Summary of Recent Activities and Site Locations in TxDOT San Antonio District

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This report summarizes the activities that have been conducted by the team at the University of Texas at Austin on roadway projects located in the TxDOT San Antonio District. A general description of each activity along with sample data generated as the results of that activity is presented first, followed by an overview of the main features of each site and specific activities conducted at each site.

Section 1: Overview of Activities

Condition Survey

Visual condition surveys have been conducted in accordance with the instructions recommended in the TxDOT Pavement Management Information System, Rater's Manual. In particular, the distress data of field test sections were considered in the 10 categories recommended by this manual for flexible pavements. However, much of the distress information would not be relevant to the focus of the research. Therefore, the focus of visual condition surveys conducted in most test sections was on characterization of environmental longitudinal cracks, which have been recognized as the main damage caused by subgrade swell and shrinkage. Figure 1 shows an example of longitudinal cracks observed during condition surveys.

Fig. 1. Example of longitudinal cracks

Table 1 illustrates an example of visual condition survey forms used by members of the evaluation team during the surveys. General information on the test section, including section number, geosynthetic type (if used), section length, and starting and ending station are summarized on top. The severity and extent of each distress type is then detailed in the following rows. The location of each distress has been recorded by its distance from the beginning of the section or experimental area. Picture numbers associated with each distress are documented in the next column. Remarks by road evaluators are included in the last column of the survey form.

Table 1. Example of visual condition survey data collected as part of the monitoring program

Sect #	Actual		Original		Lane	Starting Station	Start Readg (ft)	Ending Station	Ending Readg (ft)	Section Length (feet)
	Name	Layout	Name	Layout						
26	1Eb2	Cont	was 4Eb	GT	K1 -1	176 + 50	4050	181 + 50	4500	450

LOCATION				Pic	@YL	Long. Crack				Other Cracks										Patching and Potholes								Surface		Shoulder Drop off	Patched Shoulder	Rutting (mm)		Comments (Water bleeding-Plished aggregate)
Dist. Readg (ft.)		Length	Starting at Station			wheel		non-wheel		Alligat.	Block		Edge		Shoulder		Transverse			Patching				Potholes(min d >150mm)				Flush	Ravel					
From	To	(feet)		#		<3	(L,M,H)	<3	(L,M,H)	(L,M,H)	(L,M,H)	Width	<3	(L,M,H)	<3	(L,M,H)	<3	(L,M,H)	No.	(L,M,H)	No.	Width	Length	(L,M,H)	No.	Width	Length	Width	Width	Drop hight		W.L.	Y.L.	
4055		---	176 + 55	175-176																														
4055	4187	132	176 + 55	177-78			L																											Might be previous alligator crack
4065	4187	122	176 + 65	79-80										L																				
4200		---	178 + 00	81 End of Big Patch Area																														
		---	--- - ---	82 Facing Back																														
4204	4225	21	178 + 04	83-84																														
4190	4302	112	177 + 90	Aggregate On Shoulder																														
4320		---	179 + 20	Ranch Entrance																														
4382		---	179 + 82	85																														Shoulder Erosion of
4440		---	180 + 40	86-87																L	1	5"	5"											Coring Location
4508		---	End of Sect	88 End																														
		---	--- - ---																															
4050	4086	36	Start of Sect	8	x	x																												
4090	4139	49	176 + 90	9																														
4139	4306	167	177 + 39						L																									
4239	4246	7	178 + 39	10										L																				
4050	4090	40	Start of Sect	7					L																									

Figure 2 presents an example of the analysis conducted for comparative evaluation of performance in geosynthetic-stabilized versus non-stabilized test sections. This example is shown for the percentage of longitudinal cracks in test sections. The horizontal axis of this graph corresponds to the test section numbers, sorted into reinforced versus non-reinforced groups. The vertical axis displays the percentage of longitudinal cracks calculated from condition survey data. The potential benefit of geosynthetics in reducing the percentage of cracks on the road is underscored in this example. While the average percentage of cracking in the geosynthetic-stabilized test sections located in the middle of the experimental area was 8%, other test sections located on the west and east sides had significantly larger percentage of cracks.

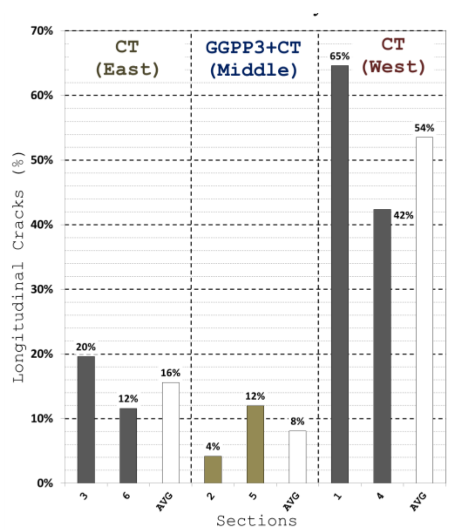

Fig. 2. Example of analysis for comparative evaluation of performance under environmental loads among test sections

Total Station Survey

This section describes the activities involving the procedure to monitor vertical deformation of roads constructed on expansive subgrades and correlate the deformation with road performance. The mechanisms associated with this type of vertical deflection are fundamentally different from those involved in the development of deflections under traffic loads.

Conceptual Model

As illustrated in Figure 3, construction of a relatively impervious pavement structure over expansive soil restrains the access to water for the area located beneath the center of the road. However, the shoulder areas have unrestrained access to water. Consequently, while the shoulder areas can freely swell and shrink with changes in moisture content, the center area experiences little moisture change and thus little swelling and shrinkage. Therefore, the edges of the pavement structure tend to bend downward during dry seasons and upward during wet seasons (Figure 4). Cyclic wet and dry seasons result in a non-uniform uplift loading applied to the pavement structure, and, consequently, a differential movement between the center and edges. This leads to points of high compressive stress in wet seasons and high tensile stress in dry seasons, and subsequently generates longitudinal cracks in the pavement. Consistent with this envisioned mechanism, longitudinal cracks have been reported to occur or widen toward the end of dry seasons. The cracks have also been reported to often partly close during wet seasons. Total station surveys were conducted to monitor changes in the cross-sectional profile of the road surface to evaluate this conceptual model for geosynthetic-stabilized and non-stabilized test sections.

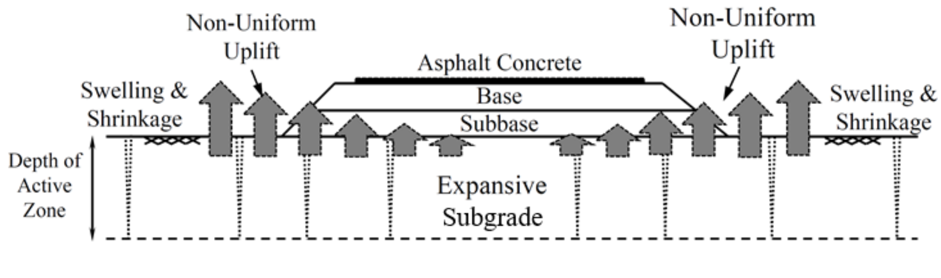

Fig. 3. Non-uniform environmental loading imposed on road structures by expansive subgrades

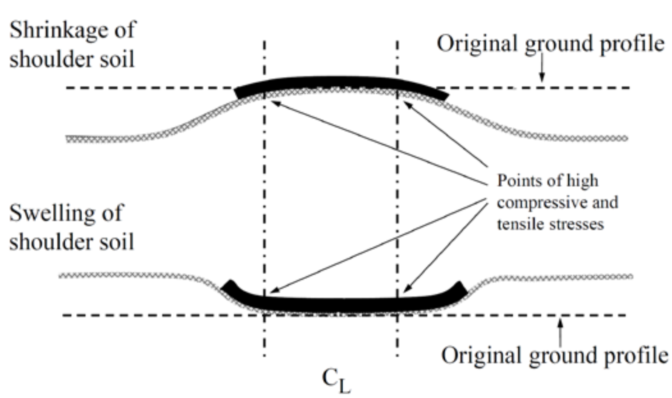

Fig. 4. Conceptual model for generating environmentally induced longitudinal cracks in pavements (Gupta et al. 2008)

Marking Transverse Sections

To monitor vertical deformations of the road, transverse sections were selected from areas found to perform well and areas with poor performance in terms of environmental longitudinal cracks. This facilitated a comparative evaluation of the vertical deformation behavior between well-performing and poorly-performing areas and correlation of the findings with the development of longitudinal cracks.

The pavement surface of the selected transverse sections were carefully marked, as presented in Figure 5. First, a transverse stripe two to three inches wide was marked perpendicular to the central line of the road using duct tape (Figure 5a), after which the stripe was painted with permanent white spray paint (Figure 5b). Next, moving from the centerline toward the edges of the pavement, circular orange marks were painted on top of the white stripe and spaced 1 foot apart (Figure 5c). Displacements of the orange marks were subsequently monitored to evaluate vertical deformation of the road surface over time.

Fig. 5. Marking transverse test sections: (a) marking a stripe with duct tape; (b) painting the stripe with white spray paint; (c) painting circular orange marks on the white stripe

Deformation Monitoring with Total Station

Total station surveying was used to obtain information on the vertical deformations of the marked transverse sections. The instrument model and distance of shooting were selected to provide a minimum accuracy of 2 mm in reading elevations. As pictured in Figure 6, the operation was first carried out using a regular total station in which a prism is held at the target point. The regular total station was then replaced with a non-prism total station that allows shooting at target points without a prism. The second model provided faster and safer operation in the field as well as the same level of accuracy.

Fig. 6. Using total station and prism to monitor vertical deformations of the marked transverse sections

To read the elevation of the marked transverse sections, the total station was installed no farther than 200 feet from each section on the side of the road. The instrument was then pointed at each orange mark along the transverse section and the coordinates of the point were recorded. A transverse profile of the road could be obtained by analyzing the coordinates recorded and connecting them accordingly. Transverse profiles for all marked sections have been obtained on a regular basis over time and changes in elevations have been studied.

Example Results

The total station surveying function used for this study is a coordinate output in the northing (X), easting (Y) and Z directions. Each survey was done by shooting the center point marked on the center line of the road and, continuing toward the shoulder, shooting each marked point at approximately one-foot intervals (Figure 7).

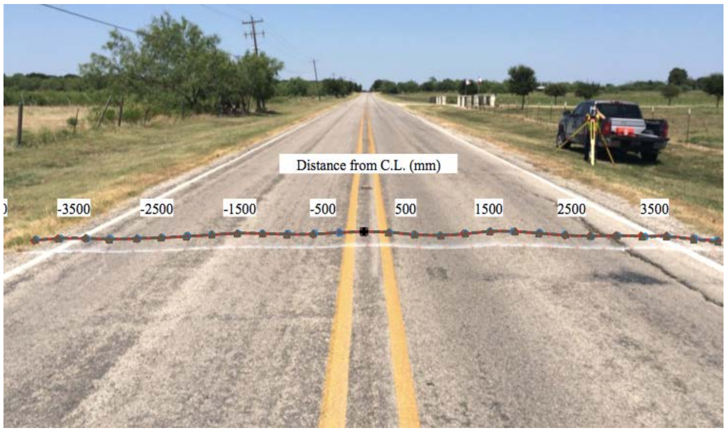

Fig. 7. Total station survey of the marked sections in the field

After performing the total station survey, the coordinate data can be downloaded from the total station to the computer and plotted using a template created in Excel. The plots are created using the Pythagorean Theorem by subtracting the X and Y coordinates from the center point, taking the root of the squared difference, and plotting that distance with the elevation difference. The plots contain the survey results from previous site visits and are used to compare cross-section profiles over time. In addition to the plots, the slope of each side of the road is calculated and displayed in tabular form in the spreadsheet. An example of results from total station surveys is shown in Figure 8 and Table 2.

Table 2. Example of results from total station surveys

FM 1979-Westbound Readings-Section#8-Visit #1							FM 1979-Eastbound Readings-Section#8-Visit #1						
	Total Station Coordinate Reading Relative to center line			Modified coordination for cross section of the road				Total Station Coordinate Reading Relative to center line			Modified coordination for cross section of the road		
	Z	X	Y	Z	X	Y		Z	X	Y	Z	X	Y
Pt.	m	m	m	mm	mm	mm	Pt.	m	m	m	mm	mm	mm
1	0	0	0	0	0	0	1	0	0	0	0	0	0
2	-0.00762	0.217932	0.224028	-7.62	313	0	2	-0.0061	-0.19812	-0.22403	-6.096	299	0
3	-0.01981	0.428244	0.44196	-19.812	615	0	3	-0.02286	-0.39472	-0.4511	-22.86	599	0
4	-0.02134	0.641604	0.673608	-21.336	930	0	4	-0.02896	-0.61265	-0.67208	-28.956	909	0
5	-0.01524	0.839724	0.897636	-15.24	1229	0	5	-0.01829	-0.80467	-0.89002	-18.288	1200	0
6	-0.01372	1.042416	1.124712	-13.716	1533	0	6	0.001524	-1.03327	-1.11404	1.524	1519	0
7	-0.02591	1.260348	1.344168	-25.908	1843	0	7	0	-1.23292	-1.33807	0	1819	0
8	-0.03658	1.444752	1.56972	-36.576	2133	0	8	-0.01372	-1.43256	-1.54991	-13.716	2111	0
9	-0.04877	1.674876	1.7907	-48.768	2452	0	9	-0.02743	-1.6322	-1.7907	-27.432	2423	0
10	-0.05334	1.868424	2.013204	-53.34	2747	0	10	-0.03505	-1.83032	-2.01168	-35.052	2720	0
11	-0.05944	2.112264	2.25552	-59.436	3090	0	11	-0.03048	-2.04673	-2.24028	-30.48	3034	0
12	-0.05334	2.289048	2.465832	-53.34	3365	0	12	-0.03505	-2.2479	-2.4704	-35.052	3340	0
13	-0.05486	2.526792	2.692908	-54.864	3693	0	13	-0.03505	-2.45212	-2.68834	-35.052	3639	0
14	-0.06706	2.706624	2.912364	-67.056	3976	0	14	-0.05486	-2.67919	-2.91084	-54.864	3956	0
15	2.717292	-12.7559	3.003804	2717.292	13105	0	15	-0.0701	-2.87426	-3.14554	-70.104	4261	0

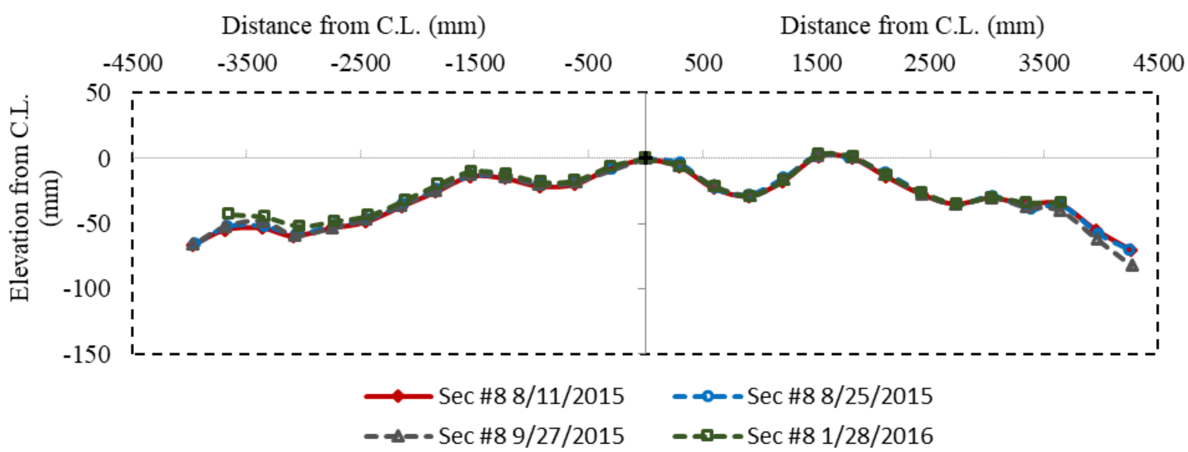

Fig. 8. Example of transverse profile of the road surface generated using total station data

Video Taping of Roadway Conditions

In addition to condition surveys and total station surveys, the road surface has been videotaped at the end of field visits to document the overall condition of the road. A camera is installed either inside the car behind the windshield or outside on the hood. Then, driving at a speed of 10-15 mph, the pavement surface is recorded. A screenshot from this activity is shown in Figure 9.

Fig. 9. Screenshot from videotape profile

Collection of Subgrade Soil Samples

Subgrade soil samples have been collected using either hand-dug test pits at shallow depths, or deeper boreholes using a continuous flight auger. In some instances, Shelby tube and SPT samples have also been collected. Sample collection from a borehole is performed using the methodology outlined in Snyder (2015) and summarized below:

- Once the site is found and the specific sampling location is determined, the vegetation is cleared using tools (e.g. rake or hoe) from an area about 3 feet by 3 feet where the auger will be placed for sampling.
- A tarp with a circular hole just wider than the auger flight diameter is placed on top of the cleared area and kept in place during sampling by weights.
- The auger is then lowered on top of the hole in the tarp and begins slowly digging down into the subsurface. All soil that was lifted to the surface until the auger reaches a depth of at least 6 inches is discarded because of contamination from organic material (e.g. roots and top soil) found at the sites.
- If the target soil has been reached after a depth of 6 inches, samples are then collected.
- A boring log is maintained throughout the process, and the auger is periodically lifted out of the hole so the depth to the bottom of the borehole can be measured.
- At a depth of 1 foot and 18 to 24 inches, the auger is lifted for the collection of a moisture content/density sample. A cutting ring is pushed and/or driven into the base or sidewall of the borehole, and then retrieved with a posthole digger if the ring was driven into the base, or a screwdriver if the ring was driven into the sidewall.
- The soil is then trimmed away from the cutting ring until the sample is flush on both the top and bottom of the ring. The soil is then extruded from the ring, wrapped in tin foil, placed into a plastic bag, and marked with site location and depth of sample.
- After collecting the second sample, the auger continues to the maximum depth of 3 feet. (In some projects, samples are collected every 2 feet from the top 10 feet of the soil profile)
- The auger is then lifted for a final time, and any remaining clean soil is removed from the auger flights.

Fig. 10. Continuous flight auger and soil surface cleared of vegetation

Fig. 11. Soil cuttings being removed from tarp-covered borehole and cutting ring for density sample

Characterization of Expansive Properties using Centrifuge

The expansive properties of the specific clay are measured using either the single or double-infiltration centrifuge approach (Armstrong, 2014) (Zornberg, et al 2016). In the double infiltration method, samples are remolded or trimmed into cutting rings. After a consolidation phase in the centrifuge, water is added and the samples then swell under load in the centrifuge. Up to 6 samples can be tested at any one time. Porous brass disks of different weights are used to apply overburden to each soil sample, allowing the generation of the whole stress swell curve in a single test. This data is then fed into the PVR calculation using the direct measurement of swelling – centrifuge (DMS-C) approach, as outlined in subsequently in this report. Figures 12 to 14 show the centrifuge layout for these methods.

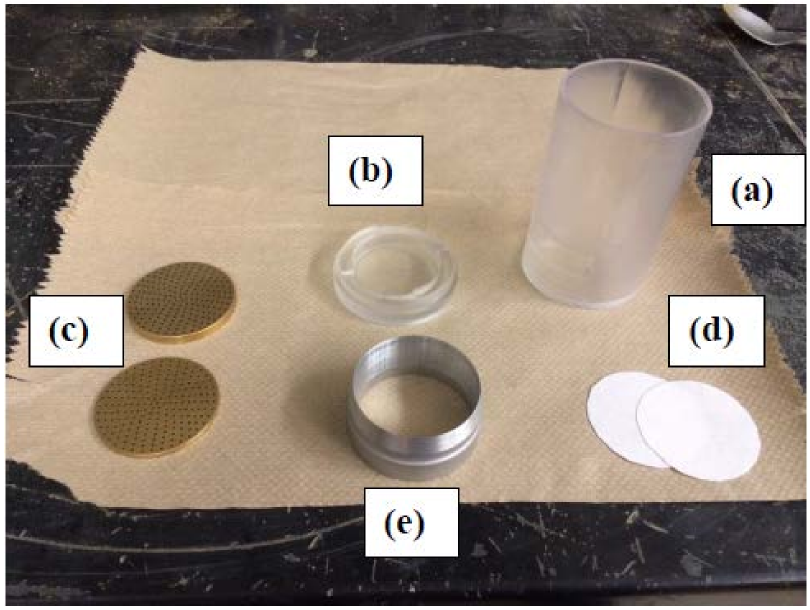

Fig. 12. Layout of double infiltration setup: (a) top cup; (b) base cup; (c) porous disks; (d) filter papers; (e) cutting ring

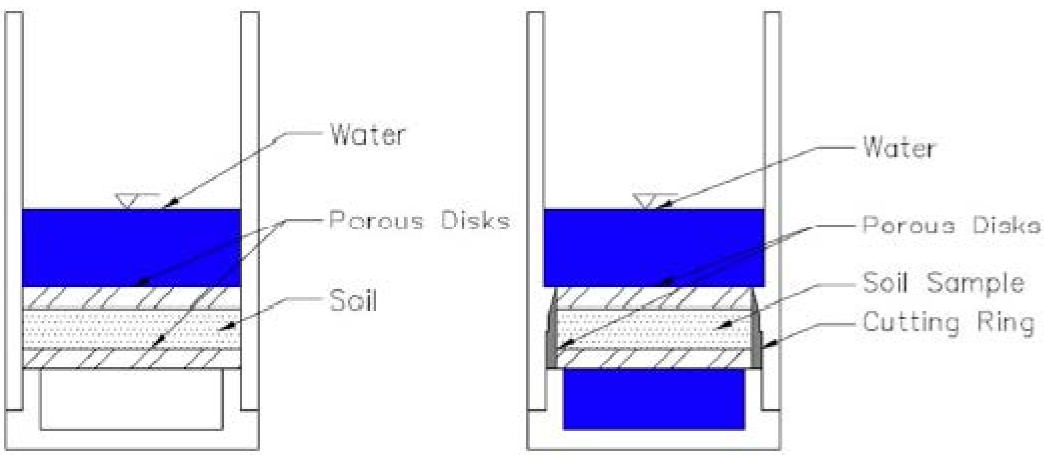

Fig. 13. Schematic of single and double infiltration setups

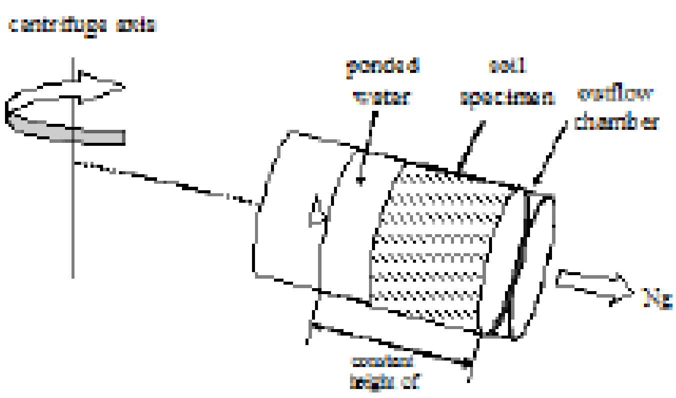

Fig. 14. Schematic of centrifuge test setup

Prediction of Potential Vertical Rise (PVR)

The prediction of potential vertical rise (PVR) is performed using the direct measurement of swelling-centrifuge approach, as well as Tex-124-E. Soil profiles are assumed based on the data (swell tests, Atterberg limits, dry density) and the swelling for each layer is integrated over the depth to determine the amount of vertical rise at the ground surface. An example calculation of this process is demonstrated here for Boring 4 from the US 87 site (Site 13).

<u>Assumed Soil Profile for US 87 B-04</u>

The soil samples from this site were taken within the Houston Black soil complex. The assumed pavement structure used for PVR calculations had an asphalt depth of 4 inches and a base layer of 10 inches. This assumption is consistent with the sampling locations to provide a similar comparison between sites in terms of the range of stresses. Soil samples were obtained and characterized from depths of 0' – 2', 2' – 4', and 4' – 6', and each were treated as separate layers. To be more directly comparable to other borings from the site, Layer 3 was extended to a depth of 10 feet. Layer 1 was assumed to be at a dry of optimum moisture content of 21.6% and a relative compaction of 100%, resulting in a dry unit weight of 94 pcf and a total unit weight of 114 pcf. Layer 2 was assumed to be at a dry of optimum moisture content of 22.1% and a relative compaction of 100%, resulting in a dry unit weight of 93 pcf and a total unit weight of 114 pcf. Layer 3 was assumed to be at a dry of optimum moisture content of 22.1% and a relative compaction of 100%, resulting in a dry unit weight of 93 pcf and a total unit weight of 114 pcf. The soil profile used for both methods is shown in Table 3 below.

Table 3. Assumed soil profile for Houston Black at US 87 B-04

<table>
<tr><th rowspan="2">Layer</th><th colspan="2">Depths (ft)</th><th rowspan="2">Soil</th><th rowspan="2">Liquid Limit</th><th rowspan="2">Plastic Limit</th><th rowspan="2">Plasticity Index</th><th rowspan="2">Water Content (%)</th><th rowspan="2">Unit Weight (pcf)</th><th colspan="2">Average Pressure</th></tr>
<tr><th>From</th><th>To</th><th>(psf)</th><th>(psi)</th></tr>
<tr><td>-</td><td>+1.2</td><td>0</td><td>*Asphalt + Base Material</td><td>0</td><td>0</td><td>0</td><td>-</td><td>Varies</td><td>173</td><td>1.2</td></tr>
<tr><td>1</td><td>0</td><td>2</td><td>Houston Black</td><td>72</td><td>21</td><td>50</td><td>21.6%</td><td>114</td><td>402</td><td>2.8</td></tr>
<tr><td>2</td><td>2</td><td>4</td><td>Houston Black</td><td>74</td><td>24</td><td>50</td><td>22.1%</td><td>114</td><td>629</td><td>4.4</td></tr>
<tr><td>3</td><td>4</td><td>6</td><td rowspan="3">Houston Black</td><td rowspan="3">74</td><td rowspan="3">22</td><td rowspan="3">52</td><td rowspan="3">22.1%</td><td rowspan="3">114</td><td>856</td><td>5.9</td></tr>
<tr><td>3</td><td>6</td><td>8</td><td>1084</td><td>7.5</td></tr>
<tr><td>3</td><td>8</td><td>10</td><td>1311</td><td>9.1</td></tr>
</table>

*Asphalt + Base Material Pressure is assumed as a total applied surcharge load on top of soil layer

<u>PVR Calculations for US 87 B-04</u>

The soil conditions for the centrifuge testing program on the Houston Black soil from US 87 B-04 included an initial moisture content of 21.8%, 21.3% and 20.7% for Layers 1, 2 and 3, respectively, and a relative compaction of 100% for all layers. Tests were completed at the prescribed stresses in the same centrifuge test to generate the necessary data. Data from centrifuge tests were input into the DMS-C spreadsheet. From the data in Table 4, it is apparent that this soil will be fairly expansive and will likely require remediation efforts.

For the Tex-124-E method, the soil profile from Table 3 was used with the sample moisture contents and unit weights. Using wet sieve analysis data, the soil layers were found to have 92%, 94% and 94%

passing a No. 40 sieve for Layers 1, 2 and 3, respectively. Dry conditions for the test were assumed, which corresponded to moisture contents of 23.4%, 23.8% and 23.8% for Layers 1, 2 and 3, respectively, per the correlations in Tex-124-E. The sample unit weights as previously determined were used, yielding density corrections of 0.91, 0.91 and 0.91 for each one of the three layers, and modified No. 40 factors of 0.92, 0.94 and 0.94, respectively, for the sample. The inputs used for the PVR calculations are shown in Table 4.

Table 4. Tex-124-E PVR input values for B-04

Depth to Bottom of Layer (ft)	Layer	Soil	Average Load (psf)	Average Load (psi)	Liquid Limit, LL	Moisture (%)	Unit Weight (pcf)	Percent -No.40	Plasticity Index, PI
0	-		173.3	1.2	-	-		-	-
2	1	HB	401.7	2.8	72	23.4	114	92	50
4	2	HB	629.0	4.4	74	23.8	114	94	50
6	3	HB	856.3	5.9	74	23.8	114	94	52
8	3	HB	1083.6	7.5	74	23.8	114	94	52
10	3	HB	1310.9	9.1	74	23.8	114	94	52

By numerically integrating the curve-fitted function from Figure 15 using the trapezoid rule with 1,000 divisions between the top and bottom stresses of 173 and 1,311 psf, the PVR of the subgrade was determined to be 5.17 inches. For the Tex-124-E method, an Excel workbook calculated the PVR based on the input parameters from above and produced a PVR of 2.16 inches. The results for both methods, including the PVR curves—i.e. the swelling of each subgrade layer versus the original height of the subgrade layer—are shown in Figure 16, and the comparison between the cumulative PVR versus depth is shown in Table 5.

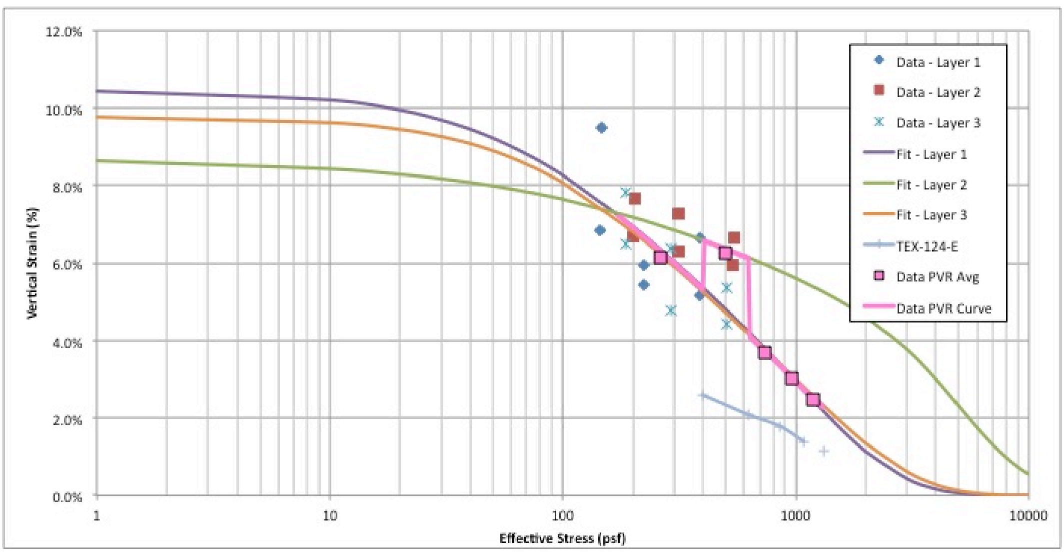

Fig. 15. Comparison of swelling curves from centrifuge data and Tex-124-E for B-04

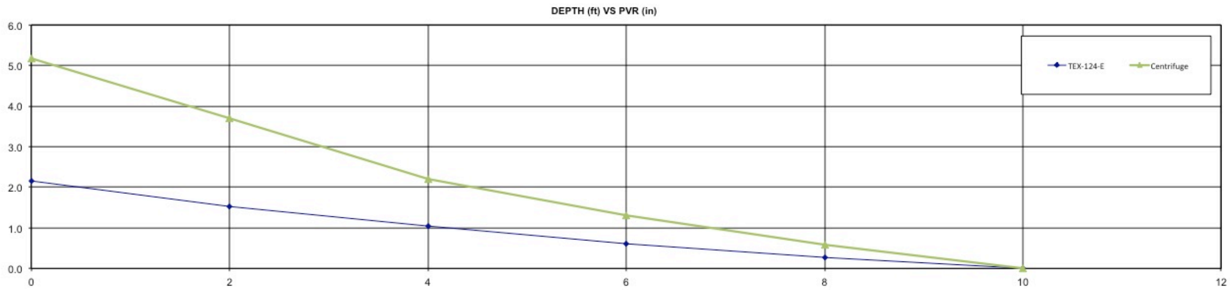

Fig. 16. Comparison of PVR calculations from centrifuge data and Tex-124-E for B-04

Table 5. Comparison of PVR values from centrifuge data and Tex-124-E for B-04

Depth to Bottom of Layer (ft)	Layer	Soil	Average Load (psf)	Tex-124-E PVR (in)	Data PVR (in)
0	-	-	-	2.16	5.17
2.0	1	HB	402	1.54	3.70
4.0	2	HB	629	1.04	2.20
6.0	3	HB	856	0.61	1.31
8.0	3	HB	1084	0.27	0.59
10.0	3	HB	1311	0.00	0.00

Characterization of Lime-stabilization Technique using Centrifuge

Centrifuge swelling tests have also been performed on lime-treated soils to assess the effectiveness of this treatment alternative in reducing the volumetric changes associated with wetting and drying cycles. This program is designed to help determine whether lime-treatment would be technically effective, as well as to optimize the dosage should the swelling reductions be favorable.

Samples were taken from air-dried, processed material taken from the site. The material was moisture conditioned to the pre-determined water content, after which hydrated lime was mixed into the soil as a powder, and samples were then compacted to the target dry density. Swell testing in the centrifuge proceeded in accordance with the testing procedures. The treated PVR was then calculated according to the DMS-C procedure, substituting the stress-swell curve for the treated soil in place of the native soil for a desired depth of treatment. Figure 17 and Table 6 show some typical swelling results obtained for Boring 2 at the US 87 site (Site 13). The addition of hydrated lime was found to reduce the swelling significantly for this soil.

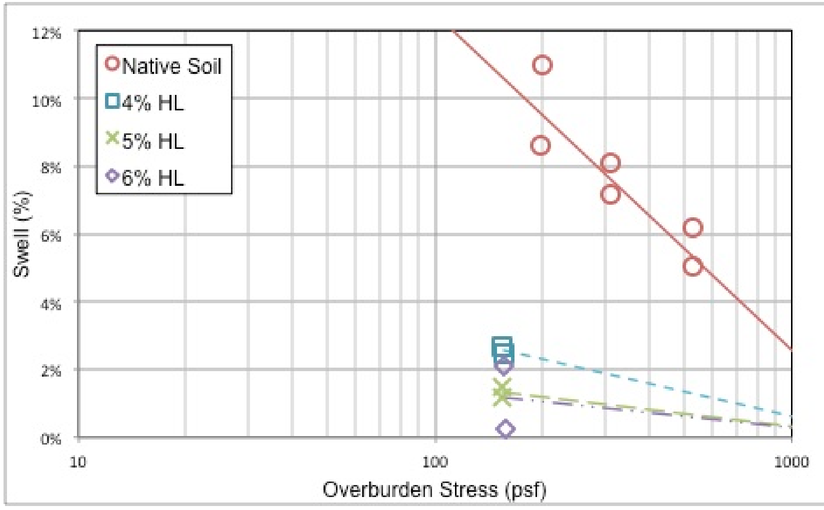

Fig. 17. Typical native and lime-treated stress-swell curves from US 87 B-02 (0.5' – 4')

Table 6. Initial conditions for data shown in B-02 (0.5' – 4') stress-swell curve

% Lime Added	Compacted WC	Compacted Dry Density (kN/m^3)	Compaction Void Ratio	Overburden Stress (psf)	Swell (%)
0	20.6%	15.13	0.754	198	8.63%
0	20.5%	15.30	0.741	199	10.98%
0	20.7%	15.08	0.761	309	8.11%
0	21.0%	15.06	0.767	311	7.14%
0	21.0%	15.06	0.766	527	5.05%
0	21.8%	15.04	0.770	527	6.19%
4	22.6%	14.90	0.779	156	2.45%
4	23.3%	14.84	0.785	154	2.68%
5	24.2%	14.74	0.797	155	1.16%
5	24.2%	14.78	0.796	154	1.48%
6	23.0%	14.90	0.778	156	2.11%
6	23.0%	14.88	0.781	157	0.24%

Section 2: Site Locations and Activities Conducted

Overview

A total of 15 sites, all located in the TxDOT San Antonio District, have been investigated. Table 7 summarizes the main site characteristics and activities conducted at each location. The approximate site locations in relation to the city of San Antonio are presented in Figure 18.

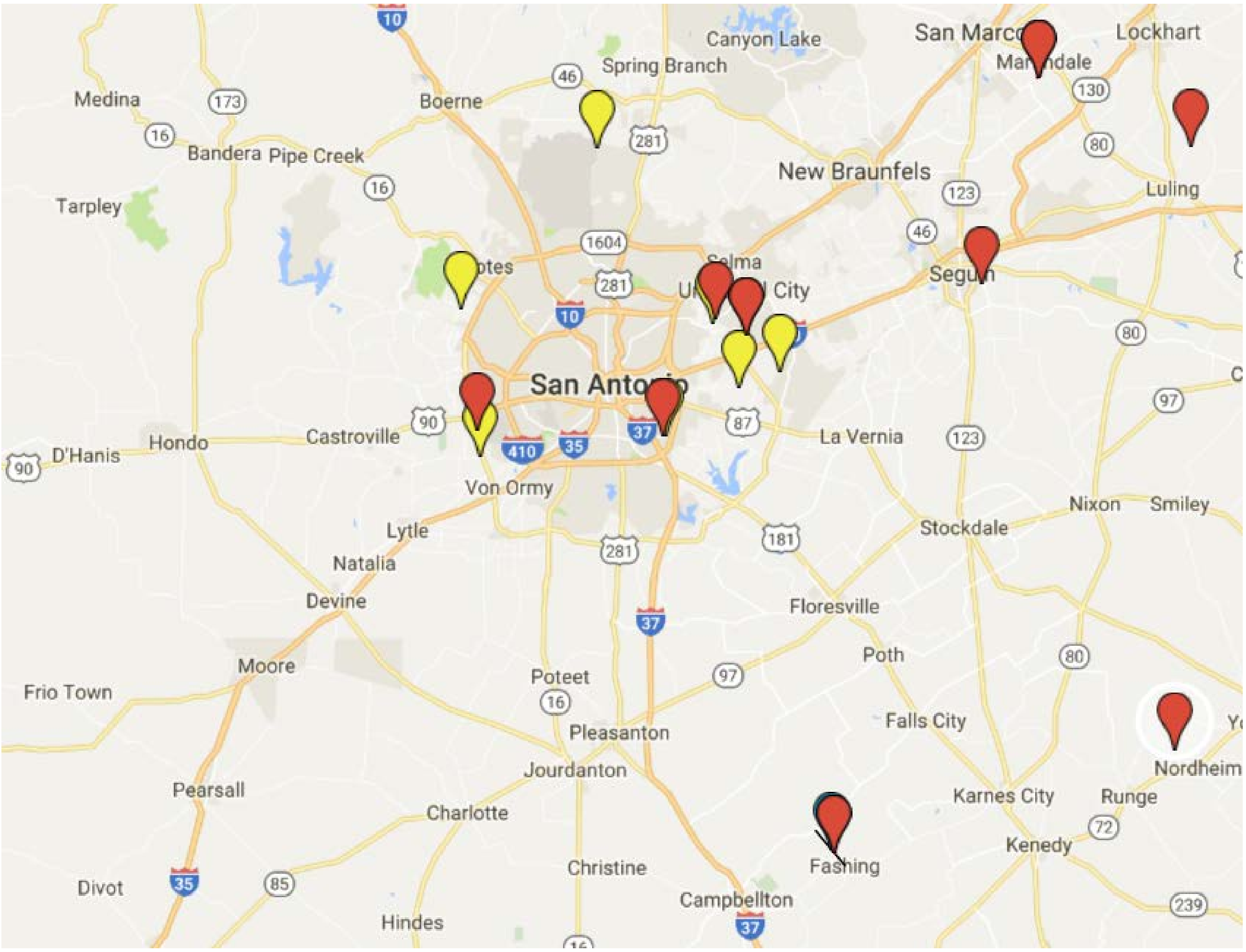

Fig. 18. Approximate site locations

Table 7. Summary of site locations and activities

Site No.	Roadway	TxDOT District	Condition Survey	Total Station Survey	Video Taping	Subgrade Sample Collection	Centrifuge Test	PVR Calculation	Lime-stabilization Characterization
1	Interstate-10 & Hausman Rd.	San Antonio				✓	✓	✓	
2	Loop 410 & Ray Ellison Blvd.	San Antonio				✓	✓	✓	
3	Interstate-10 & New Braunfels Avenue	San Antonio				✓	✓	✓	
4	Loop 1604 & Pue Rd.	San Antonio				✓	✓	✓	
5	Loop 1604 & Graytown Rd.	San Antonio	✓			✓	✓	✓	
6	FM 1976	San Antonio				✓	✓	✓	
7	FM 1979	San Antonio	✓	✓	✓	✓	✓	✓	
8	FM 2924	San Antonio	✓	✓	✓	✓	✓	✓	
9	FM 466	San Antonio				✓	✓	✓	
10	SL-13 (Southeast Military Drive)	San Antonio	✓			✓	✓	✓	
11	George Beach Avenue & I-35	San Antonio				✓	✓	✓	
12	Walnut Avenue Bridge & I-35	San Antonio				✓	✓	✓	
13	US-87 from IH-10 to Rigsby Rd, San Antonio	San Antonio				✓	✓	✓	✓
14	Old Pearsall Rd	San Antonio				✓	✓	✓	✓
15	IH 10	San Antonio	✓	✓	✓	✓	✓	✓	

Site 1: Interstate 10 & Hausman Rd., San Antonio

Site 1 was located at a construction area on the eastbound side of Interstate 10, between the access road and Exit 558 off-ramp. The excavation was about 10 feet wide, 20 feet long and 6-8 feet deep. A yellow-tan to grey clay layer (Del Rio Clay), extending below a depth of 2 feet in the excavation, was identified for extensive characterization and testing. Centrifuge swelling tests and soil characterization were utilized to compare the PVR using the DMS-C approach and Tex-124-E.

Fig. 19. Soil from stockpile sampled at Site 1

Fig. 20. Google Earth view of site

Soil characterization at a glance:

Del Rio Clay

Fines content: ~94%

Liquid limit: 48

Plasticity index: 34

Compaction tests: standard Proctor

Optimum dry density: 110 pcf

Optimum water content: 18.5%

PVR:

Tex-124-E: **1.80 in**

DMS-C: **1.46**

Current status:

No ongoing activity by the University

Site 2: Loop 410 & Ray Ellison Blvd., San Antonio

Site 2 is located in Southwest Central San Antonio along the frontage road of SW Loop 410, between Ray Ellison Blvd. and Old Pearsall Road. The pavement at this site showed extensive longitudinal and transverse cracking as well as heaving.

Soil samples were collected from three borings drilled to a depth of 3 feet through the asphalt along the frontage road.

Centrifuge swelling tests and soil characterization were utilized to compare the PVR using the DMS-C approach and Tex-124-E.

Fig. 21. Damage to pavement

Fig. 22. Location of borehole

Soil characterization at a glance:

Houston Black Clay

Fines content: ~84%

Liquid limit: 72

Plasticity index: 48

Compaction tests: standard Proctor

Optimum dry density: 92.3 pcf

Optimum water content: 23%

PVR:

Tex-124-E: **3.61**

DMS-C: **7.59**

Current status:

No ongoing activity by the University

Site 3: Interstate 10 & New Braunfels Avenue

Site 3 corresponds to a construction site on the main lanes of eastbound Interstate 10 in which the subgrade soils were being excavated and replaced underneath the New Braunfels Avenue overpass. Two distinct, highly expansive soil types were sampled directly from the excavation and tested by the University. Centrifuge swelling tests and soil characterization were utilized to compare the PVR using the DMS-C approach and Tex-124-E.

Fig. 23. Excavation pit at Site 3

Fig. 24. Site location

Fig. 25. Soil profile at Site 3

Soil characterization at a glance:

Houston Black Clay

Fines content: 83%

Liquid limit: 62

Plasticity index: 42

Tan Taylor Clay

Fines content: 99%

Liquid limit: 95

Plasticity index: 69

Compaction tests: standard Proctor

Houston Black

Optimum dry density: 94 pcf

Optimum water content: 24.5%

Tan Taylor

Optimum dry density: 94 pcf

Optimum water content: 26%

PVR:

Tex-124-E: **5.33**

DMS-C: **4.42**

Current status:

No ongoing activity by the University

Site 4: Loop 1604 & Pue Rd.

Site 4 corresponds to a section of West Loop 1604 near Pue Rd. and FM 143. Road conditions at this site showed extensive longitudinal and transverse cracking.

Soil samples were collected between depths of 1 and 3 feet from a boring just off the edge of the shoulder.

Centrifuge swelling tests and soil characterization were utilized to compare the PVR using the DMS-C approach and Tex-124-E.

Fig. 26. Damage to pavement and clay in borehole

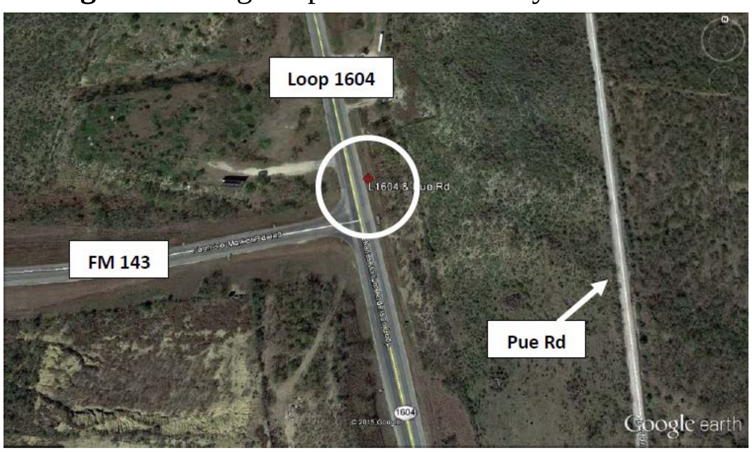

Fig. 27. Location of borehole

Soil characterization at a glance:
Houston Black Clay
Fines content: ~90%
Liquid limit: 64
Plasticity index: 42

Compaction tests: standard Proctor
Optimum dry density: 94.5 pcf
Optimum water content: 24.5%

PVR:
Tex-124-E: **2.65 in**
DMS-C: **2.14 in**

Current status:
No ongoing activity by the University

Site 5: Loop 1604 & Graytown Rd.

The location of Site 5 is a section of Graytown Road approximately ¼ mile from its intersection with Loop 1604 on the northeast side of San Antonio. The road conditions at the site showed signs of longitudinal cracking as well as major ruts and alligator cracking.

Soil samples were recovered between 1 and 3 feet deep from a boring 3 feet off the edge of the pavement on the south side of the road.

Centrifuge swelling tests and soil characterization were utilized to compare the PVR using the DMS-C approach and Tex-124-E.

Fig. 28. Damage to pavement and borehole

Fig. 29. Location of borehole

Soil characterization at a glance:

Houston Black Clay

Fines content: ~90%

Liquid limit: 80

Plasticity index: 58

Compaction tests: standard Proctor

Optimum dry density: 90 pcf

Optimum water content: 26.5%

PVR:

Tex-124-E: **4.87 in**

DMS-C: **5.79 in**

Current status:

No ongoing activity by the University

Site 6: FM 1976

Site 6 lies on FM 1976 just inside Loop 1604 near Miller Road, on the northeast side of San Antonio. Longitudinal cracking was present along the shoulder of the roadway.

Soil samples were collected from a 3 foot boring for analysis.

Centrifuge swelling tests and soil characterization were utilized to compare the PVR using the DMS-C approach and Tex-124-E.

Fig. 30. Damage to pavement and borehole

Fig. 31. Location of borehole

Soil characterization at a glance:
Houston Black Clay
Fines content: ~91%
Liquid limit: 75
Plasticity index: 54

Compaction tests: standard Proctor
Optimum dry density: 93 pcf
Optimum water content: 24%

PVR:
Tex-124-E: **5.04 in**
DMS-C: **3.80 in**

Current status:
No ongoing activity by the University

Site 7: FM 1979

FM 1979 is a two-lane road in Guadalupe County, in Geronimo, near Martindale, TX, and extends about 9.2 miles between TX-80 and TX-123. This road is primarily traveled by civilian traffic, underlain by an expansive subgrade and has a biaxial pavement stabilization layer. The average daily traffic in 2008 was 1,700 and the predicted traffic in 2028 is 2,900. The total number of equivalent 18k single-axle load for a 20-year period is 691,000 for flexible pavement and 908,000 for rigid pavement with a structural number of 3.

A condition survey showed signs of rutting and differential elevation changes on the road. Soil samples were collected from a boring to 3 feet. Centrifuge swelling tests and soil characterization were utilized to compare the PVR using the DMS-C approach and Tex-124-E.

A total of eight transverse sections were marked along FM 1979, starting with Section 1 about 1.5 miles from TX-80 and ending at Section 8 in the westbound direction. The area of interest is about 0.26 miles in total length. The test sections were marked along areas with poor pavement conditions and consist of Sections 2, 3, 5 and 8. Sections 1, 4, 6 and 7 are comparatively better performing sections for the site and located near each of the test sections.

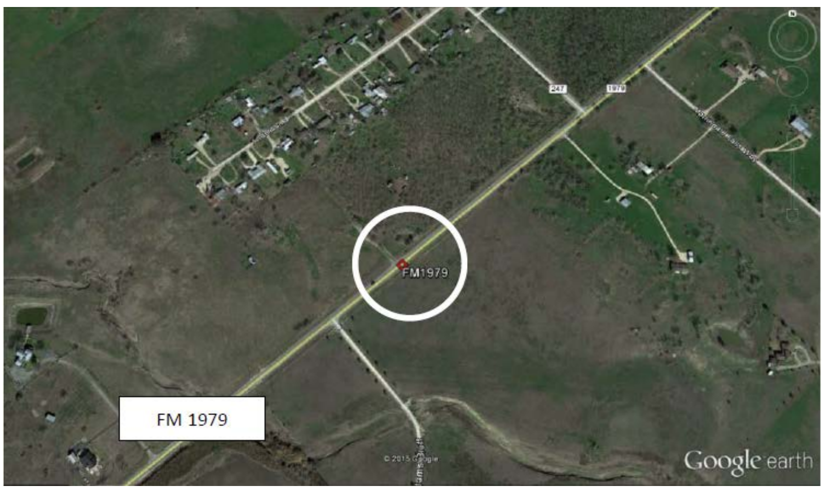

Fig. 32. Location of borehole

Fig. 33. Damage to pavement and clay in borehole

Soil characterization at a glance:

Houston Black Clay

Fines content: ~91%

Liquid limit: 82

Plasticity index: 58

Compaction tests: standard Proctor

Optimum dry density: 90 pcf

Optimum water content: 26.5%

PVR:

Tex-124-E: **4.99 in**

DMS-C: **3.97 in**

Field surveys:

Visual condition surveys: **5**

Total station surveys: **10**

Current status:

Condition of the road has been continuously monitored through visual condition surveys, total station surveys and videotaping of the road

Site 8: FM 2924

FM 2924 is a two-lane road in Atascosa County, located about 70 miles south of San Antonio, and extends about 4.14 miles southeast from FM 791 to FM 99. The road is primarily traveled by heavy traffic, due to oil and gas activities nearby, and underlain by an expansive subgrade. Roadway performance was reported as particularly poor prior to pavement stabilization using a biaxial geogrid.

Soil samples were collected between 6 inches and 3 feet from a boring on the east side of the road because of a pipeline running along the west side. Centrifuge swelling tests and soil characterization were utilized to compare the PVR using the DMS-C approach and Tex-124-E.

A section of the road extending for approximately 1,100 feet was selected and split into six test sections that were divided by white stripe markings in the transverse direction. Orange circles to be used for total station monitoring were added to the white stripe markings every foot from the centerline to shoulder. The first marked transverse section (Transverse Section 1) is located on the northwest side approximately 2 miles from FM 791. The last marked transverse section (Transverse Section 7) is located on the southeast side of the road. The locations of the transverse sections were chosen based on the existing pavement condition and thus Sections 2, 4, 5 and 6 are considered as poorly-performing test sections and Sections 1, 3 and 7 are considered as well-performing sections.

Fig. 34. Location of borehole

Fig. 35. Damage to pavement and clay in borehole

Soil characterization at a glance:

Monteola Clay

Fines content: ~87%

Liquid limit: 80

Plasticity index: 56

Compaction tests: standard Proctor

Optimum dry density: 85 pcf

Optimum water content: 24%

PVR:

Tex-124-E: **5.10 in**

DMS-C: **7.05 in**

Field surveys:

Visual condition surveys: **3**

Total station surveys: **9**

Current status:

Condition of the road has been continuously monitored through visual condition surveys, total station surveys and videotaping of the road

Site 9: FM 466

Site 9 is located on FM 466 near Jim Barnes Middle School just outside of Seguin, Texas.

Subgrade soil samples were collected from a hand-dug hole 2 feet deep.

Centrifuge swelling tests and soil characterization were utilized to compare the PVR using the DMS-C approach and Tex-124-E.

Fig. 36. Site location

Fig. 37. FM 466 pavement conditions

Soil characterization at a glance:

Branyon Clay

Fines content: ~53%

Liquid limit: 42

Plasticity index: 24

Compaction tests: standard Proctor

Optimum dry density: 99 pcf

Optimum water content: 23%

PVR:

Tex-124-E: **0.56 in**

DMS-C: **0.19 in**

Current status:

No ongoing activity by the University

Site 10: SL-13 (Southeast Military Drive)

Site 10 corresponds to a section of Southeast Military Drive near Alsobrook Drive just off Interstate 37, in Southeast Central San Antonio.

A condition survey was conducted and soil samples were collected from a hand-dug hole 2 feet deep. Centrifuge swelling tests and soil characterization were utilized to compare the PVR using the DMS-C approach and Tex-124-E.

Fig. 38. Site location

Soil characterization at a glance:
Heiden-Ferris Complex
Fines content: ~79%
Liquid limit: 53
Plasticity index: 31

Compaction tests: standard Proctor
Optimum dry density: 102 pcf
Optimum water content: 21.5%

PVR:
Tex-124-E: **1.93 in**
DMS-C: **1.02 in**

Current status:
No ongoing activity by the University

Fig. 39. Pavement distress

Site 11: George Beach Avenue & I-35

Site 11 is located at the intersection of George Beach Avenue and I-35 in San Antonio, Texas. Samples were provided to the University of Texas by TxDOT. Centrifuge swelling tests and soil characterization were utilized to compare the PVR using the DMS-C approach and Tex-124-E.

Soil characterization at a glance:

Branyon Clay

Liquid limit: 52

Plasticity index: 30

Density correlations: standard Proctor

Optimum dry density: 96.7 pcf

Optimum water content: 22.8%

PVR:

Tex-124-E: **1.94 in**

DMS-C: **0.06 in**

Current status:

No ongoing activity by the University

Fig. 40. Site 11 location

Site 12: Walnut Avenue Bridge & I-35

Site 12 corresponds to the Walnut Avenue Bridge at I-35 in New Braunfels, Texas.

TxDOT provided the University with samples from a depth of 5 to 6 feet. Centrifuge swelling tests and soil characterization were utilized to compare the PVR using the DMS-C approach and Tex-124-E. The soil at this site was determined not to exhibit significant swelling.

PVR:

Tex-124-E: **1.11 in**

DMS-C: **0.00 in**

Current status:

No ongoing activity by the University

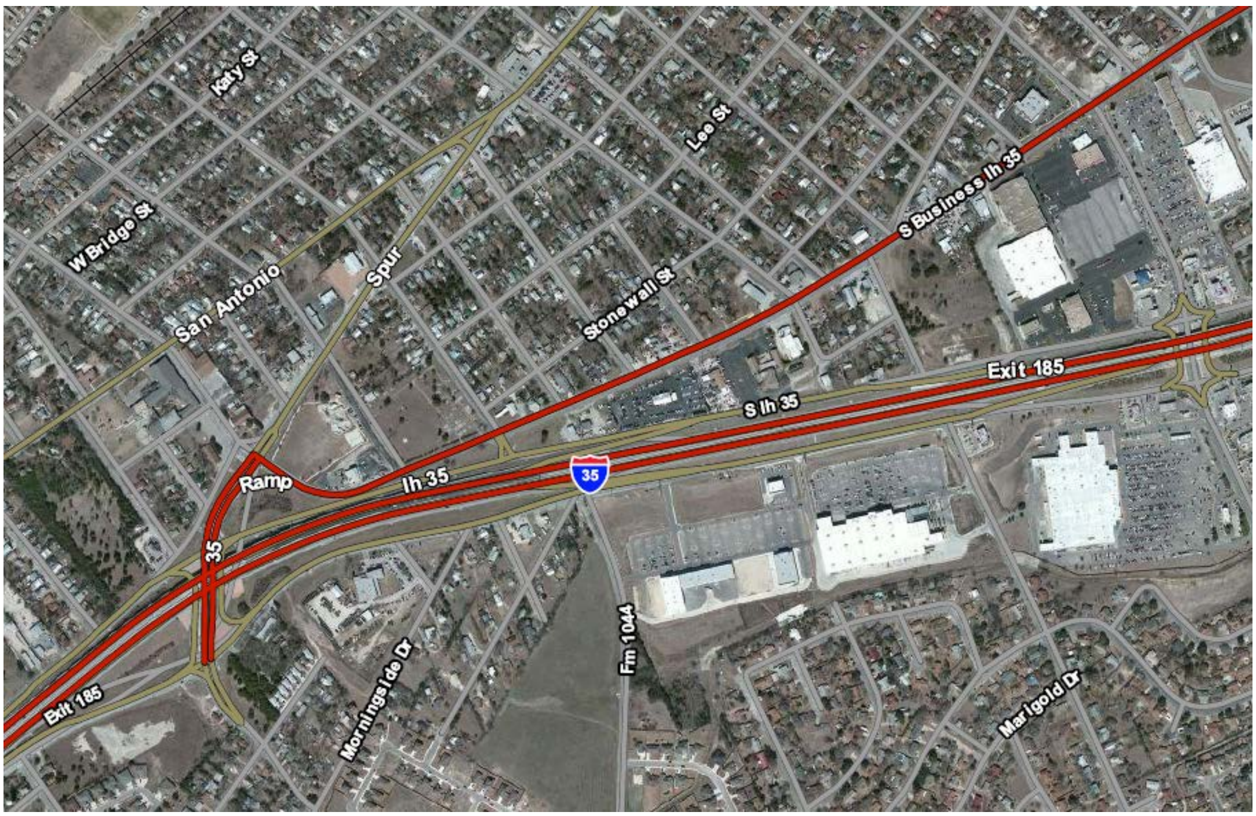

Fig. 41. Site 12 location

Site 13: US 87 from IH-10 to Rigsby Rd., San Antonio

Site 13 corresponds to a roadway rehabilitation project covering a half-mile sloping stretch.

The roadway at this site exhibited extensive cracking and heaving.

Samples were collected from the top 8 feet of 4 borings that were 10 and 20 feet deep.

Centrifuge swelling tests and soil characterization were utilized to compare the PVR using the DMS-C approach and Tex-124-E.

Centrifuge swelling tests were also performed on lime-treated samples to assess required lime dosages for targeted PVR reduction.

Fig. 42. Pavement distress on US 87 at Boring #2

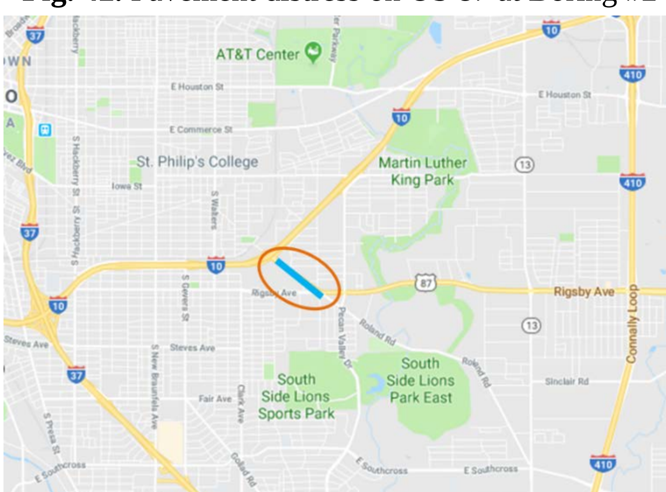

Fig. 43. US 87 site

Soil characterization at a glance:

Houston Black Clay

Fines content: 90-95%

Liquid limit: 75-90

Plasticity index: 50-70

PVR:

Tex-124-E: **3.86 in**

DMS-C: **5.35 in**

Current status:

Continued testing on lime-treated samples by the University

Site 14: Old Pearsall Rd, San Antonio

Site 14 corresponds to the intersection of Old Pearsall Road and Five Palms Drive in Southwest Central San Antonio. Soil samples were collected to a depth of 7.5 feet in August 2017 from a boring placed in a grassy area off the shoulder.

Centrifuge swelling tests and soil characterization were utilized to compare the PVR using the DMS-C approach and Tex-124-E.

Centrifuge swelling tests were also performed on lime-treated samples to assess required lime dosages for targeted PVR reduction.

Fig. 44. Pavement distress at Old Pearsall Rd.

Fig. 45. FM-2673 Old Pearsall Rd. boring location

Soil characterization at a glance:

Houston Black Clay

Fines content: 90-95%

Liquid limit: 90-100

Plasticity index: 60-70

PVR:

Tex-124-E: **1.38 in**

DMS-C: **1.53 in**

Current status:

Continued testing on lime-treated samples by the University

Site 15: IH-10

The IH-10 reconstruction site covers 4 miles on IH-10, extending from N. Foster Road on the west to 1,000 feet east of Graytown Road, in Bexar County, San Antonio, Texas. The University comprehensively characterized the subgrade soil in this area by conducting index soil tests and centrifuge testing on samples collected from the subgrade.

A survey was conducted to evaluate the road condition before reconstruction. Twenty-four test sections have been designed to be constructed on the westbound and eastbound frontage roads of IH-10. The team at the University collaborated with TxDOT personnel, consultants and contractors on supervision of construction.

Fig. 46. Site location and location of boreholes

Soil characterization at a glance:

Houston Black Clay

Liquid limit: 30~150

Plasticity index: 30~80

PVR:

Tex-124-E: **0.37~3.2 in**

DMS-C: **0.32~13.84 in**

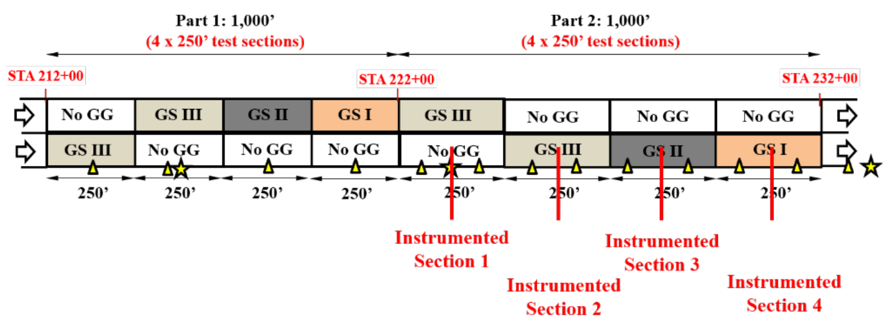

Fig. 47. Example design of test sections

Current status:

Continued monitoring of construction

Continued characterization of base material, subgrade and geosynthetics

Installation of instruments in test sections

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