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16. Abstract
Level-up patching is a common corrective maintenance activity in Texas performed by most districts. It involves laying down a thin asphalt mix layer over an existing pavement (rigid or flexible) in areas of sagging or rutting to improve the ride score, reduce pavement roughness, improve drainage, and restore cross-slope. Level-up patching is applied in areas of surface-related failures rather than areas with foundation (base/subgrade) problems. TxDOT uses level-up patching in most of the districts as a corrective pavement treatment. Total expenditures for patching/ overlaying costs are in the order of $180m annually. This report documents the best level-up practices for the benefit of the TxDOT districts. It provides them with guidelines on materials, equipment, and best practices for improving the quality of patching and extending its service life, which ultimately will produce significant cost savings statewide.

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SYNTHESIS OF BEST PRACTICES FOR THE PLACEMENT OF LONG AND SHORT PATCHES FOR RIDE QUALITY: TECHNICAL REPORT

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DISCLAIMER

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CHAPTER 1: INTRODUCTION

Level-up patching is a common corrective maintenance activity in Texas performed by most districts. It involves laying down a thin asphalt mix layer over an existing pavement in areas of sagging or rutting to improve the ride score, reduce pavement roughness, improve drainage, and restore cross-slope. Level-up patching is a relatively, quick, straight forward, simple and inexpensive operation. Patching is primarily performed using two distinct methods, namely blade and laydown. Common activities associated with this patching include surface preparation, placement, paving, compaction, and surface evaluation. Three types of materials are used for level-up patching: hot mix hot-laid asphalt (HMA), limestone rock asphalt (LRA), and 100% reclaimed asphalt pavement (RAP) blended with emulsions.

TxDOT uses level-up extensively. Overall, level-up patching plus overlay operation expenditures amount to roughly $180 million annually. Level-up patching is mainly performed by state in-house personnel, while a small percentage is out-sourced to sub-contractors. There is a need to compile the best practices among districts for level-up patching so their quality can be improved not only to reduce road roughness, but also to improve their durability. Identifying the best practices for level-up patching will lead to improve durability, extended service life, and ultimately result in significant cost savings statewide.

This study documents the current practices for level-up patching as established from a thorough literature review and from information collected from various TxDOT districts through a preliminary survey, comprehensive interviews using a questionnaire, and site visits. It is intended to provide guidelines to TxDOT district directors, field maintenance engineers, laboratory personnel, crew chiefs, and foremen as well as sub-contractors who perform this work for TxDOT.

OBJECTIVES

The main objectives of this study are to:

1. Collect comprehensive information on the current practices of level-up patching in Texas, across the USA and internationally.
2. Visit selected districts and survey the current practices for level-up patching operation.
3. Identify and document the best practices for level-up patching for use by the maintenance offices in the districts.

ORGANIZATION

This report is divided into five chapters:

- Chapter 1 is an introduction on the level-up operations and the needs and objectives of the study.
- Chapter 2 is a literature review through searching current practices of level-up in state DOTs and internationally.

- Chapter 3 summarizes extensive information collected from TxDOT district offices through an online survey, personal interviews with maintenance engineers and directors of maintenance, site visits to on-going patching operations, and data collected from TxDOT's maintenance management information system (MMIS). Details on level-up operations, equipment, crews, materials, performance, costs are described in this chapter.
- Chapter 4 describes the factors affecting the selection and performance of level-up patching.
- Chapter 5 provides a summary and highlights the conclusions of the study.

In addition to this report, a stand-alone manual was published earlier to provide guidelines to field personnel on level-up patching techniques (Dessouky and Papagiannakis 2012). This manual documented the best practices of level-up patching including details on recommended equipment, materials, responsibility of field personnel, as well as the method to be used for post-construction performance evaluation.

CHAPTER 2: LITERATURE REVIEW

This chapter summarizes the findings from the literature-documented research on level-up patching from transportation agencies in the USA and overseas. The maintenance handbooks and research studies developed by a multitude of agencies were used to develop this chapter.

BACKGROUND

Level-up patching is a routine corrective maintenance operation that is performed to restore a pavement surface to an acceptable level of ride quality. It involves leveling the surface using two principal approaches:

- Milling the top defective layer or the high spots and applying a new thin layer.
- Applying a new thin layer over the existing surface in the areas with lower spots.

The first approach is used to remove damaged materials (e.g., cracked/faulted materials) and establish a firm surface. The second approach is used for undamaged surfaces. Either approach can be used for both pavements types flexible and rigid. However, milling is cost effective in preparing only flexible pavement surfaces. The application of a new thin patching layer is carried out using either a blade or a laydown machine. More details on each method are described later in this chapter.

Level-up patches are considered as non-structural layers that do not require a detailed structural design, nor generally contribute to the overall structural capacity of the repaired pavement. Patches differ from overlays by being much thinner (i.e., they range from 0.5 to 1.5 inch) (NAPA 1995). Level-up patching is often used to prepare pavements for subsequent surface treatments or overlay operations. The latter consist of uniform lifts (2 inch thick or higher) and generally contribute structurally to the pavement structure.

Level-up patches are generally applied where repairs are required over areas too large to be hand repaired by typical field crews (WSDOT 2002). They are applied to remedy surface-related failures rather than pavement foundation (base/subgrade) problems. Shallow rutting (< 1 inch), depression, and bleeding are typical distresses that can be effectively repaired by level-up patching. The majority of the level-up patching operations address flexible pavement problems. However rigid pavements with poor ride can also be repaired effectively by level-up patching to improve their surface smoothness.

KEY FACTORS RELATED TO LEVEL-UP PATCHING

The following sections summarize the research literature on the key factors related to level-up patching performance. These include patching materials, equipment, timing, failure mechanisms, and construction costs. The cost of materials is the largest component of the level-up patching cost. Hence, material selection is crucial in achieving a cost-effective repair.

Materials

The New Mexico Department of Transportation (NMDOT) uses two types of mixes for blade patching, namely hot mix cold-laid and commercial cold mix. The hot mix cold-laid material is less temperature sensitive than conventional hot-mix and allows more time for laydown and can produce longer patches. Cold mix patching material prepared with an emulsion is used where hot mix asphalt is not available. Patching with hot mix cold-laid has the advantage of setting quickly. It does, however, require a considerable investment in labor, equipment, and materials (NMDOT 2007).

The Asphalt Institute (1974) recommended using a fine gradation of 3/4 inch through 3/8 inch maximum aggregate size for level-up patching mixes according to Table 2-1. Some applications may also allow for No. 4 and No. 16 maximum aggregate size gradation. The aggregate gradation should be selected to meet the requirements of thickness, aggregate availability, and traffic level.

Table 2-1. Composition of Asphalt Paving Mixtures (Asphalt Institute 1974).

	Asphalt Concrete			Sand Asphalt	Sheet Asphalt
Sieve Size	Mix Designation and Nominal Maximum Size of Aggregate				
	3/4 in. (19.0 mm)	1/2 in. (12.5 mm)	3/8 in. (9.5 mm)	No. 4 (4.75 mm)	No. 16 (1.18 mm)
	Grading of Total Aggregate (Coarse Plus Fine, Plus Filler if Required) Amounts Finer than Each Laboratory Sieve (Square Opening), weight percent				
1 in. (25.0 mm)	100				
3/4 in. (19.0 mm)	90 to 100	100			
1/2 in. (12.5 mm)		90 to 100	100		
3/8 in. (9.5 mm)	56 to 80		90 to 100	100	
No. 4	35 to 65	44 to 74	55 to 85	80 to 100	100
No. 8	23 to 49	28 to 58	32 to 67	65 to 100	95 to 100
No. 16				40 to 80	85 to 100
No. 30				25 to 65	70 to 95
No. 50	5 to 19	5 to 21	7 to 23	7 to 40	45 to 75
No. 100				3 to 20	20 to 40
No. 200	2 to 8	2 to 10	2 to 10	2 to 10	9 to 20
	Asphalt Cement, weight percent of Total Mixture				
	4 to 10	4 to 11	5 to 12	6 to 12	8 to 12

Equipment

The Missouri Department of Transportation listed the complete set of equipment needed for level-up patching as follows (MoDOT 2006):

- Motor blade, pull paver, or self (laydown) for mix placement (Figure 2-1).
- Propelled paver for mix placement.

- Spreadbox (drag box) for mix placement in small jobs.
- Roto-Mill or rumble strip mill.
- Sweeper for cleaning the surface.
- Asphalt distributor for shooting the tack coat.
- Compaction rollers (steel or pneumatic) for compacting the patching layer.
- Dump trucks for mix transplant to site.
- Traffic control equipment.

Figure 2-1. Level-up Patching Using Laydown Paver and Roller Compactor (MoDOT 2006).

Timing

The state of practice suggests that level-up patching should be done in warm dry weather. Wet and cold conditions will interfere with the adhesion of the patching materials to existing pavement surfaces (NMDOT 2007; WSDOT 2011).

Since typically level-up patching is not an emergency pavement repair, it is recommended to carry it out during daylight hours only. The Alberta Ministry of Transportation requires that level-up patching should be performed during daylight hours only, unless adequate artificial lighting can be provided that gives a visibility of at least 2300 ft. No work should be performed when the visibility is less than 2300 ft.

Service Life

The expected service life of level-up patching can be quite long, if the causes of the initial pavement problem are corrected prior to its application (NMDOT 2007). For cost-effective operations and to reduce frequent repairs, it is best to make each level-up patching repair permanent, where possible. Rogge (1992) estimated that the blade level-up patching life ranges from 6 months to 20 years. However, the most likely life expectancy range is between 2 to 5 years with a median value of 3.6 years.

Failure

The NMDOT describes the factors that lead to premature level-up patching failures as follows (NMDOT 2007):

1- Loss of material from the surface of the patch through raveling resulting from a variety of causes, such as inadequate cohesion within the repair mix or poor compaction.
2- Pushing or shoving of the patching mix, which may be the result of a poorly compacted mix, bleeding of tack coat, or poorly designed mix.
3- Reflective cracking originating in old, underlying pavement and propagating into the patch.
4- Delamination or peeling away of thin overlays of asphalt concrete from the surface of the roadway due to poor adhesion.
5- Poor drainage where the repair is in a low-lying area that remains wet over extended periods of time.

COST AND ECONOMIC ANALYSIS

The three main elements of level-up patching cost are materials, labor, and equipment. The material costs include the cost of either the hot mix or the cold mix asphalt used. The labor cost includes the cost of the operators of equipment and the cost of the traffic control workers. The equipment cost depends on the operation method (e.g., dragbox, blade, or laydown) and the associated tools. Traffic control costs depend on traffic levels and the lane closure plan used in any given situation. External costs, such as public delay costs during lane closures, are not normally considered (Wilson and Romine 1999). The life-cycle cost of level-up patching depends on the overall cost and the service life of a particular level-up patching repair.

A survey conducted by Rogge (1992) documented nation-wide costs of blade patching operations. The results showed that the unit cost including materials and labor of blade patching ranges between $28.7/ton and 85.5/ton with a median value of $44/ton. Twenty-one to twenty-nine states cited values between $30 and $50/ton. The cost per lane-mile ranged from $1,300 to $12,800 with a median value of $7,099/lane-mile. Responses to the survey from 43 state agencies in the United States indicated that the states using the highest tonnage of patching material are Texas, Kansas, and Missouri.

Other conclusions from this study are summarized as follows (Rogge 1992):

- Blade patching is considered as a temporary treatment to maintain the surface until an overlay can be constructed.
- Blade patching raises the condition rating of the pavement by approximately one level (e.g., from poor to fair).
- Based on economic analysis, blade-patching is not recommended where the average daily traffic (ADT) exceeds 1,500 vehicles per day or where more than 125 tons/mile of patching material are required at a particular roadway location.

LEVEL-UP PATCHING PROCESS

The maintenance manuals of several state DOTs (e.g., New Mexico, Missouri, and Washington) document the standard steps of level-up patching operations. The common steps involved are summarized below:

1. Setting up traffic control measures: Depending on the class of highway, crews need the protection of correct signing, flaggers, or other traffic control. Adequate traffic control must be provided. This ensures a safe working environment for the maintenance crew and safe travel lanes for vehicles. Traffic control operations should disturb the flow of traffic as little as possible. Traffic control agencies are responsible for providing a work area that is as safe as possible for both workers and drivers and for ensuring that all necessary steps are always taken to maintain safety (Wilson and Romine 1999).

2. Milling surface layer only: Using a jackhammer or milling machine to remove any deteriorated pavement and to reach a firm base. Where possible, patching should start and end on a level grade. If the shoulder is higher than the mat, it is suggested cutting the shoulder down to the same level as the mat.

3. Cleaning: This involves removing all debris from the surface and thoroughly cleaning it using a sweep/broom machine.

4. Surface Preparation: This involves tack coating at a uniformly spraying rate to ensure good bonding between the existing surface and the new patching mix and preventing raveling in thin patch areas. Tack materials include: asphalt cement, cut-back asphalt, and emulsified asphalt. Most of the current tack coatings are made from asphalt emulsion that contains about 28–40% asphalt. This emulsion is generally applied at a rate of 0.03 to 0.10 gallons per square yard. The tack coat should extend a sufficient distance beyond the edge of the repair area to allow for feathering of the patching material (Alberta MOT 2010).

5. Placing the mix using dump trucks over the tacked areas: This can be carried out through one of three methods, namely by drag box, blade, or laydown paver, as described below.
    a. Drag Box Patching: Drag box pavers are convenient and economical equipment for small paving jobs. These pavers hook to the rear of the trucks that are hauling the mix. The asphalt is dumped directly in the hopper of the paver, which places it on the roadway. As the towing vehicle moves ahead, the mix is struck off by an adjustable height blade and is surface-finished by the screed (WSDOT 2002). An even towing speed is necessary to maintain a uniform spread thickness. The drag boxes can work well where large surface irregularities are pre-leveled

    b. Blade Patching: Blades are especially valuable for leveling to eliminate sharp depressions or sags and to lay a leveling course over pavement. They are excellent for placing a leveling course to restore the roadway profile when this cannot be done with a paver or a drag box. Road blades with a long wheel base and smooth-tread tires are often used for spreading hot mix and cold mix asphalt in level-up operations. It is preferable to lay the patch before the mix gets cold, keeping the coarse mix away from the ends of the patch, making smoother approaches, and helping to maintain a straighter edge. Two blades facing each other provide an efficient way for patching (WSDOT 2002). It allows inexperienced blade operators to gain experience with this dual equipment.

   c. Laydown patching: Patching with a laydown machine is similar to paving a new surface course layer. The asphalt is dumped directly into the hopper of the paver, which places it on the roadway. Laydown paver patching with hot plant-mix material has the advantage of providing a smooth finished surface. As the towing vehicle moves ahead, the mix is leveled by an adjustable height blade (cutter bar or screed) and is surface-finished by the screed. Deep ruts, depressions, or humps should be repaired or pre-leveled in advance of the laydown patching placement. Repairing these areas prior to the overlay is necessary to provide a level platform for even compaction (WSDOT 2002).

6. Rolling compaction using a steel wheel or pneumatic tire compactor: Compaction is the most important step of the level-up patch operation. Long or short level-up patches must be compacted to consolidate the material, reduce the air voids, increase weather durability, and increase the stiffness to sustain traffic loading. Compaction is performed by steel wheel, vibratory and pneumatic wheel rollers. Rolling compaction should be performed at a particular range of temperature, typically between 185 and 300ºF. Rolling a mix at lower temperatures may cause cracks, while rolling a mix at higher temperatures may cause uncontrollable flow/shoving.

7. Allowing the mix to cool and cure before opening to traffic.

8. Removing traffic control devices.

9. Installing temporary pavement marking and adding required signs, as needed.

The New Mexico DOT documented their blade-patching practice in a comprehensive movie at http://www.archive.org/download/gov.dot.fhwa.ttp.vh-82/gov.dot.fhwa.ttp.vh-82.mpeg. In this movie a step-by-step process for blade operation is included, with some footage shot from the operator's perspective. Blading, cleaning, tack coating, and spreading pre-mix are demonstrated. Windrowing and laying material in as few passes as possible are emphasized. The first lift, patch tapers, compaction, second lift, and finish lift are shown in detail.

CONSTRUCTION CONCERNS WITH LEVEL-UP PATCHING

Prior to patching, all areas should be tack-coated to ensure a good bond and minimize raveling. NAPA (1995) remarked that when addressing pavement lower spots due to rutting or depressions, the new mix should be placed in several lifts to allow uniform compaction. This will help prevent the ruts from reflecting onto the finished patches. Compaction should be done by rubber tired and steel wheel rollers. In general, compaction is more difficult and more variable in thin lifts than in thick lifts. Construction concerns associated with thin patching were highlighted by NAPA (1995):

- Thin lifts require less HMA per foot of road length than thick lifts. This can allow higher paver speeds. Compaction, however, may not be able to keep pace with these higher speeds.
- Thin lifts will cool quicker than thick lifts. This may result in reduced time for compaction before the thin overlays reach cessation temperature. Therefore, roller variables should be set to compensate for this (e.g., more rollers and an adequate roller pattern to compact the material before it reaches cessation temperature).
- Thin lift construction produces greater screed wear. If the lift depth is less than about twice the maximum aggregate size, the HMA may tear under the paver screed. Very thin lifts (less than 1 inch) can be damaged by the screed dragging large particles.
- Thin lifts are more sensitive to vibratory rolling. Incorrectly chosen amplitude, frequency, or roller speed may result in aggregate degradation and damage of the bond between the overlay and the existing pavement.
- Density control is difficult. Thin lifts provide less mobility for aggregate particles to rearrange under compaction. Thus, mat densities may be less uniform than those associated with thicker lifts.

The Asphalt Institute (1974) emphasized that the thickness of the level-up patching is designed to improve lower-than average pavement conditions, but not to provide additional structural strength. This patching is used to repair weak localized spots and provide a uniform foundation prior to the application of a major surface treatment such as a seal coat or a thin overlay. It plays an essential role in enhancing the performance of the final surface treatment.

Leveling is required to restore the longitudinal and cross-slope profile of pavements to achieve proper surface drainage and smooth ride, where the surface is distorted due to excessive crown slope, rutting, or localized depressions (Figure 2-2) (Asphalt Institute 1974). Leveling should be performed in several lifts, where the required patch thickness is more than 3 inch. Figure 2-2 illustrates the proper way for level-up patching to overcome excessive crown.

Figure 2-2. Illustration of the Correct Way to Place Level-up Patches in Sag or Excessive Crown Areas (after Asphalt Institute 1974).

TRANSPORTATION AGENCY EXPERIENCE WITH LEVEL-UP PATCHING

Washington State DOT

Asphalt layers varying in thickness along their length tend to compact to varying degrees. It is well accepted that that conventional mixes will compact approximately 0.25 inch per 1 inch of un-compacted thickness. This results in differential compaction between thin and thick patch areas (TRB 2000). Therefore, before applying a final surface course, the existing pavement is typically leveled by either leveling/pre-leveling or milling (WSDOT 2011). The leveling layers are initial lifts placed directly on the existing pavement to fill low spots (Figure 2-3). Typically, pavers keep the screed tow point constant regardless of the tractor unit's vertical position. This allows the paver to drive over a rough, uneven pavement, yet place a relatively smooth lift with extra patch material at low spots and less patch material at high spots. Leveling lifts need to be as thick as the deepest low spots and can be compacted with the equipment available. The level-up layer is not tightly specified or controlled because it is not the final wearing course. Although level-up patching can help produce a smoother pavement, it is inherently prone to differential compaction as pointed our earlier (i.e., thicker areas compact less than thinner areas) (WSDOT 2011).

Figure 2-3. Photo Showing the Existing Pavement (Left, Front), a Leveling Course (Left Rear), and the Final Surface Course (Right) (after WSDOT 2011).

On the contrary, milling is used to smoothen existing flexible pavement layer surfaces. It consists of removing the high spots, instead of applying a level-up layer to fill the low spots. For flexible pavements, milling can help eliminate differential compaction problems.

Alberta Ministry of Transport, Canada

The following provides a summary of the level-up patching process developed by the Alberta Ministry of Transportation (MOT) (Alberta MOT 2010):

- For patching, the tack coat shall extend to a sufficient distance beyond the edge of the repair area to allow for feathering of the patching material.
- Patching material on the edges of a patch shall be feathered using rakes or lutes. Coarse material shall be removed from the patch edges.
- Patching material shall be spread, by motor blade, in uncompacted lifts not exceeding 4 inch in depth and compacted to produce a hard, stable surface that does not rut or otherwise distort under traffic loading.
- Patching material placed in a depression shall be compacted in a way that the completed patch is approximately 0.6 inch higher than the surrounding undisturbed pavement. The material at the edges should be feathered to provide a smooth transition between the patch and the existing pavement surface.
- Asphalt pavement material placed in a rutted depression in the direction of travel shall be compacted in a way that the completed patch is leveled with the adjacent undisturbed

pavement. In addition, the material at the edges of the patch shall be feathered to provide a smooth transition between the patch and the existing pavement surface.

Australia (Austroads)

The AUSTROADS Pavements Research Group (APRG) performed a thorough review of the current practice in the use of non-structural level-up/overlays, through a questionnaire sent out to all State Road Authorities. The major findings are (APRG 1992):

- Approximately 25% of all asphalt laid is placed in overlays, averaging about 1.38 million tons per year.
- Seventy percent of all asphalt overlays are for non-structural purposes.
- The major purpose of these overlays is to remedy a deficient surface condition, grade, texture, or general deterioration.
- Over half of all asphalt users do not use any objective measure of pavement condition in deciding the need for non-structural overlays.

SUMMARY

The level-up patching practices summarized in this chapter have come from a thorough review of domestic and international literature. They include details on operations, equipment, applications, and costs. The following summarized the findings from the literature review:

- Level-up patching is a corrective/preventive maintenance treatment applied to pavement structures to improve their ride, texture, and cross-slope.
- Level-up patching is considered as a non-structural thin layer and generally contributes little, if anything, to the overall structural capacity of the pavement. Its average service life is approximately 3.6 years.
- Two major practices are commonly associated with level-up patching, namely removal of the defective pavement surface by milling or covering of the defective area with a thin patching layer using a blade or a laydown machine.
- Based on the review of the current practices of level-up patching by state agencies, it appears that patching of thin layers can be carried out in Texas using a blade, a laydown machine, or a drag box. This is supported by successful applications of these methods in neighboring states, such as New Mexico.

CHAPTER 3: CURRENT PRACTICE OF LEVEL-UP PATCHING IN TXDOT DISTRICTS

This chapter summarizes the findings of two TxDOT district surveys. The first was a short online survey sent to TxDOT districts to capture their overall experience with level-up patching. The second survey was based on the findings of the first survey and targeted the districts that have the most extensive and unique experience with level-up patching. The latter involved a comprehensive questionnaire to collect detailed information related to the process used by TxDOT districts for level-up patching. This questionnaire covered various aspects related to existing pavement conditions, patching materials, equipment types, construction methods, staff skills, and performance evaluation methods. The questionnaire responses were collected during site visits intended to observe on-site patching operations.

The chapter presents the responses of the short survey, followed by a description of the detailed questionnaire and the responses collected. It gives examples of level-up operations collected during field visits to selected districts and concludes with a summary of the costs associated with the level-up patching methods determined using data from the Maintenance Management Information System (MMIS).

SHORT SURVEY

Preliminary information on level-up patching was collected from the TxDOT districts through a short online survey. The survey was sent to the directors of maintenance of each district office to seek preliminary information on materials used on patching, their experience with patching performance, and the patching distresses encountered. This survey form is shown in Appendix A. The survey results were used to identify the districts with a unique approach and methodology in conducting level-up patching operations. The 18 districts that responded included Corpus Christi (CRP), Brownwood (BWD), Paris (PAR), Dallas (DAL), Houston (HOU), San Antonio (SAT), Laredo (LRD), Lufkin (LUF), Bryan (BRY), Yoakum (YKM), Beaumont (BMT), Wichita Fall (WFS), El Paso (ELP), Abilene (ABL), Pharr (PHR), San Angelo (SJT), Lubbock (LBB), and Waco (WAC) (i.e., a 18/25 response rate). All responders indicated that level-up patching is currently implemented in the districts with the exception of El Paso that does not use this treatment. The following section provides a summary of these responses. The detailed results are given in Appendix B.

Regarding the type of pavement distresses usually treated with level-up patching, districts were given the option to select alligator cracking, rutting, longitudinal and transverse cracking as well as combinations of cracking and rutting, loss of subgrade support, shoving, depressions, potholes, corrugation, and failed patches. Their responses indicated that at least 80% of the districts are using level-up patching to correct pavement rutting and depressions, while 50% use patching for correcting shoving problems. It was also found that fewer than 25% of the districts responded consider using level-up patching to correct alligator or longitudinal surface cracking.

Regarding the length of the patches, districts were given the option to choose long (> 100 ft), short (< 100 ft) or both. Responses remarked that 80% of districts that responded use level-up patching for both long and short patches, while only 25% selected long patches only.

Regarding the factors affecting the decision on using level-up patching, districts were given the choices of roadway functional class, ADT, existing surface mix, climate condition, and timing of placement. Sixty-five percent of the responding districts indicated that ADT and placement timing are the deciding factors in using level-up patching. Surface mix type was the influential factor, due to the fact that level-up can be applied on any surface mix type.

Regarding the crews engaged in this operation, 95% of the responding districts claimed that the in-house crews are engaged in the level-up patching, while only 15% of the responding districts indicated that they outsource this operation to sub-contractors. Clearly, some districts use both approaches for level-up patching, depending on their resources.

For the type of patching mix used, districts were given the choices of hot mix, warm mix, cold mix with emulsion, reclaimed asphalt pavement (RAP), emulsion only, and other. Seventy percent of the responding districts indicated that hot and cold mixes are the most commonly used. A small percentage indicated that they use 100% RAP in the patching mixtures blended with emulsions to restore the mix flexibility and ease of compaction. With respect to the preferable gradation structure of the patching mix, 85% of the responding districts indicated that they are using fine gradation. This is explained by the fact that most of the patching work is performed in thin layers.

Responses to the question on the main causes that lead to pavement surface failure suggest that expansive soils, base failures, asphalt aging, moisture damage and under design pavement structures were all contributing. These distresses accounted for 70% of the responding districts.

With respect to the methods used to evaluate the quality of patch finishing, districts were given the choices of profile test, straight edge, visual inspection, no inspection, and other. All districts responded that visual inspection is the main method for evaluation. Only few districts indicated that they test ride after the work is completed.

Ninety-five percent of the responses suggested that districts do not have a stand-alone QC/QA protocol for level-up patching. Instead, districts use the QC/QA protocols of laying down conventional mixtures as the patching guideline.

Regarding the patching performance and life spans, 50% or more of the districts indicated that the average life of the patching lasts from one to five years and that their overall performance is between good and acceptable.

SELECTION OF DISTRICTS FOR SITE VISITING

Based on these results, several districts were chosen for circulating the detailed survey questionnaire. The basis of the selection was the uniqueness in their level-up patching process, weather/soil conditions, traffic volumes, and their geographic location (i.e., urban versus rural). Table 3-1 lists the selected districts and the criteria behind their selection. San Antonio and Dallas metropolitan districts were selected due to their high traffic volumes. Paris and Bryan Districts were chosen due to their expansive soils and annual high rainfall. Lubbock and Lufkin were included for their unique use of 100% RAP as a patching material. Abilene is one of few districts that performs all its level-up operations in-house, while San Angelo was included because of its unique application of milling as a routine surface preparation prior to patching.

Table 3-1. Districts Selected for the Comprehensive Survey and the Associated Criteria.

District	Urban (U)/ Rural (R)	Weather	Comment
SAT	U	Hot and dry	
DAL	U	Cold and wet	Overall performance is poor
PAR	R	Cold and wet	Foundation of soft clay expansive soil
ABL	R	Cold and wet	90% or more of level-up operations performed by in-house crew
SJT	R	Hot and dry	Use milling in surface preparation
LUF	R	Cold and wet	Use of 100% RAP as a patching mix
BRY	R	Hot and wet	Foundation of soft clay expansive soil
LUB	R	Cold and wet	Use of home-made patching mix

QUESTIONNAIRE STRUCTURE AND ORGANIZATION

The questionnaire was the main source of information gathered in this project. Therefore, the development of a well-designed, short, clear, concise, and well-targeted questionnaire was one of the most important aspects of this project. This questionnaire targeted primarily decision maker(s) who oversee manage the level-up operation in each district. The person/persons that responded to the questionnaire held various positions in the districts selected.

The questionnaire is divided into five parts (Appendix C).

A. The first part gathered background information on the responder.

B. The second part queried the factors affecting the selection of level-up patching type.

C. The third asked questions on crew training and responsibility.

D. The fourth covered the patching/filling material types and characteristics.

E. The fifth covered the construction and placement process.

F. The final part covered performance evaluation methods and allowed free comments to be provided.

The research team obtained comprehensive responses to the questionnaire by visiting the eight selected TxDOT districts and meeting their directors of maintenance and/or maintenance engineers who have experience with level-up patching operations. This ensured collecting comprehensive information on level-up patching methods. In addition, district visits allowed the research team to photograph and witness examples of patching operations. Interview discussions were voice recorded to ensure accurate capturing of the information. After the interview discussion, pavement site visits were conducted. After each district visit, the voice recordings were transcribed for later review and comparison with information collected from other districts. The following section summarizes the results of the questionnaire responses. The questionnaire responses reflect the opinion of the responders based on his/her experience with these operations.

QUESTIONNAIRE RESPONSES

Part A of the questionnaire solicited information on the credentials of the responders. The majority of the responses to the questionnaire were obtained from the directors of maintenance and maintenance engineers who have long experience with level-up patching in their districts.

Part B of the questionnaire solicited information on the type distresses that are usually repaired with level-up patching and the key factors (e.g., distresses, traffic, highway classification, pavement types, and climate) that affect the selection of patching type, and the materials used. Responses suggested that rutting in the wheel paths, depressions in localized large areas, and rough ride were the best candidates for level-up patching particularly if they are of low severity. As recommended, the maximum depth of rutting and depression is 1 inch. Exceeding 1 inch rutting is considered as a sign of a major failure in the underlying layers and/or the subgrade that may require heavy rehabilitation.

A summary of the questionnaire responses related to the key factors affecting the selection of patching operations and materials is given in Table 3-1. Choices of patching materials were HMA, limestone rock asphalt (LRA), and RAP, while choices of operations were laydown machine and blade machine. This table suggests that the patching operation is generally decided by the availability of local materials and equipment rather than the distress type to be treated. However, given the materials and equipment available, the preferences of the responding districts as to the patching method and the distresses treated are given in Table 3-2. It can be seen that there is a preference among districts to select HMA for roads of higher functional class and traffic volume, where higher quality, strength, and durability are warranted. The LRA on the other hand, is preferred for lower traffic volume roads. Placement of level-up patching can be used on any surface type, flexible or rigid, dense graded, or fine graded, asphalt concrete or surface treatment with no major changes in the patching materials or equipment used.

Table 3-2. Suggested Key Factors and Their Influence in Selecting Patching Materials and Process.

Key factor	Notes
Functional class (e.g., IH, US, SH, FM) and traffic level	HMA: high volume traffic (e.g., IH, US) LRA: medium volume traffic (e.g., SH and FM) RAP: low volume traffic
Pavement type (e.g., flexible and rigid)	No effect. Both types will take same patching treatment process with the exception that no milling on rigid pavement.
Existing surface mix design (e.g. dense graded, fine graded, SMA, PFC)	Patching operation is not affected by existing surface design. However, for PFC and SMA the tack coat shoot rate should be pre-determined to avoid overshooting.
Flexible pavement surface type (e.g., ACP and surface treatment)	No effect
Climate conditions (e.g., wet and dry zones)	Patching should be done in dry conditions. After rolling and compaction rain fall has negligible effect in the patching layer
Timing of placement (e.g., hot and cold seasons)	Placement in hot seasons is mostly preferable. For cold seasons, LRA is a preferable choice
Others	Above recommendations are suggested based on availability, cost and quality of materials in the district

Part C of the questionnaire solicited information on the training of the in-house crews and responsibilities of the crew chief. As pointed out by the responses of the district survey in Chapter 2, 95% of the districts (particularly rural districts) are using their state personnel for the majority of the level-up patching jobs. Responses suggested that the crews are given a basic training and skills improvement course named *On the Job Training (OJT).* This course covers general training on duties of maintenance operations including operating construction equipment (e.g., blade, laydown, sprayer, broom, and roller). The *OJT* course is designed to ensure that the trainee consistently receives the level and quality of training necessary to perform as a journeyman in their respective skilled trade classifications. More detailed in this program can be found at ftp.dot.state.tx.us/pub/**txdot**-info/civ/fy_09_**ojt**_prog_man.doc.

This part of the questionnaire also solicited information on the responsibilities of the crew chief, the lead operator at the job site. He/she is in charge of preparation and planning for the job, material selection, equipment and crew selection, management and monitoring of the operation, solving any problems arising during the operation, making decisions, and evaluating the smoothness of the final layer. Other responsibilities include ensuring that the equipment is calibrated, selecting the timing in response to weather conditions, ensuring the safety of the crew members, and cleaning and preparing the site for traffic control. He/she must be familiar with the level-up patching process and know how to achieve quality results. The following tasks are the summary of the crew chief responsibilities prior, during, and after any patching operation:

Before the day of operation:

- Inspect the job site for any hindrances or obstacles that need prior arrangements.
- Review the job plans and estimate the amount of materials required.
- Estimate the time required to complete the job and the maximum length. (footage/mileage) of patching per day.
- Arrange for the proper equipment needed for the job.
- Ensure that the equipment is calibrated.
- Arrange for the staff required at the site.

During the operation:

- Ensure that the traffic control arrangements are made.
- Manage the time to ensure that the job can be completed in the same day.
- Ensure that the asphalt is sufficient in the distributor truck and that it is heated to the correct temperature.
- Determine if enough material is being applied to the roadway.
- Monitor the operation to check the quality.
- Recognize and correct any problems that arise.
- Check if the weather is suitable for completing the patching operation. Make a decision to discontinue and postpone the operation if the weather deteriorates.
- In some cases, operate the blade and/or rolling compactors. This includes spreading and feathering the patching mix to create a thin layer followed by compaction.

After the operation:

- Evaluate the quality of the work and the smoothness of the finished roadway surface.
- Order additional work if the desired quality is not achieved (e.g., re-patching, compacting).
- Removing and cleaning the site from any debris or obstacles.
- Ensure the safety of workers and drivers working at the site.

Part D of the questionnaire solicited information on the type, design, and characteristics of the patching mixtures used in level-up patching operations. The responses suggested that the majority of the districts are using primarily HMA and LRA. Few districts (e.g., LUF, LUB) are using a 100% RAP mix for their low volume roads, primarily due to the lack of local materials. Type C, D, and F are the most commonly used designs for the HMA using limestone aggregates. The PG 64-22 and 70-22 are the most common asphalt binder grades used by the districts, the actual choice being dictated by the geographic location and the climatic conditions. The CC (medium surface), DS (fine surface), and FS (thin surface) are the most commonly used LRA designs. Up to 25% RAP can be included in the HMA, while the LRA should include only 100% virgin rocks. The 100% RAP is produced from a type D fine grained recycled mix blended with a RC250 emulsion. Level-up patching that utilizes LRA and RAP produces surfaces that can be opened to traffic shortly after the rolling compaction is completed. Level-up patching that utilizes HMA requires a longer period for cooling prior to opening to traffic to prevent tires from peeling off the aggregate particles. The questionnaire responses suggested that there is no current district protocols specific to level-up patching material selection, placement, and quality control. Most of the information needed for patching mixes preparations, gradations, designs, lab testing and performance evaluation is specified in TxDOT's Material Specifications Manual (2004). A summary of this information is given in Chapter 4.

Part E of the questionnaire solicited information on the equipment, construction, and placement processes used for level-up patching. Two types of operations are most commonly used, one involving a laydown machine and one involving a blade. Table 3-3 lists the equipment used in each operation. The laydown machine is most commonly used with HMA, while blading can be used for all types of patching mixes. The laydown machine performs two tasks. First levels the existing surface by filling the thin mat in the wheel path areas and second lays a 1.5 inch layer of patch. The calibration and maintenance of this equipment is performed by the crews prior to the operation.

Selection of the operation methods is dependent on many factors including, equipment availability, traffic level, and crew chief/staff experience with particular operation over the other. For example, responses suggested that laydown is best used with high volume roadways due to its higher operation cost.

Table 3-3. List of Equipment Used in Each Level-up Operation Process.

Blade	Laydown
Blade (maintainer)	Self-Propelled Paver
Sweeper	Sweeper
Roto-Mill machine (option)	Roto-Mill machine (option)
Drag box (option)	Dump Trucks
Dumb Trucks	Asphalt Distributor
Asphalt Distributor	Water truck
Water truck	Roller (Steel and rubber wheel)
Roller (Steel and rubber wheel)	Hand rakes
Traffic Control Equipment	Traffic Control Equipment

Figure 3-1 provides a pictorial catalog of the equipment and processes involved in the patching process.

Traffic Control

Surface preparation

Roto-Mill machine for full-lane milling

Broom/sweeper

Tack coat application

Asphalt Distributor for tack coat application

Mix placement

Dump truck/Drag box

Dump truck (end-dump)

Belly dump truck

Paving

Self-propelled paver / Lay-down machine

Blade

Compaction

Steel wheel roller (vibratory or static)

Pneumatic wheel roller

Water truck for filling the rollers water reservoir

Figure 3-1. Pictorial Catalog of the Equipment Used in Level-up Patching.

Surface preparation is achieved by milling the top 1/2- 1 inch of the surface using a roto-milling machine to remove the existing distressed materials and/or reduce surface roughness. If a roto-milling machine is not available, patching over the existing surface can be performed directly. In this case, scrapping traffic reflectors and markings and dry-brooming the surface from the debris are the only process performed for surface preparation.

The questionnaire responders suggested that the best timing for level-up patching placement is during the day time in dry and warm conditions. Wet pavements and cold weather affect adversely the adhesion of the hot mix patch material to the existing pavement.

The last questionnaire section, Part F, solicited information on the performance measures used to evaluate the quality of the patching. Smoothness and levelness of the final surface are key quality control criteria for the finished level-up patching. Successful operations are evaluated by the crew chief through visual inspection and/or test ride after the operation is complete. As obtained from the short survey, this inspection applies to all districts. An informal follow-up inspection after the site is open to traffic is performed to determine if additional leveling is required. Most responses suggested that extensive evaluation by roughness test, surface profile measurement, and skid test are not conducted after completion of level-up patching. Such measurements are part of the routine Pavement Management Information System (PMIS) data collection. Another reason for not conducting an evaluation following level-up patching is that it is not typically considered as a final driving surface, but rather a preparation to a subsequent surface treatment (e.g., seal coat, chip seal, or overlay).

SUMMARY OF DISTRICT QUESTIONNAIRE RESPONSES

The current practice of level-up patching was documented using questionnaire responses from eight districts. The questionnaire covered many aspects related to level-up patching, such as key factors to consider patching treatment, staff and crew responsibility, materials types, construction and placement methods, and performance evaluation methods. Responses agreed that blade and laydown are the most common methods for level-up patching. Depending on traffic level, the HMA, LRA, and RAP are the most selected patching materials.

FIELD VISITS

The following sections document examples of current operations with a step-by-step description of practices by district visited (Table 3-4).

Table 3-4. Description of the Job Site Operations at the Districts.

District	Highway	Mix Type	Length	Volume Traffic*	Operation
LUB	FM 179	LRA	> 300ft	Low	Blade (in wheel path only)
SJT	US 87	LRA	> 300ft	Medium	Blade/Milling(full lane width)
SAT	LP 1604	LRA	< 300ft	Low	Blade (full lane width)
LUF	FM 1	RAP	> 300ft	Low	Blade (full pavement width)
BRY	FM 979	LRA	< 300ft	Low	Blade (full pavement width)
PAR	Multiple	HMA	< 300ft	High	Blade
ABL	US 180	HMA	< 300ft	Low	Blade (full pavement width)
DAL	US 287	HMA	> 300ft	High	Laydown (full pavement width)

Low: < 3000 vehicle/day, medium: 3000–30,000 vehicle /day and high: > 30,000 vehicle/day.

FM 179 (Lubbock District)

Description: Blade-patching was performed due to rutting in the wheel path. Existing condition shows 1 inch rutting in the wheel path close to the shoulder causing rough ride.

Step 1: Setting the traffic control at both ends of the patching site. Cones shall be used along the worked lane to isolate the crew and workers from traffic. Flagger or pilot truck can be used to control through traffic.

Step 2: Removing the grass along the shoulder through blading. This step is essential only when the grass is over-covering the shoulder or the travelling lane.

Step 3: Cleaning the proposed patching surface from the debris using the broom machine.

Step 4: Shooting the tack coat on the patching area to bond the new patching mix with the existing surface layer. The blend and spraying rate should meet the TxDOT specifications.

Step 5: Laying down the patching mix (district in-house made cold-mix with emulsion) using a dragbox on top of the wheel path. It is not necessary to control the patching layer thickness as it will be maintained by the blade in Step 6. However, it should fill up the rut areas.

Step 6: Distributing the patching mix along the surface through blading. This can be done in several passes. In each pass, the blade fills the rut areas in thin layer increments. The process continues until the mix completely fills the rut areas and the final surface is leveled with the existing pavement cross slope. At the ends of the patching lane, the blade driver should feather in the mix to level up with the existing surface layer.

Step 7: Finishing up the surface with a steel wheel compactor to compact the layer and provide a smooth surface. This step can be preceded by a pneumatic compactor (preferable) for better results. The pneumatic compactor provides better compaction for narrow patches.

Step 8: Evaluating the cross slope by visual inspection using a straight edge at various spots. Driving on the finished surface also provides a feedback on the longitudinal slope and the ride smoothness.

US 87 (San Angelo District)

Description: Blading over the full-lane width to correct rough ride. Existing distresses include bleeding of binder/tack coat causing low skid resistance. This section was seal-coated immediately after the blade patching operation was completed. This is due to the insufficient curing time provided for the patching mix and tack coat prior to the seal coat treatment.

Step 1: Milling the upper 0.5 inch surface layer until the distressed layer is removed. Milling provides better bonding and longer lasting patches. The resulting RAP can be used in slope stabilization and for covering up the unpaved shoulder.

Step 2: Shooting the tack coat at 0.10 gal/yd^2 and hauling-in the patching mix using the drag box. The LRA Type DS design was used.

Step 3: Blading the mix along the full lane in several passes until it becomes flush with the existing cross slope.

Step 4: Finishing up the surface with a pneumatic compactor.

Step 5: Inspecting the level-up patching by the supervisor.

Step 6: Removing the traffic controls and opening for traffic.

This section was scheduled for fog sealing three months after this blade patching operation was performed to prevent aging and raveling of the surface. Also, a year later a seal coat is planned to provide a finished surface. The time span between the blade patching and seal coating is to allow proper traffic compaction to the patching mix and enough time for the tack coat oil to cure.

Loop 1604 Frontage Road (San Antonio District)

Description: This operation involved blade patching the full lane width on the frontage road of Loop 1604 in the San Antonio District. Existing pavement distresses included depressions, rutting, and rough ride resulting from expansive soil subgrade activity. The rut depth in this section ranged from 0.5 to 1 inch. The length of the section patched was 300 ft. The following describes the steps taken place for blade patching operation.

Step 1: Setting the traffic control at both ends of the patching site.

Step 2: Cleaning the surface from the debris using the broom machine.

Step 3: Shooting the tack coat; a type SS1 emulsion at 120°C.

Step 4: Laying down the LRA patching mix. No drag box was used. The dumped material is

used to complete one lift of 0.5 inch thickness.

Step 5: Blading the mix in 0.5 inch thickness with multiple back-and-forth passes.

Step 6: Pneumatic compacting of the 0.5-inch patching layer. Better compaction is achieved with thin lifts.

Step 7: Repeating steps 4–6 for multiple lifts until the final surface is leveled with the existing pavement.

Step 8: Finishing up the surface with steel wheel compactor to compact the multiple layers and provide a smooth surface. Blade the excess from the side to for a smooth slope along the shoulder.

Step 9: Removing the traffic control and opening to traffic.

FM 979 (Bryan District)

Description: This job involved two blade-patching over the full pavement width of FM 979 in Bryan District. The distress to be addressed was deep seated cracks caused by embankment slope failures.   Existing condition at Milam County northeast of Cameron between FM 485 and Brazos River showed 0.75 inch ruts in the wheel path close to the shoulder causing rough ride. This area gets considerable amount of annual precipitation. The subgrade soil is primarily expansive clay that tends to show large volume changes throughout the year.

Step 1: Setting the traffic control at both ends of the patching site. Cones shall be used along the worked lane to isolate the crew and workers from traffic. Flagger or pilot truck can be used to control through traffic.

Step 2: Removing the grass along the shoulder using the blade. This step is essential only when the grass is over covering the shoulder or the travelling lane.

Step 3: Cleaning the proposed patching surface from the debris using the broom machine.

Step 4: Shooting the tack coat on the patching area to bond the new patching mix with the existing surface layer.

Step 5: Laying down the patching mix with dump truck in multiple piles over the tacked areas.

Step 6: Distributing the patching mix along the surface using two facing blades. Each blade patches over a single lane with overlapping to ensure smooth feathering over the center line. With dual blades this operation can be completed in shorter period of time allowing faster opening to traffic.

Step 7: Finishing up the surface with steel wheel compactor to compact the layer and provide a smooth surface.

Step 8: Evaluating the cross slope by visual inspection using a straight edge at various spots. Driving on the finished surface also provides a feedback on the longitudinal slope and the ride smoothness.

FM 1 (Lufkin District)

Description: This job involved blade-patching over the full lane width using 100% RAP on FM 1 at Lufkin District. The existing distresses included 0.5 inch rutting and flushing in the wheel paths.

Step 1: Setting the traffic control. The project length was 1 mile long and a pilot truck was used to navigate the through traffic on the remaining single lane.

Step 2: Sweeping the debris and dust from surface.

Step 3: Shooting the tack coat (CRS 2-P) at 0.04–0.10 gal/yd^2 and hauling-in the patching mix using a drag box. A cold-laid type D mix contained of 100% recycled asphalt was used. The mix was blended with 3% CCS-1 emulsion before the lay down.

Step 3: Blading the mix along the full lane width in several passes until it becomes flush with the existing cross slope.

Step 4: Compacting the mix with pneumatic compactor and finishing with steel wheel compactor.

Step 5: Installing temporary reflectors, removing the traffic controls and opening for traffic.

Summary of Site Visits

A step-by-step description of the level-up operations observed at eight districts; LUB, SJT, SAT, LUF, BRY, PAR, ABL, and DAL was presented. All operations were performed over flexible pavement. However, based on survey responses the level-up patching over rigid pavement is performed in the same manners as on flexible pavement. The only exception is that milling is not performed as part of the operation.

COST ANALYSIS USING MMIS DATA

The cost of the various level-up patching operations is essential for establishing their life-cycle cost. Operations that achieve longer performance life with lower construction cost are clearly preferable. The purpose of this section is to summarize cost information associated with level-up patching operations in Texas. In addition, it presents data on the frequency of application of each type of level-up application. The MMIS database was utilized to extract cost information for fiscal years 2009 and 2010 for each district. In the MMIS, each operation method is assigned a function code as follows:

- Code 211 is used for all activities associated with leveling or overlaying of pavements using the laydown machine. It includes the application of a tack coat, addition of hot mix to the repair area, placement and leveling with a laydown machine, and rolling of the repaired area.
- Code 212 is used for all activities associated with blade level-up on the pavement surface. It includes the application of a tack coat, addition of HMA, or LRA application to the repair area, placement and leveling with a blade and rolling the repaired area.
- Code 214 is used for all activities associated with level-up projects that use a drag box attached to trucks or motor blades. It includes the application of a tack coat, addition of HMA or LRA application to the repair area, placement and leveling with a dragbox and rolling the repaired area

According to the MMIS database, the total expenditures in combined operations of patching and overlaying are in the order of $180m annually. A breakdown by operation is shown in Table 3-5. The unit cost for the treatment under each code is determined by dividing the total expenditures of the operation by the work unit. The work unit is defined as the area of patching in square yards (e.g., Unit Cost ($) = Total Expenditures/Work units).

Table 3-5. TxDOT Total Expenditures of Level-up Patching in 2010 (MMIS Database).

	level/overlay with laydown	level/overlay with blade	level/overlay with drag box
In-house	$60,854,000	$79,901,000	$4,460,000
Sub-contractors	$33,659,000	$1,966,000	$16,000
Total	$94,513,000	$81,867,000	$4,476,000

To evaluate the frequency of each operation in each district, the expenditures corresponding to each function code were divided by the total expenditures corresponding to each level-up patching code. The function codes 213 and 212 were combined because the dragbox is used for mix placement and the blade is used for mix distribution, leveling, and feathering. The distribution of lay-down and blade operations per district is showed in Table 3-6 for FY 2009 and 2010. These data suggest the following:

- Blade operation is the primary level-up method in CHS, ELP, BWD, AUS, WAC, ABL, SJT, BRY, ODA, LUB, and PAR districts based on the expenditures in the two fiscal years.
- Laydown operation is the primary level-up method in FTW, HOU, DAL, and TYL districts based on the expenditures in the two fiscal years.
- Both operation methods are equally used in LRD, YKM, LFK, and WFS districts.
- In FY2010, the WFS, AUS, CRP, ODA, and SAT districts increased their laydown operation expenditures by 16% compared to FY 2009.
- In FY2010, the BMT, PHR, and BWD districts substantially increased their laydown operation expenditures by 55% compared to FY 2009. This switch from blade to laydown

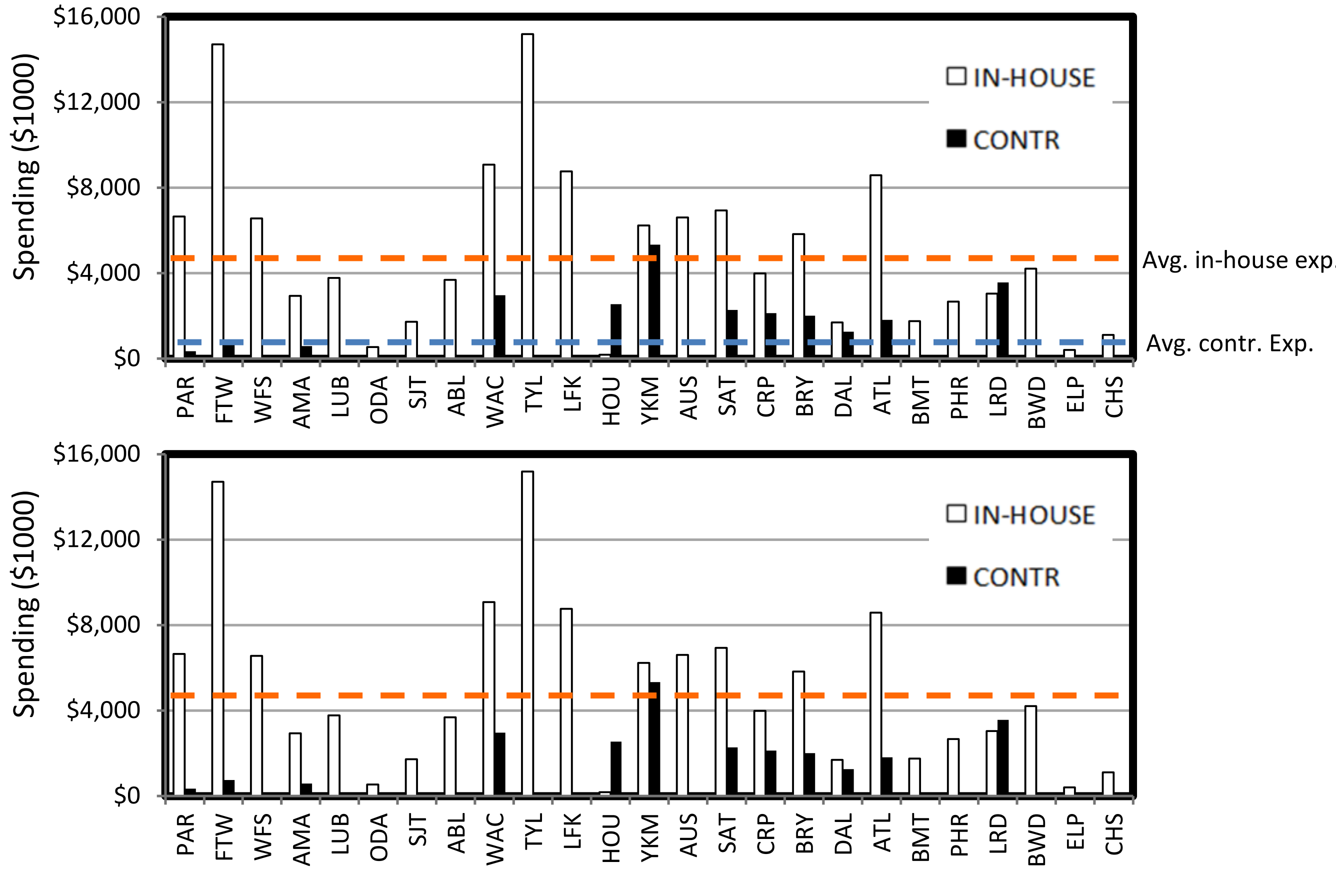
method which is primarily performed by sub-contractors may be due to lack of access to equipment and/or materials.

Table 3-6. Percentage of Level-up Patching Operation by Method.

		PAR	FTW	WFS	AMA	LUB	ODA	SJT	ABL	WAC	TYL	LFK	HOU	YKM	AUS	SAT	CRP	BRY	DAL	ATL	BMT	PHR	LRD	BWD	ELP	CHS
2009	Lay-down	11	87	34	40	10	0	0	0	23	71	58	100	42	5	33	40	40	75	57	0	4	50	0	0	0
	Blade	89	13	66	60	90	100	100	100	77	29	42	0	58	95	67	60	60	25	43	100	96	50	100	100	100
2010	Lay-down	18	91	51	38	11	16	2	10	26	86	63	100	41	21	51	53	24	72	38	69	67	48	32	0	0
	Blade	82	9	49	62	89	84	98	90	74	14	37	0	59	79	49	47	76	28	62	31	33	52	68	100	100

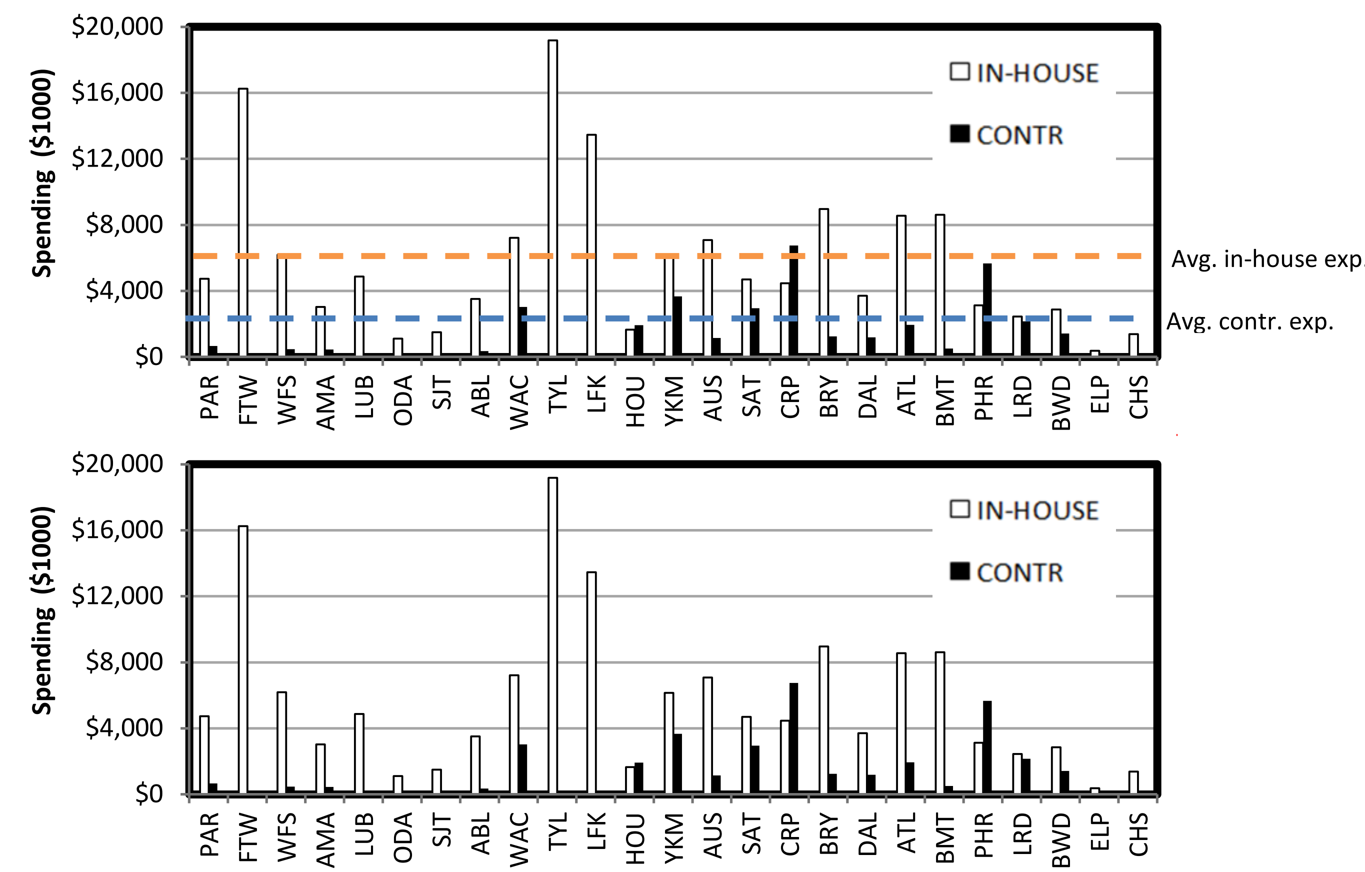
District expenditures for in-house state personnel and sub-contractors personnel performed in FY 2009 and FY 2010 are plotted in Figure 3-2. This figure shows also the statewide average expenditures for in-house and sub-contracted operations. For each operation type, the average expenditure was determined by dividing the total level-up expenditures by the number of districts using each particular operation. These records suggest that the average level-up patching expenditures increased by 14% for in-house operations and by 38% for sub-contracting operations from FY 2009 to FY 2010.

Level-up patching expenditure records for FY 2009 and FY 2010 suggest that the FTW, WFS, WAC, TYL, LFK, YKM, AUS, BRY, and ATL districts spent above the average statewide of in-house operations, while the WAC, YKM, SAT, and CPR districts spent above the average statewide of sub-contracting operations.



$16,000
$12,000
$8,000
$4,000
$0
Spending ($1000)
IN-HOUSE
CONTR
Avg. in-house exp.
Avg. contr. Exp.
PAR
FTW
WFS
AMA
LUB
ODA
SJT
ABL
WAC
TYL
LFK
HOU
YKM
AUS
SAT
CRP
BRY
DAL
ATL
BMT
PHR
LRD
BWD
ELP
CHS

a) FY 2009



b) FY 2010

Figure 3-2. Total Expenditures (in Millions) by In-House Personnel and Sub-Contractors for Level-up Patching for FY 2009 and 2010.

The unit cost of level-up patching by district is shown in Figure 3-3. These data suggest that the laydown operations are more expensive than the blade operations. However, to eliminate the influence of the number of work units in determining the unit cost, selected districts with comparable patching volumes were considered. In the LUF district, where the volume of blade and lay down operations was similar and the work was performed by in-house personnel, the average unit cost was $3.74/SY and $8.43/SY, respectively. Another comparison considered the PAR and ATL districts, where some of the level-up patching work was done in-house and some was out-sourced to sub-contractors. The unit cost for in-house patching was $6.85 and $7.67/SY for blading and laydown operations, respectively. The unit cost for sub-contractors patching was $14.28 and $10.29/ SY for blading and laydown operations, respectively. These comparisons suggest that blade operation performed by in-house state crews had significantly lower level-up patching unit costs than those charged by sub-contractors. The cost of the patching materials is factored in the estimation of these unit costs. However, it is impossible to separate the unit cost of the materials by each mix type (e.g., LRA, HMA and RAP) using the current cost figures available in the MMIS.

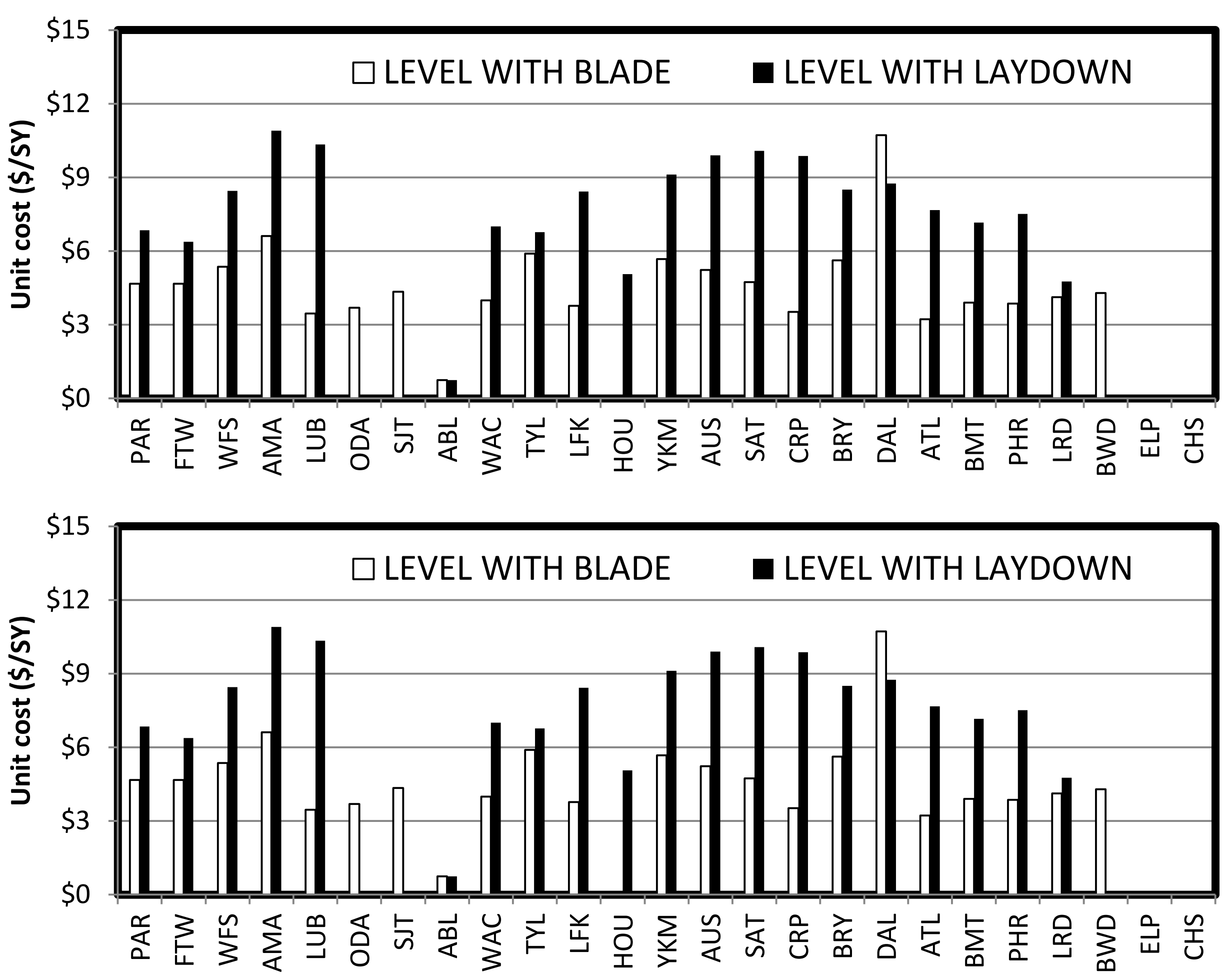


Figure 3-3. Comparison of Unit Costs for Level-up Operations by Blade and Laydown for Each District.

SUMMARY

This chapter summarized extensive information collected from the TxDOT district offices through an online survey, a detailed survey questionnaire conducted in person through interviews with maintenance engineers and directors of maintenance, and site visits to observe on-going operations. Information on the level-up patching operations, equipment, crews, materials, performance, and costs were described. In summary:

- A preliminary TxDOT district survey suggested that level-up patching is a common treatment used to improve ride quality, surface texture, and cross-slope drainage.
- Rutting (less than 1 inch) in the wheel path, and rough ride on the surface layer are the best distress candidates for level-up patching treatment.
- The HMA, LRA, and RAP are the common choices of patching materials depending on availability, cost, and traffic level.
- The most common methods for level-up patching involve a laydown machine or a blade.

- The crew chief is responsible for planning, site preparation, management, and monitoring of the operation. The quality of the patching is highly dependent on his/her experience and familiarity with the operation and the equipment.
- Site visits were conducted to eight districts, LUB, SJT, SAT, LUF, BRY, PAR, ABL, and DAL. Sites were selected to cover different pavement conditions including; traffic volume, materials types, climate condition, operating method, and highways classifications. A step-by-step description of the level-up operations observed at each district was documented.
- Cost analysis extracted from the MMIS database suggested that the blade operation is the commonly used and less expensive method for level-up patching compared to the laydown operation. Rural districts are considering blade-operation for the majority of their level-up patching work, which is most often performed by in-state staff. Urban districts are using laydown machines as their most common level-up patching operation.
- The results presented in this chapter are primarily for flexible pavement, the most common pavement type in TxDOT districts. Level-up patching over rigid pavement is performed in the same manners as on flexible pavement. The only exception is that milling is not performed as part of the operation.

CHAPTER 4: LEVEL-UP PATCHING: SELECTION FACTORS AND PERFORMANCE

INTRODUCTION

The primary application of pavement level-up patching is to restore the vertical alignment of the pavement and to provide smooth and safe ride. It is applicable where pavement surfaces experience deformation in the form of rutting, depressions, corrugations, or roughness. Depressions and excessive wheel path rutting can be hazardous to motorists. Heavy vehicle dynamics exacerbated by depressions amplify pavement damage (Figure 4-1). In some cases, level-up patching is the final exposed surface of the pavement.

Figure 4-1. Example of Pavement Depression.

A secondary application of level-up patching is to prepare the pavement for another surface treatment (e.g., seal coating, chip sealing, or microsurfacing). This surface treatment should be applied after a considerable period of time (e.g., six months) from the completion of the level-up operation to ensure complete curing of the patching mix.

The expected life of level-up patching is approximately three years. The expected life of patching used to prepare pavement surfaces for additional treatment is masked by the life expectancy of the surface treatment itself. To maximize the surface life of surface treatments, it is critical to understand the key factors affecting the performance of level-up patching operation and the pavement conditions that warrant the selection of this operation as an appropriate treatment.

This chapter is divided into two sections: the description on the factors that affect the selection of a surface treatment and the description of the factors affecting its performance.

FACTORS AFFECTING SELECTION OF LEVEL-UP PATCHING IN PAVEMENT TREATMENT

Typically, the following factors are used in deciding the use of level-up patching as a maintenance treatment:

- Types of distresses on existing pavement surface including; rutting, depression, and roughness. A detail description of pavement distresses most appropriate for level-up patching is given in the next section.
- Cost of the level-up patching compared to that of other treatments (e.g., overlay, mill, and inlay). Estimates of patching costs were given in Chapter 3.
- Timing and schedule of surface treatment cycles in the existing pavement, particularly if level-up patching is considered as a surface preparation step.

PAVEMENT DISTRESSES

Identifying the root causes of pavement distress is a key in selecting treatments to rectify the problem. A visual inspection by experienced engineers performing a forensic analysis is essential in establishing the main causes of the distress and deciding on the appropriate rehabilitation treatment. This section describes the types of pavement distresses best treated with level-up patching.

Low/Medium Rutting (< 1 Inch)

Rutting is defined as surface depressions in the wheel paths resulting from many factors including: insufficient compaction, base consolidation, poor asphalt mix materials, or insufficient structural design capacity and heavy traffic loads. Examples of rutting are shown in Figure 4-2. Rutting that exceeds 1 inch is a sign of foundation or base failure that require major rehabilitation.

a) b)

Figure 4-2. Shallow Rutting in the a) Wheel Path along a Travel Lane and b) at an Intersection.

Depressions (< 1 Inch)

Depressions are defined as localized pavement surface areas with slightly lower elevations than the surrounding pavement. Common areas with frequent depressions are at bridge approaches and sag areas in roadway cuts (Figure 4-3). The major cause of depressions is improper compaction of underlying layers or moisture damage. Depressions smaller than 1 inch measured at their lower point could be treated with level-up patching.

Figure 4-3. Depressions on the Pavement Surface Causing Water Collection.

Roughness

Roughness is defined as irregularities on the pavement surface that adversely affect the ride quality. Pavement roughness is quantified by the international roughness index (IRI). The IRI reflects a set of characteristics of the longitudinal pavement profile related to the ride quality of passenger cars. Subjective measures of ride quality are computed from the IRI to reflect the opinion of the driving public being referred to as ride score (i.e., scale 0 to 5 or 0 to 100%). Increases in IRI indicate decreases in ride score. Typically, a ride score value of 2.0–2.5 is the minimum acceptable depending on the functional classification of the road. This corresponds to a maximum acceptable IRI value of about 65–75 inch/mile (TxDOT 2004). Examples of rough sections are shown in Figure 4-4.

a)

b)

c)

Figure 4-4. Roughness Caused by a) Corrugations along the Longitudinal Direction, b) Shoving, c) Transverse Cracks or Damaged Joints.

Low Skid Resistance

Low skid is the defined as the condition of pavement surface texture is low enough to potentially cause vehicular accidents. Causes of low texture include polished aggregates and asphalt bleeding (Figure 4-5). Incomplete curing of surface treatments and excessive tack coat are also contributing to reduced pavement texture. The skid resistance is expressed in terms of the Skid Number, SN (i.e., 0 to 100). The SN reflects the coefficient of friction between the pavement surface and standardized tires that is the ratio of the shear force generated at prescribed levels of slippage divided by the normal force exerted on the pavement. Skid numbers lower than 40 are unacceptable and required resurfacing (TxDOT 2008). Milling the surface and patching is a permanent treatment for this problem.

a) b)

Figure 4-5. Asphalt Bleeding a) across the Travel Lane and b) in the Wheel Path Reducing the Skid Resistance Particularly in Warm Temperatures.

Existing Patches

Deterioration of old existing patches is caused by insufficient compaction and curing, improper mix design and strength, incomplete/rough blading, and moisture damage (Figure 4-6). Deteriorated patches should be removed and re-patched.

a) b)

Figure 4-6. Patch Deterioration in the Form of a) Improper Mix Design and Compaction and b) Corrugation and Roughness due to Insufficient Compaction.

FACTORS AFFECTING PATCHING PERFORMANCE

Climatic Conditions

Patching is affected significantly by the climatic conditions during construction. The ideal conditions are warm, sunny days with low humidity. Spring and summer are the best season for level-up patching. Caution should be exercised when patching in humid or cool weather. These conditions may reduce HMA laydown temperatures resulting in a tender mix that is hard to compact and is more susceptible to damage by traffic. Cold weather may also affect adversely the LRA performance by delaying their curing time. Rain can cause major problems when patching. If the mix was not completely compacted, water can penetrate through the aggregate causing moisture damage and debonding of aggregate particles and binder. Hence, patching should be postponed when rain showers are expected.

Patching Materials

Two types of materials are involved in level-up patching, namely the tack coat and the patching mix.

The tack coat is a light application of asphaltic emulsion or cutback applied to the existing pavement surface. It is used to provide a good bond between the existing pavement surface and the patching mix. Tack coats should have the following characteristics:

- When applied, the binder should be fluid enough to be sprayed and cover the surface uniformly, yet viscous enough to remain in place and not puddle in depressions or run off the pavement.
- After application, it should retain the required consistency to wet the surface.
- It should develop adhesion quickly.
- When applied in the proper amount, it should not bleed or strip under traffic or with changing weather conditions.

Tack coats are primarily made from either asphalt emulsions (SS-1, SS-1H, CSS-1H, EAP&T) or asphalt cutbacks (RC-250). A brief description of emulsions and cutbacks follows.

Asphalt emulsions consist of three basic ingredients, namely asphalt binder, water, and emulsifying agent. At times, other additives such as polymers are also included. Polymers are either pre-blended with the asphalt binder before emulsification or added later as latex. Emulsions are typically classified by how quickly they set (i.e., cure), as follows:

- Slow-setting (SS) emulsions used for tack coats include four grades, namely SS1, SS1H, CSS1, and CSS1H. Original slow-setting emulsions contain a maximum of 43% water and additives and may be diluted with additional water. Specifications and properties of the slow-setting grades are shown in Table 4-1.
- Medium-setting (MS) emulsions are made by adding a specially formulated additive that reduces the setting time. They are formulated not to break immediately upon contact with aggregate and will remain workable for a few minutes to several months depending upon the formula.
- Rapid-setting (RS) are emulsions containing polymer modifiers. Rapid-setting emulsions contain a maximum of 45% water and additives and must not be diluted with additional water.

Table 4-1. Emulsified Asphalt Properties (TxDOT 2004).

Property	Test Procedure	Type-Grade							
		Slow-Setting						Medium-Setting	
		SS-1		SS-1H		CSS-1H (Cationic)		EAP&T (Specialty Emulsions)	
		Min	Max	Min	Max	Min	Max	Min	Max
Viscosity, Saybolt Furol 77°F, sec. 122°F, sec.	T 72	 20 -	 100 -	 20 -	 100 -	 20 -	 100 -	 - -	 - -
Sieve test, %	T 59	-	0.1	-	0.1	-	0.1	-	0.1
Miscibility	T 59	Pass		Pass		-	-	Pass	
Cement mixing, %	T 59	-	2.0	-	2.0	-	2.0		
Demulsibility, 35 ml of 0.02 N $CaCl_2$, %	T 59	-	-	-	-	-	-	-	
Storage stability, 1 day, %	T 59	-	1	-	1	-	1	-	1
Freezing test, 3 cycles	T 59	Pass		Pass		-		-	
Particle charge		-		-		Positive		-	
Distillation test: Residue by distillation, % by wt. Oil distillate, % by volume of emulsion	T 59	 60 -	 - 0.5	 60 -	 - 0.5	 60 -	 - 0.5	 - -	
Tests on residue from distillation: Penetration, 77°F, 100 g, 5 sec. Solubility in trichloroethylene, % Ductility, 77°F, 5 cm/min., cm Float test, 140°F, sec	 T49 T44 T51 T50	 120 97.5 100 -	 160 - - -	 70 97.5 80 -	 100 - - -	 70 97.5 80 -	 110 - - -	 - - - -	 - - - -
Particle size, % by volume < 2.5 µm	Tex-238-F	-		-		-		90	-
Residue by distillation, % by wt.	T 59	-		-		-		60	-
Tests on residue after all distillation(s): Viscosity, 140°F, poise	 T 202	 -		 -		 -		 800	 -

Asphalt cutbacks are asphalt cements mixed with a solvent. The addition of the solvent allows laying and mixing with aggregates without heating. Curing involves evaporation of the solvent, which allows the asphalt cement to return to its hardened state. Cutbacks allow patching during cooler weather, where HMA would cool and set too quickly. They are environmentally less desirable than emulsions, because their curing releases hydro-carbons into the atmosphere. There are two general types of cutback asphalt used by TxDOT, namely rapid curing (RC) and medium curing (MC). Rapid curing cutbacks contain a solvent in the gasoline-naphtha boiling range. Medium curing cutbacks contain a solvent in the kerosene boiling range. TxDOT has continued to reduce the amount of cutback asphalts used in construction and maintenance operations.

The RC-250 is recommended for tack coats where the patching operation needs to be expedited. TxDOT Standard Specification Item 300 provides the cutback properties suitable for tack applications as shown in Table 4-2.

Table 4-2. Rapid Curing Cutback Asphalt Properties (TxDOT 2004).

Property	Test Procedure	RC-250	
		Min	Max
Kinematic viscosity, 140ºF	T 201	250	400
Water, %	T 55	-	0.2
Flash point, T.O.C., ºF	T 79	80	-
Distillation test:	T 78		
Distillate, percentage by volume of total distillate to 680°F			
to 437°		40	75
to 500°F		65	90
to 600°F		85	-
Residue from distillation, volume %		70	-
Tests on distillation residue:			
Penetration, 100 g, 5 sec., 77°F	T 49	80	120
Ductility, 5 cm/min., 77°F, cm	T 51	100	-
Solubility in trichloroethylene, %	T 44	99.0	-
Spot test	Tex-509-C	Neg.	Neg.

There are three types of patching mixes, namely LRA, HMA, and 100% RAP mixes. Figure 4-7 shows pictures of these mixes.

HMA LRA 100% RAP

Figure 4-7. Examples of the Surface Mixes Used in Level-up Patching.

Limestone Rock Asphalt Mixes

These mixtures contain LRA aggregates, flux material, water, and additives (Type I LRA). A variation of this mix could be used containing a combination of virgin aggregates and LRA material (Type II LRA).

Aggregates must meet Item 330 of the Texas Standard Specifications. Coarse aggregate stockpiles should have no more than 20% material passing the No. 10 sieve. Crushed gravel, crushed limestone, and natural LRA are examples of common coarse aggregates. Fine aggregate stockpiles should have no more than 30% material retained on the No. 10 sieve. Gradation of LRA aggregates must meet the CC, D, DS, and FS gradations as shown in Table 4-3.

Flux material, a blend of flux and aromatic oils, should meet the requirements summarized in Table 4-4. The flux material must remain in workable condition while stockpiled for periods over 6 months. The additives, such as hydrated lime or commercial lime slurry and/or liquid anti-stripping agent, can be used in accordance with Item 301 "Asphalt Anti-stripping Agents" of the TxDOT's Standard Specifications (2004).

Table 4-3. Gradation Requirements for LRA Used in Patching (TxDOT 2004).

Sieve Size (inch)	Type I Grade		Type II Grade	
	CC Medium Surface	D Fine Surface	DS Fine Surface	FS Thin Surface
1-1/2	--	--	--	--
1-1/4	--	--	--	--
1	--	--	--	--
7/8	--	--	--	--
¾	--	--	--	--
5/8	--	--	--	--
1/2	0	--	0	
3/8	0-2	0	0-2	0
¼	--	0-2	--	--
#4	35-50	10-25	10-25	0-15
#10	50-65	50-65	50-65	35-60

Table 4-4. Flux Material Properties (TxDOT 2004).

Property	Material	Flux Oil		Aromatic Oil	
	Test Procedure	Min	Max	Min	Max
Kinematic viscosity, 140°F, cSt	T 201	60	200	–	150
Loss on heating, % by wt.	T 47	–	10	–	12
Water, %	T 55	–	0.2	–	0.2
Flash point, C.O.C., °F	T 48	200	–	135	–

Hot Mix Hot-Laid Asphalt

Dense graded HMA asphalt mixtures have been traditionally used for surface mixtures design. Type C and D designs are more applicable to surface level-up patching due to their finer grained structures. These mixtures consist of asphalt cement, aggregates, and additives. Item 300 of the TxDOT Standard Specifications distinguish five asphalt cement types suitable for patching mixes, namely AC-0.6, AC-1.5, AC-3, AC-5, and AC-10. Material specifications for these asphalts should comply with Tables 4-5. The aggregates materials (coarse and fine) should meet the specifications shown in Table 4-6 and the gradations of mix types C or D as shown in Table 4-7. Hydrated lime or commercial lime slurry and/or liquid anti-stripping agents can be used as additives in accordance with Item 301 "Asphalt Anti-stripping Agents" in the TxDOT's Standard Specifications.

The use of RAP in HMA should be limited to 10%. If RAP is incorporated into the patching mix, the special provision 340-003 "Dense-Graded Hot-Mix Asphalt (Method)" of the TxDOT Standard Specifications should be adhered to.

Table 4-5. Properties of Asphalt Cement (TxDOT 2004).

Property	Test Procedure	Viscosity Grade									
		AC-0.6		AC-1.5		AC-3		AC-5		AC-10	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Viscosity	T 202										
140°F, poise		40	80	100	200	250	350	400	600	800	1,200
275°F, poise		0.4	–	0.7	–	1.1	–	1.4	–	1.9	–
Penetration, 77°F, 100g, 5 sec.	T 49	350	–	250	–	210	–	135	–	85	–
Flash point, C.O.C., °F	T 48	425	–	425	–	425	–	425	–	450	–
Solubility in trichloroethylene, %	T 44	99.0	–	99.0	–	99.0	–	99.0	–	99.0	–
Spot test	Tex-509-C	Neg.		Neg.		Neg.		Neg.		Neg.	
Tests on residue from Thin-Film Oven Test:	T 179										
Viscosity, 140°F, poise	T 202	–	180	–	450	–	900	–	1,500	–	3,000
Ductility[1], 77°F 5 cm/min., cm	T 51	100	–	100	–	100	–	100	–	100	–

Table 4-6. Require Gradation Bands (% Passing by Weight or Volume) (TxDOT 2004).

Property	Test Method
Coarse Aggregate	
SAC	AQMP
Deleterious material, %, max	Tex-217-F, Part I
Decantation, %, max	Tex-217-F, Part II
Micro-Deval abrasion, %, max	Tex-461-A
Los Angeles abrasion, %, max	Tex-410-A
Magnesium sulfate soundness, 5 cycles, %, max	Tex-411-A
Coarse aggregate angularity, 2 crushed faces, %, min	Tex 460-A, Part I
Flat and elongated particles @ 5:1, %, max	Tex-280-F
Fine Aggregate	
Linear shrinkage, %, max	Tex-107-E
Combined Aggregate[4]	
Sand equivalent, %, min	Tex-203-F

Table 4-7. Require Gradation Bands (% Passing by Weight or Volume) (TxDOT 2004).

Sieve size (inch)	C Coarse Surface	D Fine Surface
1-1/2	-	-
1	-	-
3/4	95-100	-
1/2	-	98-100
3/8	70-85	85-100
#4	43-63	50-70
#8	32-44	35-46
#30	14-28	15-29
#50	7-21	7-20
#200	2-7	2-7

Reclaimed Asphalt Mixes

The RAP is produced from the removal of asphalt concrete. To be reused in paving, it is typically crushed to sizes finer than 2 inch. This material can be used as a level-up patching material by mixing it with asphaltic emulsions. A mix with 100% RAP has been used by the Lufkin District. It is composed of milling aggregates from pavements and crushing them to fine gradations (i.e., type C or D) and producing a cold-mix patching material by blending it with 3% of an emulsified recycling agent (e.g., CCS-1). The purpose of the recycling agent is to produce the workability required for the construction and compaction of the mix. The RAP obtained from coarse grained pavements should be crushed to smaller sizes to meet the gradations shown in Table 4-3. The recycling agent should comply with the specifications shown in Table 4-8. This type of mixes should be only used in low volume roads (i.e., AADT lower than 3000 vehicle/day).

Traffic

Level-up patching is applicable to roadways of various traffic levels. The actual material to be used depends on the level of traffic. HMA is preferable for roads with high traffic volumes, while LRA is preferable for roads with low to moderate traffic volumes (i.e., up to several thousand vehicles per day). The reason is that HMA has a higher durability and hence reduces the potential of flying aggregates that could cause damage to vehicle windshields during and immediately after construction. The following guidelines are recommended for the selection of patching method:

- HMA for high traffic volume (AADT > 30,000 vehicle/day).
- LRA for high to medium traffic (AADT 3,000–30,000 vehicle/day).
- 100% RAP for low volume roads (AADT < 3,000 vehicle/day).

Table 4-8. Recycling Agent and Emulsified Recycling Agent (TxDOT 2004).

Property	Test Procedure	Recycling Agent		Emulsified Recycling Agent	
		Min	Max	Min	Max
Viscosity, Saybolt Furol, 77°F, sec.	T 72	–	–	15	100
Sieve test, %	T 59	–	–	–	0.1
Miscibility[1]	T 59	–		No coagulation	
Residue by evaporation[2], % by wt.	T 59	–	–	60	–
Tests on recycling agent or residue from evaporation:					
Flash point, C.O.C., °F	T 48	400	–	400	–
Kinematic viscosity,	T 201				
140°F, cSt		75	200	75	200
275°F, cSt		–	10.0	–	10.0

Structural-Related Distresses and Condition of Underlying Layers

The level-up patching layer adds little structural capacity to the pavement layer system. As a result, it is not a recommended treatment where traffic-associated distresses (e.g., alligator cracking) occur. It could, however, be used to repair shallow longitudinal cracking caused by aging. In such cases, milling and patching over the affected area is recommended. Generally, areas that show load-associated cracking due to damage in underlying layers, such as subgrade soil movement or base failure, may require major repairs. A rehabilitation or reconstruction is normally required to correct these distresses. Level-up patching is primarily a treatment of surface distresses and does not solve problems with the lower layers and the subgrade. These problems will eventually propagate to the pavement surface regardless of the quality of the patching mix. An example of a pavement foundation problem resulting in rutting is shown in Figure 4-8. This pavement was leveled-up with an HMA to repair wheel-path rutting. After one year, the shallow rutting reappeared indicating the need for base repair.

Figure 4-8. Rutting Reappeared in FM 979 after One Year of Level-up Patching due to Soil Movements.

Construction Techniques

The recommended procedure and best practices for level-up placement, compaction, and finishing involves 10 steps (Dessouky and Papagiannakis 2012):

Step 1: Setting the traffic control at both ends of the project site. Traffic control provides a safe working environment for the maintenance crew and safe travel lanes for vehicles.

Step 2: Milling the upper ½ to 1 inch to remove the distressed material. For better bonding and longer lasting patches, milling provides a stable base surface for the patching process. Milling is applicable where major distresses are confined to the upper surface such as low skid resistance, bleeding, and deteriorated patches.

Step 3: Removing the vegetation along the shoulder and scraping markers by blading.

Step 4: Cleaning the pavement surface from debris and dirt using a broom machine. As a major step in surface preparation, cleaning surfaces from debris is essential to achieve higher quality level-up patching.

Step 5: Distributing tack coat over the existing surface using an asphalt distributor. Tack coat is used to provide a good bond between the existing pavement surface and the patching mix. Uniform application rate of 0.04–0.10 gal/SY over the surface is recommended to ensure full coverage and prevent flowing off and dripping.

Step 6: Patching mix transport and placement. The transport includes truck loading, weighing, hauling to the site, dumping the mix on the roadway, into the paver or material transfer vehicle (MTV) hopper, and returning to the production plant (Roberts et al. 1996). Dump trucks, bottom dumps, MTV, and drag box are examples of current transport methods use for transporting all types of mixes.

Step 7: Mix paving. Two methods of operations are mostly used, namely blade and laydown machine. The blade operation is only performed by in-house personnel, while the laydown operation is performed by both in-state personnel and sub-contractors.

Step 8: Roller compaction. Two types of roller compactors can be used, namely pneumatic wheel and steel wheel rollers. The pneumatic rollers provide a more uniform degree of compaction, a denser surface that decreases permeability. The vibration mode of steel compactor adds greater compactive effort and facilitates the movement of the aggregates to allow them reaching an embedded position and increasing interlock.

Step 9: Visual inspection and ride test. The crew chief should perform visual inspection to evaluate the transverse and longitudinal slope using a straight edge and/or a test drive.

Step 10: Set temporary asphalt markings and open for traffic. After completion, equipment and traffic control should be removed and patched surface should be cleaned with broom machine.

CHAPTER 5: SUMMARY AND CONCLUSIONS

SUMMARY

This study aimed at documenting the current practices of level-up patching operations. Level-up patching is used to improve ride quality, rectify distresses, such as rutting, as well as restore longitudinal and cross slope grades. It is also used for preparing the surface for overlay or other surface treatment operations. Level-up patching operations are considered corrective maintenance treatments that are used commonly by the TxDOT districts.

Level-up patching is considered as a non-structural layer that does not require a detailed structural design nor generally contributes to the overall structural capacity of the repaired pavement. This operation is different than overlaying in that it is applied in thin layers that range from 0.5 to 1.5 inch to restore the surface grade. Overlays involve application of uniform asphalt concrete lift of 2 inch (or more) over an existing or pre-leveled surface to restore overall surface conditions.

Level-up patching involves laying down a thin asphalt mix layer over an existing pavement in areas of sagging or rutting. They are applied in areas of surface-related failures rather than in areas with foundation (base/subgrade) problems. Rutting, depressions, and roughness are typical distresses where level-up patching can be effectively used in quickly restoring the surface. Surface preparation prior to patching is essential to form a platform of smooth surface for the overlay mix or surface treatment. It is performed through filling-in the low spots in the pavement or by milling to remove the high points. It is effectively to use milling to help eliminate differential compaction problems.

A short online survey sent to all districts and a comprehensive questionnaire was sent to selected districts to collect detailed information on their current practice of level-up patching. The MMIS were used to extract cost data associated with the operations performed by state forces and sub-contractors. Examples of current operations in the districts were demonstrated in Chapter 3. Factors that affect the selection and performance of patching were described in Chapter 4.

Three types of level-up patching mixes are used, namely HMA appropriate for high traffic roadways, LRA appropriate for medium traffic roadways, and special mixes such as 100% RAP appropriate for low volume roads.

Two methods of operations are mostly used, namely blade and laydown machine. The blade operation is only performed by in-house personnel, while the laydown operation is performed by both in-state personnel and sub-contractors. Cost data from the MMIS database suggest that the blade operation performed by state personnel is the most cost-effective approach for level-up patching. Details on the best practice for level-up patching are given in a separate publication (Dessouky and Papagiannakis 2012).

CONCLUSIONS

The following conclusions can be drawn from this study:

- TxDOT uses level-up patching as a corrective pavement treatment to improve ride, texture, and cross-slope drainage. Level-up patching is also used as a preparatory step for an overlay or surface treatment or for some cases as a final exposed surface. Often, the process is preceded by milling of an existing surface, essentially keeping the same profile while improving functional characteristics. Prior to level-up patching, surveys should be undertaken to evaluate the existing pavement condition and to reveal whether milling is necessary.
- Site visits to eight districts have revealed that the operation processes are technically quite similar. The main difference among districts is the availability of materials and equipment.
- LRA can be used for medium to low volume (3000–30,000 vehicle/day) traffic roadways while HMA can be used for high volume traffic (>30,000 vehicle/day). Mixes with 100% RAP can be implemented on low volume roads (<3000 vehicle/day).
- Milling is an essential operation prior to patching used to smooth an existing flexible pavement prior to overlaying. For flexible pavements, milling can help eliminate differential compaction problems.
- Blade operations are better suited for medium to low volume roads (<30,000 vehicle/day), while lay-down machines are best suited to high volume roads (>30,000 vehicle/day).
- The selection of the type of level-up patching operation is relatively independent of existing pavement surface design and type, but it is affected by the climatic conditions at the time of placement.
- Rutting in the wheel path, depressions in localized areas and rough ride in the surface layer are the best candidates for level-up patching, particularly if they are of low severity. The maximum depth of rutting and depressions that can be treated is 1 inch. Exceeding the 1 inch is a sign of major problems in the underlying layers and/or subgrade that require a heavier rehabilitation.
- The key to a successful blade patching is a knowledgeable crew chief and experienced blade operator.
- Best timing for placement is during the day time in dry and warm conditions. Wet pavements and cold pavements will interfere with the adhesion of the hot mix patch material to the existing pavement.
- According to MMIS data, total expenditures in all level-up operations and overlaying are in the order of $180m annually. The blade method is the primary level-up patching operation used by CHS, ELP, BWD, AUS, WAC, ABL, SJT, BRY, ODA, LUB, and PAR districts. The lay-down method is the primary level-up patching operation used in FTW, HOU, DAL, and TYL districts.
- The unit cost for the blade operations is $3.74/SY and for the laydown operation is $8.43/SY. The unit cost of in-house laydown operations is $7.00/SY and for sub-contractor performed operations is $12.5/SY. The cost of the patching materials is factored in the estimation of these unit costs.

- Drag box-equipped dump trucks are best suited for patching partial lane-widths or narrow strips and for small paving jobs. For large scale jobs (more than 2 miles in heavy traffic zones), material transfer vehicles (MTVs) are best suited to maintain a constant flow of material from the haul trucks to the paver allowing the paver to operate continuously without stopping.
- Tack coat application should extend to a sufficient distance beyond the edge of the intended repaired area to allow for feathering the patching materials onto the existing surface level.
- Using two blades facing each other is an efficient way for patching HMA before it gets cold, making smoother approaches, and helping to maintain a straighter edge. Also, it offers a chance to train inexperienced blade operators.
- When repairing rutting or depressions, the new mix should be placed in thin lifts to get uniform compaction. This helps preventing existing ruts from reflecting onto the finished patch. Compaction should be done by a rubber-tire roller in the rutted areas. After the ruts are filled, a steel wheel roller can be used as a finisher.
- The literature review documented that the service life expectancy of level-up patches constructed with a blade operation is 3.6 years. The actual life expectancy depends on the materials used and quality of the operation at a particular site. The expected life of level-up patching used to prepare pavement for a subsequent surface treatment depends on the expected service life of the latter. It is essential to execute such operations as permanent treatment to improve their durability and reduce overall life-cycle cost.
- The evaluation of level-up patching after the completion of a project can be performed by visual inspection and a test ride. A follow-up evaluation using the data collection for the PMIS can also be performed.

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APPENDIX A
SHORT ONLINE DISTRICT SURVEY

TxDOT study: Synthesis of Best Practices for the Placement of Long and Short Patches for Ride Quality

District:________________
Responder:______________
Date:___________________

Definition:
Rutting and minor alligator cracking at the wheel path are two of the main forms of distresses that affect ride quality. Level up patching is a treatment process of filling in, covering, and restoring the pavement surface deterioration to improve ride quality. This patching technique is widely used by the districts and is conducted in many different ways.

This survey is to obtain information on the level-up patching only to improve ride quality in short length (less than 100ft) or long length (more than 100ft) spans.

Questions about the Engineer Experience and Familiarity with Patching:

1. What is your current position at TxDOT? ____
____
____
2. How long have you been working for TxDOT? ____________________________________
____
____
3. Are you familiar with patching activities in your district? If yes, describe.
____
____
____

Patching Selection and Type

4. Do you use level-up patching in your district?
   - ☐ Yes
   - ☐ No

5. What are the common pavement distress that warrant ride quality (level-up) patching in your district (select all applicable):
   - ☐ Alligator cracking
   - ☐ Rutting
   - ☐ Longitudinal and transverse cracks
   - ☐ Combination of cracking and rutting
   - ☐ Loss of subgrade support
   - ☐ Shoving
   - ☐ Depression
   - ☐ Potholes
   - ☐ Corrugation

- ☐ Failed patches
- ☐ Others__________________

6. On average, how long are the level-up patches mostly performed by the district?
   - ☐ Long (more than 100ft)
   - ☐ Short (less than 100ft)
   - ☐ both

7. Are any of the following factors affecting the patching placement? (select all applicable)
   - ☐ Functional class
   - ☐ ADT (average daily traffic)
   - ☐ Existing surface mix design (dense graded; fine graded, PFC, seal coat, etc.)
   - ☐ Climate condition
   - ☐ Timing of placement (e.g., summer, winter)

8. Which staffs are mostly engaged with level up placement?
   - ☐ In-house crew
   - ☐ Sub-contractors

<u>Patching Filling Materials</u>

9. What are the back-filling materials mostly used in level up patching? (select all applicable)
   - ☐ Hot mix asphalt
   - ☐ Warm mix asphalt
   - ☐ Cold mix asphalt
   - ☐ RAP
   - ☐ Aggregate/asphalt emulsion combinations (for injection patches)
   - ☐ Others______________________

10. Is there a special design for the patching materials? (select all applicable)
    - ☐ Fine graded
    - ☐ Coarse graded
    - ☐ Fine graded w/RAP
    - ☐ Coarse graded w/RAP
    - ☐ Commercial patching materials
    - ☐ Others______________________

11. In your district, what are the main causes that lead to pavement surface deterioration (e.g., depression, wheel path rutting, alligator cracking)?
    - ☐ Expansive soil
    - ☐ Base failure
    - ☐ Surface aging
    - ☐ Moisture damage
    - ☐ Under design pavement structure layers
    - ☐ Others____________________

Patching Performance

12. How does the district evaluate the performance of the patches? (select all applicable)
    - ☐ Roughness/profile test
    - ☐ Straight Edge
    - ☐ Visual inspection
    - ☐ Not applicable
    - ☐ Others______________________________

13. Does your district have a protocol for QC/QA of patching placement?
    - ☐ Yes
    - ☐ No

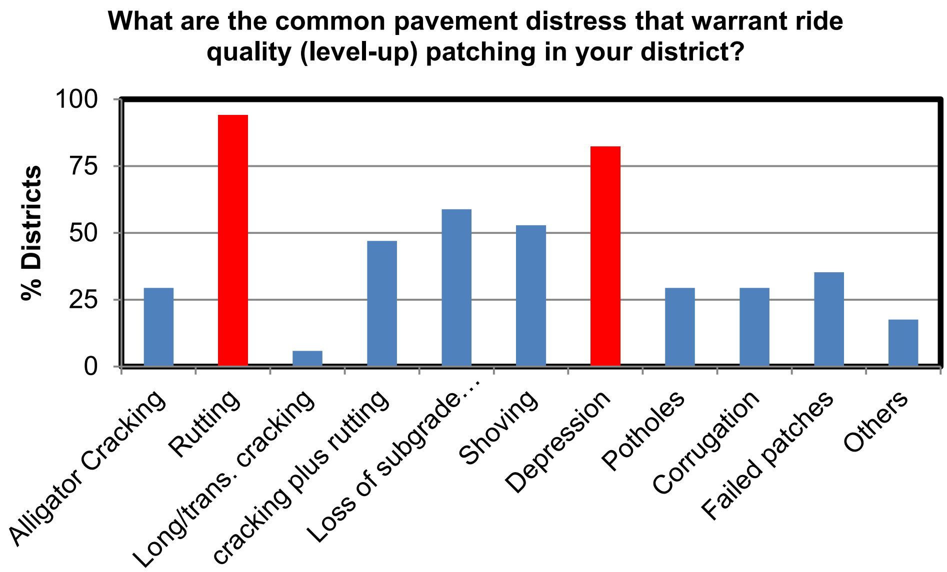
14. After placement, on average, how long the patches last on your district?
    - ☐ Less than 1 yr.
    - ☐ 1–3 yrs.
    - ☐ 3–5 yrs.
    - ☐ More than 5 yrs.

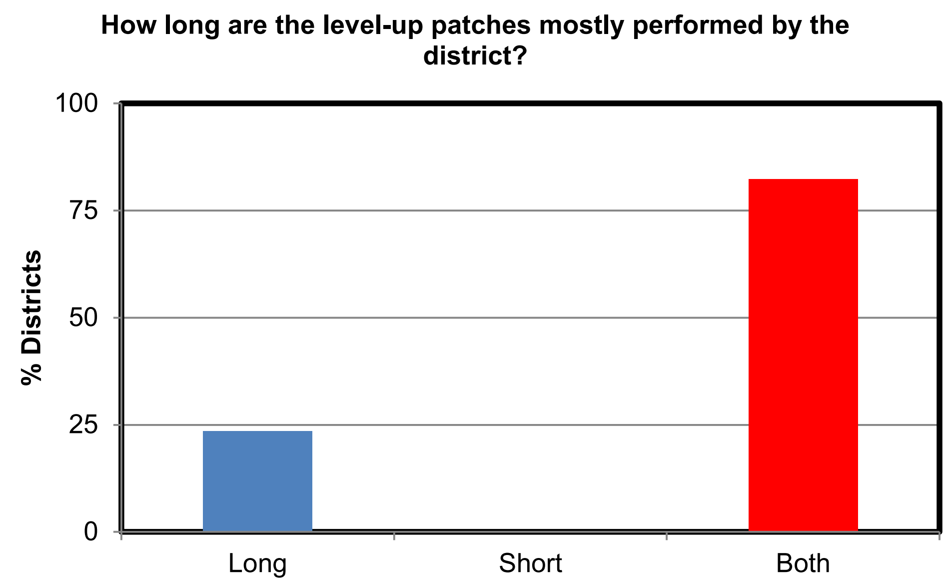
15. In your opinion, what is the overall performance of the patches in your district?
    - ☐ Excellent
    - ☐ Good
    - ☐ Fair
    - ☐ Poor

16. Is there an expected level-up patching job in the next <u>three</u> months?
    - ☐ Yes
    - ☐ No

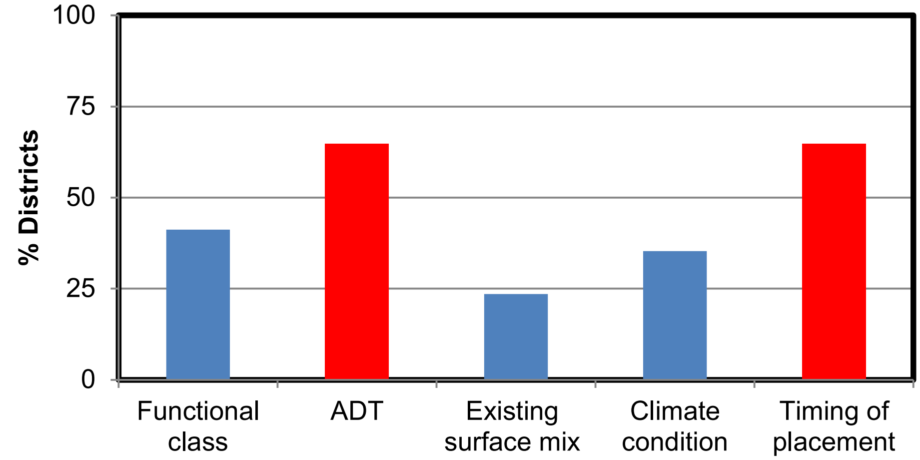
17. Can you list the locations of patches that are greater than 100 ft in length so that we might compare the IRI before and after patching?
    - ☐ Yes
    - ☐ No

APPENDIX B
SUMMARY OF DISTRICT SURVEY RESPONSES

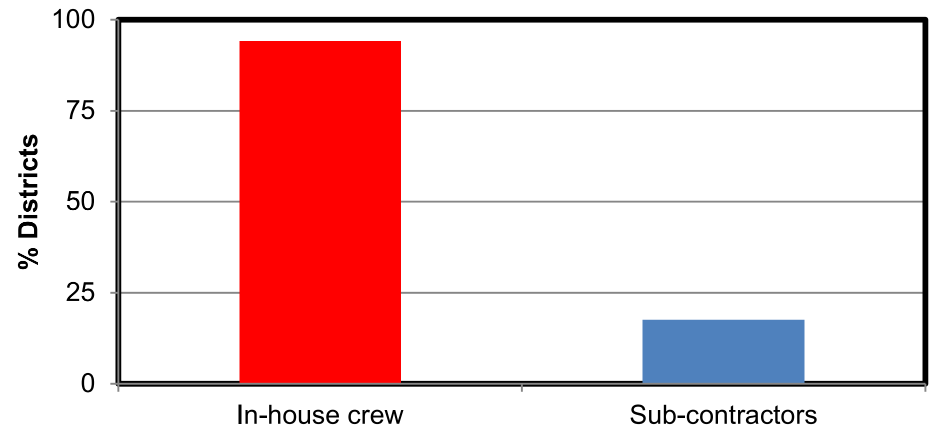

What are the common pavement distress that warrant ride quality (level-up) patching in your district?
% Districts
100
75
50
25
0
Alligator Cracking
Rutting
Long/trans. cracking
cracking plus rutting
Loss of subgrade…
Shoving
Depression
Potholes
Corrugation
Failed patches
Others

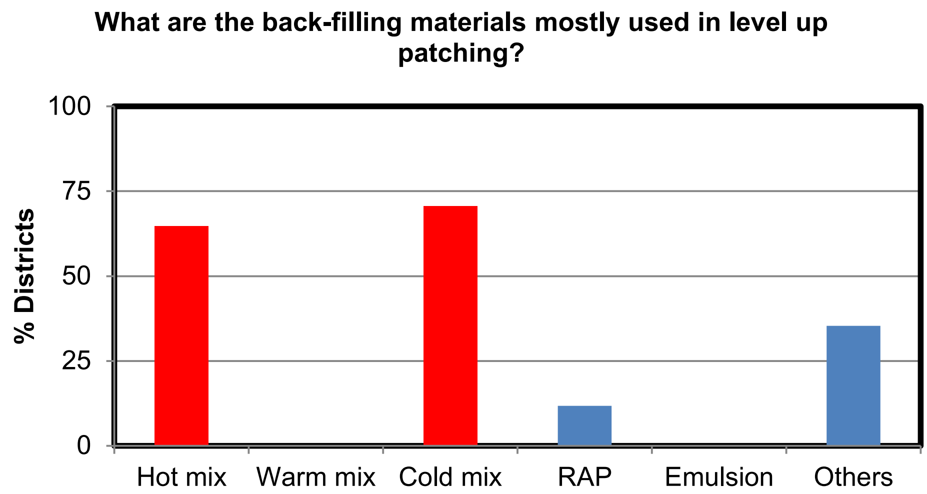

How long are the level-up patches mostly performed by the district?
% Districts
100
75
50
25
0
Long
Short
Both

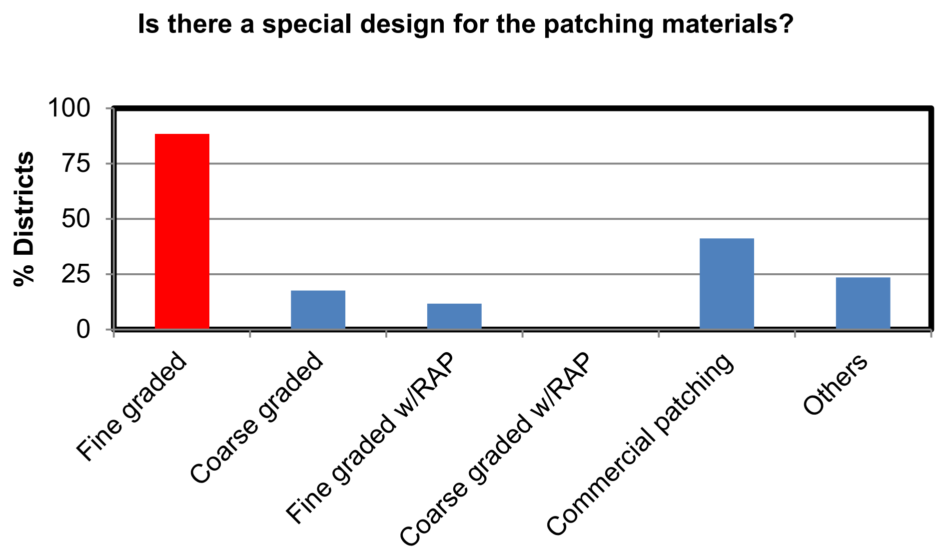
Are any of the following factors affecting the patching placement?

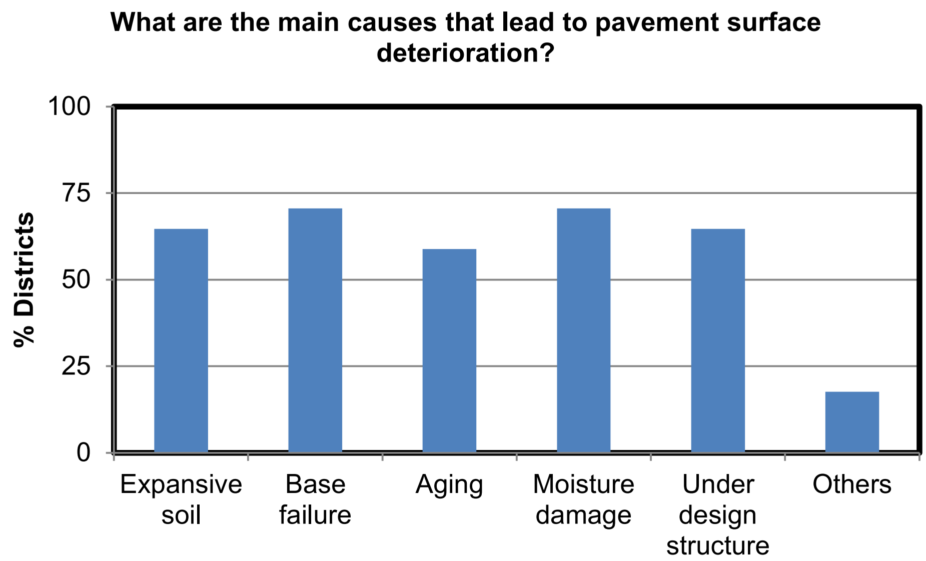


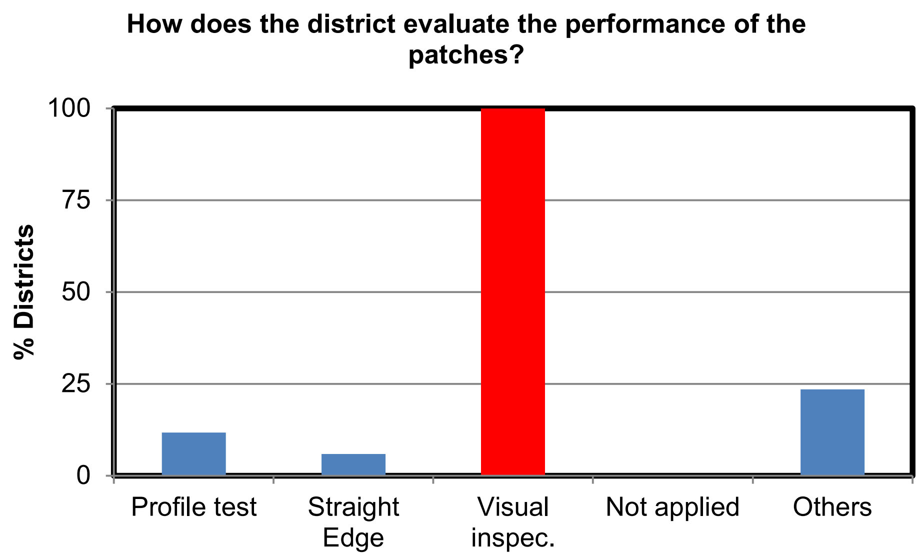
Which staffs are mostly engaged with level up placement?



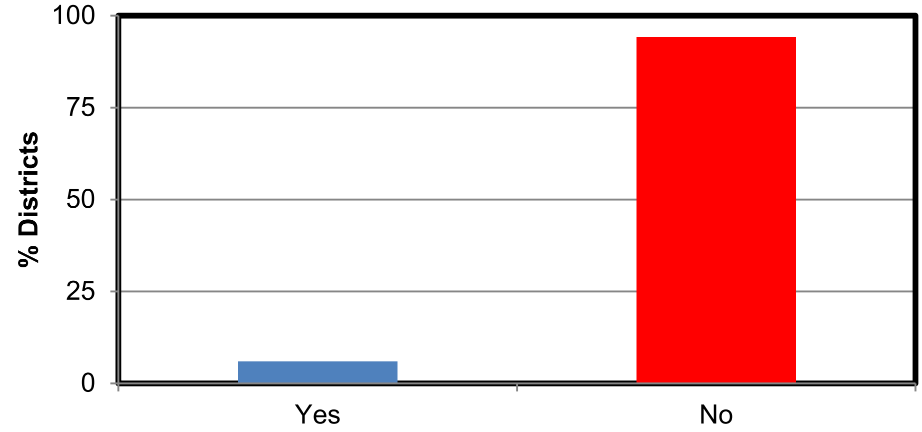

What are the back-filling materials mostly used in level up patching?
% Districts
100
75
50
25
0
Hot mix
Warm mix
Cold mix
RAP
Emulsion
Others


Is there a special design for the patching materials?
% Districts
100
75
50
25
0
Fine graded
Coarse graded
Fine graded w/RAP
Coarse graded w/RAP
Commercial patching
Others

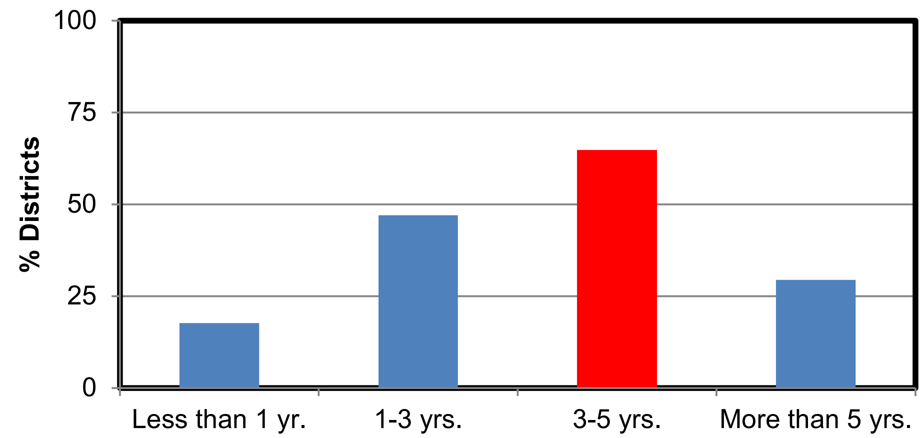

What are the main causes that lead to pavement surface deterioration?
% Districts
100
75
50
25
0
Expansive soil
Base failure
Aging
Moisture damage
Under design structure
Others


How does the district evaluate the performance of the patches?
% Districts
100
75
50
25
0
Profile test
Straight Edge
Visual inspec.
Not applied
Others

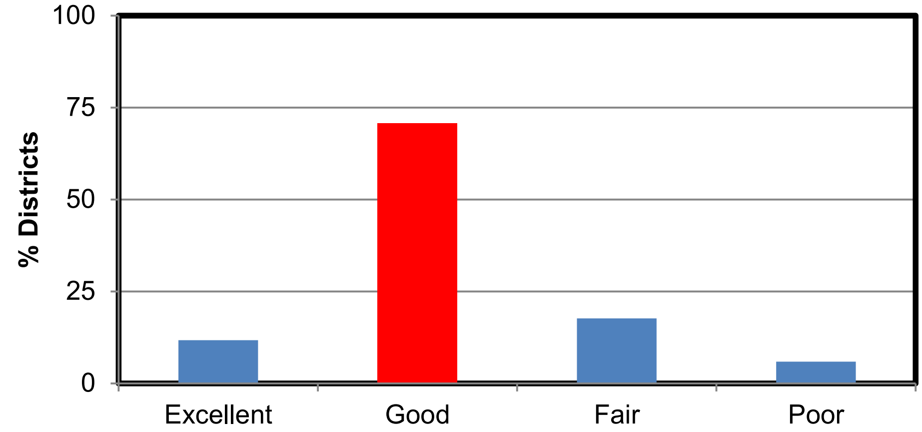
Does your district have a protocol for QC/QA of patching placement?



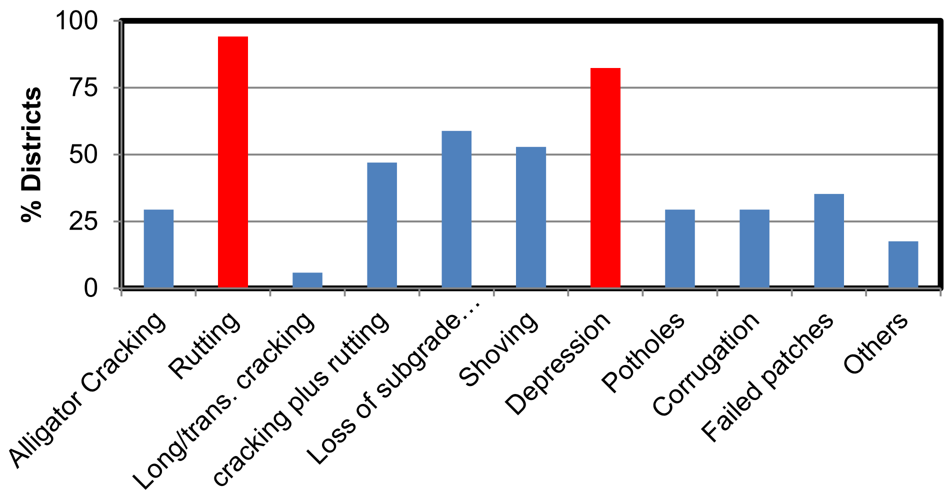
After placement, on average, how long the patches last on your district?

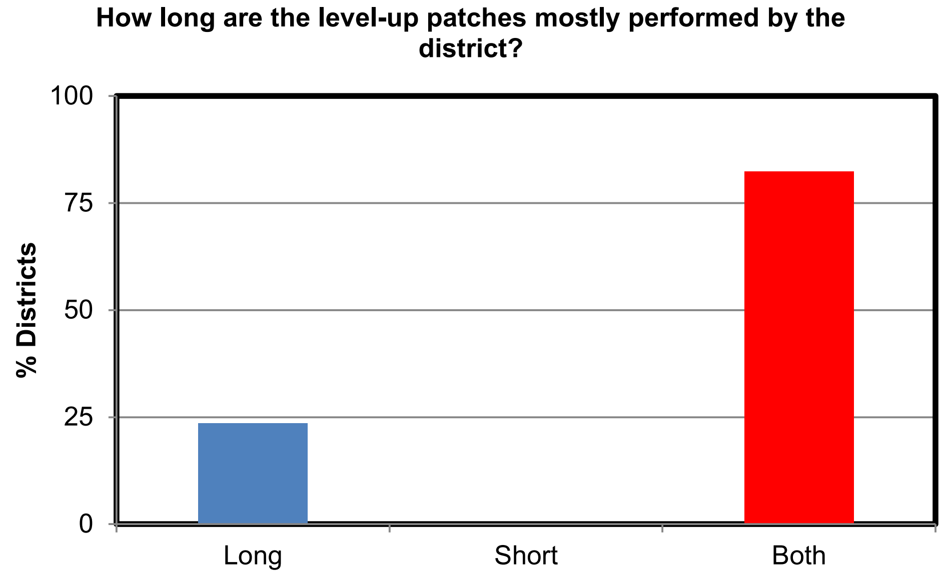


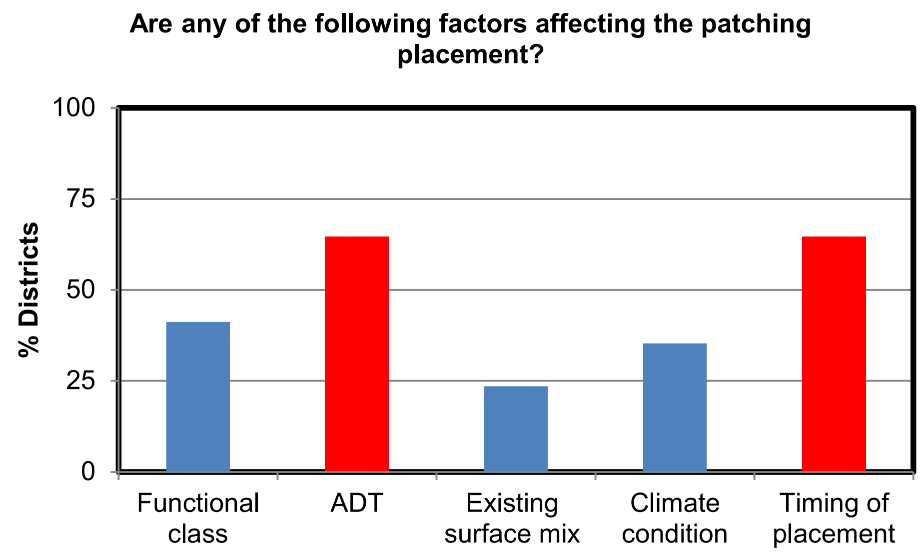
What is the overall performance of the patches in your district?



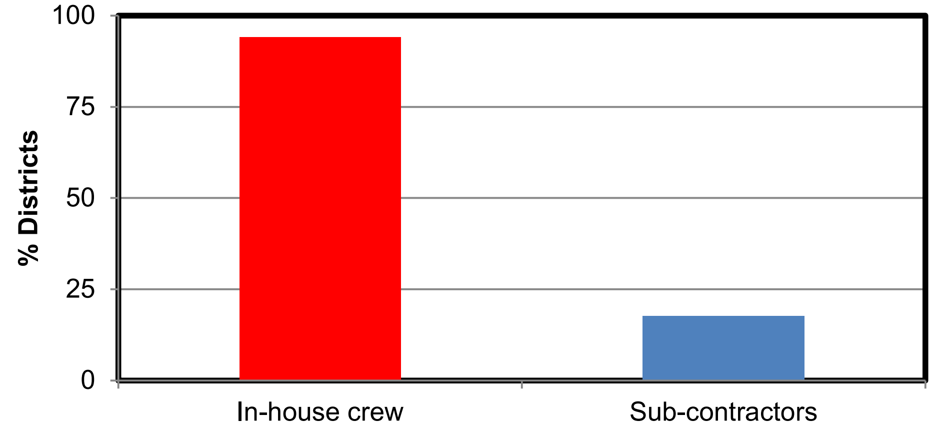
What are the common pavement distress that warrant ride quality (level-up) patching in your district?



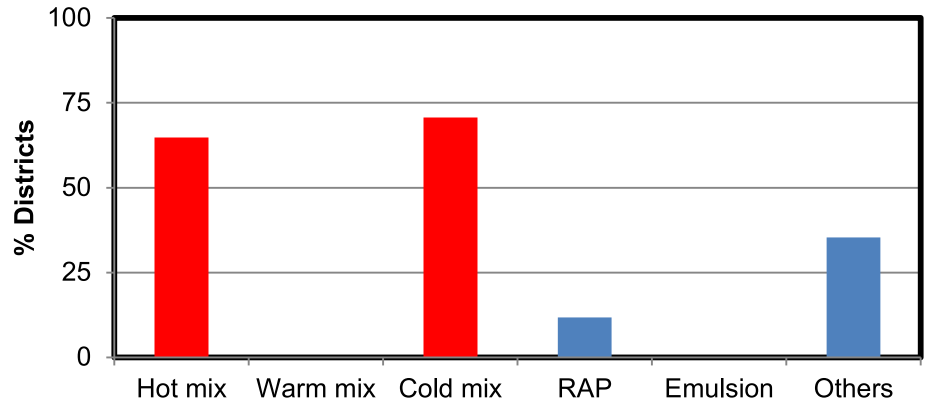

How long are the level-up patches mostly performed by the district?
% Districts
100
75
50
25
0
Long
Short
Both

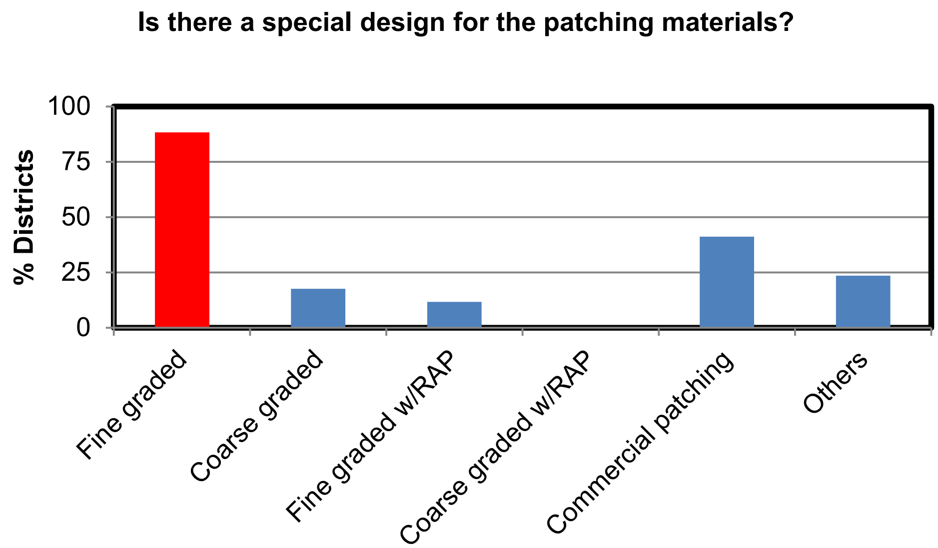

Are any of the following factors affecting the patching placement?
% Districts
100
75
50
25
0
Functional class
ADT
Existing surface mix
Climate condition
Timing of placement

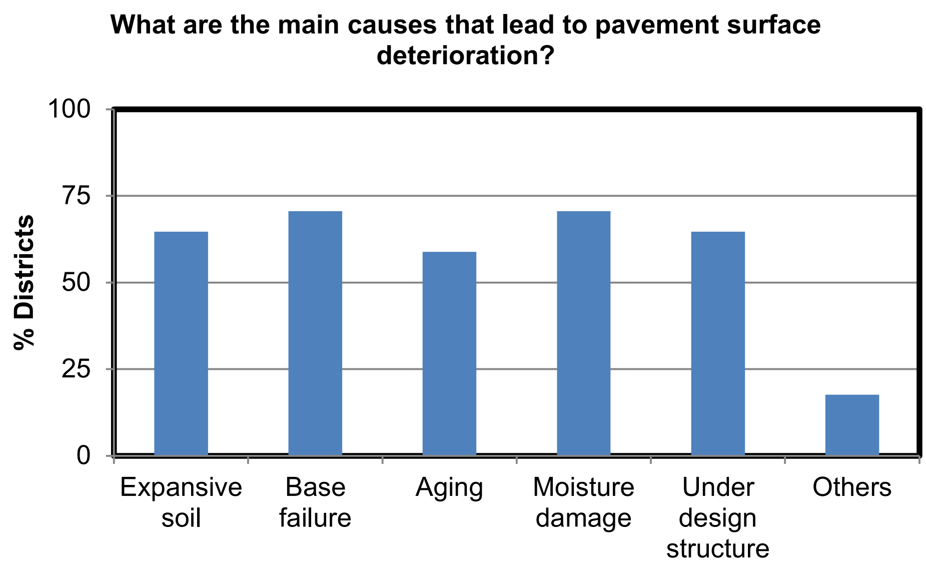
Which staffs are mostly engaged with level up placement?

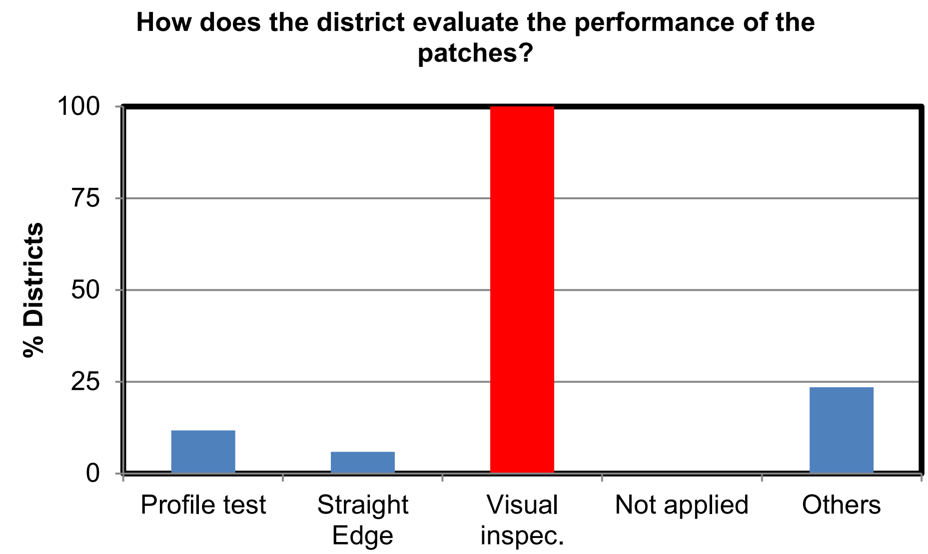


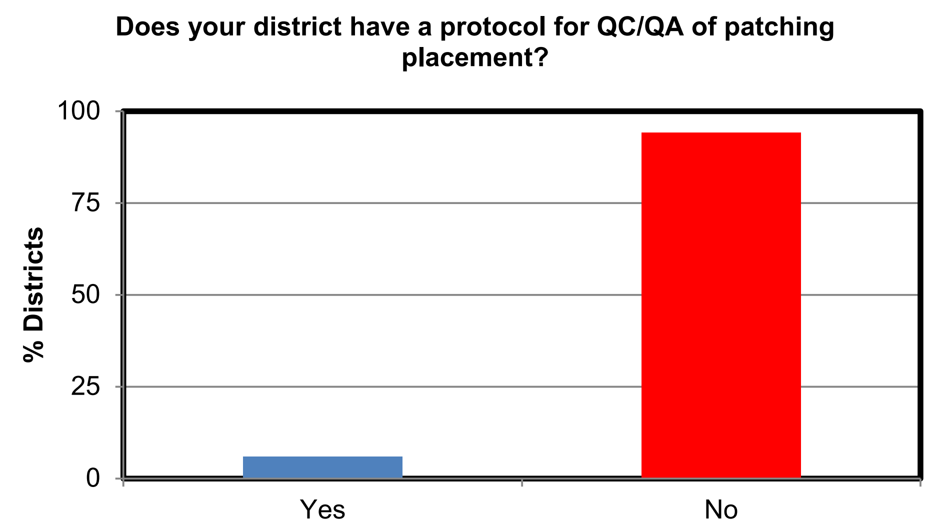
What are the back-filling materials mostly used in level up patching?

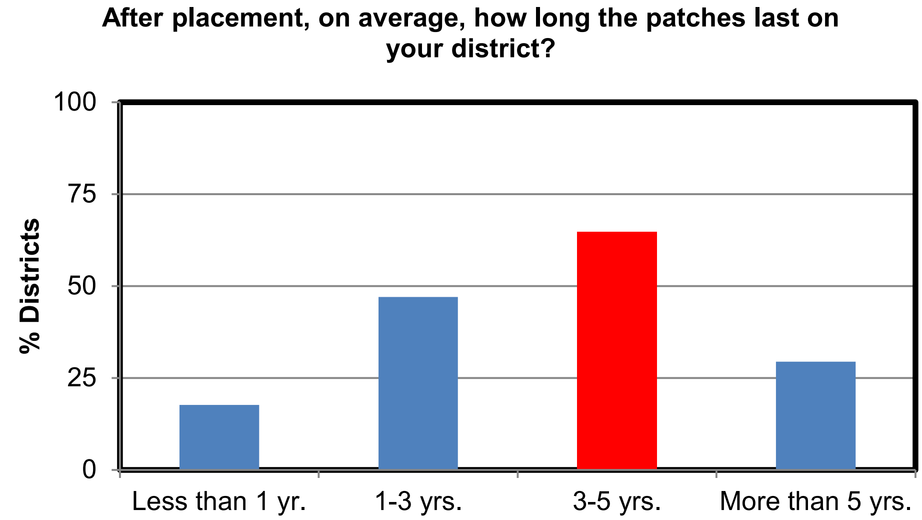


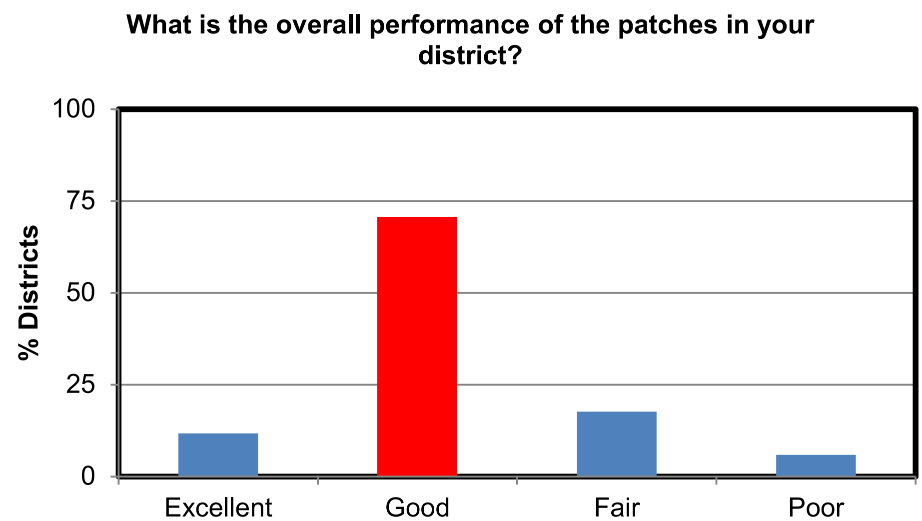

Is there a special design for the patching materials?
% Districts
100
75
50
25
0
Fine graded
Coarse graded
Fine graded w/RAP
Coarse graded w/RAP
Commercial patching
Others


What are the main causes that lead to pavement surface deterioration?
% Districts
100
75
50
25
0
Expansive soil
Base failure
Aging
Moisture damage
Under design structure
Others


How does the district evaluate the performance of the patches?
% Districts
100
75
50
25
0
Profile test
Straight Edge
Visual inspec.
Not applied
Others


Does your district have a protocol for QC/QA of patching placement?
% Districts
100
75
50
25
0
Yes
No


After placement, on average, how long the patches last on your district?
100
75
50
25
0
% Districts
Less than 1 yr.
1-3 yrs.
3-5 yrs.
More than 5 yrs.


What is the overall performance of the patches in your district?
100
75
50
25
0
% Districts
Excellent
Good
Fair
Poor

APPENDIX C
LEVEL-UP PATCHING COMPREHENSIVE QUESTIONNAIRE

Part A: Questions about the Engineer Experience and Familiarity with Patching:

1. What is your current position at TxDOT? ______________________________________
____
____
2. How long have you been working for TxDOT? _________________________________
____
____
3. Are you familiar with patching activities in your district? If yes, describe.
____
____

Part B: Patching Selection and Type

4. The following are examples of distresses that may warrant long patching treatment in your district. Specify the severity and thresholds of those distresses that warrant patching, if applicable:

Distress	Severity			Others
	Low	Medium	High	
Rutting (depth)				
Longitudinal cracking (length)				
Depression (depth)				
Potholes (area)				
Rough Ride				

5. Describe the effect of the following factors, if any, in the patching materials and placement

☐ Functional class: (e.g., IH, US, SH, and FM)

____
____
____
____

☐ ADT (e.g., high, above 3000, and low, below 3000)

____
____
____
____

☐ Pavement type (e.g., flexible and concrete)

☐ Existing surface mix design (dense graded and fine graded)

☐ Flexible pavement types (e.g., ACP and surface treatment)

☐ Climate condition (e.g., dry and wet)

☐ Timing of placement (e.g., hot and cold season)

☐ Others

Part C: Crew Training and Responsibility

As most of the long patching jobs are performed by in-house crews in your district, in the light of this preliminary information respond to the following:

6. Are the in-house crews trained for performing patching placement?

7. What kind of training, if any, do they receive to perform patching or any other PM procedures?

____
____
____
____

8. What are the duties of crew chiefs during patching placement?

____
____
____
____

Part D: Patching Filling Materials

9. Describe the aggregate types and gradation for the following mixes only If not following TxDOT specification:

   ☐ Hot mix hot-laid:
   - Aggregate type: limestone, granite, gravel, available in district
   - Gradation: Fine or coarse (Type B, Type C, Type D, etc.)
   - Binder PG

   ☐ Hot mix cold-laid:
   - Aggregate type: limestone, granite, gravel, available in district
   - Gradation: Fine or coarse (Type B, Type C, Type D, etc.)
   - Binder PG

   ☐ Limestone rock asphalt (LRA)
   - Gradation: (AA, CC, CS, DS, etc.)

10. What are the main factors that govern the selection of patching materials?

____
____
____
____

11. If RAP is included in the patching materials, what is the maximum percentage allowed?

____
____
____
____

12. Do the patching materials go through performance testing prior to placement (e.g., Hamburg, IDT)?

____
____
____
____

13. Does the district have a documented protocol for the current practice of patching including materials selection, placement, performance measures, etc.?

14. How long are the patches allowed to cure before traffic is allowed on it?

Part E: Patching Construction and Placement

15. What are the tools and equipment used in placement? Are they going through annual inspection and calibration by the district?

16. Describe briefly the current practice of patching placement including, filling, smoothing, compacting, etc.

17. Describe briefly the surface preparation of the affected area prior to placement.

18. In most cases, long patches are added on top of existing pavement, however, do you ever consider removal of existing pavement prior to patching? Describe.

19. What is the best timing for patching during the day? Describe the benefits and differences of daytime versus night placement, if applicable?

Part F: Patching Performance

20. How is "successful" placement defined and measured?

21. Visual inspection has been shown to be the main process used to evaluate the patching performance. What are you looking for during the inspection? (e.g., smoothness, roughness)

22. What if the patch did not meet the inspection? Do you consider removal and replacement or re-patching?

23. Do you frequently perform inspection in annual or bi-annual basis to monitor the performance of the patching? Explain

Closing Questions

24. What budget does patching in your area come from the patching placement is utilized (e.g., PM category, Strategy 105, Strategy 144)?

25. Do you consider patching as PM (Preventive maintenance) or routine maintenance?

26. Additional comments, if any.