Current TxDOT Practices for

Repair of Road Damage Associated with Energy Development and Production

Implementation Report IR-14-01

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Maintenance Division

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INTRODUCTION

During the last decade, 12,000 to 24,000 oil and gas wells were permitted each year in Texas (1). The development of the state's oil and gas reserves has provided a significant economic impact to the state and nation and is expected to continue for over a decade into the future.

The rapid development of the state's oil and gas resources has required and continues to require large volumes of relatively heavily loaded trucks per well developed. Estimates of truck traffic for well development and production range from 1,000 to 4,000 loaded trucks per well (2). This truck traffic and other associated traffic has significantly impacted the Texas Department of Transportation (TxDOT) Farm to Market (FM) road network as well as some of its trunk State Highway (SH) and United States (US) route designated highways.

Roadway Impacts

One of the major issues facing TxDOT maintenance forces is the repair of this road network. The maintenance and repair of this roadway system has required an ever increasing amount of TxDOT's financial resources and available workforce. Repair costs for state and local government roadways have been estimated at $2 billion per year (2). If financial resources are not available to repair the roadways the cost to the energy development industry for equipment damage and lower operating speeds due to rough roads is expected to be in the $1.5 to 3.5 billion range annually (3).

Relatively narrow FM roads in the energy impacted areas of the state have experienced severe damage and dramatic increases in maintenance costs over the last several years. The FM system is over 50,000 miles in length and was designed and constructed to provide access for the state farmers and ranchers to their markets. These roadways were initially designed for relatively low traffic volumes. Many of these roadways are 18 to 22 ft in width without paved shoulders.

Typical oil/gas well development and production truck vehicles have maximum widths of 10 to 10.5 ft from outside edge to outside edge of side view mirrors. Special haul vehicles can have load widths in excess of 10 ft and payloads that exceed 90,000 lb. Thus, when these types of vehicles pass on narrow roadways the outside truck and car tires are often near, partially off, or off the paved surface of the roadway. The unpaved shoulders offer little lateral support to the traveled surface pavement and consequently edge drop-offs, edge raveling, and edge disintegration often results. Without repair these roadway surfaces will disintegrate from the outside edge towards the center of the pavement. Repair and widening of these roadways is important not only from a pavement performance standpoint but also from a safety standpoint. Narrow roadways increase the potential for severe accidents.

In addition to the FM road network, several SH and US designated routes are subjected to traffic volumes in excess of those used in their design. These roads are transportation corridors for hauling base rock for drilling and production pads and access roads, drilling equipment, drill stem pipe, drilling muds, completion chemicals and equipment, sands, fresh water, salt water, Portland cement, casings, production equipment, crude oil, etc.

Economic Impact

Oil and gas development in Texas has a substantial economic impact on the state's economy.

The economic impact of the industry on two selected study areas of the state, one in west Texas and the other in south Texas, has been estimated by the Center for Community and Business Research at the University of Texas at San Antonio (4, 5). The Center estimated that a ten county study area in west Texas had an economic impact of nearly $14.5 billion for the year 2012. The industry supported 21,450 full time jobs, paid $1 billion in wages and salaries, generated almost $472 million in state revenues (including $187 million in severance taxes) added approximately $6.2 billion in gross regional product and contributed $447 million in local government revenue. By 2020 the impacts are expected to be $20.5 billion per year (4).

The south Texas economic impact for the 14 counties most heavily associated with the Eagle Ford Shale play in south Texas was estimated at $46 billion for 2012. The industry supported 86,000 jobs. For a larger 20 county area in the Eagle Ford Shale development area, the economic impact was estimated at $61 billion with 89,000 jobs created for 2012. The economic impact for the 20 county area in 2022 is expected to be $89 billion, supporting 127,000 jobs (5). The economic benefit provided by the oil and gas industry to Texas is obviously greater than these two limited county study areas.

The Eagle Ford Shale development is the largest single oil and gas development area in the world based on capital expenditures. Estimated expenditures by oil and gas companies for 2013 totaled approximately $28 billion. These expenditures include well development and production activities as well as the considerable infrastructure (operations centers, pipelines, terminals and processing plants) required for oil/gas activities (5).

BACKGROUND

The roadway damage resulting from oil and gas development activities in the state of Texas has significantly increased pavement routine maintenance and rehabilitation costs at both the state and local government levels. It is estimated that TxDOT will expend approximately $500 million annually for maintenance and rehabilitation of roadways impacted by oil and gas development each year for fiscal years 2014 to 2017. Local governmental agencies are expected to expend over $200 million during this same fiscal year period.

Information Gathering

TxDOT's Maintenance Division and the Texas A&M Transportation Institute (TTI) initiated an Interagency Agreement Contract (IAC) to explore methods to reduce the costs associated with the repair and rehabilitation of the energy impacted roadways. This project includes tasks associated with the following work activities:

1. Definition of current TxDOT maintenance rehabilitation practices in the energy impacted areas.
2. Determination of the number and weights of truck traffic associated with oil/gas well development and production.
3. Determination of the location of well permitting and drilling operations.
4. Development of guidelines for selecting repair and rehabilitation strategies.
5. Establishment of methods for evaluating existing roadways to determine appropriate repair and rehabilitation strategies.
6. Defining the performance of maintained and repaired roadways.
7. Development of communication tools to deliver project findings to TxDOT operating units.

This report presents a summary of current maintenance and rehabilitation practices presently used by TxDOT. The report has been prepared based on three primary information sources:

1. A report on district maintenance and repair practices prepared by Lynn Passmore in 2013 (6).
2. District visits by the research team in the fall of 2013 and spring of 2014.
3. TxDOT workshops on maintenance and repair practices used in the energy sector held in the spring of 2014.

Mr. Passmore visited 11 districts. The research team visited with nine TxDOT District staffs during the period of September 2013 to April 2014 as shown in Table 1. Meetings were held with the following districts: Amarillo, Childress, Corpus Christi, Laredo, Lubbock, Odessa, San Angelo, San Antonio, and Yoakum.

Table 1. District Visits Dates.

Date	District	Date	District
September 25,	San Antonio	April 2, 2014	Odessa
November 13, 2013	Yoakum	April 3, 2014	Amarillo
December 5, 2013	Corpus Christi	April 3, 2014	Lubbock
December 20, 2013	Laredo	April 4, 2014	Childress
April 2, 2014	San Angelo		

In addition to the district visits, regional workshops were held in Corpus Christi for the south Texas districts (March 5, 2014) and Lubbock for the west Texas districts (April 17, 2014). South Texas districts attending the Corpus Christi workshop included the host district and the Bryan, Laredo, San Antonio, and Yoakum districts. District personnel from Abilene, Amarillo, Childress, Lubbock, Odessa, and San Angelo attended the Lubbock workshop. Presentations delivered at these workshops by district personnel are available to all districts on TxDOT SharePoint — https://txdot.sharepoint.com/sites/division-MNT/SitePages/Home.aspx. The presentations contain photographs and narrative associated with the various maintenance practices. These details are useful for those interested in specific district methods used for maintenance and repair of oil and gas impacted roadways.

Pavement/Shoulder Widths

Many of the Farm to Market roadways in Texas were originally constructed from 18 to 24 ft in width. A significant number of these narrow Farm to Market roadways have been impacted by oil/gas development and production activities. The widening of these roadways and the addition of paved shoulders is a significant activity associated with maintenance and repair activities on these roadways.

Table 2 contains a summary of paved pavement and shoulder widths preferred by the various districts. Most districts prefer a minimum 32-ft wide paved surface (two 12-ft lanes and two 4-ft shoulders).

Table 2. Desired Shoulder/Pavement Width.

District	Location	Lane Width, ft	Shoulder Width, ft	Two Lane Roadway Paved Surface Width, ft.
Corpus Christi	So. Texas	12	2	28 min, greater widths on curves Prefer 32
Laredo	So. Texas	12	2	28 min
		12	4	Prefer 32
San Antonio	So. Texas	11	2	26 min
		11	3	
		12	2	Prefer 28 for energy sector
		12	4	32 construction projects
Yoakum	So. Texas	11	1	24 some roads, poor performance
		11	2	26 min
		11	3	Prefer 28
Amarillo	West Texas	12	2 to 4	26-28 min. often start with 18 to 22 ft roadway
Childress	West Texas	12	2	26-28
Lubbock	West Texas			28 min.
Odessa	West Texas	12	4	Shoulders (4-10 ft)on FM and SH roads for several years, Permian Basis developed in 1950s
San Angelo	West Texas	12	4	28 to 32 ft prefer

Financial constraints often require that 28-ft paved surfaces be used (two 12-ft lanes and two 2-ft shoulders). These widths are common on FM roadways in Corpus Christi, Laredo, San Antonio, Amarillo, Lubbock, Odessa, and San Angelo. Some districts have utilized 24 to 26-ft paved surfaces with poor results in the energy sector.

Almost all districts stripe pavements for 12-ft travel lanes. San Antonio and Yoakum have some experience with 11-ft travel lanes in order to encourage traffic to move away from the pavement edge.

Current district practices show that a minimum travel lane of 12 ft and a minimum shoulder width of 2 ft should be used. The preferred paved shoulder width should be 4 ft or greater as shown by a pavement thickness/edge support design study completed as part of this project (7). Safety would also be greatly improved by the use of shoulders in the 4 to 6 ft range with 12-ft travel lanes.

Maintenance Repair Activities

For the purposes of information gathering and reporting, maintenance and repair techniques were divided into several types. The types of maintenance techniques identified are common to routine maintenance practices currently used in the state. Repair/rehabilitation activities were established based on funding sources as well as common practices currently used by the districts. Interviews with district staffs and the workshops were conducted to insure that these maintenance and repair techniques were discussed. The maintenance and repair techniques are shown below:

- Shallow Patch
- Deep Patch
- Level-Up Patch
- Shoulder/Edge Repair
- Surface Treatment/Seal Coat (Chip Seal)
- Pavement Strengthening (performed by maintenance forces)

- Maintenance Contracts
- Construction Contracts

Information was gathered and reported for the south Texas districts associated with the Eagle Ford shale activities and west Texas districts associated with the Permian Basin and panhandle area. The information gathered and reported uses numerous abbreviations to designate highway routes (Table 3), types of asphalt binders (Table 4), aggregate gradations used for chip seals (Table 5), and types of materials and operations (Table 6). Information obtained from the districts is summarized below for each of these types of operations.

Note that a wide variety of repair materials and techniques are used by TxDOT districts. The materials selected and the techniques utilized are based on district experience and preference. Some of these techniques are capable of extending the pavement life longer than others.

Table 3. Abbreviations Used for Highway Route Designations.

Abbreviation	General Description
FM	Farm to Market
SH	State Highway
US	United States
IH	Interstate Highway

Table 4. Abbreviation Used to Designate Asphalt Binder Materials.

Abbreviation	Brief Description	TxDOT Specification Item
CRS-1	Cationic rapid set emulsion	300
CRS-1h	Cationic rapid set emulsion with hard base asphalt	300
CRS-2	Cationic rapid set emulsion	300
CRS-2P	Cationic rapid set emulsion with polymer	300
CRS-2TR	Cationic rapid set emulsion with tire rubber	
CMS-1P	Cationic medium set emulsion with polymer	300
HFRS-2	Anionic high float rapid set emulsion	
HFRS-2P	Anionic high float rapid set emulsion with polymer	300
CHFRS-2	Cationic high float rapid set emulsion	
CHFRS-2P	Cationic high float rapid set emulsion	300
MS-2	Anionic medium set emulsion	300
SS-1	Anionic slow set emulsion	300
SS-1h	Anionic slow set emulsion with hard base asphalt	300
RC-250	Rapid curing cutback with 250 to 500 cSt viscosity @ 140 F	300
MC-250	Medium curing cutback with 250 to 500 cSt viscosity @ 140 F	300
MC-800	Medium curing cutback with 800 to 1600 cSt viscosity @ 140 F	300
AC-5	Asphalt cement with viscosity of 500 poises @ 140 F	300
AC-10	Asphalt cement with viscosity of 1000 poises @ 140 F	300
AC-15P	Asphalt cement with viscosity of 1500 poises @ 140 with polymer	300
AC 5-2TR	Asphalt cement with viscosity of 500 poises @ 140 F with 2% tire rubber	
AC 10-2TR	Asphalt cement with viscosity of 1000 poises @ 140 F with 2% tire rubber	300

AC 15-3TR	Asphalt cement with viscosity of 1500 poises with 5% tire rubber	
AC 20-5TR	Asphalt cement with viscosity of 2000 poises @ 140 F with 5% tire rubber	300
AR	Asphalt rubber-reacted crumb rubber modifier and asphalt cement at 350 F	300
PG 64-22	Asphalt cement with good performance expected from 64 to -22 C	300
PG 70-22	Asphalt cement with good performance expected from 70 to -22 C	300
PG 76-22	Asphalt cement with good performance expected from 76 to -22 C	300

Table 5. Abbreviations Used to Designate Chip Seal Aggregate Gradations.

Abbreviations	General Description	TxDOT Specification Number
Gr. 3 (surface treatments/seal coats)	Chips for surface treatment/seal coat-large size	302
Gr. 4 (surface treatments/seal coats)	Chips for surface treatment/seal coat-medium size	302
Gr. 5 (surface treatments/seal coats)	Chips for surface treatment/seal coat-small size	302
Gr. 1 (flexible base)	Flexible base, most stringent specification requirements	247
Gr. 2 (flexible base)	Flexible base, reduced requirements	247
Gr. 3 (flexible base)	Flexible base, reduced specification requirements, no triaxial strength requirements	247
Gr. 4 (flexible base)	Flexible base as shown on plans	247

Table 6. Abbreviations Used to Designate Maintenance/Rehabilitation Materials.

Abbreviation	Brief Description	TxDOT Specification Number
BB	Black Base (hot mixed-hot laid)	292
CM-CL	Cold Mixed-Cold Laid patching material	
FB	Flexible Base (aggregate base)	247
FDR-CM	Full Depth Recycling-Cement Modified (2 to 3 percent portland cement)	275
FDR-Cement	Full Depth Recycling-cement stabilize (4 plus percent Portland cement)	275
FDR-EM	Full Depth Recycling-asphalt emulsion modified	
FDR-Foam	Full Depth Recycling-foamed asphalt	
FS	Fog Seal (light application of diluted asphalt emulsion	315
GG	Geogrid, fabric	410
HMA	Hot Mix Asphalt (hot mixed-hot laid)	340, 341
HM-CL	Hot Mixed-Cold Laid patching material	334
IP	Inverted Prime application of asphalt binder and aggregate-similar to ST or SC)	
LRA	Limestone Rock Asphalt	330
RAP	Reclaimed Asphalt Pavement	
SC	Seal Coat (chip seal)	316
WMA	Warm Mix Asphalt (warm mixed-warmed laid)	340, 341
1-ST	One course Surface Treatment	316
2-ST	Two course Surface Treatment	316

SHALLOW PATCH

Description/Purpose

Shallow patches are typically used to repair localized pavement distress that can be temporarily repaired with removal and replacement of pavement materials to a depth of 2 to 3 inches. Typical repairs treat pot holes and localized undulation (roughness) in the pavement surface. Shallow patching is typically used as a short term remedy until more extensive techniques can be performed. Materials used for patching are typically hand placed by maintenance crews.

Equipment and Crew Sizes

Small crew sizes (2 to 4 maintenance workers) use limited equipment for this routine maintenance operation. Materials and hand tools are typically placed in 6 to 10 cubic yard dump-type trucks. The patched areas may be prepared by removing all loose materials as well as "sound" materials to form a rectangular area for placement of the patch material. A tack coat is typically applied to the bottom and sides of the prepared area. Materials are hand placed and often compacted with the dump truck tires or small "parking lot" size compactors.

Traffic Control

This operation is most likely considered a mobile operation. A mobile operation is defined in the Texas Manual on Uniform Traffic Control Devices (TMUTCD) as work that moves continuously or intermittently. The definition allows for stopping for up to 15 minutes. Typical Application (TA) 17 in Part 6H of the TMUTCD provides minimum guidance for a mobile operation on a two-lane roadway (9). In TA-17, truck mounted attenuators (TMAs) on the shadow vehicles are optional. However, construction and maintenance plans include traffic control plan (TCP) sheets that require the use of TMAs. TCP (3-1)-13 provides guidance on mobile operations and requires at least one shadow vehicle with a TMA. This standard requires an engineer to determine if an additional trail vehicle is required and if it is, it must also be equipped with a TMA. TCP (3-1)-13 also requires an engineer determination of whether or not a lead vehicle is required (10). It is suggested that districts develop standard operating procedures for traffic control used in these situations. It is further recommended that TCPs be used for both in-house and contract work rather than TMAs.

Traffic control selection will affect budget and resource allocation. Many TxDOT districts now use contracts for most of their TMA needs. This requires scheduling with the private vendor. Additionally, the use of TMA contracts affect Strategy 144 budgets. TxDOT also has in-house availability of TMAs, but using these TMAs can dedicate a dump truck and employee that is needed elsewhere. Traffic control is an integral part of the frontend planning process and has effects on budget, equipment and labor allocations. Districts should establish clear expectations for traffic control.

Materials

South Texas districts report the use of Type CC and D hot mixed-cold laid (HM-CL) and limestone rock asphalt (LRA) patching materials. Some commercially available patching materials packaged in small quantities are also used (Table 7a).

Table 7a. Shallow Patch-South Texas (Function 330, Task P08).

District	Materials	Equipment	Crew Size	Production	Cost	Comments
Corpus Christi (16)	HM-CL					
	HM-CL Type CC if shallow repair areas	Pneumatic and flat wheel roller, maintainer, backhoe, 2-belly dump trucks, distributor		2 to 4 areas per day depending on area to be repaired and traffic		If area is deep use BB with 2% cement
Laredo (22)						
San Antonio (15)						
Yoakum (13)	HM-CL					Poor performance in cold weather
	Commercial Cold patch material					

West Texas districts report the use of HM-CL materials and Type D LRA. A commercially available material has also been used. Reclaimed asphalt pavement (RAP) has been used in two forms: 1) a mixture of RAP and diesel and 2) a mixture of RAP and an asphalt cutback prepared in a hot mix plant. These are called HM-CL patching materials. Some hot mixed-hot laid (HM- HL) materials are also used on a limited basis. Hot mix materials are often not available and it is difficult to hold the high temperature needed for successful placement and compaction for an extended time (Table 7b).

Table 7b. Shallow Patch-West Texas.

District	Materials	Equipment	Crew Size	Production	Cost	Comments
Amarillo (4)	HM-CL, RAP mixed in HMA plant, commercial material					Little success with HM-CL, commercial material some success
Childress (25)	LRA, HM-CL, blade HMA, commercial mixture					Use tack coat, patching material and seal coat
Lubbock (5)	LRA Type D, RAP plus diesel, HM-CL, commercial material					
Odessa (6)	LRA Type D, Commercial material, SS-1h, AC 20-5TR					
San Angelo (7)	LRA-Type D, HM-CL, Commercial material					

Comments
The life of these types of patches depends on the general condition of the pavement, the degree of patched area preparation, the quality of the patching material used, the quality of the placement and compaction, as well as the general weather conditions during patching and several days following the placement of the patch.

The placement of shallow patches without proper road preparation, with and without the use of a hot mixed-hot laid materials is likely temporary in nature. Preparation should include removal of all loose materials and some sound materials to form a rectangular patched area followed by a tack coat. Moderate to high traffic on HM-CL materials and some LRA materials as well as commercial patching materials will likely shove or rut under traffic during the warmer summer months.

DEEP PATCH

Description/Purpose
Deep patches are typically used to repair localized pavement distress. Deep patches usually involve the removal and replacement of existing pavement material to approximately 6 to 8 inches.

Deep patches are typically used to treat areas of pavement distress associated with subgrade and base failures caused by traffic loads. Alligator cracking, rutting in unbound materials and deep pot holes are typical distresses treated with this method.

The purpose of the deep patch is to strengthen the pavement in localized areas and provide a relatively smooth riding surface until more extensive maintenance operations can be performed.

Equipment and Crew Size
Depending on the size of the area repaired with deep patching 8 to 16 crew members may be needed for the repair and traffic control operations. Small milling machines, either self-powered or mounted on other types of equipment, are typically used for material removal. Backhoes also may be used for pavement removal operations in some areas.

A prime or tack coat is typically applied by an asphalt distributor or hand wand to the prepared patch area. Various types of patching materials are placed in the prepared areas by hand or with a tailgate spreader. Maintainers, sometimes called motor patrols or blades, may be used for spreading the patching materials. Compaction is performed with rubber and/ or steel wheel rollers. Loaders and dump trucks are used to load and haul removed materials and the patching materials. Some districts place a seal coat (chip seal) on the surface of the patching material. When chip seals are placed, an asphalt distributor and chip spreader or dump truck with a tailgate spreader is required. A power broom is used to remove loose material after completion of the patch.

Traffic Control
This type of work requires daily lane closures. According to the TMUTCD, this work is considered short-term stationary because it occupies a location for more than one hour during the day (9). It is important to note that if this work is expected to extend into nighttime operations or

is planned as night work, requirements associated with intermediate-term stationary work must be complied with. As mentioned in the Shallow Patching section, the TMUTCD contains typical applications, but it is recommended to use TxDOT TCP standards for traffic control. The TCP 2 series governs lane closures. This TCP series consists of eight TCP sheets representing most lane closure situations. For specific questions regarding channeling devices that should be used, TxDOT BC sheets should be consulted. Also, when permanent striping is removed, BC(11)-14, BC(12)-14 and WZ (STPM)-13 should be consulted for temporary striping requirements. Per Item 662 in TxDOT's Standard Specifications and WZ (STPM)-13, temporary markings should only be left in place for 14 calendar days. This limit should be accounted for in the planning process and permanent stripe should be scheduled far enough in advance to meet the specification. Finally, the use of temporary rumble strips has become more common (required in some locations) throughout TxDOT. The use of this traffic control device is governed by WZ (RS)-14 (10). Standard operating procedures for temporary rumble strips should be made clear to all parties.

Traffic control planning and determining whose responsible for set-up and take down is an important part of the work plan. Companies are available to contract with the set-up and take down traffic control, freeing up valuable TxDOT resources to increase production in a safe manner. This will affect strategy 144 expenditures. Additionally, finding these companies in fairly remote areas of south and west Texas can be challenging.

Materials

The Corpus Christi District uses HM-CL (Type BB, B, and CC) treated with 2 to 3 percent cement as patching materials. Portland cement is added to provide rutting resistance in hot weather and help provide an initial "set" for the patching materials. High float rapid setting emulsions (HFRS-2) are used as a tack coat. A two course chip seal/surface treatment is used as the final surface. HFRS-2 is applied at a rate of about 0.40 gal. per sq. yd. with a Grade 3 chip for the first chip seal application, and HFRS-2 applied at a rate of about 0.35 gal. per sq. yd. with a Grade 4 chip is used as the second chip seal application. Production rates are generally 1500 square yards per day for a crew of 12 (Table 8a).

The San Antonio District uses Type AA limestone rock asphalt (LRA) mixed with portland cement as a patching material. A high float rapid setting emulsion (HFRS-2) is used as the tack coat and also used with a Grade 4 or 4S chip to place a one course surface treatment on the patched area (Table 8a).

The Yoakum District uses Type B HMA, HM-CL, and a commercial material for patching. The hot mix asphalt material is used when possible as cold laid materials experience shoving in hot weather (Table 8a).

The Corpus Christi District reports some pavement removals to a depth of 2 to 3 ft. The materials at the bottom of the excavation is then treated with 2 to 3 percent cement and mixed. A tack coat is placed and HM-CL patching material is used with a surface treatment (Table 8a).

The San Antonio District uses a localized full depth recycling (FDR) operation with 2 to 3 percent portland cement to repair deep areas. A one course surface treatment is place on the surface (Table 8a).

Table 8a. Deep Patch-South Texas.

District	Materials	Equipment	Crew Size	Production	Cost	Comments
Corpus Christi (16)	HM-CL Type B as surface, at depth use BB with 2 % cement and 2-ST with HFRS-2 (0.40 gal./sq. yd.) and Gr. 3 chip and HFRS-2 (0.35 gal./sq. yd.) and Gr. 4 chip), use HFRS-2 for tack coat	Pneumatic and flat wheel roller, maintainer, backhoe, 3-10 yd. dump trucks, distributor, broom, skid steer, milling machine	12	1500 sq. yd./day with 150 to 200 cu. yd. of HM-CL		Typically mill about 4 inches, compact base, tack with HFRS-2 (0.05 gal/ sq. yd.)
	Excavate 2 to 3 ft, add cement at bottom of excavation, fill with BB mixed with 2 to 3% cement, HFRS-2 tack coat (0.20 gal/sq. yd.), HM-CL Type CC	Pneumatic and flat wheel roller, maintainer, backhoe, loader, 3-10 yard dump trucks, belly dump, distributor	16	2 to 4 areas per day depending on size of area repaired and traffic		Remove 2 to 3 ft of materials
Laredo (22)						
San Antonio (15)	LRA Type AA mixed with cement, HFRS-2 as tack coat and 1-ST with HFRS-2 Gr. 4 or 4S as chip	Dump trucks, haul trailer, loader, maintainer, pneumatic and flat wheel roller, distributor, broom, water truck				Remove and replace Mill 6 to 8 inches
	FDR-CM with cement, 1-ST with HFRS-2 or HFRS-2P and Gr. 4 or Gr. 4S	Dump trucks, haul trailer, loader, maintainer, FDR pulverizer/mixer, pneumatic an flat wheel roller, distributor, broom, water truck				FDR-CM, some use of LRA D-S before placing ST
Yoakum (13)	HMA-Type B					Use when possible, difficult to keep hot
	HM-CL					Shoving in hot weather
	Commercial cold patch material					

West Texas districts utilize small milling machines for removal (typically 6 to 8 inches) and stabilization. Flexible base from the site, salvaged flexible base from other sites and new flexible base is often used with 2 or 3 percent portland cement and, in some cases, fly ash. HM-CL, LRA, and HMA have been used as surface patching materials. Single and double surface treatments are sometimes used as surfacing materials on top of the patching materials. Two west Texas districts report the use of a cationic rapid setting emulsion (CRS-2) as the asphalt binder and a Grade 4 chip for the surface treatment (Table 8b).

Table 8b. Deep Patch-West Texas.

District	Materials	Equipment	Crew Size	Production	Cost	Comments
Amarillo (4)	FB with 2% cement, ST, HMA	Zipper, small milling machine, Bomag no longer in fleet				Remove with small milling head, stabilize with 2 % cement, ST or HMA surface, 6 to 8 inches deep
Childress (25)	FDR-CM with 6% fly ash or with 3% cement	Small milling machine, Bomag no longer in fleet				FDR-CM with stabilizer, 2-ST, 6 to 8 inches
Lubbock (5)	HM-CL, fly ash, cement, FB, CRS-2, Gr. 4 chip	Small milling machine, distributor, tailgate spreader, water truck	2-traffic control, 5-7 for operation	¼ lane mile per day		
Odessa (6)	LRA, HMA	Milling machine, Bomag				HMA less than 4 in. poor performance
San Angelo (7)						

Comments

When HM-CL or CM—CL patching materials are used in deep patches, it is difficult for the volatiles in the asphalt binders to escape to the atmosphere which inhibits curing. Rutting and shoving under traffic in warm and hot weather can occur due to the lack of curing. Small percentages of portland cement may be used to improve stability.

Fly ash is available in the panhandle area of Texas. Some of these materials have cementing characteristics and, as a minimum, they are pozzolans that react with the hydration products of portland cement or lime.

When placed at depths less than 4 inches on flexible base, HMA materials have experienced poor performance in the Odessa District.

LEVEL-UP PATCH

Description/Purpose
Level-up patches are typically limited in length and can be full or partial lane width. This type of patching is primarily used to repair rough roads and roads with localized rutting. Level-up patching typically involves the placement of a tack coat on the existing surface followed by the placement of a patching material. This operation is most frequently performed without significant removal of existing pavement materials.

Equipment and Crew Size
Crew sizes typically range from 8 to 10 workers. Asphalt distributors are used to apply tack coats. Patching materials are often placed with a maintainer and compacted with a pneumatic and/or steel wheel roller. When ruts are being filled a “rut box” may be attached to a dump truck. Three ten cubic yard dump trucks are used by one district. A power broom is used to remove loose materials (Tables 9a and 9b).

Production rates of the order of 8,500 square yards per day in 3 to 4 areas of a pavement section can be expected.

Traffic Control
Traffic control will most likely be similar to that used for deep patching. Daily lane closures will be required. The same temporary and permanent striping requirements mentioned for deep patching apply here as well. Depending on the scope of this operation, an edge condition can be created. TxDOT has a worksheet for edge condition treatment options that must be signed and sealed for use. Also, WZ (UL)-13 provides guidance on uneven lanes (10). From a safety perspective, it is advisable to pull all edges at the end of the day to eliminate drop-off conditions. Addressing edge conditions should be included in the planning process.

Materials
South Texas districts typically use HM-CL Type CC and CM-CL Type C. HFRS-2 is used as a tack coat in these districts (Table 9a).

Table 9a. Level-Up Patch-South Texas.

District	Materials	Equipment	Crew Size	Production	Cost	Comments
Corpus Christi (16)	HM-CL Type CC	Pneumatic and flat wheel roller, maintainer, backhoe, two belly dumps, distributor		2 to 4 areas per day depending on area treated and traffic		Blade lay
	CM-CL Type 1, Gr. C surface with HFRS-2 tack (0.05 gal/sq. yd.)	Pneumatic roller, flat wheel, maintainer, 3 ten cu. yd. dump trucks, distributor	8-10	8,500 sq. yds. using 350 cu. yds. of material		
Laredo (22)						
San Antonio (15)						
Yoakum (13)						

West Texas districts use Type D or F HMA, HM-CL, Type D LRA, and a commercial cold placed mixture. Tack coats are typically used. One district indicated that a tack coat was not used with the commercial patching material (Table 9b).

Table 9b. Level-Up Patch-West Texas.

District	Materials	Equipment	Crew Size	Production	Cost	Comments
Amarillo (4)	HMA Type D or F	Rut box				20 to 25% of maintenance budget
Childress (25)						
Lubbock (5)	HM-CL, commercial mixture					Don't use tack coat in some areas with commercial mixture
Odessa (6)	LRA, HM-CL					Thin layers of HMA on FB poor performance
San Angelo (7)	LRA Type D, HM-CL					

Comments

A significant portion of the budget is allocated for level-up patching in some districts. Due to the relatively thin layers of cold laid materials in this type of operation, rutting is typically not a problem. Surface raveling can be a problem if proper compaction is not obtained. Fog seals can be used to control raveling.

When thin layers of HMA are utilized as level-up materials and placed on pavements with flexible base courses as the primary structural component, poor performance can be obtained. Tack coats are recommended for all types of materials used in level-up operations.

SHOULDER/EDGE REPAIR

Description/Purpose
Pavement edge repair techniques including patching (non-continuous), strip seals and widening operations. Spot or non-continuous patching should be considered as only a temporary fix. Typically these techniques, regardless of the materials utilized, are short-lived and the pavement sections should be considered for widening and perhaps strengthening as soon as financial resources and crew time are available.

Strip seals refer to techniques that are continuous in nature and consist of fog seals and strip chip seals or seal coats. Widening includes increasing the width from the pavement edge to some distance beyond the current edge. The widening may function as part of the travel lane and/or become a paved shoulder.

Shoulder/edge repair methods are utilized to control the disintegration/abrading/raveling of the paved shoulder and to widen the paved surface. Widening operations will typically improve safety as well as reduce the rate of deterioration of the paved surface used as travel lanes.

Traffic Control
There are multiple shoulder operations listed below that could require diverse traffic control. An exhaustive traffic control analysis for each work type would be cumbersome within this report. It suffices to say that traffic control should be part of the planning and budgeting process. It is recommended that TCPs be used in lieu of TAs from the TMUTCD. The use of a TMA is encouraged in all operations, even those that are stationary. The TMA provides an excellent safety feature at the buffer zone, prior to the actual work locations. The use of contract TMAs and traffic control companies should be investigated to assist TxDOT crews in freeing up valuable labor and equipment forces to accomplish the require roadwork.

Patching
Patching of shoulder distress is difficult and typically has a short life. However, from a safety and scheduling point of view it may be necessary to “hold the road together” until a more permanent repair can be made by maintenance crews or under contract.

Localized patching materials used by the districts vary considerably from district to district. Some of the more common patching materials include the following (Tables 10a and 10b):

- Limestone rock asphalt
- Hot mixed-cold laid
- Reclaimed asphalt pavement mixed with emulsion or other binder
- Flexible base or salvaged flexible base
- Commercial patching material (5 gallon buckets)

Depth of patching is typically 8 to 12 inches. Districts prefer to seal these compacted materials with a chip seal or a fog seal. Materials typically used for fog seals and chip seals are discussed below.

Strip Seal
Two types of strip seals have been commonly used on the shoulder areas-fog seals and chip seals or seal coats as referenced in standard specification.

Fog Seal
Strip fog seals are typically applied 18 to 24 inches wide and span from the near the edge of the paved surface to the unsurfaced shoulder. Typical fog seal materials include the following (Tables 10a and 10b):

- Cationic slow setting emulsion (CSS-1h)
- Cationic medium setting emulsion (CMS-1h)
- Slow setting hard base asphalt emulsion (SS-1h)
- Anionic medium setting emulsion (MS-2)
- High float rapid setting (HFRS-2)

Typically these emulsions are diluted with water at the following ratios: 70 percent emulsion/30 percent water, 60 percent emulsion/40 percent water, or 50 percent emulsion/50 percent water. Typical spray rates are 0.15 to 0.20 gal. per sq. yd. with a residual asphalt binder content of approximately 0.05 to 0.08 gal. per sq. yd.. Heavier residual asphalt binder contents are sometimes used.

Chip Seal (Seal Coat)
Strip chip seals are commonly used on shoulders in the western portion of the state. The strip seals are used with or without patching and/or widening operations. These chip seals are applied from 18 to 24 inches in width and span from the near edge of the paved surface to the unsurfaced shoulder. Some districts indicated a 12-inch treatment on the existing paved surface and 12 inches on the unpaved shoulder area.

Typical "chip seal" binders utilized by the district maintenance forces include the following (Tables 10a and 10b):

- Anionic medium setting emulsion (MS-2)
- Cationic rapid setting emulsion (CRS-2)
- Cationic rapid setting emulsion with polymer (CRS-2P)
- High float rapid setting emulsion (HFRS-2)
- High float rapid setting emulsion with polymer (HFRS-2P)
- Rapid curing cutback asphalt (RC-250)

Typical "chips" or aggregate grades and "shot" quantities utilized by the district maintenance forces include the following:

- Grade 3-0.45 to 0.50 gal. per sq. yd.
- Grade 4-0.40 to 0.48 gal. per sq. yd.
- Grade 5-0.35 to 0.40 gal. per sq. yd.

Widening
Some maintenance operations utilize pavement widening operations without pavement structural section strengthening. District maintenance forces are used in these operations to remove the existing materials adjacent to the paved surface area, replace the removed materials and typically place a chip seal as described above. The chip seal typically provides a few inch overlap on the exiting pavement surface, covers the new width and extends slightly beyond it.

The typical widening operation includes removal of materials adjacent to the paved surface to a depth of 8 to 12 inches below the top of the existing pavement and to a width of 2 to 4 ft by one of the following techniques (Tables 10a and 10b):

- Maintainer
- Maintainer with a cutting attachment
- Milling machine with a milling head of 2 to 4 ft in width
- Bobcat type milling machine with a milling head of 2 to 4 ft in width

Materials used in the prepared trench include the following (Tables 10a and 10b):

- New flexible base
- Salvaged flexible base
- Reclaimed asphalt pavement
- Mixture of reclaimed asphalt pavement and new or salvaged flexible base
- Emulsion treated reclaimed asphalt pavement, salvaged base or new flexible base
- Portland cement mixed with salvaged base or new flexible base
- Hot mix cold laid Type C or D
- Limestone rock asphalt Type AA
- Type A or B hot mix asphalt or black base
- Type C hot mix asphalt

At least two districts commonly use limestone rock asphalt or hot mix asphalt materials, full depth, for widening.

Table 10a. Shoulder/Edge Repair-South Texas (Function 270 Task P07).

District	Materials	Equipment	Crew Size	Production	Cost	Comments
Corpus Christi (16)	BB (two lifts), and seal with HFRS-2 and Gr. 4 chip, tack with HFRS-2 on subgrade and BB	Pneumatic roller, maintainer, loader, 2-belly dump trucks, distributor, drag box	7-10	3,000 to 5,500 and as high as 10,000 LF/day		8 to 12 inches deep, 12 to -24 inches wide
	RAP					Poor performance unless mixed with SS-1
	HM-CL Type C or D in 2 in lifts with HFRS-2 tack					12 inches deep and 3 to 4 ft wide, temporary repair strategy
Laredo(22)	LRA					

San Antonio (15)	LRA Type AA or LRA Type AA with RAP at 1 to 1 ratio, 1-ST HFRS-2P and Gr. 4 chip, some use of FB with cement, HFRS-2 fog seal	Loader, dump trucks, maintainer, roller				8 inches deep and 2.5 ft wide, typically seal coat entire roadway after shoulder treatment
Yoakum (13)	FB, RAP, HM-CL		4 to 8			Maintainer with edge widener (commercial devices available)
	1-ST	FDR-CM with prime and some lime stabilization of subgrade	4 to 8 plus			FDR-quarter point or full width with reclaimer
	1-ST	Flex base with prime	4 to 8 plus			Milling machine notch widening

Table 10b. Shoulder/Edge Repair-West Texas.

District	Materials	Equipment	Crew Size	Production	Cost	Comments
Amarillo (4)	Salvage base, RAP, new base, ST-CRS-1, CRS-2P, MC 250, MC-800, RC-250	Cut shoe on Motor grader, small rollers, trucks				Widen from 18 to 22 ft to 26 to 28 ft
Childress (25)	RAP plus emulsion, salvaged base, ST with CRS-2 with Gr. 4	Small mill, widening tool				2 ft widening to 26 to 28 ft, 10 to 12 inches deep
	FS with CSS-1h, CMS-1P, 60:40 dilution, shoot 0.15 to 0.20					FS, 24-inch width, half on pavement half on gravel shoulder
	Strip Seal with CRS-2, CRS-2P, 0.45 to 0.50 gal./sq. yd. with Gr. 4 chips					Strip seal 3 to 4 ft. width

Lubbock (5)	FS with CSS-1h, RC-250 at 70-30 dilution, spray 0.10 to 0.15 gal./sq. yd., sand, some MS-2					FS 18 to 24 inches, 12 inches on pavement and 12 inches on gravel shoulder, performance for 2 years
	CS with CRS-2P at 0.40 to 0.42 gal./yd. sq. with Gr. 4 and 0.36 gal./sq. yd. for Gr 5					CS 18 to 24 inches or ¼ points out to edge of shoulder, performance to 2 years
	Commercial material					Edge patch
	FB, RAP, HMA, CRS-2, CRS-1h, Gr 4 chip	Grader, small milling machine, water truck, roll, dump truck, distributor, tailgate spreader	2 traffic control, 5 to 7 operations	3,000-4,000 ft per day per side of roadway		Edge widening with RAP, HMA
Oessa (6)	FS with SS-1h (50-50 blend), 0.10 to 0.15 gal/sq. yd.	Some widening with blade attachment and lay down machine				Edge FS
San Angelo (7)	LRA-Type A, AA, asphalt stabilized base, FB	Small milling machine, cut box, maintainer edge cutting tool		½ lane mile per day	20,000 per lane mile	Remove 6 to 8 inches, 2-3 ft. wide, place LRA in 4-inch lifts, fog seal

After unstabilized materials have been placed in the trench, moisture conditioned and compacted, a prime coat is placed and a single or double surface treatment (chip seal) is placed. Typical materials used for the surface treatment are discussed under strip chip seal above. If a double surface treatment is place, a Grade 4 chip (aggregate) is often used on the first course and a Grade 5 chip (aggregate) on the second course.

Comments

Some districts report poor performance with the use of reclaimed asphalt pavement as a patching material or shoulder widening material unless it is mixed with an emulsion or other suitable asphalt binder.

A minimum widening of 2 feet is suggested. Paved surface widening to 32 ft is preferred. Small milling machines and attachments to maintainers have been used for shoulder materials removal with success. TxDOT district personnel have developed attachment to maintainers. Commercially available products are also available.

SURFACE TREATMENT/SEAL COAT

Description/Purpose

TxDOT's standard specification book defines a surface treatment as one or more applications of a single layer of asphalt material covered with a single layer of aggregate (8). The process typically involves the spray application of an asphalt binder immediately followed by the placement of a nearly one-sized aggregate. Pneumatic tired rollers are used to seat the aggregate into the asphalt binder.

Several terms are used to further describe these types of applications by TxDOT and others. When this type of roadway treatment is placed on an existing hard surfaced roadway or on a stabilized base course, it is usually referred to as a chip seal or seal coat. When this treatment is place on a non-stabilized base course (flexible or aggregate base), it is usually referred to as a surface treatment. The term seal coat is usually used by TxDOT to describe a chip seal as defined above. Unfortunately, the term seal coat can be used to describe fog seals, slurry seals, scrub seal, and other types of seal coat treatments. This document uses the term "chip seal" to identify the application of an asphalt binder immediately followed by the application of a nearly one sized aggregate when the treatment is place on an existing paved surface or stabilized base course.

Surface treatments and chip seals are commonly used as both routine and preventive maintenance treatments. These types of treatments are sometimes placed on cold laid patching materials used for shallow, deep and level-up patches: as strip seals in the wheel paths or on shoulder areas or on the entire roadway width as a preventive maintenance activity.

The purpose of surface treatments and chip seals is to seal the roadway to reduce water and air penetration into the surface, reduce oxidation of the old asphalt surface, control raveling of the old surface, provide friction, and to provide a uniform surface color which can provide demarcation for the travel lanes versus the shoulder areas. Surface treatments and chip seals are commonly used by TxDOT maintenance crews.

Equipment and Crew Size

The amount and type of equipment utilized to place surface treatments and chip seals depend on the type of operation. Full pavement width operations typically involve the use of a front end loader with several dump trucks (three or more depending on the haul distance), several asphalt distributors (two to three as a minimum), a chip spreader, several pneumatic tired rollers (one to three), a broom and traffic control devices and equipment. Crew sizes for this type of operation can range from 8 to 14. Some districts have special crews for this operation that have developed their skill sets over several years.

When smaller localized areas are treated, the work equipment can be greatly reduced in terms of haul units, asphalt distributors, rollers and traffic control needs. A rear dump truck with an attached chip spreader is sometimes used for smaller operations. Crew sizes in the range of 6 to 8 are typical for these localized operations.

Traffic Control
Traffic control described for previous operations requiring lane closures will also apply to seal coat work. In addition to these requirements, attention is called to TCP(7-1)-13, a surface treatment specific TCP. This TCP addresses signing required for passing zones, the contiguous loss of the centerline and the presence of loose gravel (10). The extent of the placement of these signs should be planned well ahead of the work. Ideally, these signs are placed before the work begins and appropriate measures (e.g., bagging or turning) are taken so they are not seen by traffic. This placement allows for these signs to simply be turned or unbagged after the work has been performed. It is sometimes possible to have a traffic control contractor place these signs in advance of the work. Some districts will use internal sign crews to help with this work.

Materials
TxDOT surface treatment and chip seal crews typically use emulsified or cutback asphalts. Hot asphalt binders are not commonly used by maintenance crews. Emulsified asphalt binders are most commonly used in the summer months and under reasonable good weather conditions. Cutback asphalts are used by some districts for relatively small area and under marginal weather conditions.

High float rapid setting emulsion (HFRS-2) is a common emulsion used in south Texas (Table 11a). Spray quantities of the emulsion are approximately 0.45 gal. per sq. yd. for Grade 3 aggregates. A Rapid Curing cutback asphalt (RC-250) is used by two south Texas districts with Grade 5 aggregate and is sometimes referred to as an inverted prime.

West Texas districts report the use of cationic rapid setting emulsions (CRS-1, CRS-2, CRS-2P, CRS-2TR) an anionic medium setting emulsion (MS-2), cationic medium setting emulsion with polymer (CMS-1P), and cationic slow setting emulsion (CSS-1h) for various surface treatment and chip seal applications (Table 11b). Asphalt spray rates of 0.45 to 0.50 gal. per sq. yd. for Grade 4 aggregate and 0.28 gal. per sq. yd. for Grade 5 aggregate are utilized. Rapid curing cutback asphalt (RC-250) and medium curing cutback asphalts (MC-250 and MC-800) with Grade 4 aggregates are used by some maintenance sections.

Sand seals are used on a limited basis in a west Texas district. A cationic slow setting emulsion (CSS-1h) or anionic medium setting emulsion is utilized in combination with a blow sand to construct the seal. A maintainer with a rubber blade has been used to help distribute the sand seal and fill the cracks in the old pavement surface.

Scrub seals have been used on a limited basis in the Lubbock, Odessa and San Angelo Districts. These applications use emulsions, sand and drag brooms to “work” the sand or small chips and emulsions into the pavement cracks.

Table 11a. Surface Treatment/Seal Coat with Maintenance Crews-South Texas.

District	Materials	Equipment	Crew Size	Production	Cost	Comments
Corpus Christi (16)	HFRS-2 (0.45 gal/sq. yd.) and Gr. 3 chip	Pneumatic roller, 10 cu. yd. dump trucks with spreader box, distributor , broom	6-8			Spot seal
Laredo (22)	RC-250 with Grade 5 traprock					Emulsions bleed in the summer
San Antonio (15)						
Yoakum (13)	RC-250 Grade 5 aggregate					Shoulder repair, pavement repair surfaces

Table 11b. Surface Treatment/Seal Coat with Maintenance Crews-West Texas.

District	Materials	Equipment	Crew Size	Production	Cost	Comments
Amarillo (4)	CRS-1, CRS-2P, MC-250, MC-800, RC-250 with Gr. 4	3 small distributors, chip spreader, lease rollers				
Childress (25)	CRS-2, CRS-2P with Gr. 4, 0.45 to 0.50 gal./sq. yd.					
Lubbock (5)	CSS-1h, MS-2, 0.32 to 0.42, blow sand					Sand seal, fill voids, cracks, use SC on higher traffic facilities
		Use rubber blade on a maintainer brooms				Scrub seal, Western Emulsions
	Emulsion, Gr. 5 chip					Chip seal
Odessa (6)	CRS-2TR	Two distributors, chip spreader and heater	Special seal coat crew district wide			Strip SC with MS-2 and Gr 5 , scrub seal used
San Angelo (7)	CMS-1P, 0.28 gal/sq. yd., Gr. 5 chip	Distributor, chip spreader, roller			1.90 per sq. yd.	Scrub seal placed in one location

Comments
Performance of seal coats is dependent upon a number of factors including: weather conditions, binder application rate, aggregate spread rates, rolling, sweeping and timing of these operations. Good control of the application rates of binder and aggregate is critical.

Although the use of cutback asphalts (RCs and MCs) allows for the placement of surface treatments and chip seals under marginal weather conditions and times of the year, bleeding often occurs during the first summer after application. Several districts report that the use of polymer modified asphalt improves early life stone retention.

The use of seals which have limited macro or surface texture can cause low pavement friction in wet weather conditions and high traffic speeds.

PAVEMENT STRENGTHENING WITH MAINTENANCE CREWS

Description/Purpose
Pavement strengthening operations with maintenance crews take various forms depending upon the district and the equipment available. The most common type of operation is widening by pulverizing the existing pavement and spreading the pulverized material to the desired width (typically 28 to 32 ft). Flexible base materials are then added to the structural section and a two course surface treatment is placed as the riding surface. Pulverizing to quarter points on the pavement rather than full width, as described above, is also practiced by some districts. Quarter point repair methods typically achieve 3,000 to 5,500 linear ft per week.

As discussed below some districts use portland cement as a stabilizer with the existing roadway pulverized materials or with new or salvaged flexible base. A few districts report the use of overlays with limestone rock asphalt or hotmix asphalt.

The load carrying capacity of subgrade soils in south Texas is less than typical subgrade soils in west Texas. Consideration should be given to use wider shoulder widths and more stabilized base courses for shoulder widening in the south Texas districts as compared to the west Texas districts as these practices will provide greater stability and strength, respectively.

The types of materials used and the thickness of the various layers vary somewhat by district. Details relative to materials utilized and thicknesses of structural layers are shown on Tables 12a, 12b, 13a, and 13b and summarized in the next section.

The purpose of these types of pavement strengthening operations is to provide additional load carrying capacity both in terms of number of loads and weights of loads. Pavement widening operations not only improve the load carrying ability of the pavement but also improve safety.

Table 12a. Pavement Strengthening Maintenance Crews-South Texas.

District	Materials	Equipment	Crew Size	Production	Cost	Comments
Corpus Christi (16)	2ST-1st course, HFRS-2 (0.30-0.35 gal/ sq. yd. in summer and 0.42 gal/sq. yd. in winter) with Grade 4 nd chip: 2 course, HFRS-2 (0.29 gal/sq. yd. in summer and 0.34 gal/sq. yd. in winter) with Grade 4 chip			Quarter Point Repair-3,000 to 4,000 linear ft per week		2-ST
	Type A, Grade 1 or 2					FB
Laredo (22)	Type A, Grade 2					FB
San Antonio (15)						
Yoakum (13)	2 ST-CRS-2/CRS-2P, with Grade 4 over Grade 3 chip			Quarter Point Repair-5,000 to 5,500 linear ft per week		2-ST
	Type A, Gr. 2					FB

Table 12b. Pavement Strengthening Maintenance Crews-West Texas.

District	Materials	Equipment	Crew Size	Production	Cost	Comments
Amarillo (4)	Salvaged base, RAP, fly ash, new FB, CRS-1, CRS-2P, MC-250, MC-800, RC-250 with Gr. 4					No binder added to RAP, RAP placed in 12-inch lifts on some projects
Childress (25)	Salvage base, new FB, 2-ST with CRS-2, CRS-2P, 0.45 to 0.50 with Gr. 4					FDR-CM with cement or fly ash, 2-ST
Lubbock (5)		2 ft. milling machine on Bobcat,				
	HM-CL	Attach to motor grader, drag box,				¼ point level-up
Odessa (6)		Bomag-no longer in fleet				No quarter point repairs
San Angelo (7)	2-ST, new base, FDR-CM with 4% cement	Pulverizer, maintainer	2-3 traffic control, 5 to 7 operations	1,000 ft per day		Special jobs crew, relatively short sections, widen to 28 ft, strip 12 ft lanes
	Commercial mix			1 lane mile per day	33,000 materials cost	Thin overlay

Table 13a. Pavement Strengthening with Maintenance Forces-South Texas.

District	Surface Layer		Base Layer		Subbase Layer		Comments
	Material	Thickness, in	Material	Thickness, in	Material	Thickness, in	
Corpus Christi (16)	1-SC with HFRS-2 and Gr. 3 or 4 (applied across entire roadway)		RAP	10-15 in.			2-3 ft widening
	Old surface and new base (Type A, Gr. 1)mixed, primed, add 1-ST (SS-1 or HFRS-2 with Gr 3 after well development	2-3					Convert to unsurfaced roadway (IH 37 frontage road)
	2-ST with HRRS-2 and Gr. 3 precoated chip partial width or full width		Remove and replace with FB Type A, Gr. 1 or 2 and FDR-CM (2 %)	12			Quarter point repair and full width repair (Karnes Co.)
	Hot mix-cold laid Type B, place in 2 to 3-inch lifts, 1-ST with HFRS-2 and Gr. 3	4	Remove with milling machine	4			Deep patching for extended area, also use LRA
Laredo (22)							
San Antonio (15)	1-ST with CHFRS-2P/HFRS-2 and Gr. 4 or 5 chip		FDR-CM	8-16			Reclamation Option-Performance has varied
	1-ST with CHFRS-2P/HFRS-2 with Gr. 4 or 5 chip		Level-up Material (LRA Type DS or CC, tack coat CHFRS-2P or HFRS-2				Level-up option
	LRA AA/DS/CS/CC depending on depth, tack coat CHFRS-2P/HFRS-2	8 to 12					Remove (mill) and replace option
Yoakum (13)	2-ST		Flexible Base	6	FDR-CM	6	Widen roadway
	2-ST		Flexible Base	8	FDR-CM	8	Widen roadway,
	2-ST		Flexible Base	Add to obtain 8-inch depth	FDR-CM	8 inches of new and salvaged base	Widen roadway, limited use

Table 13b. Pavement Strengthening with Maintenance Forces-South Texas.

District	Surface Layer		Base Layer		Subbase Layer		Comments
	Material	Thickness, in	Material	Thickness, in	Material	Thickness, in	
Amarillo (4)	1-ST		Salvaged base, RAP new FB	12			Widen to 26 to 28 ft.
	HMA	2					Mill to level, or mill and fill
Childress (25)	2-ST		FB		Salvage base with 2-3% cement	6	
Lubbock (5)	CRS-2P	ST	RC-250 prime, salvaged base, RAP with diesel	6-8			Widen to 28 ft., mill 2-ft shoulders 8-inch depth, RAP with shot of emulsion open to traffic
Odessa (6)	AC 20-5TR	2ST, precoated Gr. 3 and Gr. 4	FB treat with cement at 2%	6-8			Hot ST performed under contract
San Angelo (7)	2-ST	Flexible Base		Pulverized existing base plus 4% +- cement			LRA used for some surfaces in short sections

Equipment and Crew Size

Typical equipment used by maintenance crews include a pulverizer/stabilizer, maintainer, water truck, smooth wheel compactor(s), haul vehicles, asphalt distributors, chip spreader, pneumatic tired roller, broom, and traffic control equipment. Crew size varies from 7 to 12 depending on the number of haul trucks involved. Since several distinct operations are involved in the pavement strengthening process, crew sizes will vary.

Traffic Control

The traffic control sections in the above items of work represent a fairly comprehensive overview of requirements. Traffic control for pavement strengthening work should use the same resources sited in the previous sections.

Materials/Layer Thicknesses

Subbase

As indicated above it is common practice to pulverize the existing roadway (often from 18 to 24 ft. in width) and spread the material to a width of from 28 to 32 ft. This operation is often referred to as full depth recycling.

The pulverized material is typically 6 to 8 inches in depth. New or salvaged flexible base material may also be added to increase the subbase layer to a desired depth. Many districts use 2 to 3 percent portland cement to modify this reclaimed material. The relatively small amount of portland cement increases the strength of the pulverized materials when the materials are both wet and dry. The cement contents are sufficiently low to prevent excessive transverse cracks typically associated with portland cement stabilized materials.

Base

A flexible base course material is typically added to the pavement after placement of the subbase layer. Type A, Grade 1 or 2, are common materials used as base course. Some districts report the use of salvaged base, (RAP, LRA, and HM-CL as base layer materials. The use of portland cement with either new flexible base or salvage base has also been reported by some districts.

Typically thicknesses for base course layers range from 6 to 16 inches depending on the subgrade conditions, materials utilized and the expected traffic volumes. A typical base thickness is 8 to 12 inches.

Surface

Two course surface treatments are often used by maintenance crews as part of the surfacing operation. LRA, HM-CL and HMA have also been used as surfacing materials.

When surface treatments are utilized as surfacing materials, High float rapid setting emulsion (HFRS-2) is the common emulsion used in south Texas. Two course surface treatments typically use about 0.42 gal. per sq. yd. of asphalt emulsion in the winter and 0.30 to 0.35 in the summer months. Some districts report the use of Grade 4 chips for both layers of a two course surface treatments while others use a Grade 3 chip as the first layer and a Grade 4 chip as the second layer. Some districts use Grade 4 chips as the first layer and Grade 5 chip as the second layer.
Other asphalt emulsions used in the south Texas districts include cationic rapid setting emulsions with and without polymer (CRS-2 and CRS-2P) with Grade 3 and 4 aggregates. A cationic high

float rapid set emulsions with or without polymer (CHFRS-2 or CHFRS-2P) has also been used as surface treatment binders.

West Texas districts report the use of cationic rapid setting emulsions with and without polymers (CRS-1 and CRS-2P) for various surface treatment and chip seal applications. Asphalt spray rates of 0.45 gal. per sq. yd. to 0.50 for Grade 4 aggregate are utilized. Rapid setting cutback asphalts (RC-250) or medium setting cutback asphalts (MC-250 and MC-800) with Grade 4 aggregates are used by some maintenance sections. The section of this document on "Surface Treatments and Seal Coats" provides more details along with Tables 12a, 12b, 13a, and 13b.

Comments

Pavement strengthening starting at the quarter point is no longer used by some districts. This repair strategy resulted in relatively poor performance and second repair operations to rehabilitate the center of the pavement have been needed on several projects.

The use of relatively thin layers of HMA (less than about 4 inches) placed on flexible bases should be avoided on roadways with high deflections which have been impacted by energy development and production traffic.

Maintenance crews almost always use emulsified asphalt for surface treatments and chip seals. Chip seals performed under contract usually use a hot applied asphalt binder.

MAINTENANCE CONTRACTS/CONSTRUCTION CONTRACTS

Description/Purpose

Contracts are let by both the Maintenance and Construction Divisions to perform work on the TxDOT highway system damaged by oil/gas development and production. Maintenance contracts can be "on-call" to fix shoulder drop-off problems and localized failures (deep patching) or to perform activities associated with pavement strengthening. Construction contracts are typically used for pavement strengthening operations only.

Pavement strengthening operations are very similar to those discussed above and performed by maintenance crews. Maintenance Division and Construction Division Contracts typically involve widening and strengthening with the addition of new base materials and the placement of surfacing materials ranging from two course surface treatments to hot mix asphalt (Table 14, 15a, and 15b).

Table 14. Maintenance Contracts-South Texas.

District	Surface Layer		Base Layer		Subbase Layer		Comments
	Material	Thickness, in	Material	Thickness, in	Material	Thickness, in	
Corpus Christi (16)	2-ST with AC-5 or AC-10, AC-15P, RC-250 with chip on top of base		FDR-CTB with 6 % pcc	8	Original base		Section failed within 1 year
Laredo (22)							
San Antonio (15)	HMA-Type D	1.5	FDR-CM	8			1-ST on inverted prime on FDR-CM (SH 85)
	2-ST		Flexible Base	8-two lifts	FDR-CM	6	RC-250 prime with Gr. 5 chip (FM 99)
	2-ST		Type A, Gr. 2	6	GG + FDR-CM	6	MS-2 prime coat on base (FM 624)
	2-ST, CHFRS-2P or CRS-2P with Gr. 3 chip on RC 250 with Gr. 5		FDR-CM	6-12			Spot base repair, minimum of 12 ft by 50 ft
Yoakum (13)	2-ST with AC-15P/AC 20-5TR with Grade 3 and 4, prime RC-250 with Grade 5						On call contracts, shoulder drop-off, quarter point repair, full width repair
	2-ST with AC-15P/AC 20-5TR with Grade 3 and 4, prime RC-250 with Grade 5		FB, Grade 1,2 or 5	6	FDR-CM	6	

Table 15a. Construction Contracts-South Texas.

District	Surface Layer		Base Layer		Subbase Layer		Comments
	Material	Thickness, in	Material	Thickness, in	Material	Thickness, in	
Corpus Christi (16)							
Laredo (22)	HMA-Type C	2 to 3	FDR-CTB	12-14			Premature failure, overlayed with 5 inches of HMA
Laredo (22)	2-ST with RC-250 (0.20 gal/yd. sq.) with Gr 5 chip and AC-10-2TR (0.35 gal/sq. yd.) with Gr. 3 chip		FDR-CM with new flex. base	4	FDR with no stabilizer	9	Premature failure, overlayed with HMA
Laredo (22)	HMA-Type C overlay and widen 6 ft with 6 inches of HMA-Type C	2 to 6	Existing base and surface				Widen 20-ft roadway to 32 ft
San Antonio (15)	HMA-Type D	1.5	FDR-CM	8	existing	24	Poor performance, traffic early in life
San Antonio (15)	HMA-Type D	2.0	FDR-replace 4 in. of base + EM	8	existing		
San Antonio (15)	HMA-Type D	3.0 (two 1.5-inch lifts) + 1-ST (RC-250 with Gr. 5 chip)	FDR-CM	6	Cement treat subgrade	6	FM 140
San Antonio (15)	HMA-Type D	3.5 (two lifts 2.0 + 1.5 with PG 70-22) + 1-ST	FB	6	FDR-CM	6.5	FM 791
San Antonio (15)	2-ST		FB	6	FDR-CM + GG	8	
San Antonio (15)	2-ST		FB	6	FDR-CM	6	Rough ride
San Antonio (15)	2-ST	RC-250 Gr. 5 prime + 2-ST	FB	8 (applied in two lifts)	FDR-CM + GG	6	FM 2924
Yoakum (13)	HMA overlays, Type D, PG 70-22/PG 76-22	2.0 min	FB, Grade 2	6	FDR-CM	12	

Table 15b. Construction Contracts-West Texas.

District	Surface Layer		Base Layer		Subbase Layer		Comments
	Material	Thickness, in	Material	Thickness, in	Material	Thickness, in	
Amarillo (4)	HMA Type C	3	Spot patches, 6-inch HMA in shoulder widening area, Type B/D				Add 2 ft shoulders, spot patches, HMA
Childress (25)	HMA Type D	3	FB		Pulverize existing base, add 3% cement		Widen to 28 ft
	HMA Type D	2	HMA Type B	3-ft widened section	Widened area 8 in. with 3% cement		HMA allows for faster construction
Lubbock (5)	AC 20-5TR with Gr. 4 and Gr. 5	2-ST	FDR-CM with 2.25% cement, new base	8-9 of CM salvaged and new base			Widen to 28 ft
	AC 20-5TR	2-ST	FB				Widen to 26 ft
Odessa (6)	HMA	6					Go big or go home
	AC 20-5TR	3-ST 1st-0.50 to 0.60 gal/sq. yd. with Gr 2, 2nd-0.45 to 0.55 gal/sq. yd. with Gr. 3 3rd-0.40 to 0.50 gal/sq. yd. with Gr 4	FB Type 2	12-14	Pulverize existing roadway		Don't use cement as stabilizer
	HMA	4					New construction
	HMA	2-3					Mill and fill intersections
	AC 20-5TR	3-ST (see above)	Remove all old HMA, add FB and rework	6 FB added, total of 18 inches with old in place base			

San Angelo (7)	2-ST, AC 20-5TR, asphalt rubber-wet process (0.5 to 0.6 gal/sq. yd. with Grade 3 chip on shoulder and Gr. 4 entire roadway, scrub seal with polymer modified emulsion, CRS-2TR with Gr 4 , MS-2 construction prime		FB Type 2	6	Pulverize existing materials	4	28 to 32-ft width, 6-in. shoulder removal

The most common type of operation involves the pulverization of the existing pavement structure and spreading the material to widen the pavement. Portland cement modification (2 to 3 percent) is commonly used to stabilize the pulverized material (Full-depth recycling with cement modification). Flexible base material is added on top of the pulverized materials and either a two course surface treatment or hot mix asphalt is used as the surface course. The thicknesses of the layers and the types of materials vary from district to district.

The purpose of these types of pavement strengthening operations is to provide additional load carrying capacity both in terms of number and weights of loads. Pavement widening operations not only improve the load carrying ability of the pavement but also improve safety.

Materials

Subbase

As indicated above it is common practice to pulverize the existing roadway and spread the material to a width of from 28 to 32 ft. Additional flexible base may be added to this pulverized material to increase the thickness of the layer. This operation is often referred to as Full Depth Recycling. Thicknesses of this subbase layer typically range from 6 to 8 inches with some as deep as 12 inches.

One district reported the stabilization of the subgrade with lime as part of the pavement strengthening process.

Many districts use 2 to 3 percent portland cement to modify this reclaimed material. The relatively small amount of portland cement increases the strength of the pulverized materials when the materials are both wet and dry. The portland cement contents are sufficiently low to prevent excessive transverse cracks typically associated with portland cement stabilized materials, but high enough to prevent premature degradation. Combinations of portland cement and fly ash from electrical generating plants has been used on a limited basis in the panhandle of Texas.

Geogrids have been used by a few districts to improve the load carrying capability of a pavement. These types of products are typically placed on top of the subgrade or subbase layer and prior to the placement of the base course. They have been used for several shoulder widening projects as well as full width repairs.

Base

A flexible base course material is typically added to the pavement after placement of the subbase layer. Type A, Grade 1 or 2, are common materials used. Portland cement with new flexible base has been used as a base course material on several projects as well. Some districts utilize 6 percent portland cement and others use 2 to 3 percent portland cement (cement modified).

Typically thicknesses utilized for base course layers range from 6 to 14 inches depending on the material utilized and the expected traffic volumes. A typical base thickness is 6 to 8 inches.

Surface

Two course surface treatments and hot mix asphalt are typically used as surfaces on these contracts. Both hot applied and emulsified asphalt binders are used for construction of the surface treatments. Hot applied asphalt binders without polymers or with polymers and tire rubber are typically selected for use. Hot applied materials such as AC-5, AC-10, AC-15P, AC-5-TR, AC-10-2TR, and AC-20-5TR and Grades 3, 4, and 5 chips are commonly used materials. Emulsions that have been used under contract include cationic high float rapid setting emulsion with polymer (CHFRS-2P) and cationic rapid setting emulsion with polymer (CRS-2P). A few districts have used wet processed or reacted asphalt rubber binder.

One district reported the use of a three course surface treatment. The binder utilized was an asphalt cement with tire rubber (AC 20-5TR) at 0.50 to 0.60 gal. per sq. yd. rate for the first layer along with a Grade 2 chip. The second layer had a shot at a rate of 0.45 to 0.55 gal per sq. yd. with a Grade 3 chip. The final layer was shot at 0.40 to 0.50 gal. per sq. yd. with a Grade 4 chip.

Hot mix asphalt is also commonly used as a surface material on these contract projects. Performance graded asphalt binders (PG 70-22 and PG 76-22) are typically used in the hot mix asphalt. Type C and Type D hot mix asphalt are common in these types of contracts. Thicknesses of hot mix asphalt layers are within the range of 1.5 to 6 inches. Typical thicknesses are 2 to 3 inches.

Prime coats on flexible bases constructed with rapid curing cutback asphalt (RC-250) and a Grade 5 chip (inverted prime) have been used in several districts. Other districts report the use of a medium curing asphalt (MC-30) with success. Relatively poor performance has been reported by two districts when emulsions have been used as binders for inverted primes. These inverted primes have been used under both surface treatment and hot mix asphalt surface courses.

Comments

If subgrades are very poor and they have not been previously stabilized, subgrade stabilization with lime should be considered. This will require considerable construction time as the existing, pulverized pavement must be removed and the subgrade stabilized.

Water can be trapped in a flexible base when placed between an impermeable surface (hot mix asphalt or surface treatment) and a reasonably impermeable subbase layer portland cement modified full depth recycled material (FDR-CM). This trapped water will greatly reduce the load carrying capacity of the flexible base material. It is important that the base course be allowed to drain as a minimum and that maintenance should be performed on the roadway surface to insure that rain or melted snow water does not enter the surface of the pavement.

When portland cement stabilizers are used in base courses under heavy oil/gas development and production traffic, precaution in pavement thickness designs should be taken. Adequate pavement thicknesses should be placed on top of portland cement stabilized layers to insure that they will not crack due to traffic loads. This thickness is typically greater than 4 inches of HMA. One district has reported poor performance when two course surface treatments are placed directly on cement stabilized or modified flexible base course materials. The poor performance resulted from the relatively high stresses created by loaded trucks and the relatively low strength of the cement modified/stabilized base course material.

Surface treatment performance various with individual roadways. Some districts prefer the use of Grade 3 rocks over Grade 4 rocks. One district reported poor performance with asphalt cement containing tire rubber (AC 5-2TR) in west Texas.

Thin hot mix asphalt layers should not be placed on flexible base materials under heavy traffic conditions. Thicknesses greater than 4 inches are typically required for heavier traffic volumes and weights on pavements that have high deflections due to the low quality of subgrade and base course materials and/or thicknesses of pavement layers. Thin layers of HMA placed in west Texas have performed better than thin layers of hot mix asphalt in south Texas.

When surface treatments are utilized as pavement surfaces, ride quality can be a problem. The quality of the ride with surface treatments is largely a function of the ride quality of the material below. Base smoothness specifications should be considered for projects to help provide good ride quality when surface treatments are utilized.

SUMMARY/LESSONS LEARNED

This section of the report attempts to summarize the information presented above with emphasis on lessons learned from district experiences. Note that one district's experience may differ from another's experience when the same materials are used on similar pavement structural sections. The reasons for these differences are not always readily apparent but may be dependent on the following:

1. Amount of traffic.
2. Subgrade and pavement layer support.
3. Structural section adequacy including quality and thicknesses of materials.
4. Environmental conditions.
5. Quality of construction related to crews' familiarity with materials and processes. Key points evident from the visits with district staffs and workshops are provided below:

Width of Pavement

1. Pavement width should be the first consideration when developing maintenance and
1. repair strategies.
2. Pavement widths should be selected based on traffic volumes, safety considerations, right of way widths, drainage structure (bridges/culverts) widths as well funding and crew availability.
3. Desirable pavement widths are 32 ft (two 12-ft lanes and two 4-ft shoulders).
4. The majority of the repair strategies use pavement widths of 28 ft. (two 12-ft lanes and two 2-ft shoulders).
5. Pavement widths of 24 ft often result in performance problems.
6. Narrow pavements cause more performance problems in south Texas as compared to west Texas due to soil and environmental conditions.

Routine Maintenance Operations

1. Routine costs on FM roadways impacted by oil/gas development and production will
1. increase from typical values of $500 to $1,500 per centerline mile to $35,000 to $45,000 per centerline mile.
2. A wide variety of shallow, deep and level-up patching materials have been used by the districts. Hot mix cold laid (HM-CL), limestone rock asphalt, commercial proprietary materials, reclaimed asphalt pavement with and without the addition of asphalt binder and hot mix asphalt have all been used to some extent. The use of RAP without the addition of asphalt binder is not recommended by several districts.
3. Shoulder strip seals (both fog and chip) are used in some west Texas districts with success. This type of treatment should be considered for use in south Texas districts as a temporary maintenance operation.

Pavement Strengthening Operations

1. Pavement strengthening operations are performed by maintenance crews and by contract with both maintenance and construction funding categories.

2. Pavement widening is a critical part of the strengthening operations, as well as advancing the safety of the system. A minimum of 2 to 4 ft shoulders should be used on pavements with 12-ft lanes (28 to 32-ft paved surface widths).
3. Shoulder widening is performed with a variety of equipment to remove the material near the edge of the travel lanes. The operation may include blading with a maintainer, using special cutting tools attached to maintainers and milling machines that are either self-propelled or attached to maintainers. Shoulder excavation depths should be at least 8 to 12 inches. Materials placed in the excavated shoulder area include new flexible base, salvaged flexible base, salvaged base, cement modified flexible and salvaged base, hot mix cold laid, limestone rock asphalt, commercial proprietary materials, reclaimed asphalt pavement with and without the addition of asphalt binder and hot mix asphalt. A surface treatment or chip seal is often placed on these materials as a surfacing material.
4. Pavement quarter point and shoulder widening operations are used by some districts. Most districts no longer use this method and instead use full pavement width repair methods which result in improved performance.
5. A typical pavement strengthening operation includes the following:
   a. Pulverization and widening of existing pavement materials by self-powered, pulverizers/stabilizers.
   b. Using portland cement at a level of about 2 to 3 percent to modify the recycled material.
   c. Adding flexible base materials at a depth of 8 to 12 inches.
   d. Placing a two course surface treatment or hot mix asphalt for the riding surface.
6. Some south Texas districts have noted that the use of portland cement stabilized or portland cement modified bases under two course surface treatments or thin HMA layers result in poor performance. A mix design to determine the quantity of cement can help districts prevent poor performance.
7. Two course surface treatments are typically constructed with emulsified asphalt binders when TxDOT maintenance crews are involved in the operation and hot applied asphalt binders are used when contractors are hired for placement operations.
8. Typical chips used with two course surface treatments include the following for the two layers: Grade 4 on the bottom layer and Grade 5 on the top layer or Grade 3 on the bottom layer and Grade 4 on the top layer. Some districts use Grade 4 chips on both layers.
9. Ride quality (smoothness) can be a problem when surface treatments are placed on flexible base courses.
10. Performance problems during the summer months have been experienced with the use of HM-CL, materials as a surface course
11. The use of cutback materials as binders for surface treatments and chip seals has shown some performance problems.
12. Districts have placed projects utilizing asphalt-rubber as a binder for surface treatments and chip seals. Other innovations include the use of “scrub seals” and fly ash and foamed asphalt as stabilizers.

Pavement Structural Section

1. The current TxDOT Flexible Pavement Design System (FPS-21) should be used for the thickness design of pavements.

2. Base course thicknesses should be greater in the south Texas area of the state as compared to the west Texas area. Relatively poor load carrying ability of subgrade soils and possibly base course materials and relatively high rainfall in south Texas are largely responsible for this recommendation.
3. The use of wider pavements (32 feet) and the use of stabilizers (portland cement, fly ash, foam asphalt, emulsified asphalt), and/or materials with greater load carrying ability (reclaimed asphalt pavement, limestone rock asphalt, hot mix cold laid, and hot mix asphalt) are recommended for the south Texas area.
4. Routine maintenance on repaired roadways is critical to keep moisture from entering flexible base course materials. Increases in moisture content will reduce the strength of some flexible base materials. Moisture can be trapped between a relatively impermeable surface course and stabilized subbase materials.
5. The use of relatively thin hot mix asphalt layers as surface materials on pavements with relatively high deflections under load should be avoided. A minimum thickness of 4 inches should be considered.
6. Pavement structural designs should consider the need to construct under traffic. Typically only one side of a roadway can be repaired at any given time. Traffic control on narrow FM roadways is a challenge.

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