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16. Abstract

Traditional Texas flexible bases specified under Item 247 perform well as long as they are kept dry. However, rapid and sudden failures can occur if water enters these bases. In Project 0-4358 draft specifications (proposed Item 245) were developed for high-performance flexible base materials. These specifications tighten all existing specifications, place an upper limit of 10 percent on the amount of material passing the No. 200 sieve, and introduce new procedures to ensure that the base is not moisture susceptible.

In project 5-4358-01 two TxDOT pavements containing bases that met the proposed high-performance base specifications were constructed. No handling or segregation problems were encountered. The main concern found by the contractors was the use of nuclear density gauges for measuring density. Alternative methods were investigated. The initial field moduli were measured to be 60 ksi. The long-term benefits of these low-fines bases could not be demonstrated in this short project, since all the applicable sections are new and performing well.

However performance problems were encountered on a third section constructed on SH 43. In that case the design caused a “bath-tub” effect and water became trapped in the low fines base. Based on this experience a “day-lighting” requirement was placed in the Item 245 specification.

High-performance bases will cost more than traditional bases, and they are not needed in many areas of west Texas where rainfall is low. However, these bases will be economically viable in many areas of northeast Texas, especially with the escalating prices of traditional road building materials.

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CONSTRUCTION DETAILS AND INITIAL PERFORMANCE OF TWO HIGH-PERFORMANCE BASE SECTIONS

by

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DISCLAIMER

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CHAPTER 1
INTRODUCTION

Project 5-4358-01 "Pilot Implementation of High Performance Flexible Base Specifications" was initiated to provide funds to construct and monitor two experimental sections constructed with the high performance base materials recommended in the recently completed Project 0- 4358 "Materials, Specifications and Construction Techniques for High Performance Flexible Bases **"** (Scullion, et al. 2006). High-performance bases are defined as flexible base materials which meet the requirements shown in Table 1.

Table 1. Proposed Material Properties for High-Performance Flexible Bases.

Property	Test Method	High Performance
Master Gradation (% Retained)		
1 3/4 in.	Tex-110-E	0
1 1/2 in.		0-15
7/8 in.		10-35
3/8 in.		35-55
No. 4		50-75
No. 40		70-90
No. 200		88-98
Liquid Limit [1]	Tex-104-E	≤ 25
Plasticity Index [1]	Tex-106-E	≤ 8
Wet Ball Mill, % [2, 3]	Tex-116-E	≤ 30
Max. Increase Passing No. 40, %	Tex-116-E	≤ 12
Deleterious Materials, %	Tex-413-E	≤ 1.5
Confined Compressive Strength (psi)(@15 psi Confining)	Tex-144-E	> 225
Dielectric Value	Tex-144-E	Report
Initial seismic Modulus (ksi)	Tex-149-E	Report

Notes:

1. Use Tex-107-E when the liquid limit is unattainable as defined in Tex-104-E.
2. Test material in accordance with Test Method Tex-411-A when shown on the plans.
3. The wet ball requirements do not apply when lightweight aggregates are specified. Meet the Los Angeles abrasion, pressure slaking, and freeze-thaw requirements of Item 302, "Aggregate for Surface Treatment (Lightweight)" when shown on the plans.

The high-performance base specifications include a tightening of all requirements. In particular, the proposed limits on passing the No. 200 sieve will dictate that these are coarser bases than traditionally used in Texas, where the percentage of material passing the No. 200 sieve is often in excess of 20 percent. These materials are standard specifications in surrounding states such as Arkansas and Oklahoma. One major concern about bases made under the new specifications is constructability. The current Texas bases are easy to construct and provide a smooth "tight" surface for the wearing surface. This is often important in Texas where the final surface may be only a two-course surface treatment. To investigate constructability and performance issues as described in the next section, sections were constructed with the high-performance bases in the Bryan and Tyler Districts.

CHAPTER 2

FIELD PERFORMANCE OF HIGH-PERFORMANE BASE SECTIONS

SH 31 TYLER DISTRICT

In April 2005 the Tyler District constructed a short section on SH 31 using the Granite Mountain flexible base. Granite Mountain base is from Arkansas and is not commonly used by TxDOT although it is used extensively for oilfield gravel road construction in east Texas. The reported advantage is that it performs much better as an unsurfaced gravel road than traditional Texas limestone materials. Granite Mountain material is hauled by train from Arkansas and it is stockpiled in Longview. As shown in Figure 1, a field change was executed on SH 31 and a short section (700 ft) of Granite Mountain base was included in this project. The material properties for the Granite Mountain base are shown in Table 2. The base used in the remainder of the project was a Type A, Grade 2 base supplied by Armor Material from a pit near Terrell, Texas. The triaxial strength on that base were measured to be 42 psi (unconfined) and 194 psi @ 15 psi confining.

Figure 1. Granite Mountain Base Being Placed on SH 31.

Table 2. Laboratory Test Results from Granite Mountain SH 31.

Property	Test Method	Criteria	Granite Mountain
Master Gradation (% Retained)			
1 3/4 in.	Tex-110-E	0	0
1 1/2 in.		0-15	
7/8 in.		10-35	10.7
3/8 in.		35-55	37.4
No. 4		50-75	54.3
No. 40		70-90	81.6
No. 200		88-98	92.1
Liquid Limit [1]	Tex-104-E	≤ 25	
Plasticity Index [1]	Tex-106-E	≤ 8	None Plastic
Wet Ball Mill, % [2, 3]	Tex-116-E	≤ 30	26.6
Max. Increase Passing No. 40, %	Tex-116-E	≤ 12	8.1
Deleterious Materials, %	Tex-413-E	≤ 1.5	0.7
Confined Compressive Strength (psi)(@15 psi Confining)	Tex-144-E	> 225	285
Dielectric Value	Tex-144-E	Report	9.7
Initial seismic Modulus (ksi)	Tex-149-E	Report	--

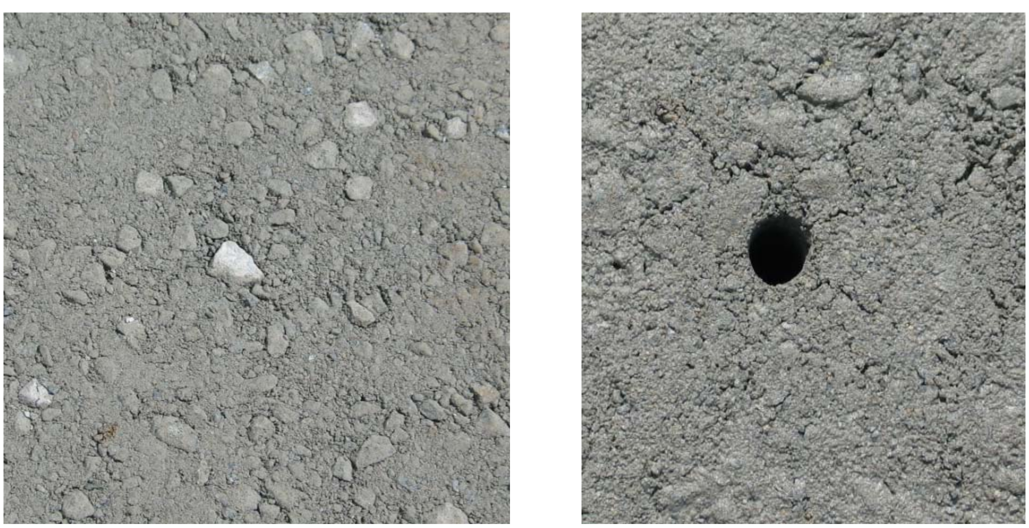
OMC 6.0% Max Dry Density 136.6 pcf

Construction Issues

The section was placed by the local contractor using the sequence shown in Figure 2. The pneumatic compactor and vibratory steel wheel worked in tandem. The first pass was immediately behind the grader. In the early passes the steel wheel was in vibratory mode. The final pass was in non-vibratory mode. The local contractor was very concerned about compacting this base because of his experience working with similar materials using the Federal Aviation Administration (FAA) airfield specification (P-154 base), which calls for less than 3 percent passing the No. 200 sieve. However, on SH 31 no problems were encountered with handling or compaction. The specifications for this job called for 100 percent of laboratory density achieved with Tex-113-E procedure. This density was achieved with three passes of the tandem configuration and one finishing pass with the steel wheel in static mode.

Figure 2. Compaction Sequence on SH 31.

A close-up of the completed base is shown in Figure 3. The surface of the base is tight with a smooth finish. Densities were checked with a standard nuclear device. One comment heard with all of these bases, is that the nuclear test could be problematic with these granular low-fines bases, particularly as they do not retain moisture. When driving the rod for the nuclear gauge cracks appear in the base, and when removing the rod some disturbance (uplift) of the base is sometimes observed. This result was not a problem on the SH 31 base, but it was a large concern with the section constructed on US 287.



a) finished base **b) cracks induced before density test**

Figure 3. Close-Up of Granite Mountain Base on SH 31.

Nondestructive Testing Results

During construction of this section the contractor ran into problems with subgrade stabilization. In one area the subgrade was very weak and wet. For the whole length the depth of subgrade treatment was changed from the designed 10 inch depth to 20 inch depth. The original plans called for 10 inches of lime treatment. Because of the poor support, this was changed to 20 inches; at the south end of the project a select material was added and it was treated with cement. The support layer for this new base is very stiff.

After compaction of the base the section received 2 inches of hot-mix asphalt (HMA) and was opened to traffic. Just prior to opening a set of Falling Weight Deflectometer (FWD) deflection data was collected. The backcalculated moduli values after one week were in the 40 to 50 ksi range. The section eventually received its full asphalt layer of 6 inches and was retested in November 2005 (7 months after construction). The average stiffness of the Granite Mountain base at that time was around 60 ksi. It was noted that the deflections on the experimental section were very uniform. The average deflection was 8 mils with a standard deviation of 1.1 mils. This low variability is attributed to the quality of support in this section. The subbase appears to be very stiff and providing excellent support.

After 2 years in service this section was performing excellently with no defects.

US 287 BRYAN DISTRICT

This section was constructed in the summer of 2005, and it is approximately 2 miles long, stretching from near the intersection with FM 488 to the Trinity River Bridge. The subgrade in the area is very wet; this entire area is next to a large dam and it is largely wetlands. The pavement is built up on select fill embankment. The pavement structure initially called for 8 inches of lime-treated subgrade, 10 inches of Grade 1 limestone base, an underseal and 4 inches of HMA surfacing. However, because of transportation problems the limestone bases (from central Texas) were not available for this project. At the last minute the contractor proposed a change to a Mill Creek granite base from Oklahoma. This new material was supplied at the same cost as the original Grade 1 limestone.

Photographs of the flexible base during and after construction are shown in Figure 4. Figure 4b illustrates some of the non-base-related construction issues with this section. The contractor had problems achieving density in the asphalt layer, and the right lane in this figure was totally replaced very early after construction.

a) underseal prior to HMA placement **b) after placement of HMA**

Figure 4. US 287 High-Performance Base Section.

The district reported that there were several problems with the HMA layer placed on this project. As seen in Figure 4b the right lane was completely milled and replaced.

Materials Used

The materials used in this section are shown in Table 3. This section used high-quality granite with a very low wet ball increase of 4 percent, substantially less than the allowable 20 percent. Subsequent testing at Texas Transportation Institute (TTI) showed the No. 200 fraction of the base to be around 8 percent. The district reported that there were several problems with the HMA layer placed on this project.

Table 3. Standard Test Results for the Mill Creek Base Materials.

Property	Test Method	Criteria	Mill Creek
Master Gradation (% Retained)			
1 3/4 in.	Tex-110-E	0	0
1 1/2 in.		0-15	
7/8 in.		10-35	8.7
3/8 in.		35-55	37.4
No. 4		50-75	55.8
No. 40		70-90	81.9
No. 200		88-98	91.8
Liquid Limit [1]	Tex-104-E	≤ 25	
Plasticity Index [1]	Tex-106-E	≤ 8	None Plastic
Wet Ball Mill, % [2, 3]	Tex-116-E	≤ 30	22.1
Max. Increase Passing No. 40, %	Tex-116-E	≤ 12	4.0
Deleterious Materials, %	Tex-413-E	≤ 1.5	1.0
Confined Compressive Strength (psi)(@15 psi Confining)	Tex-144-E	> 225	244.7
Dielectric Value	Tex-144-E	Report	9.7
Initial seismic Modulus (ksi)	Tex-149-E	Report	--

OMC 4.8%, Max Dry Density 144.5 pcf

The contractor reported major problems achieving the required field density (100 percent, Tex-113-E). He experimented with heavier rollers and different rolling patterns. His claim was that the base was well compacted but that it was difficult to get a true density measurement of this base with the nuclear device, which cracked and disturbed the base when the rod was driven in. Removal of the rod from the base was reported to be difficult, causing slight upheaval in the material. In an attempt to evaluate this claim, testing was performed with the nuclear and sand cone tests and the results are shown in Table 4. The TxDOT Item 247 specification for flexible bases does allow the sand cone to be used for density measurement. These data indicate some validity to the claim. On average the dry density with the sand cone test is 3 lb/cu ft higher than with the nuclear device.

Table 4. Base Densities Measured with Different Techniques.

Station	Nuclear Wet Density (lb/cu.ft)	Nuclear Dry Density (lb/cu.ft)	Nuclear % moisture	Sand Cone Wet Density (lb/cu.ft)	Sand Cone Dry Density (lb/cu Ft)	Sand Cone % Moisture
16+480	154.7	146.3	5.8	158.6	149.9	5.8
16+530	147.9	142.9	3.6	154.5	148.5	4.0
16+570	151.3	145.7	3.9	153.3	146.9	4.3
16+610	153.9	147.3	4.5	156.0	149.5	4.3
19+310	150.9	147.8	2.0	153.7	150.2	2.3

It is interesting to note that all of the density values provided (except the value at 16+530) are well above the laboratory value of 144.5 lb/cu ft. In fact, from the sand cone the average density was 149.0 lb/cu ft or 103 percent of optimum. More work is required in this area to set acceptable limits on field densities for these bases.

Nondestructive Testing of Section

This section was tested with the FWD and Ground Penetrating Radar (GPR) in April 2006. The average moduli value for this base is close to 60 ksi. However, for these data there is one weak area; the deflection under the 9000 lb load at one location is 24 mils (0.024 inches), well above the average for this section (13 mils). The increase appears to be related to a weakening or lack of support in the stabilized layer. The GPR also indicated moisture at the bottom of the base at the high deflection location; this is shown in Figure 5 and labeled as a wet spot. Figure 5 shows about 1000 ft of GPR data from one location next to a bridge. The top of the base is the yellow line at a depth of 4 inches, whereas the top of the lime-treated layer is at a depth of approximately 16 inches. The red areas in the reflection from the top of the lime layer indicate a build up in moisture. From the GPR data there is also some concern about the asphalt layer on this project. The surface dielectric varies, which is an indication of variable surface density, and there is an interface in the middle of the 4 inch mat. This is possibly an indication of moisture build up at the bottom of the top lift of asphalt. The GPR data did not indicate any problem with the Mill Creek base. The dielectric values for the base were all less than 10.

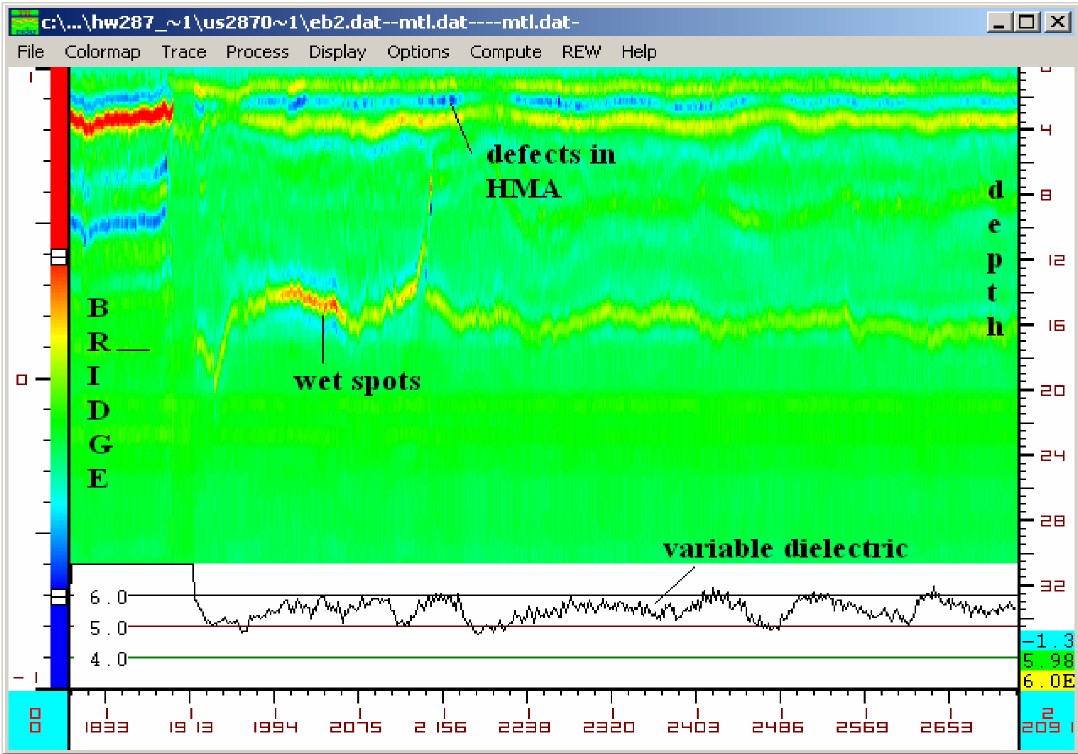


Figure 5. GPR Data from Mill Creek Base Section on US 287, Bryan District.

Summary

Discussions with the contractor indicated that this base was difficult to compact to the level specified by the density requirement. He commented that the raw base was trafficked by over 100 channelized trucks delivering concrete to a bridge construction area with no damage to the base. Meeting the density requirement is perhaps more related to the method of measurement. In control tests the sand cone test gave 3 lb/cu ft higher densities than the nuclear gauge. The GPR and FWD data from the base looked reasonable, but concerns were raised about the quality of the HMA surfacing and the permanency of the lime-stabilized subgrade. The current visual condition is very good. In this short project no long-term monitoring of these sections was performed, and both sections were around 1 year old at the conclusion of the project. As a minimum it is recommended that a visual condition, GPR and FWD survey be completed when the sections reach 3 years old (in the summer of 2008).

SH 43 ATLANTA DISTRICT

In late 2004 a test section of low fines base was included as part of a rehabilitation project on SH 43 in the Atlanta District. The 4 lane section had an existing asphalt surface. All 4 lanes were overlaid with a minimum of 8 inches of granular base. The final surface of the project was a surface treatment. In the north bound lanes the base used was a traditional crushed limestone from the Beckmann Pit in San Antonio. In the Southbound direction a low fines base from the Jones Mill pit in Arkansas was placed.

A surface treatment was placed and the initial performance of both sections was good. However problems were observed when the hot weather arrived in late spring of 2005. In both cases shelling of the surface seal occurred and the top of the flexible base was exposed. Substantial rainfall then occurred and additional stability problems (rutting) were noted in the SB lanes containing the Jones Mill base.

A forensic investigation headed by TxDOT's Construction Division was initiated. TTI helped in this investigation by collecting GPR data and by conducting a mineralogical investigation of the Jones Mill material.

The surface condition and the corresponding GPR data for both sections are shown in Figures 6 and 7. The surface condition in both sections initially looked similar. In the GPR data the depth scale in inches is on the far right of the figure, the solid blue line at a depth of approximately 8 inches is the reflection from the bottom of the existing HMA layer. The most significant feature of the GPR data is the surface dielectric data which is plotted at the bottom of the figure. This data was collected several weeks after any significant rainfall but surprisingly the surface dielectric was higher in the Jones Mill section (average above 8) than in the high fines crushed limestone section (below 6). Because of their superior drainage capabilities it is normally anticipated that the Jones Mill would have a lower more uniform dielectric than the limestone material. In this case it appears moisture is being retained in the Jones Mill material.

In the mineralogical investigation conducted by Harris (2005) samples of the Jones Mill material from an available stockpile and from a failed section of the highway were evaluated using advanced mineralogical techniques including X-Ray Diffraction. Harris evaluated the silt and clay fraction (passing the 325 mesh sieve) of both samples of the Jones Mill base and found them to be different. The sample from the roadway contained substantially more silts and clay. From the fines fraction he calculated that the roadway samples contained 10% more clay than the stockpile sample. Potential causes of the differences could have been attributed to sampling errors, over-burden contamination or addition of fines to the base. The source of the additional clay was not conclusively identified in this study.

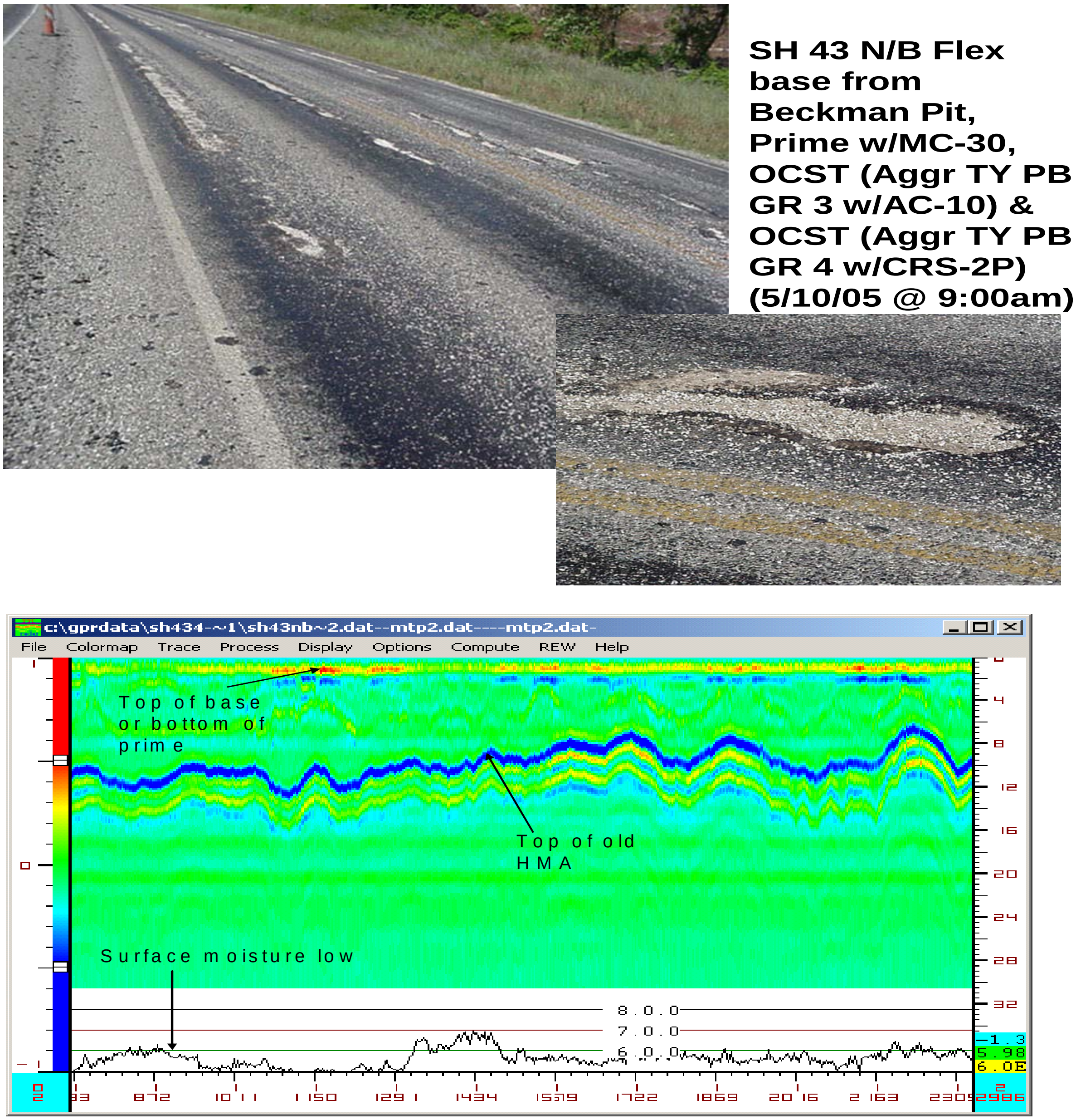


Figure 6. Seal Damage on the SH 43 Limestone Section Together with GPR Data.

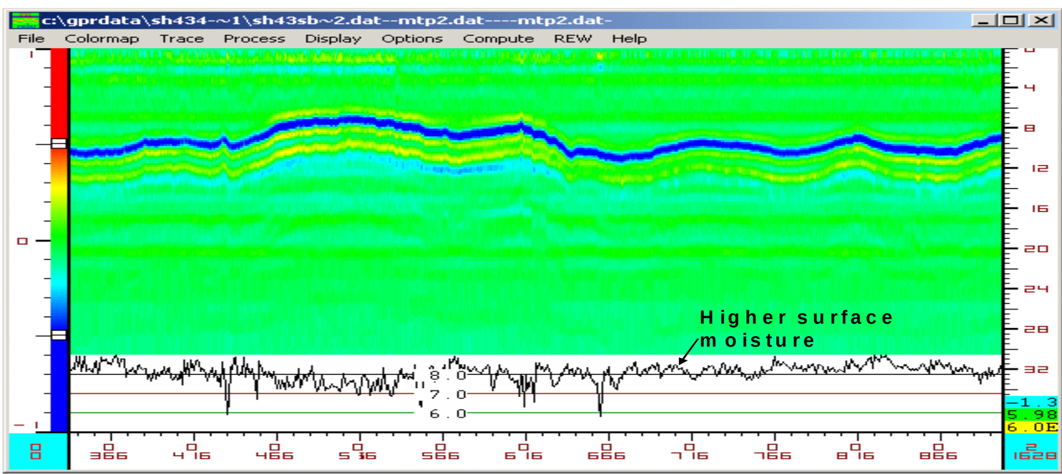


Figure 7. Seal Damage on the SH 43 Jones Mill Base Section and GPR Data.

Full details of the results of the forensic investigation can be found in the TxDOT forensic report. The TTI researcher considered that at least the following factors contributed to the stability problems in the Jones Mill base:

- The initial loss of the surface seal was not base related as it occurred on both bases.
- The cause of the stability problems in the Jones Mill bases was attributed to the bases permeability (as compared to the limestone) and <u>more importantly</u> that the base was placed directly on an existing asphalt surface and the base was not “day-lighted” at the edges. As is normal practice in Texas the existing material was bladed up against edge of the base. The existing shoulder material was clay. This in-fact caused a bath tub effect trapping water, where moisture entering the base through the surface became trapped.
- Typically Texas limestone base particularly with slush rolling which causes the fines to rise to the surface are practically impermeable
- The clay contamination of the Jones Mill base certainly contributed to the eventual failure.

Bases designed according to the Item 245 specification, which was developed as a deliverable of this study, will be more permeable than traditional high fines limestone bases. Therefore it is important ensure that they are “day-lighted” at the edge, hopefully minimizing the risk of a bath tub situation. On SH 43 the Jones Mill base was eventually treated with 3% cement and it is now performing well.

CHAPTER 3
CONCLUSIONS AND RECOMMENDATIONS

Very few construction problems were reported with the handling and placement of the bases on SH 31 and US 287. The main concern was with density measurement systems. In future projects if problems are experienced the contractor should be given the option of replacing the nuclear gauge with the sand cone or alternatively going to a “proof rolling” verification system. This recommendation was included in the draft specifications for these materials (Scullion, et. al, 2006).

The average design moduli for these bases was found to be around 60 ksi. However the true benefit of these bases could not be determined in a short project. The real benefit will be observed later in the section life when moisture has access to the base, typically through cracks in the surface layers. This could not be documented in this project, but laboratory investigations reported in the final report to Project 0-4358 found that these materials performed well in the capillary rise test and had high retained strength on wetting.

Late in Project 0-4358 new base paving materials were introduced to Texas. The base paver shown in Figure 8 was operated by Big Creek Construction Inc. on a new construction project in the Waco District. Placing base using pavers such as these is routine in other states, but has not been done in Texas (Hefer and Scullion, 2002).

Figure 8. Base Paver Operations in the Waco District.

The construction operation consisted of a pugmill for blending and adding moisture to the base (two-person operation), the base paver shown (two-person operation), and one steel wheel vibratory roller (one-person). The contractor commented that the operation was economically viable because of the reduction in labor and equipment over standard operations.

To achieve compaction the base was placed at 2 percent above optimum moisture content. The TxDOT inspector reported that the base was measured to be at 92 percent of required density before rolling. The base was left for about 30 minutes before rolling commenced. No problems were reported in obtaining the 100 percent density required in the current specification. To obtain a desired lift thickness a 1 inch roll down was anticipated, so if the design thickness was 6 inches then 7 inches was placed directly out of the paver. As shown in Figure 9 the completed section looked excellent and offered a smooth ride. Handling and working of the base was minimal; no evidence of any segregation was found with this operation.

Figure 9. Smooth Ride and Excellent Joints in Paver-Placed Base Layer.

All indications are that the base paver operation provides a more uniform base than that obtained by traditional operations. This seems particularly true with the low-fines bases promoted in this project. For that reason the pugmill and paver operation has been included in the draft Item 245 specification.

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