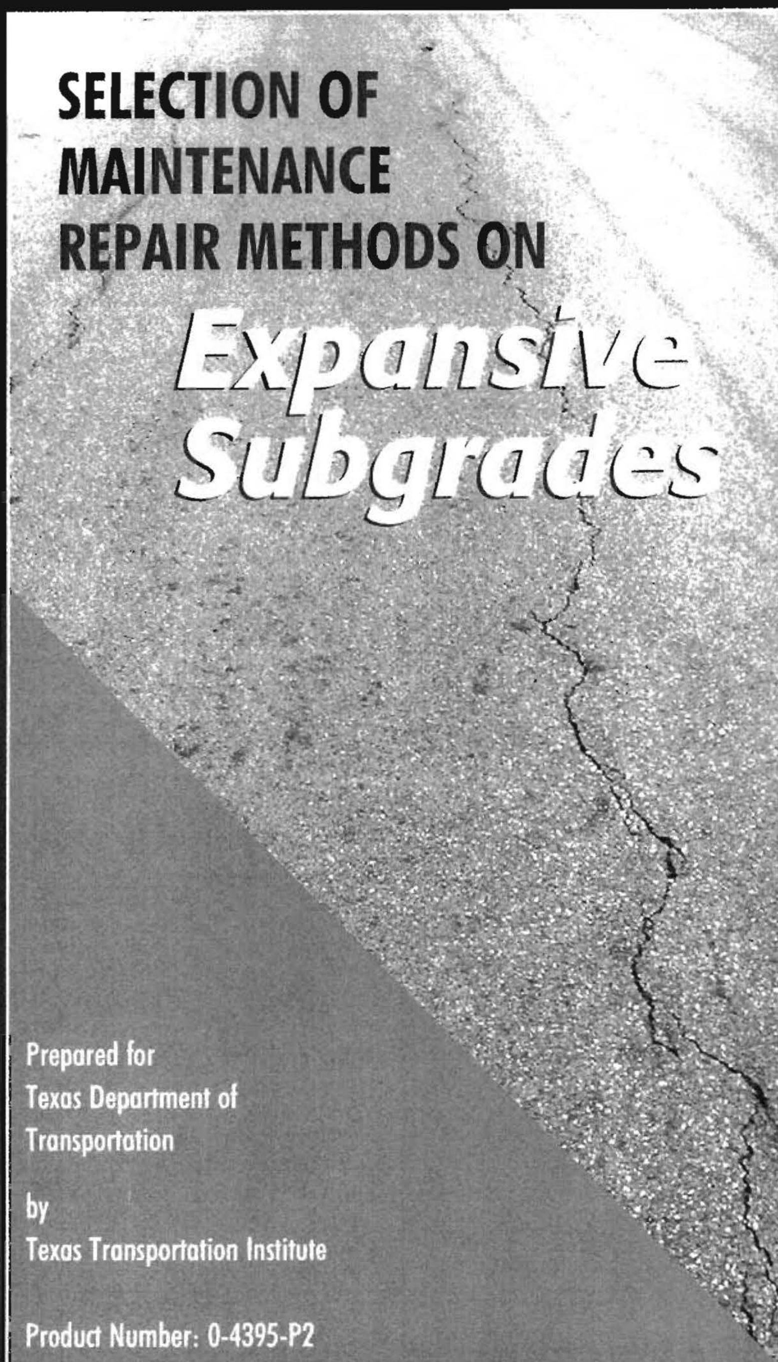

SELECTION OF MAINTENANCE REPAIR METHODS ON *Expansive Subgrades*

Prepared for
Texas Department of Transportation

by
Texas Transportation Institute

Product Number: 0-4395-P2

March 2004

Preface

This manual is designed to assist TxDOT Maintenance Section Supervisors in the selection of an appropriate maintenance treatment for pavement distresses over expansive subgrade soils. In expansive soil environments, distresses such as roughness, longitudinal cracking, and fatigue cracking may frequently be encountered; therefore, this manual will focus on these distresses. A section on rutting also is included. This manual was compiled based upon the responses of a multi-district survey within TxDOT, interviews with district personnel, observations of field performance of various repair methods, and review of existing published guidelines and manuals relevant to pavement rehabilitation.

Acknowledgments

This manual was developed as part of Project 0-4395, "Optimum Spot Base/Subgrade Repair Techniques for Moderate to High Traffic Highways Over Highly Expansive Subgrade Soils," funded by the Texas Department of Transportation (TxDOT) in cooperation with the Federal Highway Administration. Many thanks must be extended to John Saldana, P.E., for serving as the project director for this work, and Ken Boehme, P.E., for serving as the program coordinator. In addition, the following people graciously volunteered their time to serve as project advisors:

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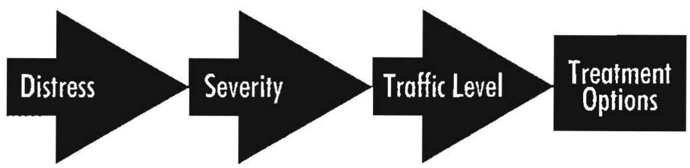
How To Use This Manual

The sections of this manual use the observed primary distress as the starting point for guidance regarding maintenance treatment selection. Thus, if fatigue cracking is the primary distress at the site, the fatigue cracking section of the manual should be referenced. Within each section, a brief definition of the distress is given, along with some possible causes of the distress and simple techniques to investigate the cause of the distress. A decision matrix is then presented to assist personnel in choosing an appropriate repair technique. The following flowchart illustrates the basic steps used in each matrix:



The matrices flow from left to right, where the first row contains prompts relevant to the pavement condition, and the columns contain responses to choose from. A brief discussion on issues specific to the distress wraps up each section. The last section of this manual provides some tips on constructing successful full-depth repairs.

When using this guidebook, keep in mind consideration must be given to factors other than what is the "best" treatment. For example, a temporary treatment may be needed to minimize safety hazards until time and/or funding allows for a more appropriate repair. In some circumstances, such as low-severity or medium-severity cracking on a low-volume road, personnel may elect to not apply any treatment at all until the pavement condition worsens, even though a seal coat or crack seal would eliminate moisture flow into the pavement and slow the rate of deterioration. Thus, care must be taken to use the decision charts only as general guides to assist in decision-making, not cookbook formulas applicable to every situation encountered.

Definitions

Most terms are specific to each distress and are self-explanatory or are explained in each section. However, the traffic level/importance of the road is a factor considered in all sections, and thus an example of each category considered is given here:

Low	A low-volume farm-to-market (FM) road
Medium	A high-volume FM road, a state highway, or a US highway
High	A high-volume US highway or interstate

ROUGHNESS

Roughness is the lack of smoothness in the longitudinal or transverse profile, resulting in poor vehicle ride quality.

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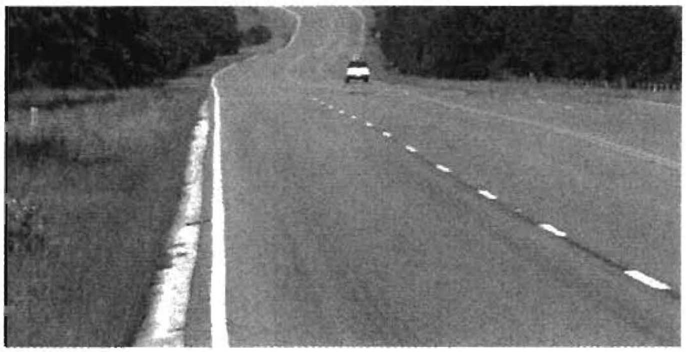

Roughness on Roadway

Likely Causes

Volume changes in underlying layers (such as subgrade), physical distresses (rutting, corrugations, slippage of hot-mix asphalt, failures, etc.)

Investigative Methods

If roughness is present and physical distresses are absent or minimal, a volume change in materials is likely responsible. Sampling and testing the subgrade for plasticity will validate whether the subgrade is the probable cause. Highly plastic clay subgrades (plastic index >35) often cause roughness due to swelling and shrinking. If the subgrade is found to not be highly plastic, poor construction or consolidation of material due to construction (density) problems could be responsible for the observed roughness. If roughness is due to physical distress, refer to the relevant section on the observed physical distress. If excessive roughness is present in sections with lime-treated subgrade soils, testing should be conducted for lime-induced sulfate heave. Simple tests are available from the District Pavement Engineer.

General Maintenance Treatment Options

Blade-on patch to smooth the ride, milling (if sufficient surfacing is present), thin hot-mix asphalt (HMA) overlay, full depth patch.

Decision Matrix

The decision guidelines for roughness assume movement of subsurface material is causing the distress. If the roughness is from physical distresses, the sections on that distress should be referenced. (See Table 1.)

Additional Information

Roughness due to environmental factors, such as subgrade shrinkage and swelling, will generally reappear unless action is taken to minimize volume changes in the soil. For example, lime treatment of highly plastic subgrade, vertical moisture barriers, or sealing of shoulders can reduce the risk of a reoccurrence of roughness. Action may be necessary to improve drainage conditions, such as installation of French drains. In some cases isolated roughness could be the result of heaving of the subgrade soil. This heaving can occur when lime or cement treatment is applied to sulfate rich material. Such heaves typically occur shortly after construction, but in some cases heaving may occur after a heavy rain several years after construction. Personnel should contact their District Pavement Engineer if sulfate-related heave is suspected. Prior to any lime stabilization, the material should be tested for sulfates and organic matter.

Table 1: **Roughness**

Caused by Physical Distress	Severity	Traffic Level	Treatment Options
Yes			see section on physical distress present
No	Low (wavy but no driver discomfort and no hazard present)	Low	do nothing and monitor
		Medium	do nothing and monitor
		High	do nothing and monitor
	Medium (some driver discomfort when driving speed limit)	Low	blade on patch
		Medium	blade on patch; mill to profile; HMA level-up
		High	mill to profile; HMA level-up; full-depth reconstruction
	High (driver discomfort and difficult to drive; requires reduced speed)	Low	blade on patch or reconstruction
		Medium	reconstruction with subgrade treatment;contact Area or District Pavement Engineer*
		High	reconstruction with subgrade treatment;contact Area or District Pavement Engineer*

*Perform sulfate test and test for organic matter before lime treatment.

LONGITUDINAL CRACKING

Longitudinal cracks are breaks in the pavement surface that generally follow a course approximately parallel to the pavement center-line.

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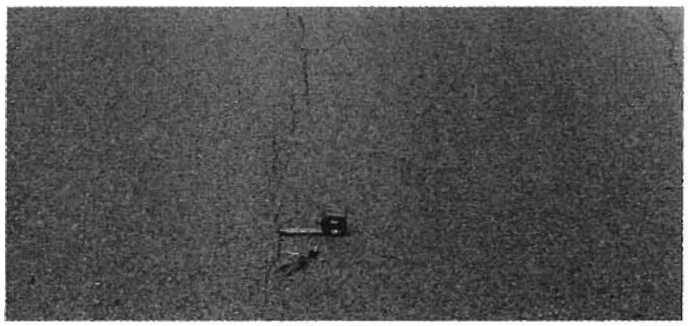


Low-Severity Longitudinal Cracking

Medium-Severity Longitudinal Cracking

High-Severity Longitudinal Cracking

Likely Cause

Longitudinal cracks can be load or non-load related. Load-related cracks are in the wheel paths and are early signs of fatigue cracking. Non-load related cracks typically result from highly plastic subgrade material. These cracks meander and often occur near the pavement edge in expansive soil environments. In some cases a lack of edge support and/or weak and wet subgrades result in faulting of these cracks.

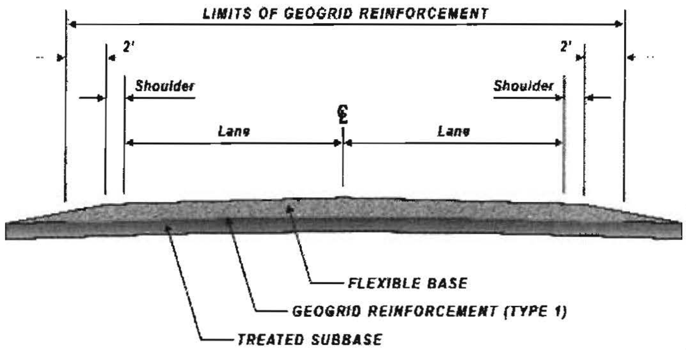
Investigative Method

Observe the location of the cracking. Cracks confined to the wheel paths are likely early stages of fatigue cracking, and thus refer to the section on low-severity fatigue cracking. If the cracking is not confined to the wheel paths, sampling and testing the subgrade for plasticity will validate whether the subgrade is a probable cause. Longitudinal cracks often result from edge drying during drought conditions in highly plastic (plastic index > 35) soils. Steep side slopes and shrubs and trees near the pavement edge can also aggravate problems with longitudinal cracks.

General Maintenance Treatment Options

Crack seal, crack fill and seal, blade-on patch (when faulting is present), seal coat or overlay, reconstruct or recycle utilizing geogrid reinforcement. The geogrid reinforcement method (see figure on next page) utilizes a synthetic grid placed between a layer of stabilized base and a thin layer of flexible base. A thin surfacing placed on top of the flex base seals the pavement. The geogrid has shown promising results for effectively stopping dry land cracks from reflecting through the pavement surface.

Geogrid Reinforcement for Reducing Longitudinal Cracking through the Pavement Surface



Schematic courtesy of Darlene Goehl, P.E.

Decision Matrix

The matrix for longitudinal cracking automatically puts faulted cracks into the high-severity category to be consistent with the TxDOT Pavement Management Information System (PMIS) severity definition. However, some faulted locations will be more distressed than others; thus the listed surface treatments for faulted cracks should only be considered for less severe faulted cracks (elevation drops of 0.5 inch or less). (See Table 2.)

Additional Information

In general, field observations reveal that crack filling and sealing has proved as effective as full-depth patching utilizing conventional methods. The life of treatments where cracks are filled and sealed is typically around two years. Investigations have shown that longitudinal cracks generally reoccur within a short time frame (6 months to 2 years) after conventional full-depth repairs. Likewise, cracks typically reoccur through surface treatments within a short time frame, although thin HMA overlays generally give better performance as compared to blade-on patches or seal coats. The short life of the full-depth repairs and surface treatments occurs because such repairs do not address

Additional Information Continued

key factors such as the subgrade and edge support. If a full-depth repair is performed, methods currently being used in the Bryan District utilizing geogrid reinforcement to prevent cracking from reflecting through the surface should be used. For more severe cases of distress, drainage improvements may need to be made, such as the installation of French drains. Extending the width of the roadway, raising up steep side slopes, and sealing shoulders should also help minimize the risk of reoccurrence of longitudinal and edge cracks.

Table 2: **Longitudinal Cracking**

Load Related	Faulted	Severity	Traffic Level	Treatment Options
Yes				See Fatigue Cracking Section
No	Yes	High	Low	crack fill/seal with blade level-up; reconstruct/recycle with geosynthetic reinforcement
			Medium	crack fill/seal with blade level-up; reconstruct/recycle with geosynthetic reinforcement
			High	crack fill/seal with HMA level-up and contact Area or District Pavement Engineer
	No	Low (mostly tight; difficult to see except after rain or on careful inspection)	Low	do nothing and monitor
			Medium	crack seal; seal coat
			High	crack seal; thin HMA overlay
		Medium (Open, < 1/2" opening; if edge cracking some disintegration occurring)	Low	crack fill/seal; reconstruct/recycle with geosynthetic reinforcement; if edge cracking reconstruct edge
			Medium	crack fill/seal; reconstruct/recycle with geosynthetic reinforcement; if edge cracking reconstruct edge
			High	crack fill/seal; reconstruct/recycle with geosynthetic reinforcement; if edge cracking reconstruct edge
		High (> 1/2" opening; if edge cracking considerable breakup occurring)	Low	crack fill/seal; reconstruct/recycle with geosynthetic reinforcement; if edge cracking reconstruct edge
			Medium	crack fill/seal; reconstruct/recycle with geosynthetic reinforcement; if edge cracking reconstruct edge; contact Area or District Pavement Engineer
			High	crack fill/seal; if edge cracking reconstruct edge; contact Area or District Pavement Engineer

FATIGUE CRACKING

Fatigue cracking ("Alligator Cracking") is a series of interconnected cracks caused by failure under repeated traffic loading.

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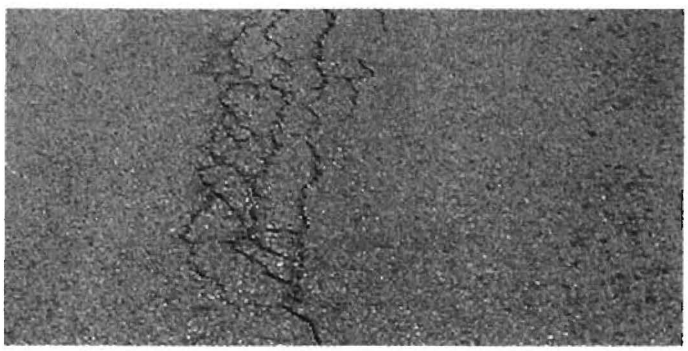
FATIGUE CRACKING

Definition Fatigue cracking ("alligator cracking") is a series of interconnected cracks caused by failure under repeated traffic loading.

Low-Severity Fatigue Cracking



Medium-Severity Fatigue Cracking

High-Severity Fatigue Cracking

Likely Cause

Typically fatigue cracking is load related and results from structural problems such as a weak base or subgrade or inadequate surface structure. Occasionally situations are encountered where fatigue cracking is not load related but caused by problems with the HMA surfacing, such as asphalt cement properties, segregation of the HMA, or debonding of layers.

Investigative Method

Fatigue cracking observed along with rutting generally indicates a structural problem. A simple and quick way to investigate if a structural problem exists is with the dynamic cone penetrometer (DCP). The results of a few tests on the distressed wheel paths should be compared with test results from an area of the pavement wheel path that is not distressed. If the rate of penetration is significantly greater in the distressed area, structural problems exist. If test results are the same between distressed and non-distressed locations, the problem is likely in the HMA surfacing and not structural. Fatigue cracking observed without any rutting typically requires further investigation and could be caused by HMA properties, segregation of the HMA, or layer debonding. Distresses caused by segregation of HMA will typically occur at regular intervals along the road and often are accompanied by a noticeable dip when riding the section. Coring can be used to examine the condition of the base and the state of bonding between the surfacing and base. The District Pavement Engineer can be contacted to assist in identifying the problem if extensive cracking is observed but no rutting is present. If in doubt, conduct repairs assuming the problem is structural. Fatigue cracking on roads that are only seal coated should be considered structural.

General Maintenance Treatment Options

A wide assortment of treatments can be used on fatigue cracking, ranging from seal coats to reconstruction, depending on the severity of the distress and whether the cracking is a structural problem. A full-depth repair is needed for fatigue cracking when structural deterioration exists, possibly with an increase of the base thickness.

Decision Matrix

No options are given in the non-structural category for low-volume roads, since these lower importance roadways will typically only have seal coat surfaces and thus fatigue cracking on low-volume roads should be considered structural. (See Table 3.)

Additional Information

The optimal treatment for fatigue cracking distress is partially dependent on what, if any, upcoming rehabilitation work is planned for the road. For example, if reconstruction or full-depth recycling of the pavement is planned for the near future (6 months to 1 year), a seal coat or thin HMA overlay may adequately serve as a temporary fix. However, if an overlay is planned for the near future, a full-depth patch is warranted. If cracking is due to debonding of the HMA surface, the debonded layer should be removed and replaced. Similarly, distress due to segregation of HMA will require replacing the distressed area with new HMA. Structural problems (look for cracking accompanied by rutting) warrant full-depth repairs. If problems are structural but cracking is at the low- to medium-severity level and no rutting is present, a seal coat or thin HMA overlay may hold until rehabilitation is possible, but a full-depth repair is the only way to be confident that the repair will last. Edge breakup may require extending the roadway width.

Table 3: **Fatigue Cracking**

Structural	Severity	Traffic Level	Treatment Options
Yes	Low (early stages; appears similar to longitudinal cracks with very few interconnected cracks)	Low	monitor
		Medium	seal coat or full-depth patch
		High	full-depth patch to solid material
	Medium (a network of cracks with a fair amount of connected cracks)	Low	full-depth patch to solid material
		Medium	full-depth patch to solid material
		High	full-depth patch to solid material
	High (extensive interconnected cracking; popouts or failures likely)	Low	full-depth patch to solid material
		Medium	full-depth patch to solid material
		High	full-depth patch to solid material
No	Low (early stages; appears similar to longitudinal cracks with very few interconnected cracks)	Medium	crack seal and monitor
		High	crack seal and monitor
	Medium (a network of cracks with a fair amount of connected cracks)	Medium	replace surface with new HMA or thin HMA overlay
		High	replace surface with new HMA or thin HMA overlay
	High (extensive interconnected cracking; popouts likely)	Medium	replace surface with new HMA
		High	replace surface with new HMA

RUTTING

Rutting is a longitudinal surface depression in the wheel path. Rutting is load related.

Rutting is a longitudinal surface depression in the wheel path. Rutting is load related.

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Rutting

RUTTING

Definition Rutting is a longitudinal surface depression in the wheel path. Rutting is load related.

Low-Severity Rutting

Medium-Severity Rutting

High-Severity Rutting

Likely Causes Rutting can result from densification of pavement layers. Rutting may be caused by problems with the surfacing and thus limited only to the HMA layer, or rutting may be the result of a structural deficiency.

Investigative Methods Observe if the rutting is progressing rapidly or if rutting is occurring slowly over time. If rutting suddenly appears and progresses rapidly, the road may have become overloaded from a change in traffic makeup (like increased truck traffic), and problems are likely structural. Observe the width of the ruts. In general, wide ruts are indicative of problems from deeper down in the pavement, while narrow ruts generally indicate problems in the upper HMA. If fatigue cracking is evident along with rutting, a structural repair is warranted. Likewise, rutting on roads that are only seal coated can be considered structural.

With the dynamic cone penetrometer, test results from rutted and non-rutted wheel paths can be compared. A significantly higher rate of penetration of the DCP in the rutted areas indicates structural deterioration. Comparison of cores from the rutted wheel path and the lane centerline can be used to investigate if rutting is confined to the HMA surfacing. For example, if a 0.5-inch rut exists and cores reveal an HMA layer thickness of 2.5 inches in the rutted wheel path and a HMA layer thickness of 3.0 inches in the centerline, the rutting is occurring in the surface layer.

General Maintenance Treatment Options Milling (if sufficient surfacing is present), blade level-up, microsurfacing (shallower ruts), remove and replace rutted surfacing, structural overlay, full-depth patch, full-depth recycling.

Decision Matrix

In general the decision tree for rutting gives treatment options assuming a treatment is going to be applied. However, often times when rutting is minor (< 0.5 inch) no treatments will be applied until the rutting worsens. Since rutting in seal coated roads will be considered structural, no treatments for low-volume roads are listed in the non-structural category. (See Table 4.)

Additional Information

It is necessary to determine what layer is causing the rutting before selecting a repair method. If rutting is confined to the surfacing, only a surface treatment is necessary. Any planned rehabilitation activities may also influence the chosen treatment. For example, if rehabilitation activities are already planned, using surface treatments to maintain a reasonable level of safety may be used until the rehabilitation work is performed. In cases of a structural deficiency, additional base depth may be needed.

Table 4: **Rutting**

Structural	Severity	Traffic Level	Treatment Options
Yes	Low (< 1/2")	Low	do nothing and monitor
		Medium	microsurfacing and monitor; full-depth repair
		High	microsurfacing and monitor; full-depth repair
	Medium (1/2" – 1")	Low	blade level up and monitor; full-depth recycling/reconstruction
		Medium	full-depth repair
		High	full-depth repair; mill and structural overlay
	High (> 1")	Low	full-depth recycling/reconstruction
		Medium	full-depth repair; mill and structural overlay
		High	full-depth repair; contact Area or District Pavement Engineer
No	Low (< 1/2")	Medium	mill; microsurfacing or blade patch; remove and replace with HMA
		High	mill; microsurfacing; remove and replace with HMA
	Medium (1/2" – 1")	Medium	mill to profile; blade patch or overlay; remove and replace with HMA
		High	mill to profile; overlay; remove and replace with HMA
	High (> 1")	Medium	mill and overlay with HMA; remove and replace with HMA
		High	mill and overlay with HMA; remove and replace with HMA; contact Area or District Pavement Engineer

TIPS FOR REPAIRS

Tips for successful

full-depth repairs.

full-depth repairs.

Tips for successful

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Tips for Repairs

Tips for Successful Full-Depth Repairs

Listed below are some tips for constructing base repairs, sorted according to the sequence of the construction process.

Replacement Material

Options for the base are to recycle the existing base or replace the base with either a granular material or blackbase. When recycling existing material or using a new granular base, treatment with cement is often used to achieve a strong material in a short time frame. Some considerations for selecting a base are:

- Existing base can often be treated and recycled. If the material is not contaminated with clays, this option may be quite attractive.
- On thin surfaced roads, the existing surfacing can usually be mixed into the existing base as part of the reconstruction process. However, the amount of old surfacing in the recycled mixture should be kept below 50 percent.
- If possible, have the laboratory determine the Texas Triaxial Class of available new aggregate materials to see how materials from various suppliers compare. Materials with a lower triaxial class number are better.
- When using cement, 2 to 3 percent of Type 1 cement is usually adequate, especially with limestone bases of reasonable quality. Too much cement typically results in block cracks that reflect through the surface and allow water into the pavement. If possible, utilize the laboratory to test the performance of candidate replacement materials at two or three levels of stabilization.
- Despite its ease of use, blackbase is more expensive and may not perform as well as a

Replacement Material Continued

treated granular base. Blackbase is most appropriate for use when a full-depth repair is needed but weather conditions are unfavorable for placement of treated granular materials.

Excavation

- If the old base will be recycled, avoid contaminating the base with clay from the subgrade during the excavation process.
- Excavate at least one foot beyond the distressed area to ensure all problematic material is removed.
- Make excavations rectangular with two edges perpendicular to the direction of traffic flow.
- Two sides of the excavation should be close to vertical to aid in compaction.

After the Excavation

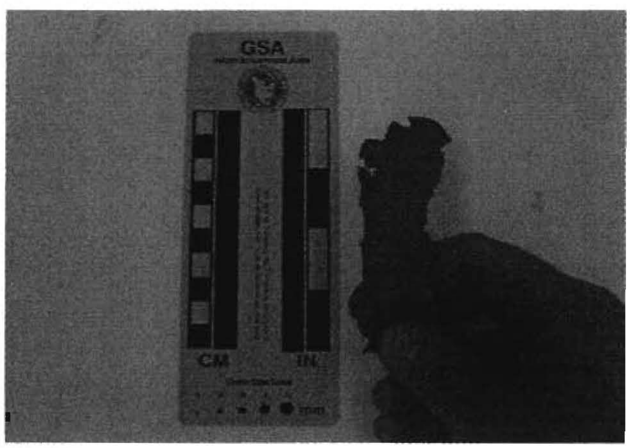
Check the condition of the subgrade. A very wet/weak subgrade may need treatment with lime and/or improvements to drainage. Another option would be to excavate deeper and search for a more stable material deeper down. If treating subgrade, it is necessary to determine if the material is suitable for treatment, the treatment must be selected, and the level of treatment must be chosen.

Determining the Suitability of Subgrade Soil for Chemical Treatment

- Most frequently cement or lime will be used for subgrade treatment.
- For lime treatment, the soil must be somewhat plastic or "clayey" for the lime to react. Test in the field by taking wet soil and squeezing it into a ribbon between the thumb and pointer finger, as shown in the photo on page 35. If the wet soil will not

form any ribbon, the soil is likely not suitable for treatment with lime. If any laboratory test data are available, the plastic index of the soil should be greater than 10 to treat the soil with lime.

- The soil should have a soluble sulfate content below 3000 parts per million. Sometimes sulfates can be visually identified in soils in the form of gypsum crystals, which typically are shiny, glass-like crystals as shown in the top photo on page 36. These crystals can vary greatly in size, as evidenced by contrasting the crystals shown in the top photo to the crystals shown in the bottom photo.
- The organics content of the soil should be below 1.0 percent.
- The District Pavement Engineer can provide assistance with estimating organic and sulfate contents.



"Ribboning" of Soil Illustrating High Plasticity

Gypsum Crystals in Soil

Large Gypsum Crystals

After the Excavation Continued

Considerations in Selecting a Subgrade Treatment

- For highly plastic soils that are suitable for treatment, lime typically reacts better with the soil; however, the lime reaction is slower than the cement reaction and thus maintenance forces oftentimes use cement even in plastic soils.

- Although soils with sulfate contents above 3000 parts per million can be treated with lime or cement, unique construction procedures are necessary which require allowing the soil to "mellow" for one day or longer prior to final compaction. Such practices are not suitable for maintenance activities because of the time requirements.

Selecting a Treatment Level

- Test Method Tex-121-E provides a graph for determining the lime content to use in soils. This graph is based upon the percent binder in the soil and the plastic index of the soil.

- In the absence of laboratory test data, 6 percent hydrated lime by dry weight is a typical treatment level for clay soils. This treatment level is also a typical "optimal" lime content for plastic soils as determined with test method ASTM D 6276, "Standard Test Method for using pH to Estimate the Soil-Lime Proportion Requirement for Soil Stabilization."

- Treatment levels used with cement in highly plastic soils are typically comparable to treatment levels with lime (3 to 6 percent).

Placing the Base

- Mix in thoroughly any treatments (cement or lime) applied to the base.
- Wet the base to as close to optimal moisture content for compaction as possible. If available, use laboratory-determined moisture-density data. When near optimal moisture content, granular bases typically will hold together when squeezed into a ball with the fist, but will bust apart when dropped onto a firm surface from a few feet.
- When the repair size is sufficiently large, place aggregate base material in lifts of no more than 6 inches. Alternatively, if placing the base in one thick lift, check specifications of the rollers to make sure compaction equipment can sufficiently compact the deep layer.
- Compact the base with several passes of a steel wheel or pneumatic roller to obtain adequate density.
- When using blackbases, apply a tack coat to the vertical faces and place the material in lifts that when compacted are approximately 1.5 inches thick.

Sealing the Surface

Always seal the surface to keep water out of the pavement. A chip seal or HMA will protect the base from moisture damage. Seal blackbases to minimize the risk of moisture damage (stripping).

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