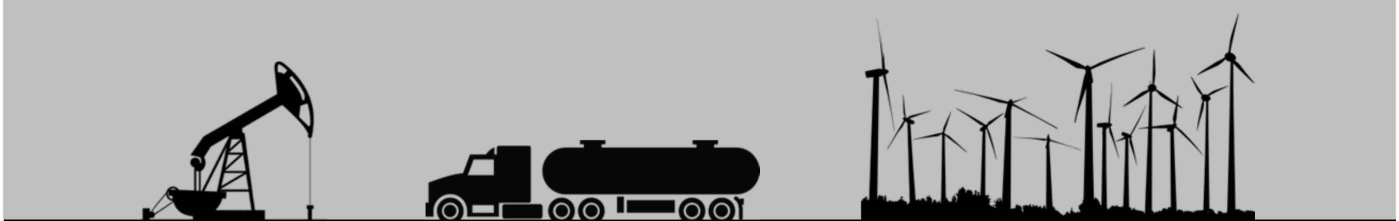
Investigation of Longitudinal Cracking and Pavement Structural Load Carry Ability on FM 443

Technical Memorandum TM-14-02



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INTRODUCTION

Longitudinal cracking is a common form of distress on pavements in Central Texas. This form of distress is typically parallel to the edge of the pavement shoulder and within 6 to 8 ft of the paved shoulder edge. A series of longitudinal cracks more or less parallel to the edge of shoulder is typical. Figure 1 shows typically longitudinal cracking in the central Texas area.

Figure 1. Longitudinal Cracking.

The primary cause of this type of longitudinal cracking is the presence of highly plastic clay soils as the subgrade material and changes in the moisture content of these soils due to climatic changes. Highly plastic clay soils undergo significant volume changes when subjected to moisture changes.

During low rainfall periods, the soils outside the edge of the paved surface and near the edge of the pavement will shrink due to a loss in moisture content. Soils near the center of the pavement will remain at relatively high moisture contents. The loss in moisture content in the clay soil and its volume change will cause cracks in a direction parallel to the paved edge of the pavement.

A second cause of edge, longitudinal cracking is traffic loads near the paved edge of the pavement. These unprotected edges of the pavement (narrow or no paved shoulders) will cause high stresses in the asphalt bound materials and longitudinal cracking. Longitudinal cracking due to either volume changes in the subgrade soil or traffic is typically not continuous along the entire length of the pavement.

Farm to Market (FM) Road 443 in Gonzales County (CSJ 0839-01-016) and within the Yoakum District experienced longitudinal cracking. The specific location of some of the damage was on the curve at FM 443 at County Road (CR) 368. The Texas A&M Transportation Institute (TTI) was asked to perform a field evaluation to determine the following:

- The cause of the longitudinal cracking (moisture change in the clay soil and/or traffic load related) at the CR 368 curve.
- The cause of longitudinal cracking at isolated locations on the project.

- Identification of repair alternative for this type of cracking.
- Identification of methods to reduce this type of cracking.

This technical memorandum presents the results from this investigation.

EVALUATION OF PAVEMENT STRUCTURE ON CURVE AT CR 368

TTI used ground-penetrating radar (GPR) and falling weight deflectometer (FWD) analysis to evaluate the pavement structure. The GPR data were analyzed to determine abnormal subsurface reflections associated with changes in structural section depths and moisture contents in the pavement materials. Figure 2 and Figure 3 show SB and NB views of the location and illustrate that the GPR data from the focus zone in the curve show no unusual traces as compared to the rest of the pavement.

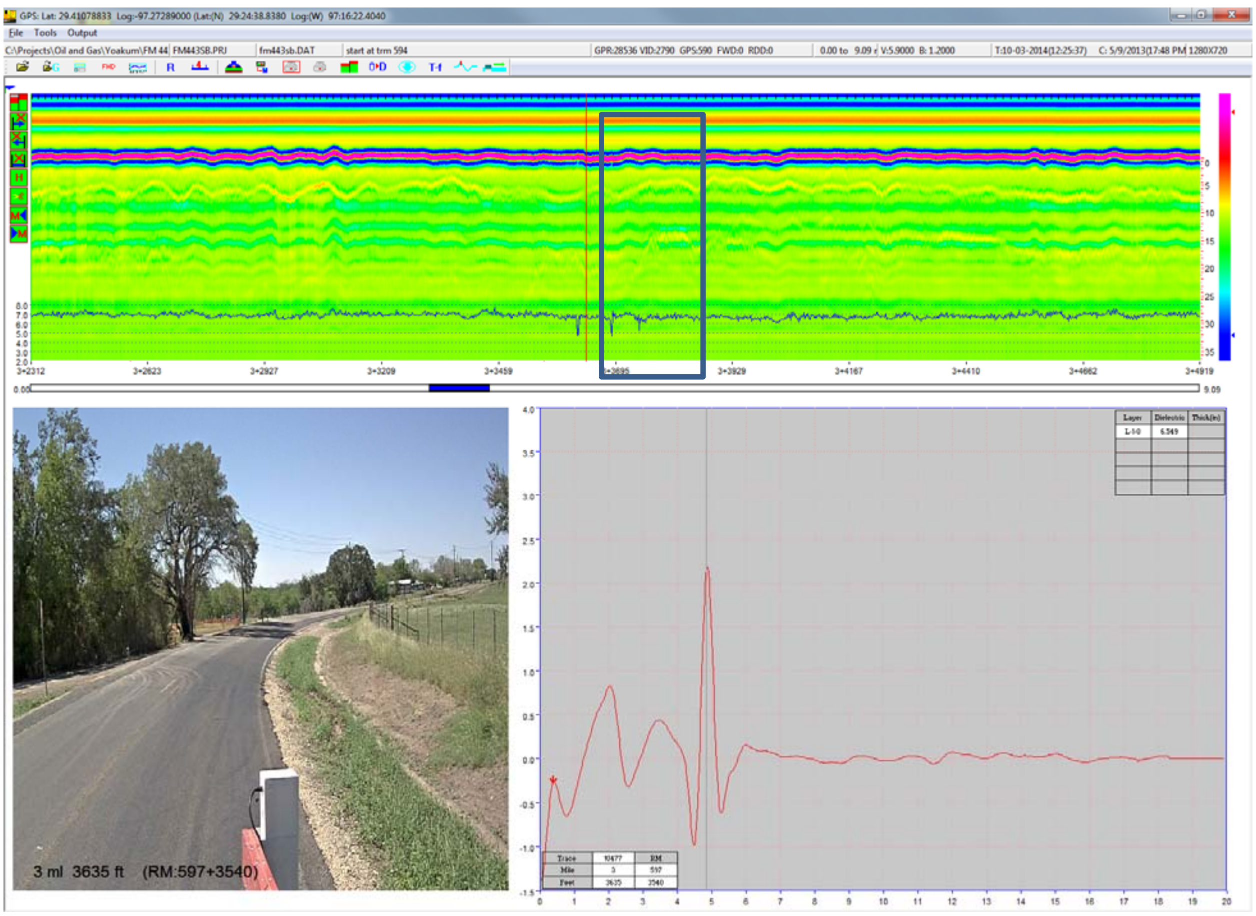

Figure 2. SB FM 443 GPR at Curve near CR 368.
Note: Boxed region of color plot shows focus area of data from the curve.

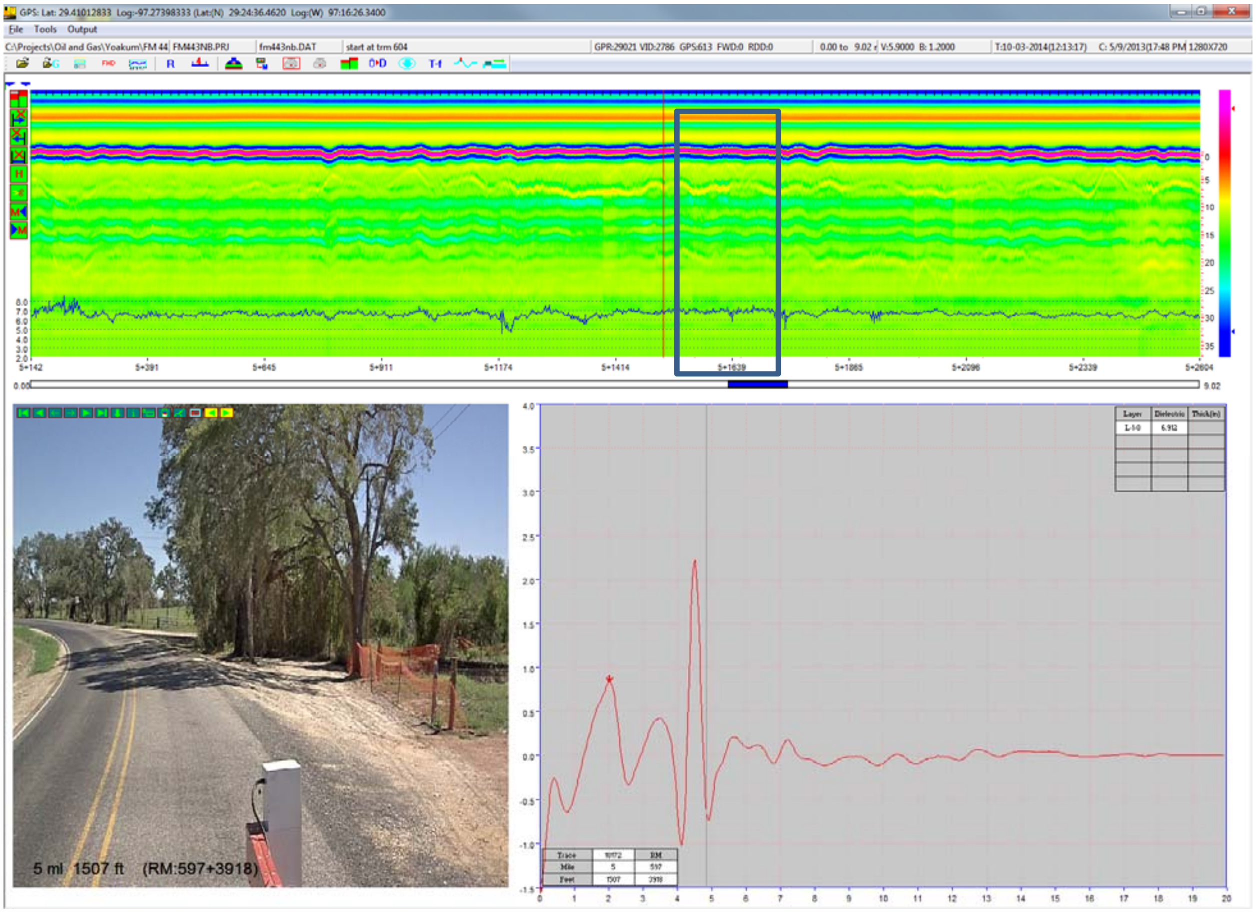

Figure 3. NB FM 443 GPR at Curve near CR 368.

Note: Boxed region of color plot shows focus area of data from the curve.

TTI collected FWD data at 50-ft intervals approaching and exiting the curve and collected FWD data at 10-ft intervals through the focus zone in the curve. Figure 4 illustrates the first sensor (W1) deflection through the tested area. Figure 4 suggests the focus zone does not exhibit pavement structure weakness. Statistical F and t tests confirm this observation as the mean deflection in the focus zone is statistically the same as the mean deflection of the pavement approaching and exiting the curve. Note that in the North Bound Lane (NBL), the mean deflections are equivalent for the study area versus the general roadway. In the South Bound Lane (SBL), the mean deflection in the focus zone is less than the mean deflection in the surrounding pavement area but not statistically different.

In summary, the data show no indication of pavement structure weakness or damage in the curve.

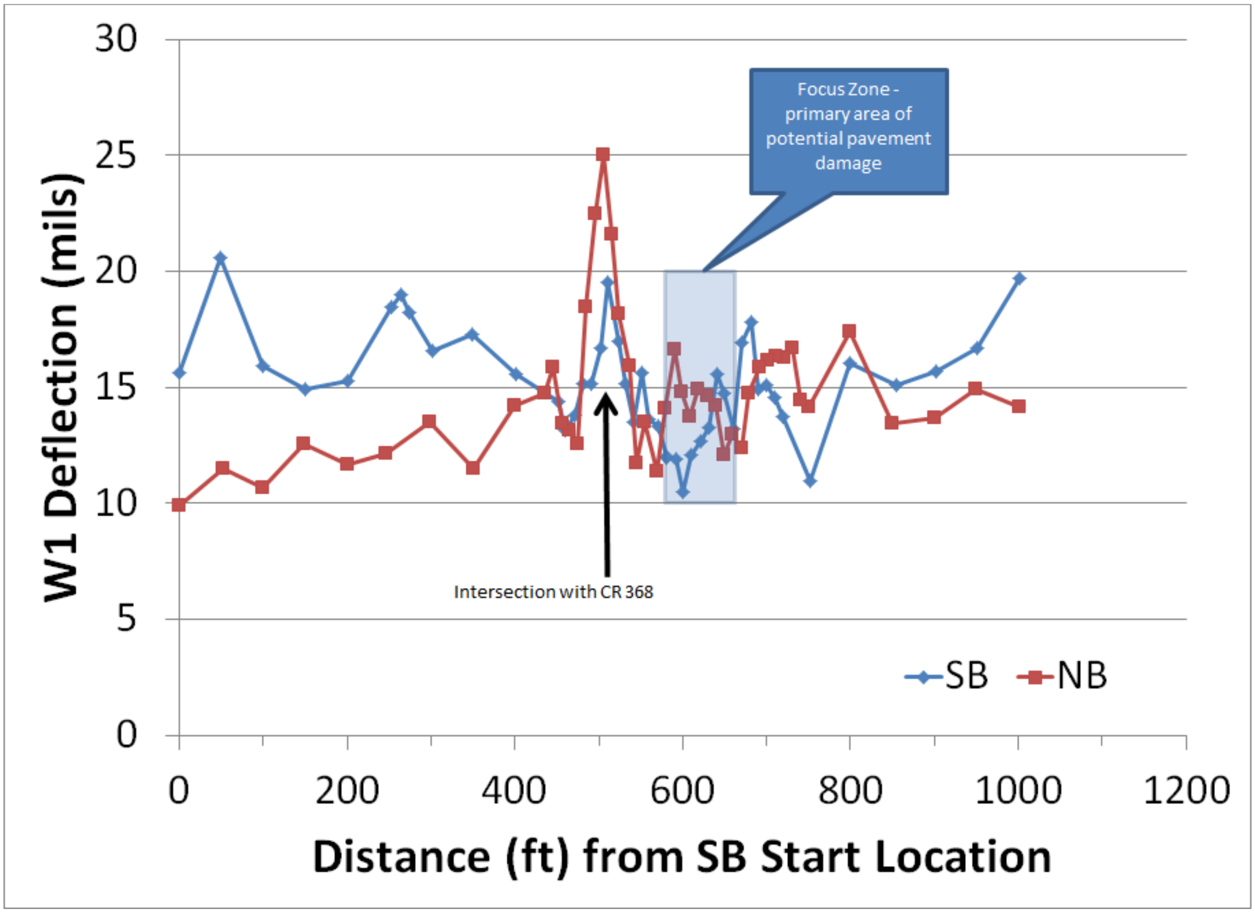

Figure 4. FWD Data through Curve on FM 443.
Note: Zero distance is sign for CR 368 in SB travel direction.

EVALUATION OF PROJECT LONGITUDINAL CRACKING

TTI used visual assessment, FWD testing, dynamic cone penetrometer (DCP) tests, and pavement coring to evaluate the cause of longitudinal cracking. The analyses focused on the region in the SB lane from STA 425 to 418 (just north of Kokernot Branch Bridge), and in the NB lane at STA 475.

Visual Observations

Figure 5 illustrates that longitudinal cracks were observed in locations that should not have been within areas of the contractor's scope of subgrade work. Subgrade soils collected on FM 443 (shown in

Figure 6) were observed to be a black clay material. Additionally, on surrounding pavements (Alt-90), numerous observations of longitudinal cracking were made. The distress of longitudinal cracking seems quite common in the geographic area of the project.

Near Kokernot bridge, crack location seems not within limits of subgrade widening

Locations of cracking observed well outside of pavement limits

Figure 5. Longitudinal Cracks in Locations outside Contractor's Scope of Subgrade Work.

Clayey soil sticks to DCP rod during testing

Black clay soil collected from drilling rig

Figure 6. Black Clay Soils Observed on Project.

FWD Results

TTI performed FWD testing both inside and outside the longitudinal crack from STA 418 to 415 as Figure 7 illustrates. The purpose of this FWD work was to evaluate whether the widened subgrade, which only called for ordinary compaction, provided similar support to the existing subgrade.

Table 1 and

Station	**Inside Crack (mils)**	**Outside Crack (mils)**
418	1.59	1.37
417.5	1.22	1.55
417	1.75	1.66
416.5	1.15	1.78
416	1.24	1.17
415.5	1.16	1.13
415	1.17	.85
AVG	1.33	1.36
StDev	.24	.33
Prob(t)	.84	

Table 2 show that, whether evaluated based on W7 or backcalculated subgrade modulus, no statistical difference in subgrade support existed between the existing and widened subgrade.

Figure 7. Performing FWD Testing outside Crack on Widened Subgrade.

Table 1. Evaluation of Widened Subgrade Support Based on W7 Deflection.

Station	Inside Crack (mils)	Outside Crack (mils)
418	1.59	1.37
417.5	1.22	1.55
417	1.75	1.66
416.5	1.15	1.78
416	1.24	1.17
415.5	1.16	1.13
415	1.17	.85
AVG	1.33	1.36
StDev	.24	.33
Prob(t)	.84	

Table 2. Evaluation of Widened Subgrade Support Based on Backcalculated Subgrade Modulus.

Station	Inside Crack (ksi)	Outside Crack (ksi)
418	15.1	15.1
417.5	16.8	14.2
417	15.1	11.7
416.5	18.9	16.4
416	16.7	18.3
415.5	17.8	17.1
415	15.5	18.7
AVG	16.56	15.93
StDev	1.44	2.46
Prob(t)	.57	

DCP Results

Figure 8 illustrates an overlay of the DCP profiles from the widened subgrade with their corresponding DCP profile from the existing subgrade at stations 421, 420+70, and 418. These data illustrate no major differences in support in the upper portion of the widened subgrade as compared to the existing. The results agree with the FWD and indicate the subgrade widening is not offering inferior support as compared to the existing subgrade.

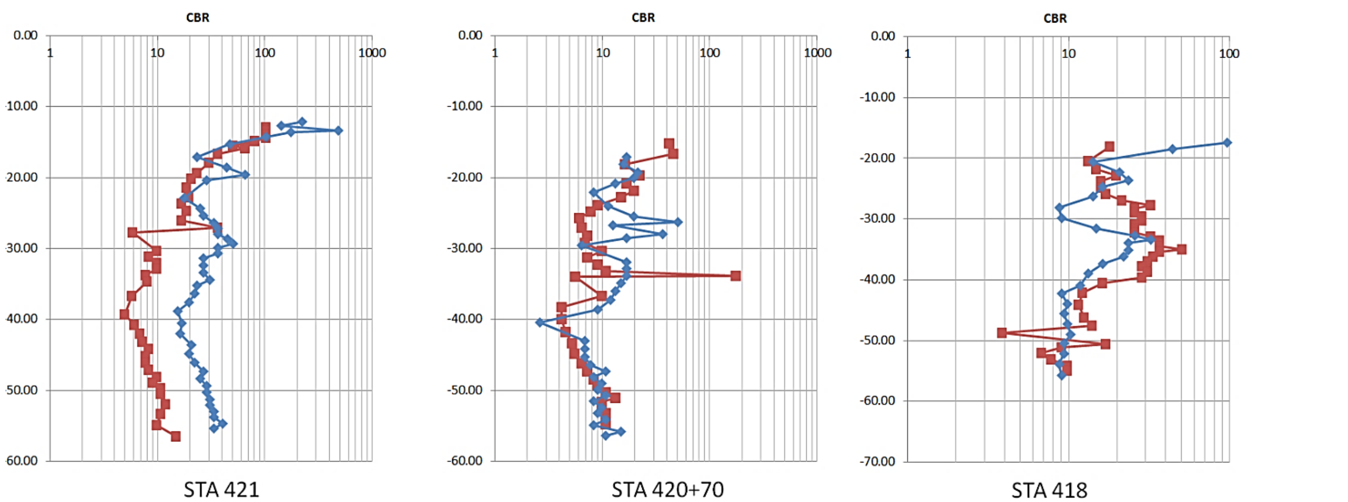

Figure 8. DCP Profiles Comparing Existing (Blue Line) and Widened (Red Line) Subgrade Support.

In addition to providing information to evaluate the adequacy of the ordinary compaction, the DCP data also serve to evaluate the originating cause of longitudinal cracking. Figure 9–Figure 11 illustrate DCP profiles from Stations 421, 420+70, and 418, all of which have longitudinal cracking distress. In each case, the DCP profile shows a localized significantly weak zone within the subgrade. The location of these localized weak zones in the DCP profile likely indicates the depth through which the longitudinal crack is passing through or originating.

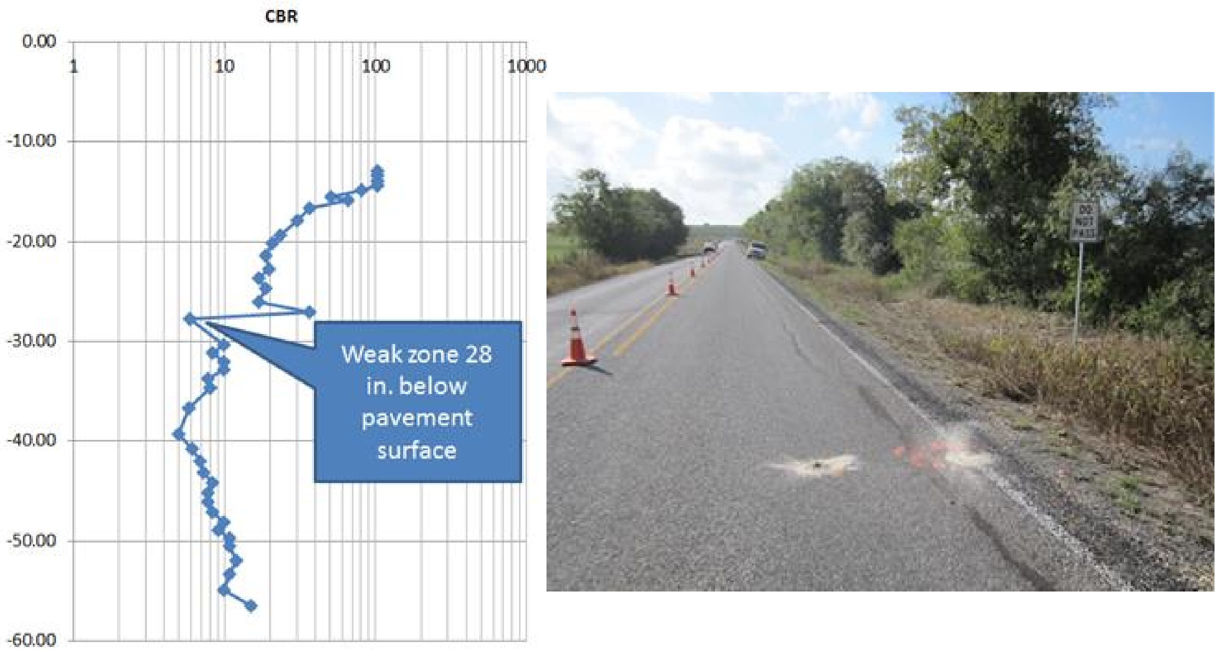

Figure 9. DCP Profile Showing Localized Weak Subgrade Zone at STA 421.
Note: DCP profile shown is from test conducted outside the crack on the white stripe.

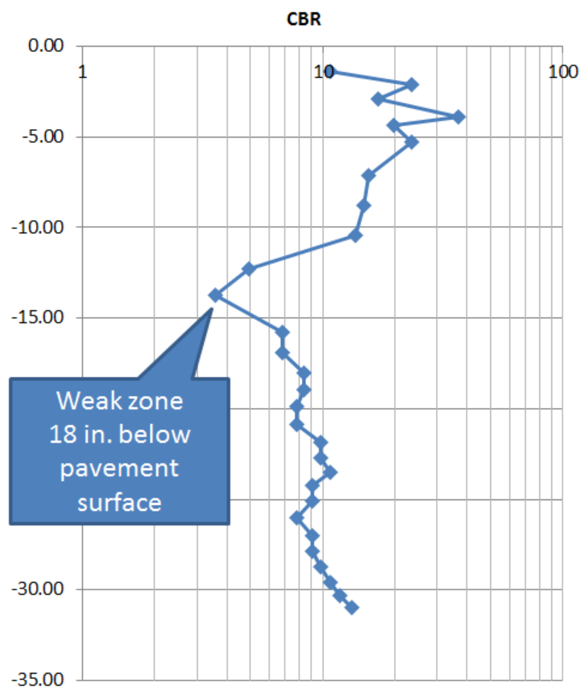

Figure 10. DCP Profile Showing Localized Weak Subgrade Zone at STA 420+70.
Note: DCP profile shown is from test conducted on the front slope, so the zero point on this DCP profile is ~ 4 in. below the pavement surface.

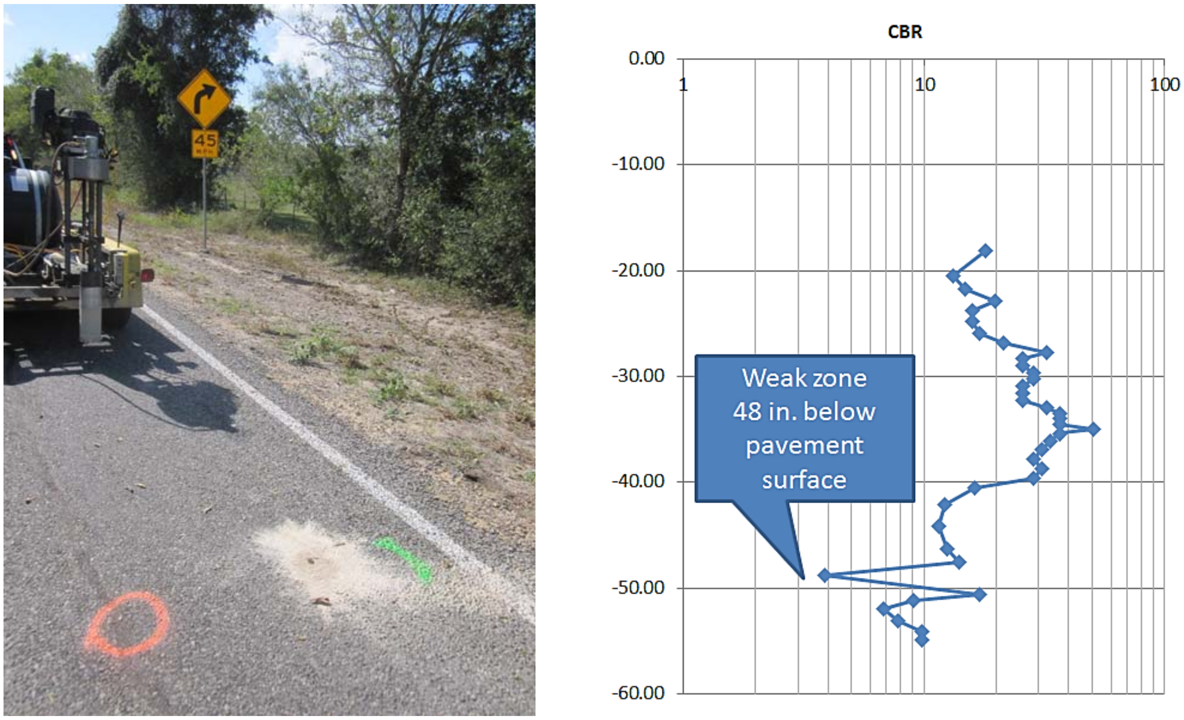

Figure 11. DCP Profile Showing Localized Weak Subgrade Zone at STA 418.

Note: DCP profile shown is from test conducted between longitudinal crack and white stripe.

Coring Results

TTI conducted coring directly over the longitudinal crack at Stations 421, 418, and 475. Figure 12 and Figure 13 show that at Stations 421 and 418 the crack clearly went through the entire depth of the Cement Treated Base (CTB) base. At Station 475, shown in Figure 14, the fines pumped out during coring, and no recoverable material existed after coring. Staff could not see the pathway of the crack in the core hole.

Figure 12. Coring Result at STA 421.

Figure 13. Coring Result at STA 418.

Figure 14. Coring Result at STA 475.

CONCLUSIONS AND RECOMMENDATIONS

The investigation of the cause of longitudinal cracking shows:

- Longitudinal cracks were observed in locations that do not appear within the limits of the contractor's subgrade work.
- The subgrade was a black clay and other pavements in the geographic area also exhibit non-load associated longitudinal cracking.
- Although the subgrade widening used ordinary compaction, data show the widened subgrade providing similar support to the existing.
- Several locations of longitudinal cracking distress show localized weak zones in the DCP profiles at depths from 12 to almost 50 in. below the pavement surface.
- Coring suggests the crack goes through the entire depth of the CTB base.

The data suggest the longitudinal cracking is bottom-up and caused by weak/shrink/swell subgrade soil behavior originating in some cases from as much as 4 ft below the pavement surface.

Due to the cause of the problem, for this project these cracks should be sealed and treated with appropriate maintenance treatments for non-load associated longitudinal cracking. In the future, potential ways to avoid recurring similar problems include:

- Perform more thorough pre-construction testing prior to project letting. Pre-construction testing can identify localized potential problem areas and help to define the risks of longitudinal cracking. High plasticity index soils, steep front slopes, narrow pavements, and vegetation with high water intake in close vicinity to the pavement all greatly increase the risk of longitudinal cracking.
- When high risk of longitudinal cracking exists, consider mitigation approaches including:
    - Construct a wider shoulder or wider stabilized layer with a membrane. This approach provides more edge support to the travel lane and results in moving the crack farther away from the travel lane.
    - Employ stress relief layers between the subgrade and the pavement surface. One approach with effective performance history is to use a geogrid directly on top of the stabilized layer, followed by a flexible base overlay and then the final surfacing. This approach may not totally eliminate cracking, but has been documented to provide substantial reduction in longitudinal cracking.
    - Consider the combined use of a crack-resistant thin overlay mix along with the geogrid and flexible base stress relief layers. Advances in asphalt mixture design have yielded mixes with much improved cracking performance.