R**	**R**	NA	NA	NA
Emulsion	300	NA	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Cutback Asphalt	300	NA	NA	NA	NA	**R**	NA	**R**	NA	NA	NA
Aggregates	302	NA	NA	**R**	**R**	**R**	NA	**R**	NA	NA	NA
Hot Mix Asphalt	341, 344	NA	NA	NA	NA	NA	**R**	NA	**R**	**R**	NA
RAP/Rejuvenated RAP	DMS 9202	NA	NA	NA	NA	NA	**R**	NA	**R**	NA	NA
Flexible base	247	NA	NA	NA	NA	NA	NA	**R**	**R**	NA	NA
Cement	DMS 4600	NA	NA	NA	**R**	NA	NA	**R**	**R**	NA	NA
Limestone Rock asphalt (LRA)	330, DMS 9210	NA	NA	NA	NA	NA	**R**	**R**	NA	NA	**R**
Cold Mix Asphalt made with emulsion	DMS 9202	NA	NA	NA	NA	NA	NA	NA	**R**	NA	**R**
Cold Mix Asphalt made with cutback	DMS 9202	NA	NA	NA	NA	NA	NA	NA	**R**	NA	**R**
Hot Mix Cold Laid	334	NA	NA	NA	NA	NA	NA	NA	NA	**R**	**R**
Asphalt Concrete Patching Materials (stockpile storage or bagged)	DMS 9202, 9203	NA	NA	NA	NA	NA	NA	NA	NA	**R**	**R**

RECOMMENDED EQUIPMENT FOR REPAIR

Choosing the right equipment is essential for performing high-quality repairs that address surface and structural problems before applying treatments such as seal coats, slurry seals, or thin overlays. This document provides recommended equipment tailored for different repair methods. Table 15 provides a reference linking each type of equipment to its specific repair application, helping improve planning and resource management for pavement maintenance activities. In Table 15 “R” indicates the recommended/allowable equipment for the repair noted, and “NA” indicates that the repair method does not usually require it.

Table 15. Recommended Equipment for Repair.

Equipment	Crack Seal	Fog Seal	Scrub seal	Micro-surfacing	Seal Coat	Level Up and Overlay	Mill and Inlay	Base Repair	Spot Seal Repair	Edge Repair	UHP Water Retexturing	Pothole repair	Full-Depth Reclamation
Router	R	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hot air lance	R	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Melter-applicator	R	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Wand	NA	**R**	**R**	**R**	**R**	NA	NA	NA	**R**	NA	NA	**R**	NA
Broom/Sweeper	NA	**R**	**R**	**R**	**R**	**R**	**R**	NA	NA	NA	**R**	**R**	**R**
Distributor truck with spray bar	NA	**R**	**R**	NA	**R**	NA	NA	**R**	NA	NA	NA	NA	**R**
Paver	NA	NA	NA	**R**	NA	**R**	NA	**R**	NA	**R**	NA	NA	NA
Aggregate spreader	NA	NA	NA	**R**	**R**	**R**	**R**	NA	NA	NA	NA	NA	NA
Steel wheel Roller	NA	NA	NA	**R**	**R**	**R**	**R**	**R**	NA	NA	NA	NA	NA
Vibratory Roller	NA	NA	NA	NA	NA	NA	NA	**R**	**R**	NA	NA	NA	**R**
Pneumatic Roller	NA	NA	NA	NA	NA	**R**	NA	NA	NA	NA	NA	NA	NA
Sheep foot roller	NA	NA	NA	NA	NA	NA	NA	**R**	NA	**R**	NA	**R**	NA
Milling machine	NA	NA	NA	NA	NA	NA	**R**	NA	NA	NA	NA	NA	NA
Sweeper	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	**R**	NA	**R**
Excavator	NA	NA	NA	NA	NA	NA	NA	**R**	NA	**R**	NA	NA	NA
Air blower	NA	NA	NA	NA	NA	NA	NA	NA	**R**	NA	NA	**R**	NA
Tack sprayer	NA	NA	NA	NA	NA	**R**	NA	NA	**R**	NA	NA	NA	**R**
Small distributor	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Grader	NA	NA	NA	NA	NA	NA	NA	**R**	NA	**R**	NA	NA	**R**
Pulverizing Mixer	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	**R**
Saw	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	**R**	NA
UHP water jet system	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	**R**	NA	NA
Water truck	NA	NA	NA	NA	NA	NA	NA	**R**	NA	**R**	NA	NA	NA
Gradall	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	**R**	**R**
Haul Truck	NA	NA	NA	**R**	**R**	**R**	**R**	**R**	NA	**R**	NA	**R**	**R**

SUMMARY

This chapter consolidates research findings into practical guidelines for selecting and performing asphalt pavement repairs before PM. It highlights a standardized workflow that starts with PMIS data analysis, visual inspections, and NDT to categorize failures and set repair limits. The chapter discusses the advantages and disadvantages of common repair methods, offers a matrix connecting distress types to suitable repair strategies, and recommends appropriate materials and equipment for each method.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSION

Decision matrix (Decision Flow Chart): District surveys confirm that maintenance supervisors make most decisions, with pavement engineers consulted when structural issues arise. This decentralized approach works best when paired with a standardized decision matrix that formalizes triggers for escalation. The flow chart is included in the best repair guide.

Pavement evaluation tools: Equipment like Grind Diagnostic (for milling/level-up limits and costs), FWD/DCP (for structural integrity), and GPR with coring (for layer condition) help crews to properly size repairs—preventing under-fixing (early failures) and over-fixing (wasted resources).

Material and delivery challenges: Local shortages of resources, such as rejuvenated RAP or LRA, must be managed using alternative methods that closely achieve the same results. Apply the distress-versus-repair alternative tables to select the most appropriate repair method.

Pre-PM repair discipline: Consistent prep and seal coat strategies extend service life and reduce lifecycle costs, resulting in a strong cost-benefit ratio. Practical implementation requires a feedback loop linking before-and-after ride measurements, PMIS updates, and three to six-month field audits to identify early distress or clear out issues. These insights should inform annual planning and SOP updates.

Bottom line: Achieving the right repair on the right road at the right time across the state is possible when districts use a standardized, data- and NDT-informed workflow, follow curing and materials controls, and complete performance monitoring. This uniform approach will improve PM survivability, cut emergency repairs, and support TxDOT's reliability goals.

RECOMMENDATIONS

Once the "Best Guidebook for Asphalt Pavement Repair" is finalized, it will become a key reference for pre-PM repairs. Meanwhile, based on the collected information, the team suggests the following evaluation framework to achieve the best Pre-PM repair.

Evaluate the roadway for repair options based on pavement distress

- Screen candidate sections using PMIS distress/ride scores; visualize trends.
- Perform visual inspections; mark limits extending into sound pavement.
- Deploy NDT (e.g., FWD/DCP, GPR, and coring) for suspected structural issues.

Evaluate viable repair options based on resources available

- Confirm material availability (e.g., hot mix, crack sealants, and RAP/LRA).
- Align repair methods with available equipment.
- Decide in-house vs. contractor based on scope and crew skill.

Evaluate repair options based on cost and time

- Use Grind Diagnostic and other tools available to TxDOT for quantities and cost estimates.
- Apply TxDOT bid item references for budgeting.
- Integrate curing windows into schedule planning.

Evaluate the timing of completing the repair

- Consider seasonal/weather conditions and traffic exposure.
- Apply fog seal when cure time is short.
- Plan bleeding mitigation (hydro-blasting or binder rate adjustments).

Evaluate repair method based on type and limits

- Classify failure (surface vs. structural).
- Define limits beyond sound pavement; avoid joints in wheel paths.
- Ensure material compatibility with PM treatment.

Evaluate the repair method based on repair performance

- Conduct three- to six-month audits for flushing and early distress.
- Compare pre/post PMIS and ride scores.
- Update SOPs and value of research (VOR) assumptions annually.

CHAPTER 7. VALUE OF RESEARCH

OVERVIEW

Proper road preparation significantly extends the lifespan of PM (seal coat) and reduces maintenance costs. For 2026, TxDOT has allocated $2,155,144,817 for PM (33 percent) and rehab (67 percent). Practical preparatory work is essential for protecting investments and saving money. The importance of this research lies in ensuring that best practices for preparatory repair are followed, thereby improving seal coat quality and reducing premature failures. The VOR expects that funds currently spent on immediate maintenance will decrease as the research is implemented.

BUILDING INITIAL COST

Through the TxDOT bid item references, the research team estimated initial cost analysis assumptions. The unit prices shown are based on recent TxDOT bid tabulations and statewide average low bid prices from the 2023–2024 letting period (with values consistent with 2024 TxDOT averages)

The following is a sample of Bid Item 316–Seal Coat (Asphalt & Aggregate) cost:

- Asphalt (AC-20-5TR): Recent bids show $780–$935 per ton.
- Aggregate (Type PB, Grade 4): $104–$126 per cubic yard.

For Preparatory Repairs, the following was considered:

- Crack Sealing (Hot-Poured Rubber):
    - Bid Item 712 6009: Average $3.51 per LF statewide.
- Pothole/Base Repair
    - Bid Item 700 6001 (Standard): $65 per SY.
    - Bid Item 700 6005 (Saw-Cut): $75 per SY.

From Bid Item 316, the research team estimated two scenarios for VOR calculations: Prep Repairs & Seal Coat and Seal Coat Only. The initial estimated unit cost per lane-mile for each treatment scenario is shown below. The estimates do not include indirect costs.

- ***Scenario 1: Prep Repairs + Seal Coat:***
    - Prep Repairs: $15,000 per lane-mile.
      Includes crack sealing, base repairs, level-up work, and edge repair.
    - Seal Coat Application: $25,000 per lane-mile.

Covers binder, aggregate, and application labor.
  - Total Initial Cost: $40,000 per lane-mile.

- ***Scenario 2: Seal Coat Only:***

  - Seal Coat Application: $25,000 per lane-mile.
    No preparatory work included.
  - Full rehabilitation: $200,000 per lane-mile in the fourth year.

Furthermore, the research team assumed a seven-year lifespan for a prepped seal coat and used a 4 percent discount rate to calculate the net present value for both scenarios. Additionally, Texas constructs about 20,000 lane miles of seal coat annually. The team assumed that 5 percent would require maintenance each year due to poor preparation, and by the seventh year, the road would need rehabilitation. Meanwhile, a well-prepped road in the seventh year will only need resealing. Based on these two scenarios, the team calculated the expected value per year to be $16,855,088. Table 16 details the project values and expected values inputted in the TxDOT VOR Form. Figure 29 shows the VOR over time, expressed as a net present value (NPV). Table 17 describes the VOR benefit areas. In Table 17 "R" indicates the benefit areas, and "NA" indicates that the area is not an applicable area of benefits.

Table 16. TxDOT VOR Form Data.

Description	Value
Project number	0-7175
Project name	Develop best practices for flexible pavement repairs
Agency	Texas A&M Transportation Institute
Project duration (yr)	2.5
Expected value duration (yr)	7
Project budget ($)	$413,069
Expected value per year ($)	$16,855,088
Discount rate (%)	4
Economic value total savings ($)	$151,282,723
Payback period (yr)	0.024507
Net present value ($)	$128,663,833
Cost-benefit ratio ($1:$_)	$1:$341

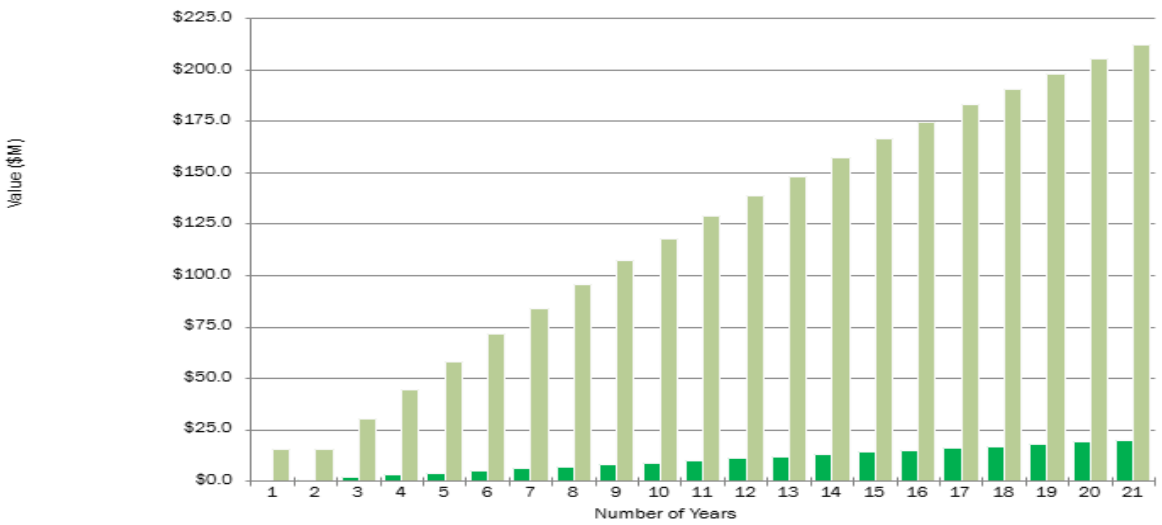


Figure 29. VOR Over Time Expressed as NPV.

Table 17. VOR Benefit Areas.

Benefit Area	Qualitative	Economic	Both	TxDOT	State	Both	Definition in Context to Project Statement
Level of knowledge	**R**	NA	NA	**R**	NA	NA	Research significantly increases the agency's understanding of prep work before PM.
System reliability	NA	**R**	NA	**R**	NA	NA	Reducing early maintenance treatments will reduce user delays and unforeseen costs to the agency.
Increased service life	NA	**R**	NA	**R**	NA	NA	An improved project will increase service life without premature failures.
Reduced user cost	NA	**R**	NA	NA	**R**	NA	A lower construction frequency will reduce lane closures and thus decrease user costs and delays.
Reduced construction, operations, and maintenance cost	NA	**R**	NA	NA	**R**	NA	Reducing premature failures saves on unexpected maintenance costs.
Materials and pavements	NA	**R**	NA	NA	**R**	NA	Research increases understanding of pre-PM repairs.
Infrastructure condition	NA	**R**	NA	NA	NA	**R**	Research improves the existing structure condition by increasing service life.
Safety	NA	NA	**R**	NA	NA	**R**	Provides a safe driving surface throughout the project's life.

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APPENDIX. SURVEY RESULTS AND ANALYSIS

The following is a summary of the responses from the survey questionnaire.

- Who determines the type of in-house repair before the PM project?
  According to the survey results, 43 percent of the responses indicated that the maintenance supervisor is the main person for the in-house repairs. Sometimes, decisions could also come from the pavement engineer or other personnel in charge (see Figure A1).

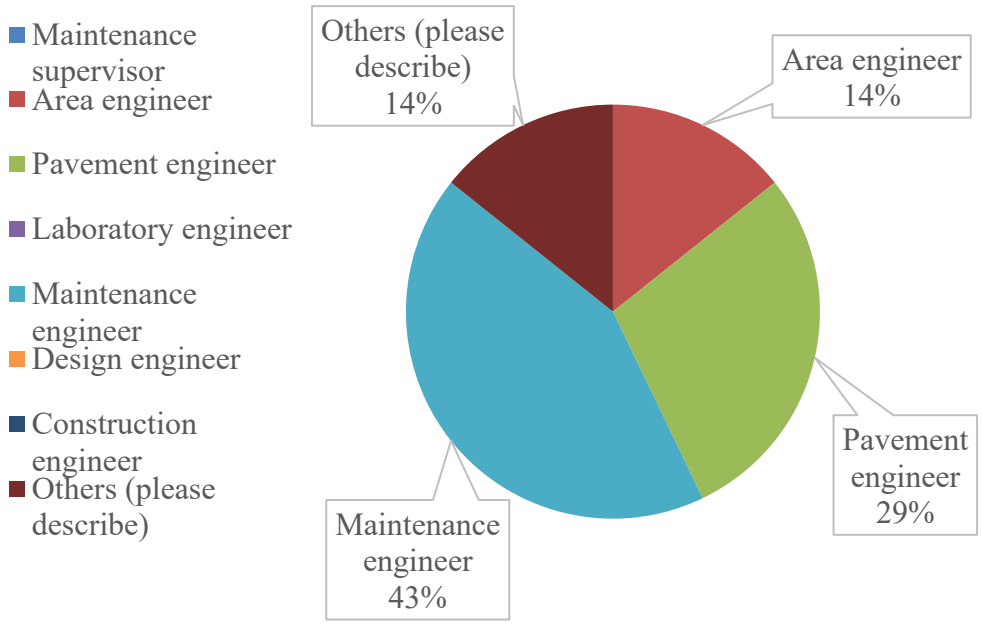

Figure A1. Personnel That Always Determine the Type of In-House Repair.

- Do you use the following PMIS/PA data to help plan repairs?
  In response to this question, 60 percent of the selections indicated skid and distress scores are always the PMSI data used to help plan repairs (see Figure A2). Ride score and IRI are also used.

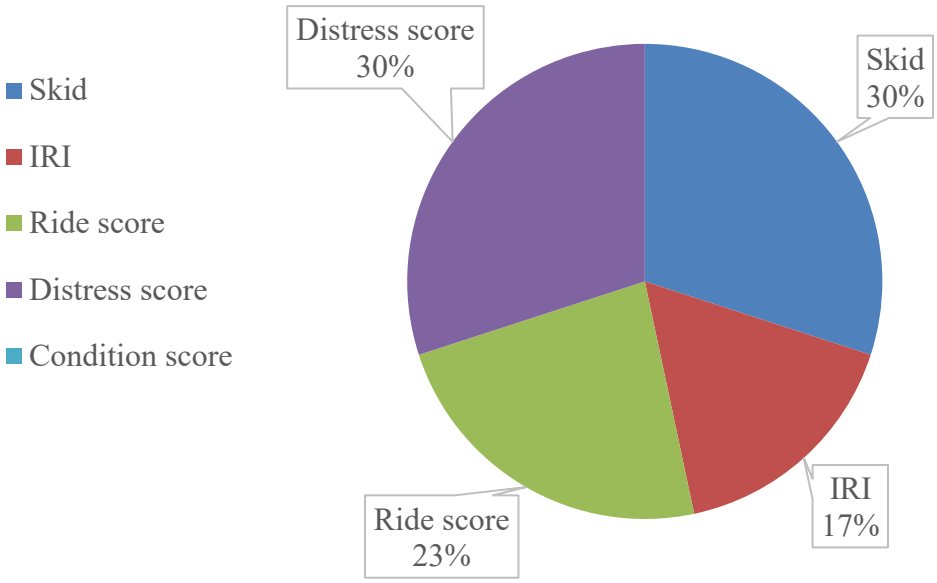

Figure A2. PMIS/PA Data Always Used to Plan Repairs.

- Do you use the following FLEXIBLE PAVEMENT PMIS data to help plan repairs?
  The responses to this question were relatively evenly distributed. The percentages of the method to help repair varied from 9 to 16 percent (see Figure A3).

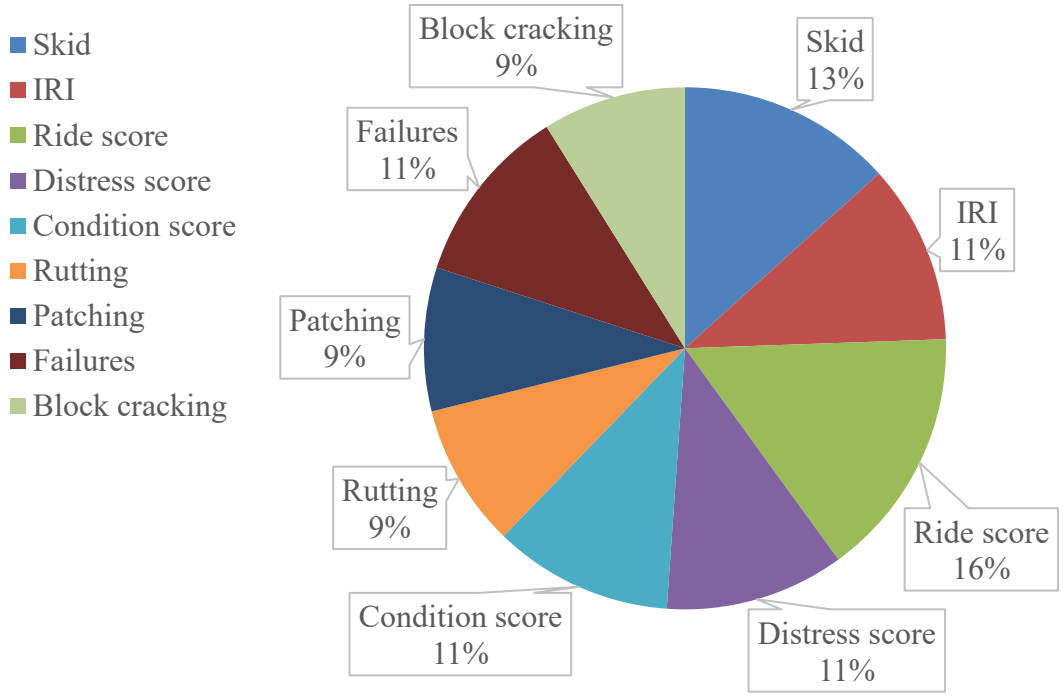

Figure A3. Flexible Pavement PMIS Data Always Used to Help Plan Repairs.

- What factors influence the type of repairs performed before the PM project?
  According to the survey results, 56 percent of the responses show that visual observation and experience were the influencing factors. Meanwhile, 15 percent of the respondents considered Budget the influencing factor. The other factors garnered less than 10 percent each (see Figure A4).

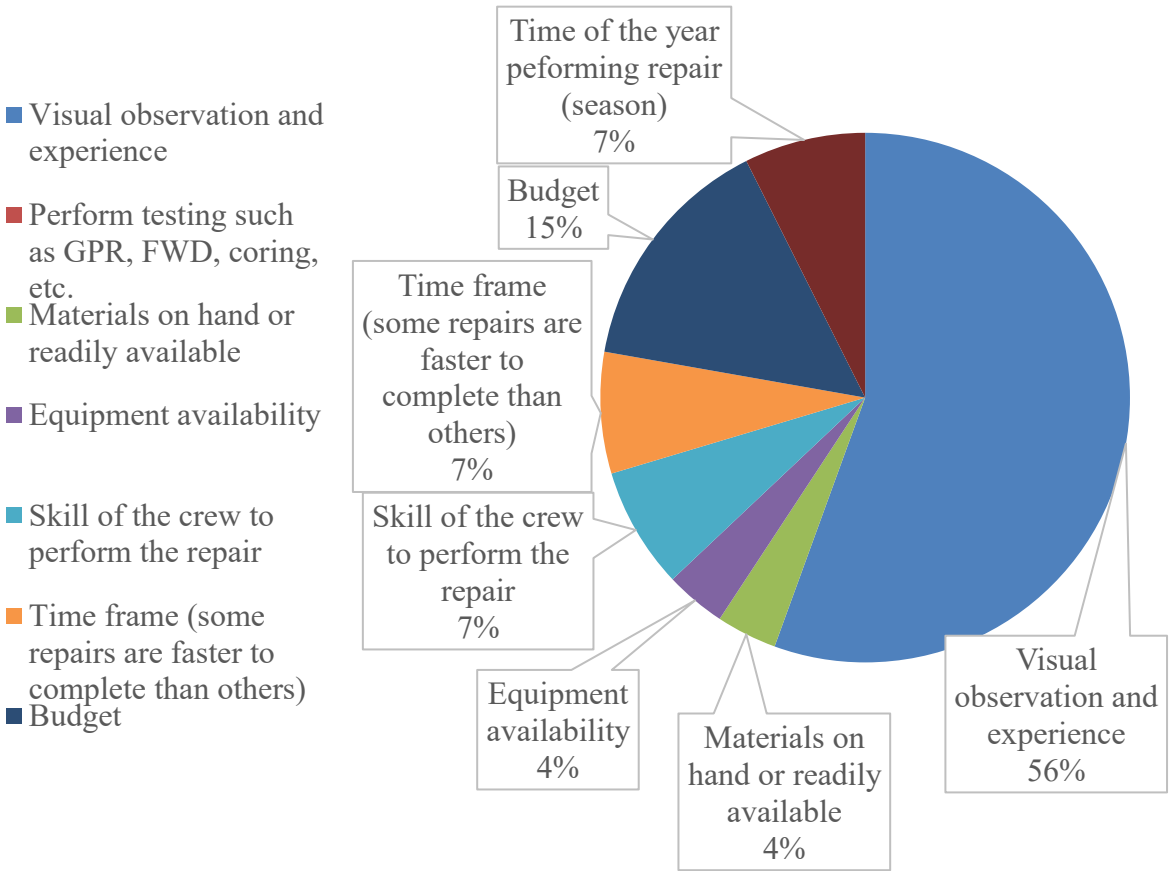

Figure A4. Factors That Always Influence Repair Type Before PM Project.

- What factors influence whether the repair is performed in-house or contracted?
  According to the survey results, most responses (38 percent) indicated that the crew's skill was the main influencing factor, followed by 25 percent, which shows that budget was the primary criterion (see Figure A5).

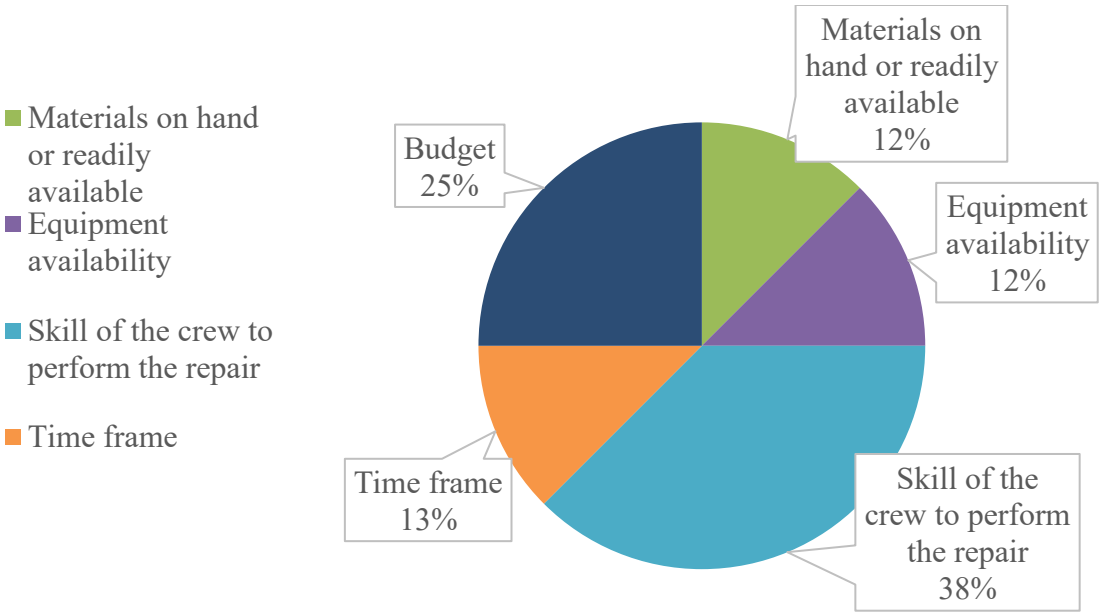

Figure A5. Factors That Always Influence Whether the Repair Is In-House or Contracted.

- Which FLEXIBLE PAVEMENT preparatory work types are typically used in your section?
  The responses indicate that Level Up (Hot Mix and LRA) and Base Repair (Full Depth with Stabilizer and Full Depth Hot Mix) are the major FLEXIBLE PAVEMENT preparatory work types that are typically used in most represented districts in the survey (see Figure A6).

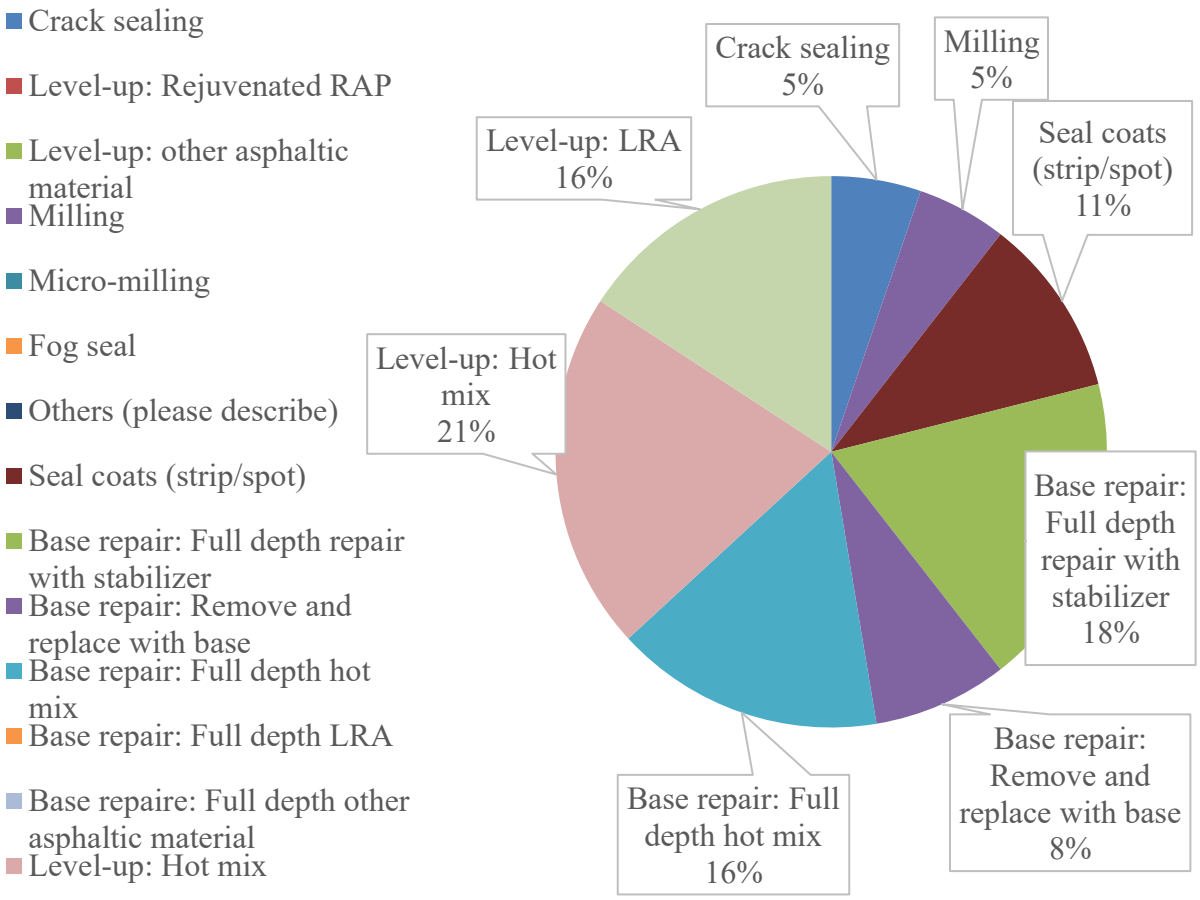

Figure A6. Flexible Pavement Preparation for Main Repair.

- For the repair materials listed, note if your section/district has access to the material needed to perform the work.
  According to the survey results, about 48 percent, 16 percent, and 12 percent of the responses indicated that the rejuvenated RAP, crack seal, and LRA are unavailable, respectively. A smaller group of respondents reported they do not have access to other materials (Figure A7). The seal coat aggregate and binder are the only materials readily accessible to all respondents (Figure A8). Additionally, Figure A8 shows the typical access points to various repair materials, with requisition and in-stock being the main methods of access.

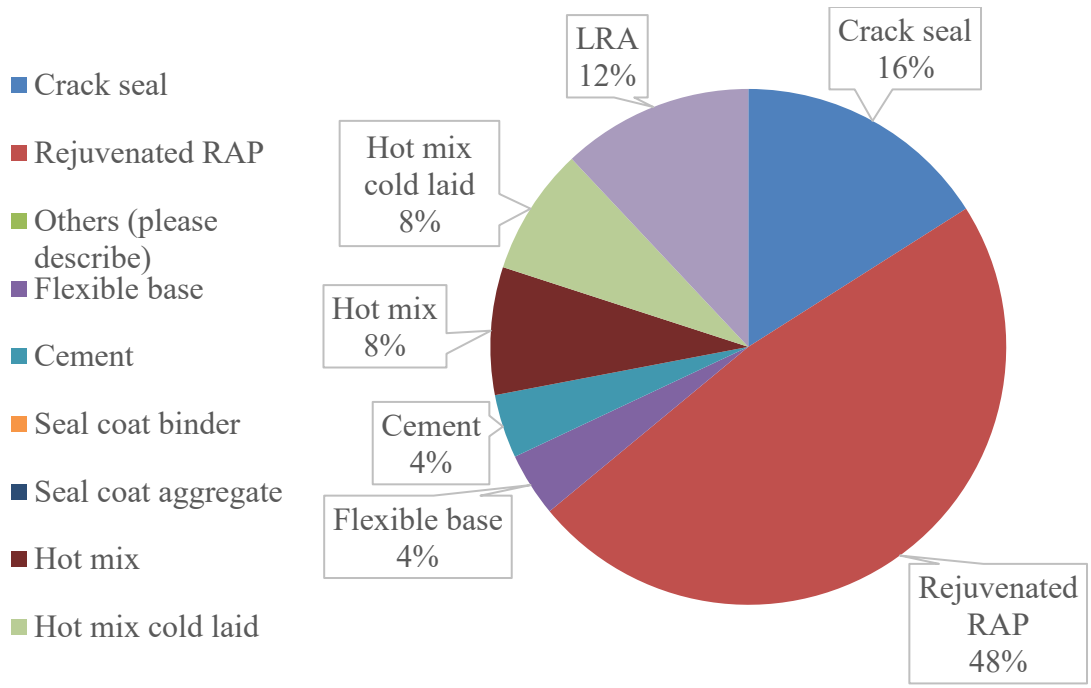

Figure A7. Unavailability of the Repair Materials.

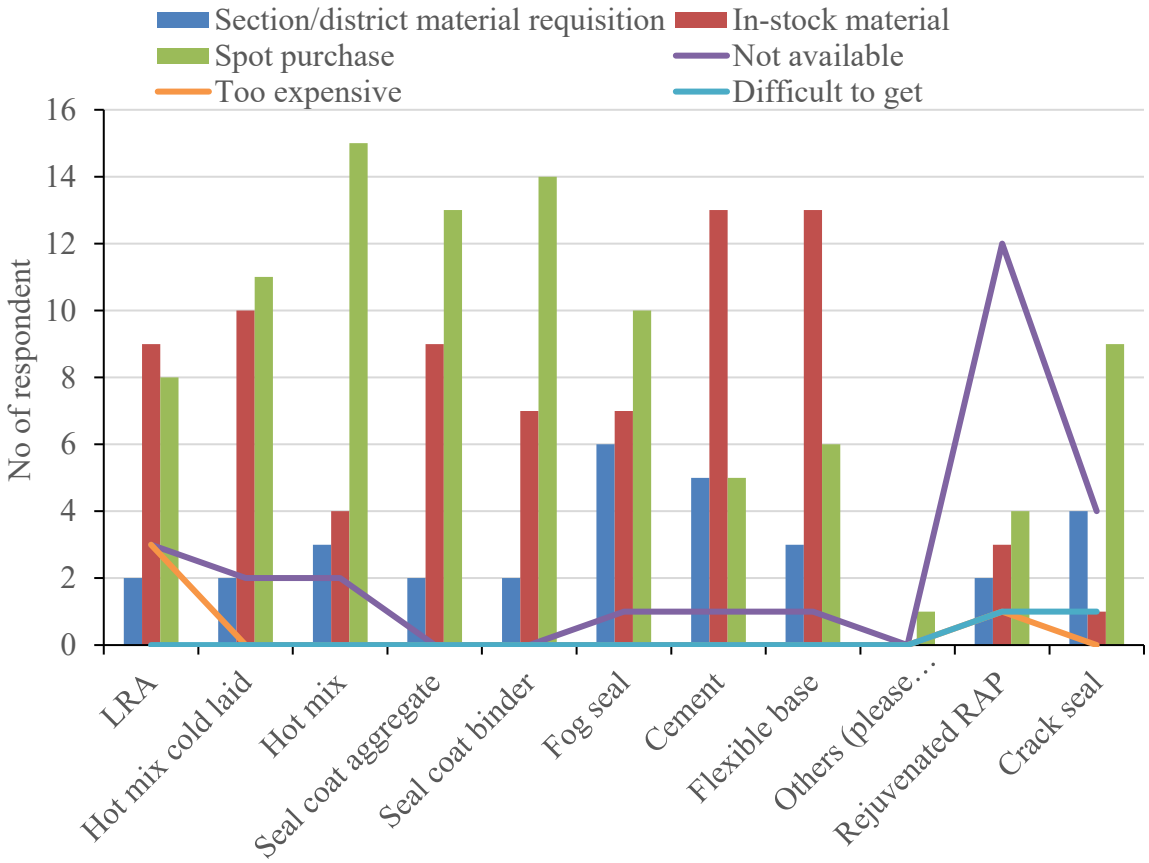

Figure A8. Repair Materials Accessibility.

- How do you determine the repair size (length, width, and depth)? Select the typical reason.
  The survey indicated that most of the time (40 percent of all selected methods), the visually distressed areas are fixed without going through a lengthy iteration of determining repair size. The cost of repair and the effect of the size performance of PM are among the significant reasons for determining repair size (Figure A9).

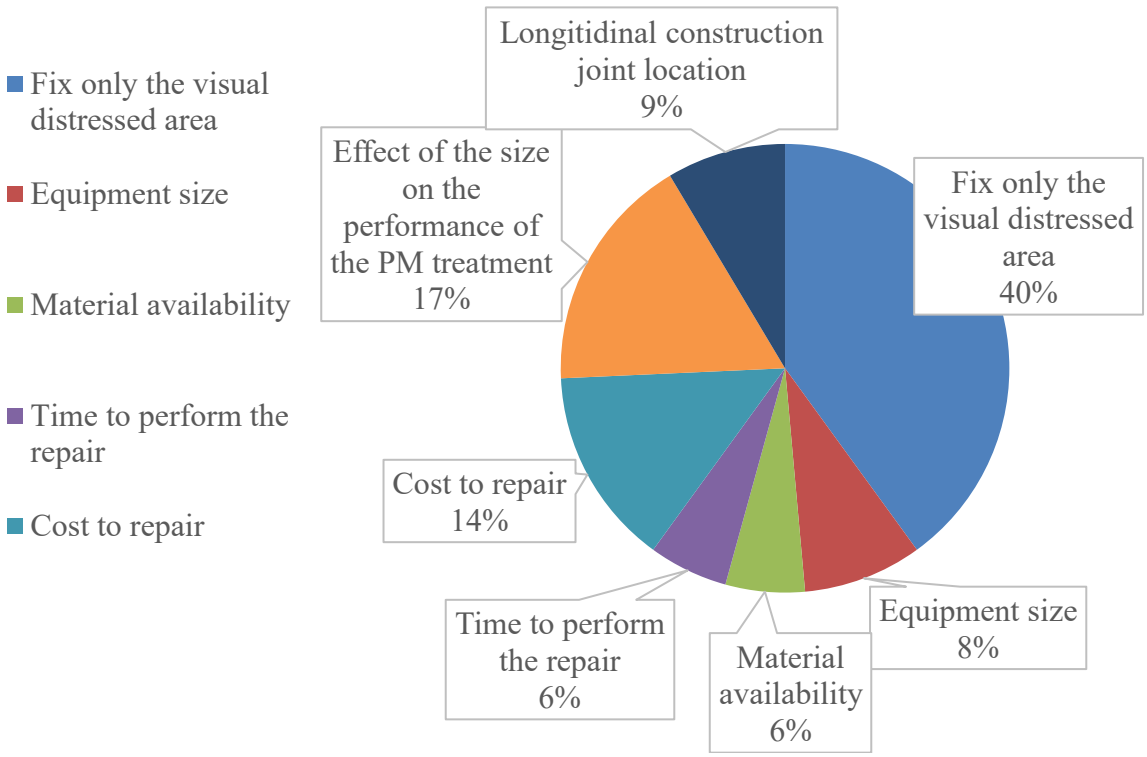

Figure A9. Typical Reason Used to Determine Repair Size.

For a given repair problem (Figure A10), do you consider how it will affect the new seal coat construction?

To a certain level, the effect of any repair problem on the new seal coat is always considered, with rutting and failure being considered most of the time (14 percent and 17 percent, respectively) (Figure A10). One respondent reported never considering block-cracking effects on the new seal coat surfaces.

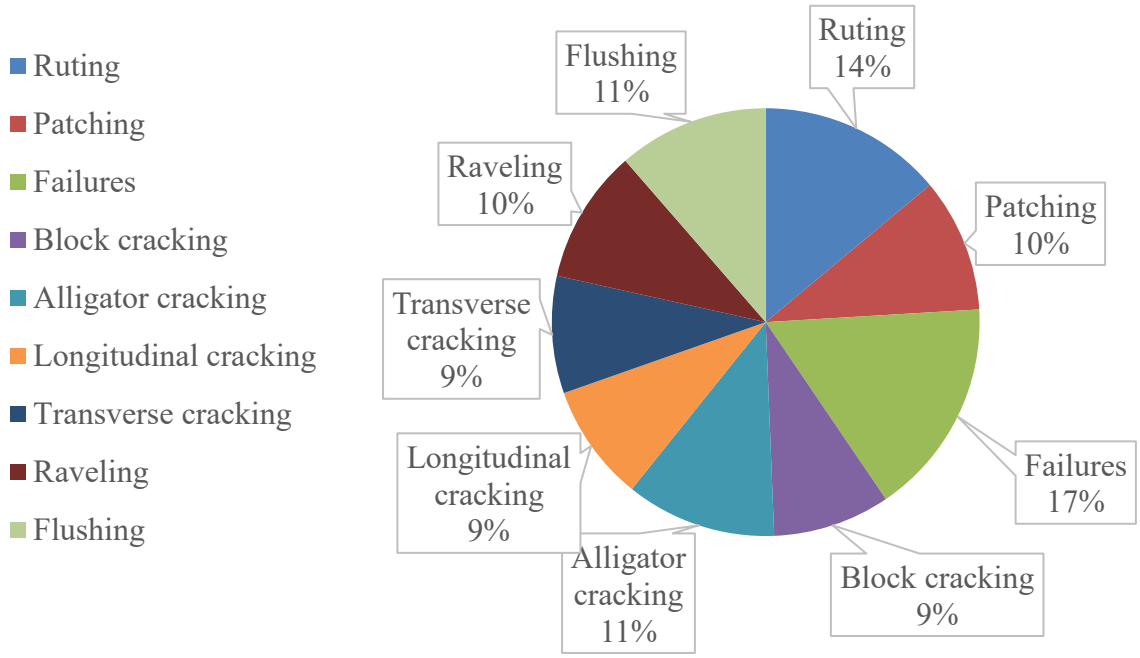

Figure A10. Respondent Considerations of Effects of Repair Problems on New Seal Coat Surface.

- What is the best repair timeframe to cure crack sealing before constructing the PM project?
  All respondents suggested that the repair timeframe before the PM was considered to range from 0 to 18 months.
- What is the best repair timeframe to cure patching material before constructing the PM project?
  All respondents suggested that the timeframe to cure patching materials before the PM was constructed ranged from 4 to 18 months for all materials except for HMA, which could range from 1 to 18 months (Figure A11).

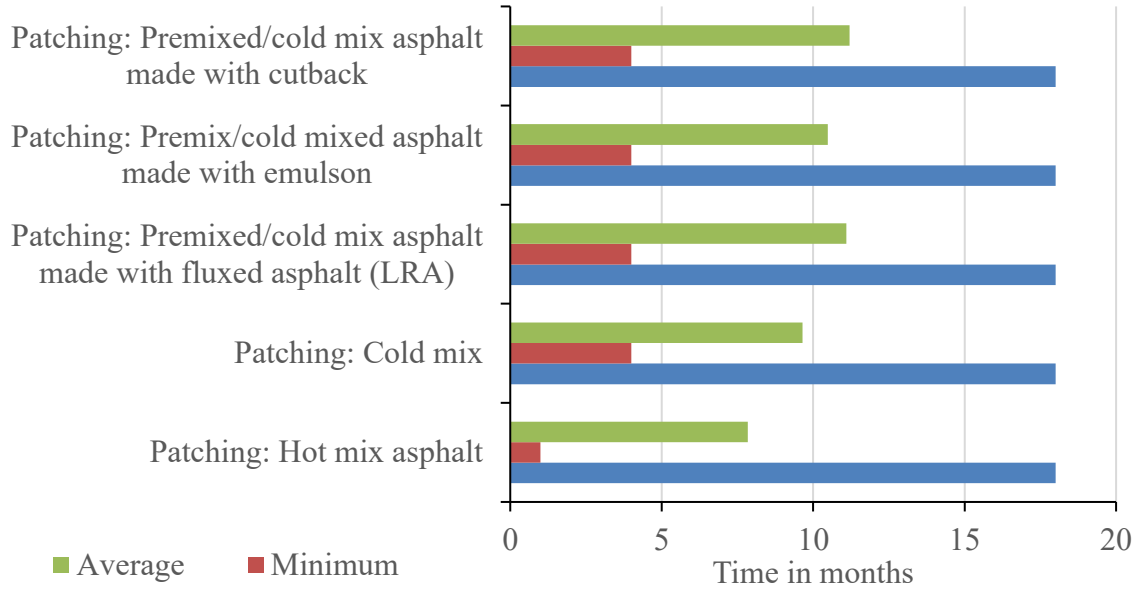

Figure A11. Timeframe to Cure Patching Material Before Constructing the PM Project Surface.

- What do you consider the best timeframe for repairs to cure surface repairs, seal coat, or micro surfacing material before the PM project is constructed?
  At a minimum, the time frame for repairing to cure surface repairs, seal coat, or micro surfacing materials varied from 0 to 4 months. Whereas 18 months is the sealing for all repair techniques (Figure A12).

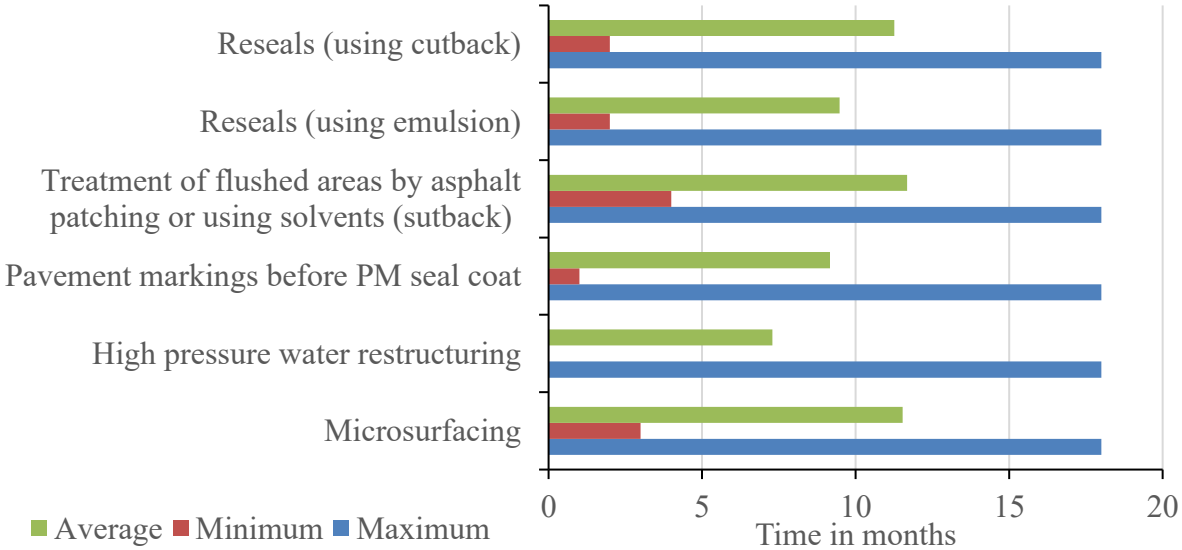

Figure A12. Timeframe For Repairs to Cure Surface Repairs, Seal Coat, or Micro Surfacing Material Before the PM Project.

- What is the best timeframe for repairs to cure structural repair material before the PM project is constructed?

All respondents suggested that the best timeframe for repairs to cure structural repair before the PM ranges from 0 to 18 months (Figure A13).

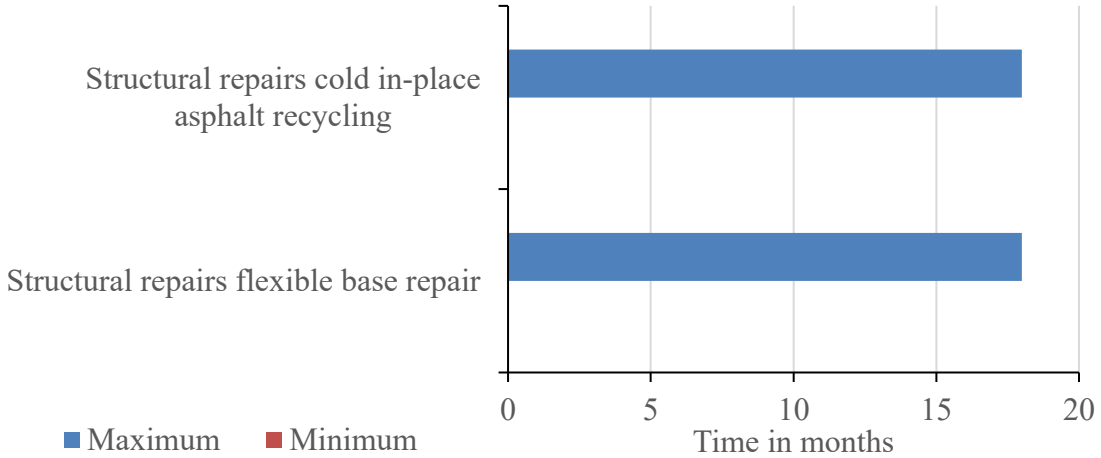

Figure A13. Timeframe for Repairs to Cure Structural Repair Material Before the PM Project.

- Do you fog seal the repair if there is insufficient time to cure before the PM project is constructed?
  About 80 percent of responses indicate that fog seal is typically applied to repairs before constructing the PM project (Figure A14).

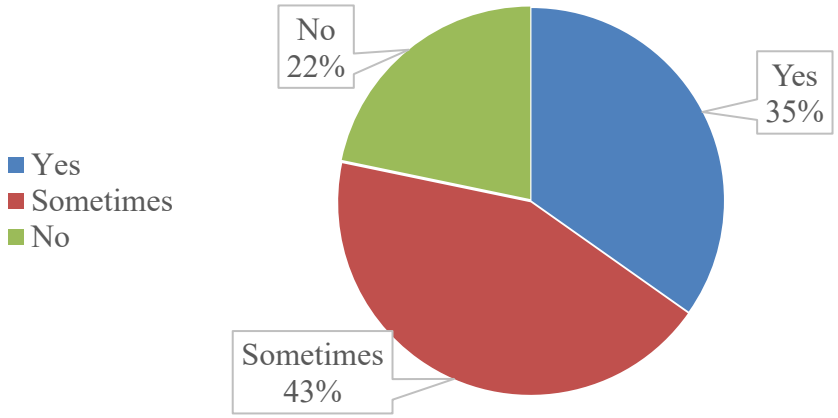

Figure A14. Fog Seal Application on Repairs.

- How do you evaluate how well the repairs worked?
  The survey indicates that visual observation, including ride quality before and after the PM contract and next year's PMIS data, is the primary method for determining how well the repair worked (Figure A15).

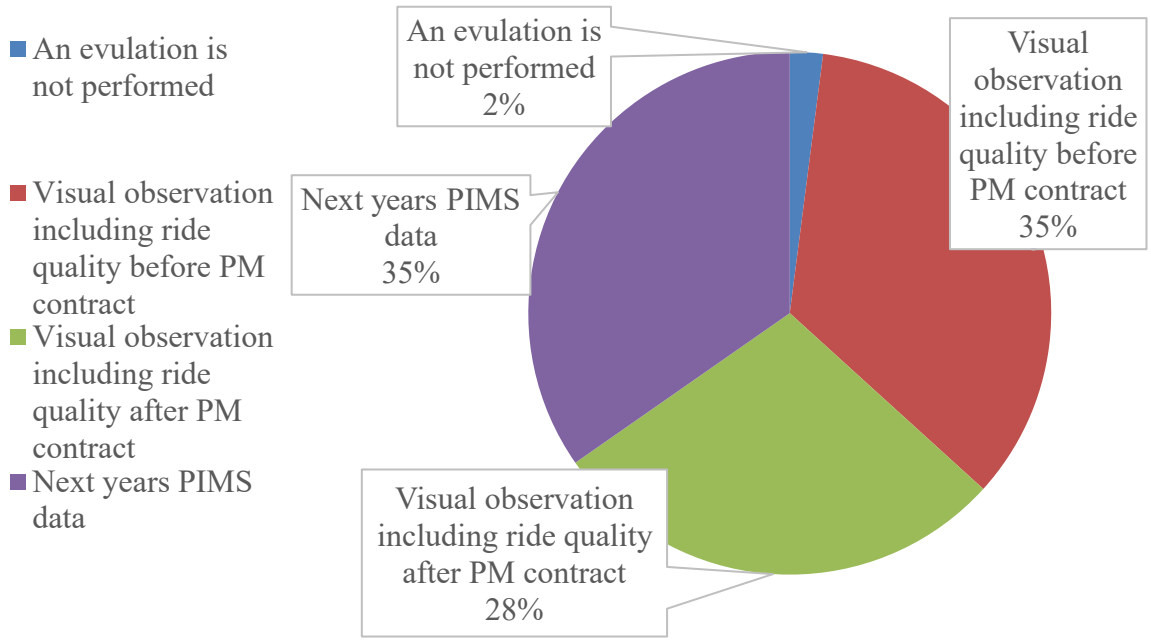

Figure A15. Evaluation of How Well a Repair Worked.

The following were responses about additional concerns with preparing roads for PM projects.

- Much flushing. There is a need to prevent flushing during seal coat instead of combatting it afterward.
- Years of seal coat built up, and most roads are constructed with at least two courses.
- A lot of the roadway prep for a seal coat depends on issues outside the typical seal coat prep. Emergencies such as hurricanes and other rainfall flooding can eat away budget, materials, and personal hours for months and take away seal coat prep time they would normally have.
- A combination of in-house and contract work completes repair work. In-house crews are very good at spot repairs, level-up, and spot seals. Districts typically contract out the longer/higher volume spot repairs and roadway rehabilitation.
- Emergency repairs are handled differently due to the lack of road preparation. Guidance is necessary for these cases.
- The truck traffic volume requires advanced materials not on inventory for maintenance sections, which would preclude in-house repair. In this situation, only temporary repairs would be done to ensure a fast response.
- Also, most of our repair work associated with the PM project, if funded by CAT 1 or contracted work, is built into the PM project.
- Curing depends on the climatic conditions the materials are allowed to experience.