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TXDOT PROJECT NUMBER 5-6005-01

STATEWIDE IMPLEMENTATION OF THE TOTAL PAVEMENT ACCEPTANCE DEVICE (TPAD)—FINAL REPORT

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16. Abstract

Construction and development of the Total Pavement Acceptance Device (TPAD) was completed at the end of August 2012 through TxDOT Research Project 0-6005-01. The TPAD is a multi-function pavement evaluation device used to profile continuously along pavements at speeds in the range of 2 to 3 mph. The multi-function features of the TPAD include (1) rolling dynamic deflectometer (RDD), (2) ground-penetrating radar (GPR), (3) distance measurement instrument, (4) high-precision differential global positioning system (GPS), (5) pavement surface temperature measurement, and (6) digital video imaging of the pavement surface and right-of-way conditions. TxDOT implementation Project 5-6005-01 was begun in mid-January 2013 and ended on August 31, 2014. The objective of the project was to implement the statewide use of the TPAD for project-level studies of the structural condition of pavements. During the 20-month period of Project 5-6005-01, the Center for Transportation Research (CTR) at The University of Texas at Austin (UT) and the Texas A&M Transportation Institute (TTI) alternately stored, maintained, and operated the TPAD and TPAD hauler. Personnel at each institute performed TPAD demonstration projects when specific TxDOT districts made requests. Ten TPAD demonstrations and eleven TPAD-level studies in eight districts were performed. The TPAD has been successfully used to evaluate the remaining life of current pavement, to help District engineers select optimum rehabilitation schemes, and to identify problematic areas over a wide range of pavements, such as hot mix asphalt, jointed concrete pavement, continuously reinforced concrete pavement, and composite pavement. In addition, the RDD functionality was improved during the project by replacing the sole air-pressure control system for the rolling sensors with three separate air-pressure control systems (one for each of the sensors), as well as by modifying and improving the towing frame used to position and raise/lower the rolling sensors.

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Disclaimers

Engineering Disclaimer

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Chapter 1. Introduction

1.1 Introduction of TxDOT Project 5-6005-01

The objective of TxDOT Project 5-6005-01 was to implement the statewide use of the Total Pavement Acceptance Device (TPAD) for project-level studies of the structural condition of pavements. The objective was pursued by performing TPAD demonstration projects requested by TxDOT Districts around the state and providing technical advice to district pavement engineers. Implementation Project 5-6005-01 was begun in mid-January 2013 and ended on August 31, 2014. Project 5-6005-01 was a joint effort between researchers at the Center for Transportation Research (CTR) at The University of Texas at Austin and at the Texas A&M Transportation Institute (TTI). The research supervisor was Dr. Kenneth Stokoe at CTR and the lead researcher at TTI was Mr. Thomas Scullion.

The TPAD is a multi-function nondestructive pavement testing device that can be used to continuously assess pavement structural conditions. The TPAD was developed through Project 0-6005-01. The multi-function features of the TPAD include (1) rolling dynamic deflectometer (RDD), (2) ground-penetrating radar (GPR), (3) distance measurement instrument, (4) high-precision differential global positioning system (GPS), (5) pavement surface temperature measurement, and (6) digital video imaging of the pavement surface and right-of-way conditions. The TPAD is presented in Figure 1.1. Currently, three RDD rolling sensors are used for TPAD deflection measurements. These three rolling sensors are positioned in an array along the longitudinal centerline of the TPAD. The array of the rolling sensors is shown in Figure 1.2. The sensors are named according to their relative locations to the loading rollers. The center sensor is located mid-way between the two loading rollers while the front sensor and the rear sensor are located in front of and behind the center sensor at a distance of about 2.1 ft. Over the project's duration, the TPAD was used on eleven project-level studies in eight districts. These projects are briefly reviewed in this report.

1.2 Activities during Project 5-6005-01

During the 20-month period of Project 5-6005-01, CTR and TTI shared responsibility for the TPAD and TPAD hauler. The TPAD and TPAD hauler were stored, maintained, and operated from mid-January 2013 through April 2013 by CTR, and then by TTI personnel from May 2013 to March 2014. The TPAD and TPAD hauler were then moved back to CTR in April 2014 and were stored, maintained, and operated by CTR personnel through the end of the project.

Whenever they were in possession of the TPAD, personnel at each institute performed TPAD demonstration projects wherever requests from specific TxDOT Districts were made. A total of ten TPAD presentations and demonstrations and eleven TPAD project-level studies were performed. Several TPAD presentations and demonstrations concerning TPAD operations and data analyses were given. Some of these occurred during symposia or short courses at CTR and TTI. In-depth demonstrations were generally performed in the districts where the TPAD implementation testing was conducted.

Representative data and results of the TPAD implementation testing performed from January 2013 through August 2014 are discussed in Chapter 2. Improvements made to the RDD functionality are presented in Chapter 3. Finally, conclusions are presented in Chapter 4.

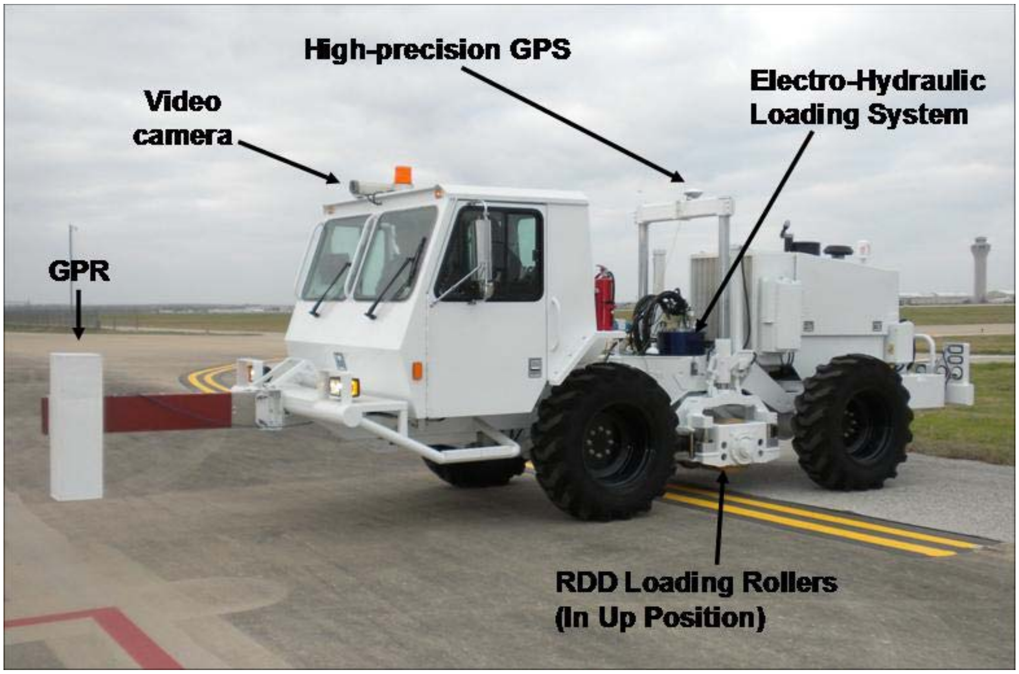


Figure 1.1: The TPAD (from Stokoe el al., 2011)

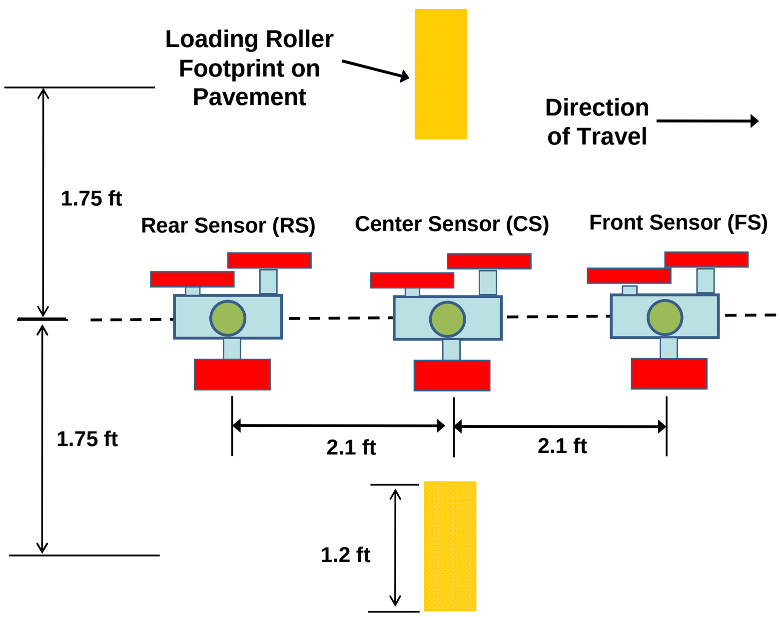


Figure 1.2: Footprint on the Pavement of the Current Array of Three RDD Rolling Sensors and Two Loading Rollers during TPAD Testing (from Stokoe el al., 2013)

Chapter 2. TPAD Implementation Testing

2.1 Introduction

Personnel from CTR and TTI performed TPAD implementation testing as requested by various TxDOT Districts. This chapter presents representative testing results and data interpretations.

2.2 Case 1: San Marcos Airport in February 2013

TPAD testing was performed at San Marcos Airport in coordination with Mr. Edward Oshinski at the TxDOT Aviation Division on February 19 and 20, 2013. Two runways, Runways 8/26 and 13/31, have asphalt surface layers. Four of the eight lanes of Runway 8/26 were profiled. However, the signals from the center sensor were not clear because of an inadequate connection between a connecting cable and the sensor. This problem was subsequently fixed. However, the other two rolling sensors performed well and supported adequate data. Two deflection profiles collected on Lanes 3 and 4 are shown in Figures 2.1 and 2.2, respectively. Testing was begun from the east end of the runway for Lane 3 and the west end of the runway for Lane 4. The deflection data collected along the two lanes show relatively small deflections, generally less than 7 mils per 10 kips of loading, indicating that the pavements are sound.

TPAD testing on Runway 13/31 was performed only on Lane 6 because of rain. The deflection data collected on Lane 6 of Runway 13/31 are shown in Figure 2.3. The deflections are generally low, with the exception of a 1000-ft long section between 3500 and 4500 ft from the northwest end of the runway. However, this 1000-ft section exhibits average deflections less than 10 mils per 10 kips of load, which indicates that this section of pavement is also structurally sound.

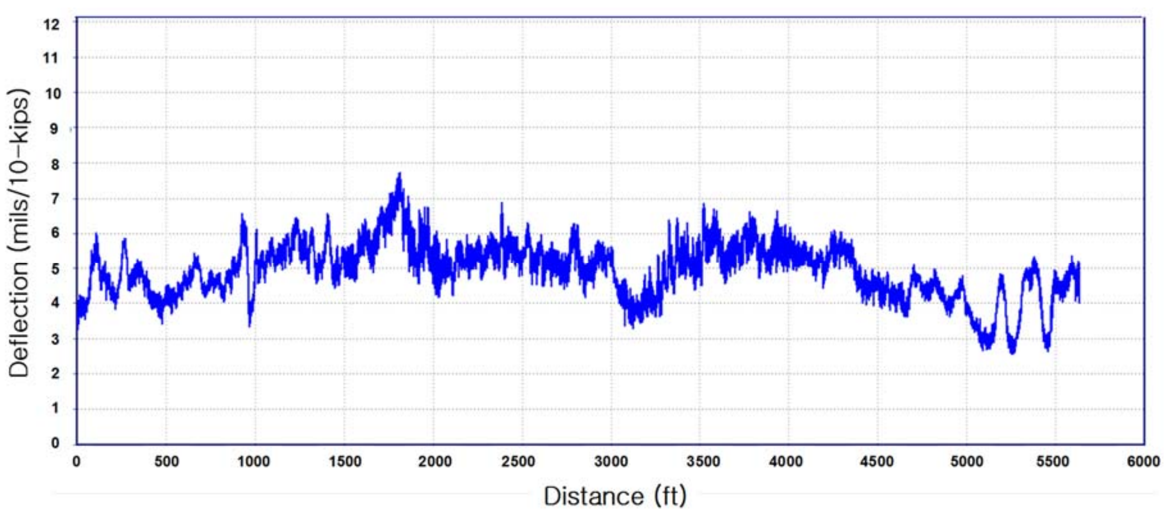


Figure 2.1: Deflection Profile Collected on Lane 3 of Runway 8/26 with the Center Sensor

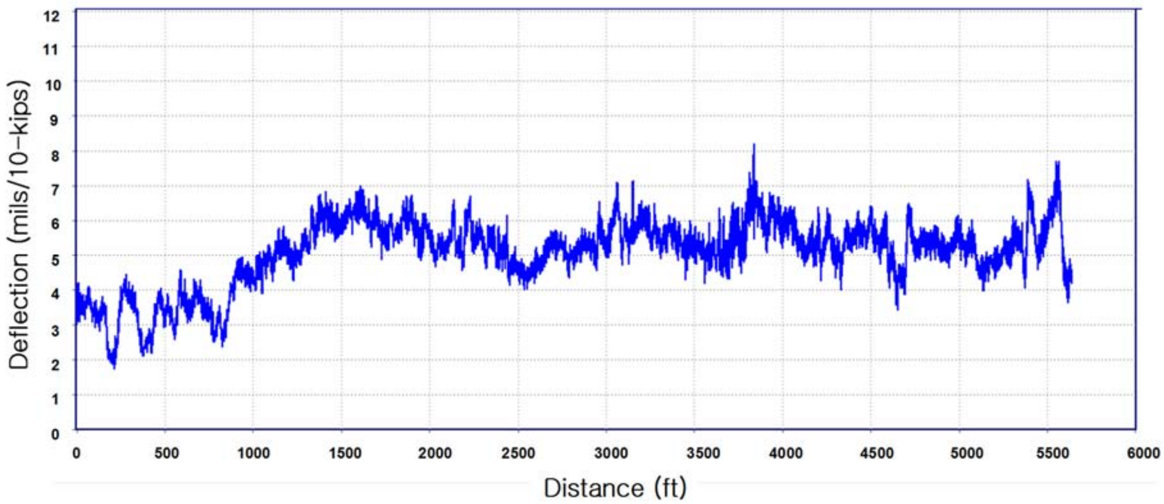


Figure 2.2: Deflection Profile Collected on Lane 4 of Runway 8/26 with the Center Sensor

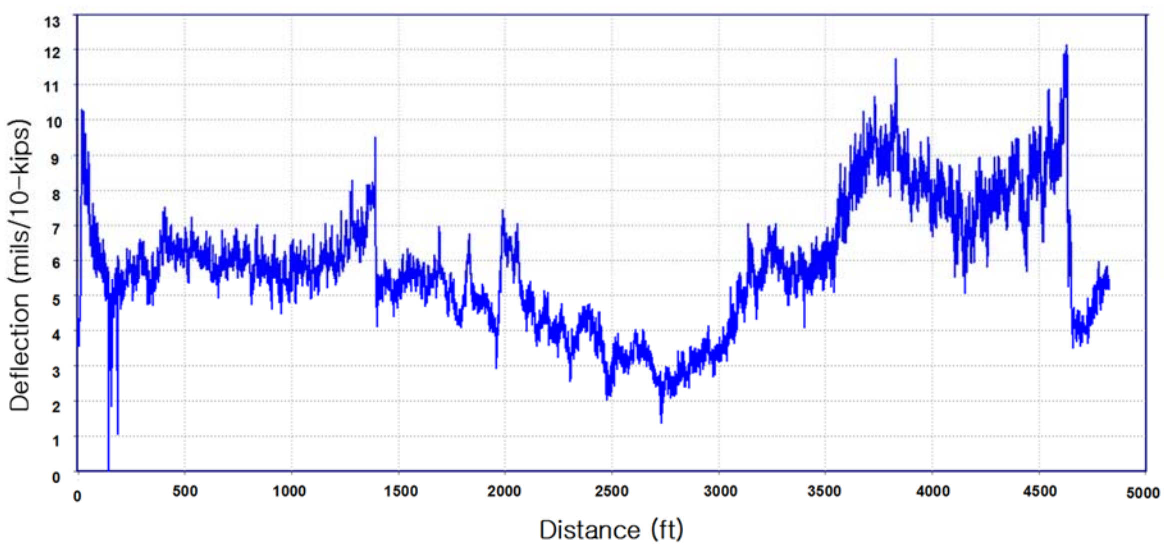


Figure 2.3: Deflection Profile Collected on Lane 6 of Runway 13/31 with the Center Sensor

2.3 Case 2: Interstate Highway 10 in El Paso in April 2013

In April 2013, TPAD testing was requested by the El Paso District as part of a corridor study. The corridor-study testing consisted of TPAD testing, GPR measurements, MIRA (ultrasonic tomography device) measurements, and pavement coring. The purpose of the testing was to determine the remaining life of the Interstate Highway (IH) 10 pavement and help develop any required rehabilitation schemes. The pavement at the site consists of a 6-in.-thick continuously reinforced concrete pavement (CRCP) overlaid on an 8-in.-thick original concrete pavement. TPAD testing was performed on the following three sections: (1) an eastbound section from Exits 19 to 23, (2) a westbound section from Texas Reference Markers (TRMs) 24 to 20, and (3) a westbound section from TRMs 38 to 34. The third section (westbound from TRMs 38 to 34) was tested as a reference section because it showed good performance and was relatively recently constructed. The inside lanes of all three sections were profiled. Additionally, the middles lanes of Sections #1 and #2 were tested. The TPAD profiling along IH 10 at night is shown in Figure 2.4.

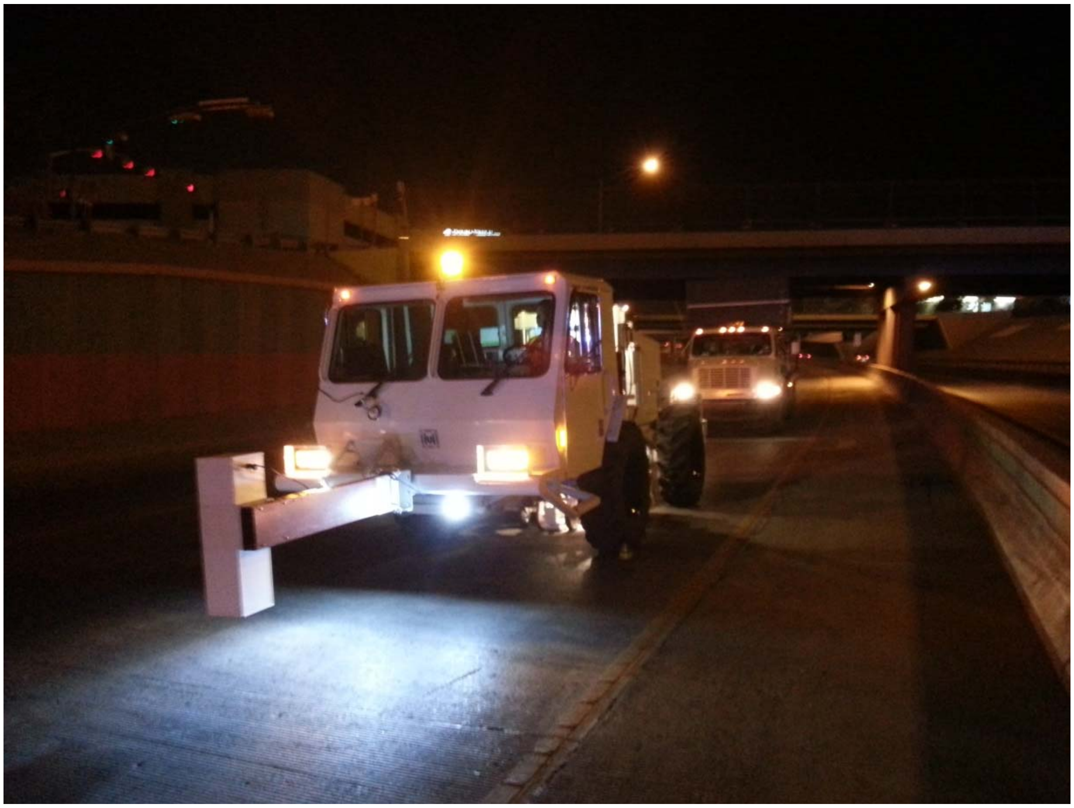


Figure 2.4: TPAD Profiling at Night along IH 10 in El Paso, TX

The deflection profile (Figure 2.5 [a]), GPR profile (Figure 2.5 [b]), and video image (Figure 2.5 [c]) collected on the good section (westbound from TRMs 38 to 34) are shown in Figure 2.5. Two figures (Figures 2.5 [d] and 2.5 [e]) next to the video image are expanded deflection profiles around the vertical red line in the first deflection profile (Figure 2.5 [a]). Deflections are low in this section, with deflections averaging around 1.5 mils/10 kips. The two large peaks around a distance of 13,000 ft are from the bridge approaches, on the arriving and departing slabs.

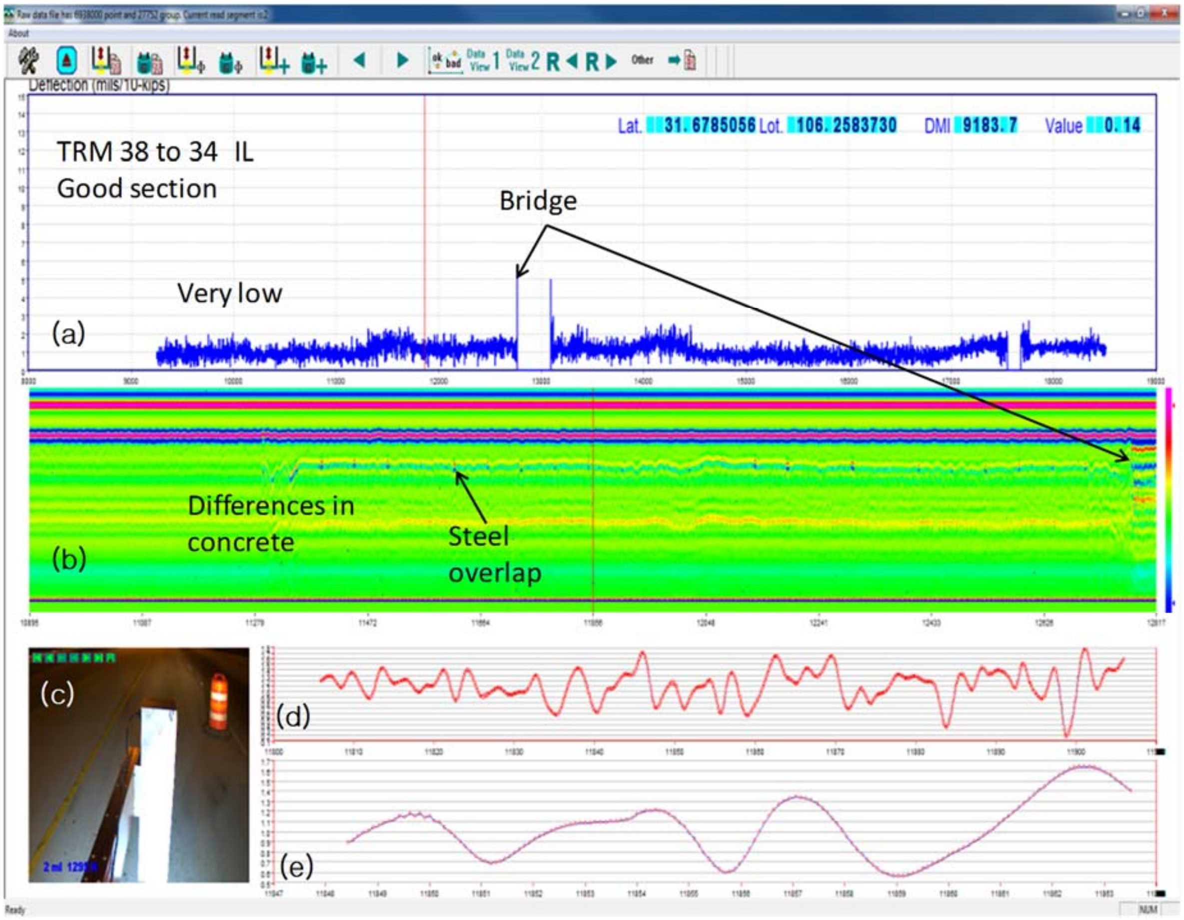


Figure 2.5: Deflection Profile, GPR Profile, and Video Image Collected on Reference Section (The "Good" Section), Westbound from TRM 38 to TRM 34: (a) TPAD, RDD Data, (b) TPAD, GPR Data, (c) TPAD Video Image, (d) Expanded RDD Data from Figure 2.5 (a) at the Red Line, and (e) Additional Expansion of RDD Data of the Red Line in Figure 2.5 (a)

The deflection profile, GPR profile, and video image collected on the middle lane of the eastbound section from Exits 19 to 23 are shown in Figure 2.6. It is interesting to see the large deflections in a section approximately 2000 ft long. These large deflections were a surprise since this section did not exhibit structural problems. This section was found by continuous deflection profiling and clearly indicated delaminations. The data collected on the inside lane also exhibited the same pattern but a representative figure is not shown in this report.

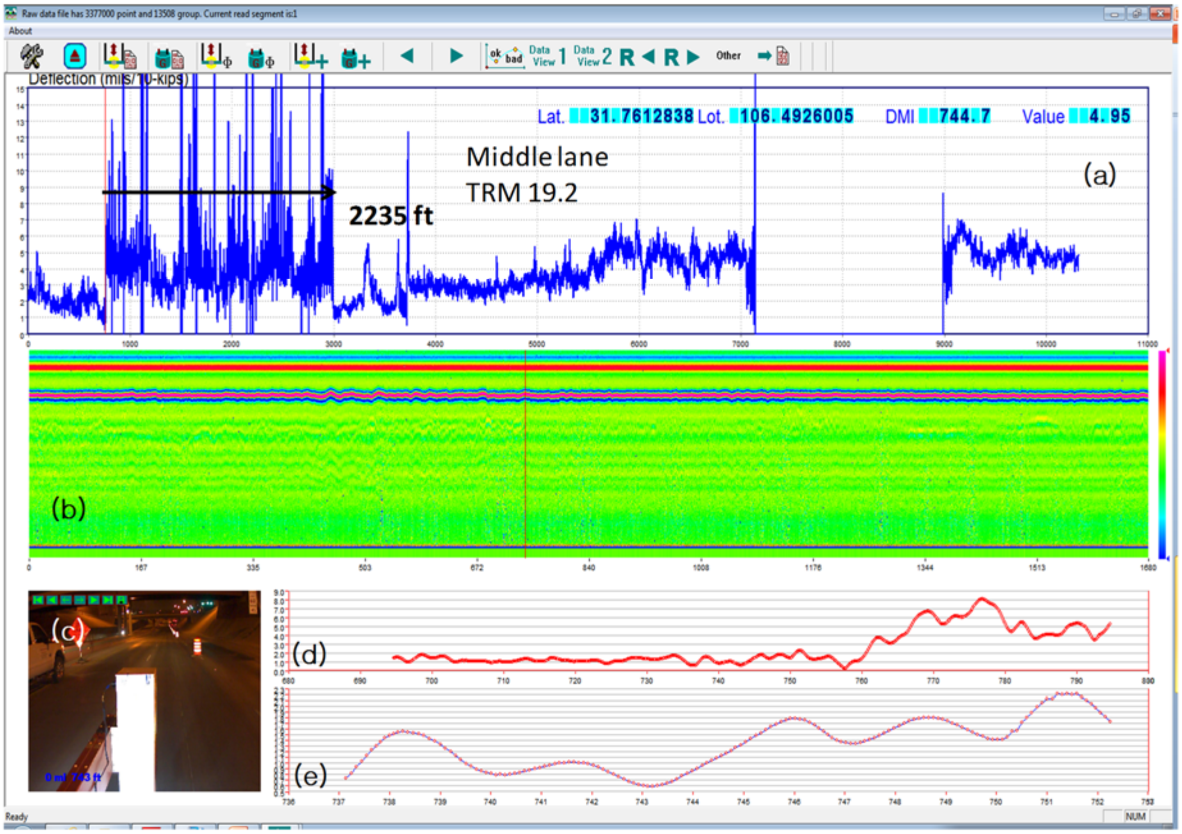


Figure 2.6: Deflection Profile, GPR Profile, and Video Image Collected on the Middle Eastbound Lane from Exits 19 to 23: (a) TPAD, RDD Data, (b) TPAD, GPR Data, (c) TPAD Video Image, (d) Expanded RDD Data from Figure 2.6 (a) at the Red Line, and (e) Additional Expansion of RDD Data of the Red Line in Figure 2.6 (a)

The deflection profile, GPR profile, and video image collected on the middle westbound lane from TRMs 24 to 20 are shown in Figures 2.7 (a), 2.7 (b), and 2.7 (c), respectively. The expanded RDD profiles are shown in Figures 2.7 (d) and 2.7 (e). A void under the concrete slab is shown in the GPR profile at the location marked in Figures 2.7 (a) and 2.7 (b). The void causes the large peak in the deflection profile.

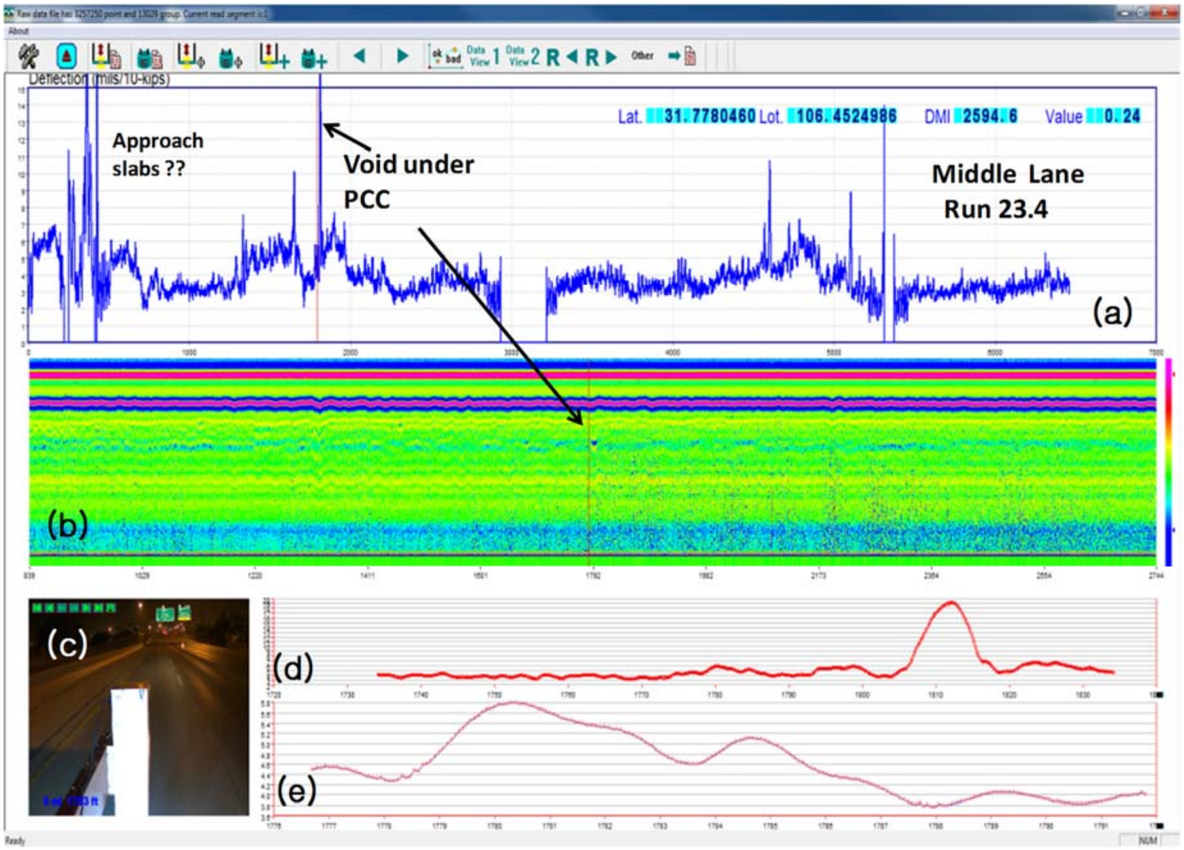


Figure 2.7: Deflection Profile, GPR Profile, and Video Image Collected on the Middle Westbound Lane from TRM 24 to TRM 20: (a) TPAD, RDD Data, (b) TPAD, GPR Data, (c) TPAD Video Image, (d) Expanded RDD Data from Figure 2.7 (a) at the Red Line, and (e) Additional Expansion of RDD Data of the Red Line in Figure 2.7 (a)

2.4 Case 3: US 75 in the Paris District in June 2013

Mr. Wade Blackmon, PE, a District Pavement Engineer, was the point of contact for TxDOT's Paris District. TPAD testing was performed along a 10-mile-long section of US 75, starting in Sherman and running north for 10 miles. The pavement has four lanes in each direction. The concrete pavement is a combination of both jointed concrete pavement (JCP) and CRCP. This highway is the major connector between the City of Dallas and the State of Oklahoma. The representative pavement condition is shown in Figure 2.8. The pavement is badly distressed, with many slabs needing to be replaced and many areas with moisture trapped beneath the slabs. However, the funding for the major reconstruction is not anticipated in the near future, so innovative treatments to keep this highway operational for the next 10 years need to be investigated.

Figure 2.8: Badly Distressed Section of US 75 Just North of Sherman, TX

The first objective of TPAD testing was to collect and interpret the TPAD's RDD deflection data for the section from TRM 202 to the existing bonded concrete overlay. This pavement is a 0.5-mile-long section and the District was planning to place a concrete overlay adjacent to the current bonded overlay in 2014. The District wanted to identify joints that should be repaired prior to placing the new overlay. The second objective is to collect TPAD data on as much of US 75 as possible so that the data can be used in Fiscal Year (FY) 2014 in other corridor analysis studies to identify problematic areas and plan repair options for this major highway. Approximately 12 lane miles of data were collected.

The data collected on the proposed bonded concrete pavement section are shown in Figure 2.9. The upper plot, Figure 2.9 (a), shows the deflection profile in terms of maximum TPAD deflection normalized to 10,000 lb. The deflection profile covers about 1.1 miles and includes the proposed test section, which is delineated by the two vertical red lines in Figure 2.9 (a). From these data, eight localized joints of high deflection were identified for further evaluation. These joints are potential locations where reflective cracks could occur in the new overlay. The GPS coordinates, distance from the start of the section, and a photograph of each high-deflection joint were provided to Paris District personnel for their evaluation. The other item of interest in Figure 2.9 is the zone bounded by the black lines in Figure 2.9 (b) (GPR profile). The key point in this zone is near the top of the base and beneath the portland cement concrete (PCC) slab. This zone, about 800 ft long, represents areas of trapped moisture beneath the PCC slab.

The TPAD was successful in detecting problem joints on this highway, and the remainder of the data collected is being used in ongoing corridor analysis studies to plan other rehabilitation options for this major route.

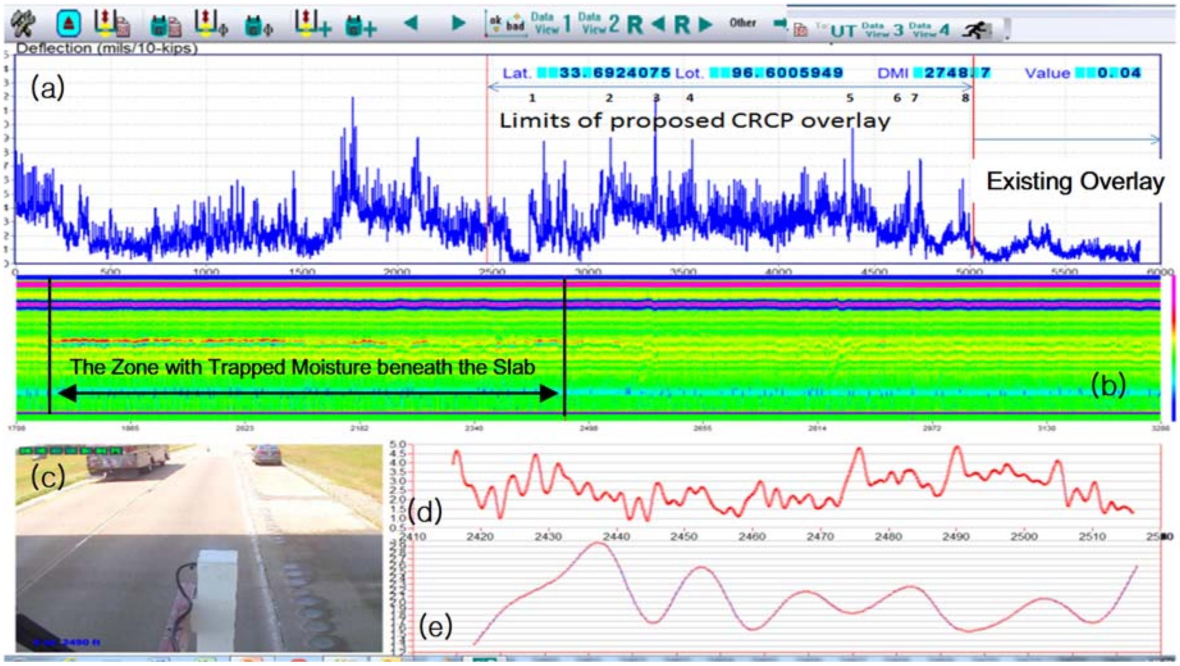


Figure 2.9: Deflection Profile, GPR Profile, and Video Image Collected over Proposed Concrete Overlay Section on US 75 in the Paris District: (a) TPAD, RDD Data, (b) TPAD, GPR Data, (c) TPAD Video Image, (d) Expanded RDD Data from Figure 2.9 (a) at the Red Line, and (e) Additional Expansion of RDD Data of the Red Line in Figure 2.9 (a)

2.5 Case 4: Interstate Highway 10 in El Paso in July 2013

Mr. Tomas Saenz, PE, the District Pavement and Lab Engineer, was the contact for the El Paso District. The District requested a full corridor analysis of IH 10 from TRM 14 to TRM 38, to determine the remaining life and the rehabilitation requirements. In the first visit to El Paso District discussed in Section 2.3, TPAD data were collected on two lanes of the depressed section close to TRM 19. In the TPAD testing during the second visit in July 2013, the following additional sections were investigated:

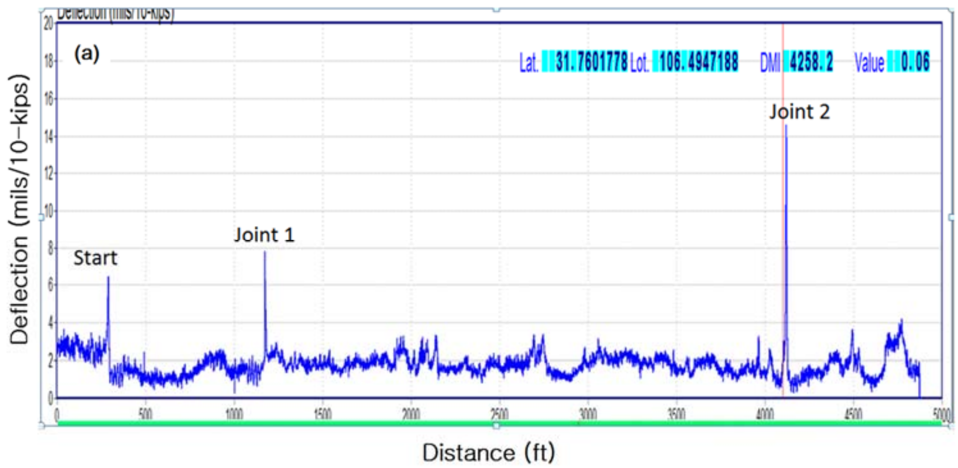
(1) TRMs 19 to 20; eastbound outside lane,

(2) TRMs 20 to 19; westbound all three lanes, and

(3) TRMs 27 to 25.5; two lanes in each direction.

Delaminated concrete was found in the two eastbound inside lanes around TRM 19.5 in April 2013. The testing conducted in July was to investigate the other four lanes in this area to determine if they have any significant structural deficiencies. The RDD deflection profile collected on the outside westbound lane from TRMs 20 to 19 is shown in Figure 2.10 (a). As the figure depicts, the deflections were found to be low, averaging about 2 mils/10 kips; hence, no structural deficiencies were found in this location. Only two areas of high deflections were found in these tests, which occurred at longitudinal construction joints. No structural defects were found in any of the additional lanes tested from TRMs 19 to 20. This finding led to the recommendation of replacing only the debonded concrete overlay. The photograph showing the problematic joint (Joint 1 in Figure 2.10 [a]) is shown in Figure 2.10 (b).

With a visual survey, the section with maintenance problems that fell in this portion of the IH 10 corridor study is near longitudinal construction joints where substantial repairs have already been made (patches seen in Figure 2.11) from TRMs 25.5 to 27. A photograph showing the longitudinal construction joints with repairs is presented in Figure 2.11. The initial distress is a crack that runs parallel and about 1 ft away from the longitudinal joint. Such cracks continue to deteriorate, becoming localized punch-outs, and then patching or other repairs are necessary. Observations made during field repairs and from discussions with maintenance personnel indicated that these are partial depth failures.



(a)

(b)

Figure 2.10: TPAD Testing along IH 10: (a) Deflection Profile Collected on Outside Westbound Lane from TRMs 20 to 19 and (b) Photograph Showing the Problematic Joint (Joint 1 in Figure 2.10 [a])

Figure 2.11: Distressed and Repaired Areas on IH 10 from TRMs 25.5 to 27

To determine the cause of these problems, TPAD RDD deflection testing was performed along the center of the slab and falling weight deflectometer (FWD) deflections were taken close to the joint. The FWD testing also included measurements of load transfer efficiency (LTE) over the failing joint. The deflection profile collected in this area is shown in Figure 2.12. As shown in the figure, no major high deflection areas were detected in the TPAD deflection data collected along the longitudinal centerline of the slab between TRMs 25.5 and 27, except for the one peak on an approach slab on a bridge deck.

The FWD testing revealed that the LTEs along the failing joint on the eastbound section were variable and, in many cases, less than 60%. From the deflection data collected with the TPAD and FWD, it was concluded that these problems are related to the longitudinal construction joints and are not associated with any overall deficiency in the pavement structure. Additional work is planned to evaluate the joint design details of the failing joints.

The condition of the westbound section of TRMs 25.5 to 27 is similar to the eastbound section. However, more maintenance repairs have been made in the westbound direction. The joint exhibiting the problem is a wide joint—specifically, a "keyed joint" with no tie bars, which is a design no longer used in Texas. Requests have been made to get schematics of the joint configuration used but this information appears to be no longer available. Figure 2.13 shows the TPAD data collected in the center lane, and again absolutely no strength or support problems appeared in the middle of the lane. The peaks in the deflections are either at approach slabs or at construction joints, as shown in the photo in the upper right of Figure 2.13. However, the LTEs by FWD testing are troublesome; long sections of the westbound direction have LTE values less than 40%.

In conclusion, TPAD deflection data were successfully used to identify defective areas on the IH 10 corridor—in particular, debonded slabs between TRMs 19 and 20. Combined TPAD and

FWD testing demonstrated clearly that the distress occurring between TRMs 25.5 and 27 was related to joint design and not a symptom of an overall structural deficiency.

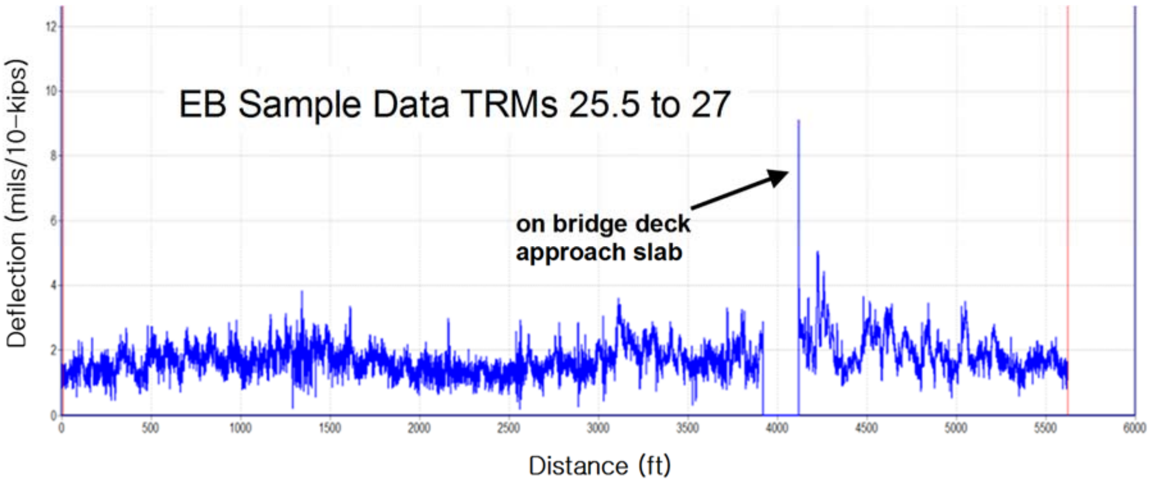


Figure 2.12: Low Center-Slab Deflections on Eastbound of IH 10 from TRMs 25.5 to 27

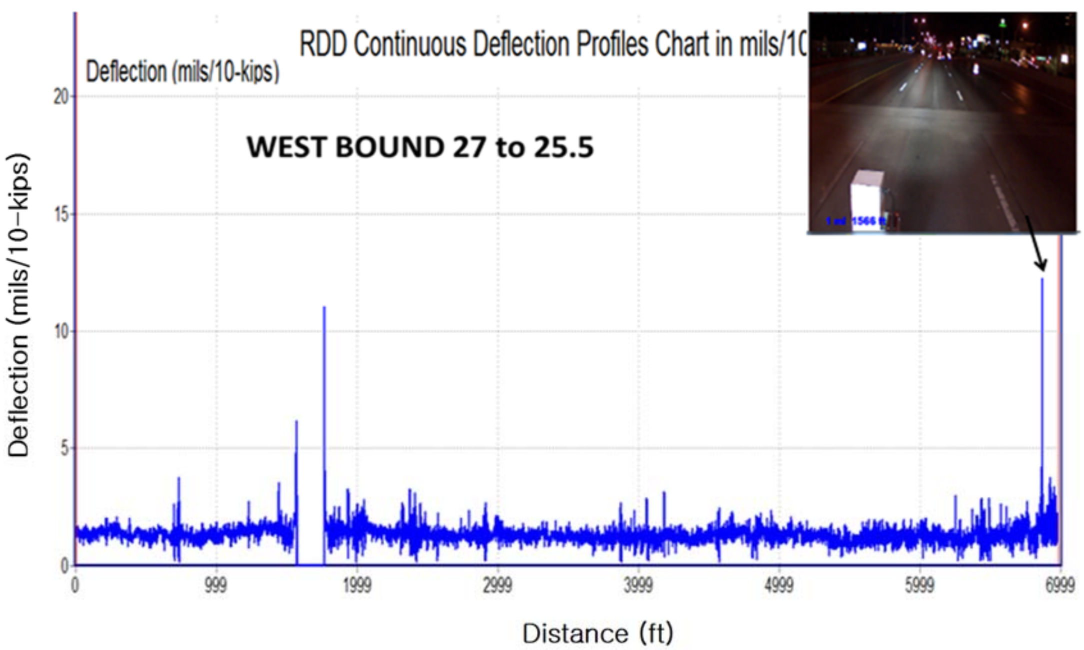


Figure 2.13: Low Center-Slab Deflections on Westbound of IH 10 from TRMs 25.5 to 27

2.6 Case 5: US 59 Frontage Road in Houston in August 2013

The District Contact in this project was Ms. Beata Kwater, PE, from the West Harris Area Office. The district requested TPAD testing to determine if the frontage road with JCP is a good candidate for a thin overlay. The concern is that the joints on this highway have poor LTE and that reflection cracks will occur quickly in this section. The section runs from Beltway 8 to Bissonett Road. The pavement section is about one mile long and the construction is planned in early 2014.

Representative TPAD data are shown in Figure 2.14. The deflection profile is shown in Figure 2.14 (a). In general, the deflections are relatively low compared to deflections collected on other JCP sections. It was, therefore, concluded that this section is overall a good candidate for a thin overlay. However, it was also concluded that approximately seven joints in each direction need further evaluation. One of the joints requiring more evaluation is shown in Figure 2.14 (b). The location of this joint is identified by the vertical red line in Figure 2.14 (a).

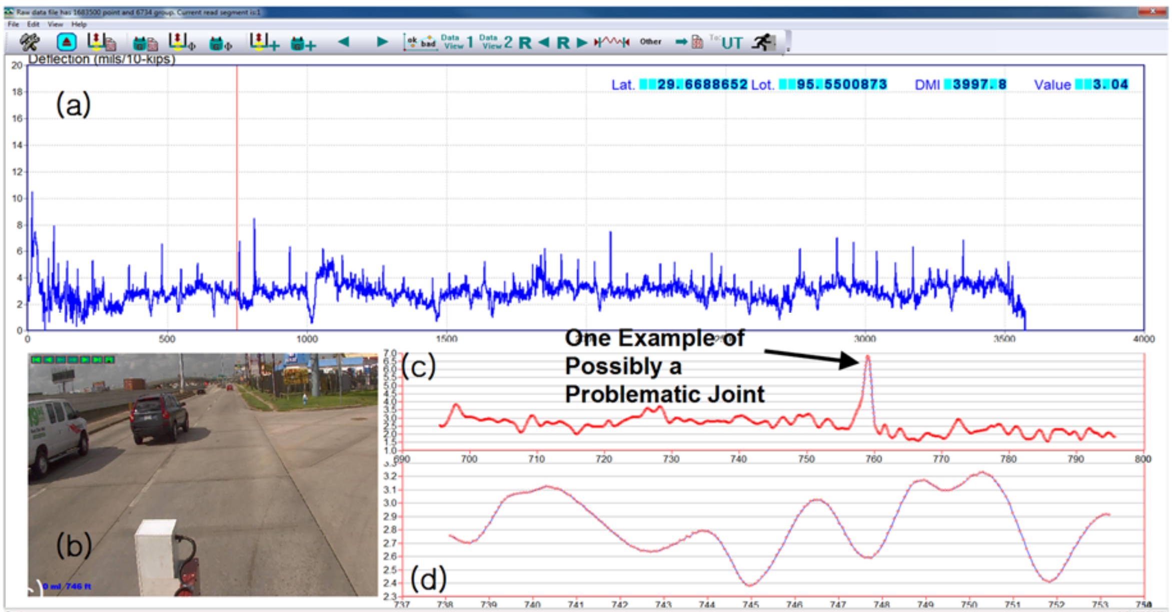


Figure 2.14: Deflection Profile and Video Image Collected on US 59 Frontage Road in Houston: (a) TPAD, RDD Data, (b) TPAD Video Image, (c) Expanded RDD Data from Figure 2.14 (a) at the Red Line, and (d) Additional Expansion of RDD Data of the Red Line in Figure 2.14 (a)

Further testing of this area will include FWD testing of the problematic joints, about seven in each direction. Those joints found to be substandard, with LTEs less than 60%, will be recommended for saw and seal repair. The TPAD testing was able to assist the Houston District in determining the suitability of this JCP for a thin asphalt overlay.

2.7 Case 6: US 59 Frontage Road in the Houston District in December 2013

TTI was asked to test the frontage roads of US 59 to determine if this JCP was a candidate for a thin overlay. The section runs from Loop 610 to Beltway 8, a distance of over 7 miles. The main lanes of US 59 have recently received a high performance thin overlay and the Area Office wanted to know if the same treatment was appropriate for the frontage roads. The big difference was that the main lanes are CRCP and the frontage roads are JCP.

It was recommended that the TPAD be run to determine the LTE of all the existing joints and cracks. If there were many suspect joints, a simple asphalt overlay would not be a good solution for this highway. The TPAD collecting data on this highway is shown in Figure 2.15.

Figure 2.15: TPAD Testing US 59 Frontage Roads

The typical maximum deflection pattern for the TPAD is shown in Figure 2.16. The start location was just north of Beltway 8. The location of the intersection with Bissonett is marked in the figure. The deflections before Bissonett Road were judged to be relatively low, with few deflections increasing to more than 6 mils. Earlier studies within TxDOT and with other projects have found that this level of deflection is judged to be reasonable for good performance from a thin HMA overlay.

Figure 2.16: Typical Maximum Deflection Pattern on the Section from BW 8 to Bissonett

In the section before Bissonett is just one joint with a high deflection; this is marked in the data at 3526 feet from the start of the project. The deflection at this location is also plotted in the lower figure; over this joint the deflection increases to over 13 mils. With a major increase such as this, a reflection crack would likely occur quickly at this location. However, this is just one problematic joint in almost 5000 feet of pavement. Except for the section described below, the rest of the data indicated similar deflection patterns. The entire run was almost 15 miles long with over 3000 joints. From a review of the TPAD data, it was concluded that there were just over 100 problem joints like the one shown in Figure 2.16. These data were presented to the Area Office personnel and it was decided to proceed with the thin overlay project while making adjustments for the joints identified as suspect. In this case, the Area Office asked if TTI could identify all of the suspect joints so that a “saw and seal” operation could be undertaken at those joints. To accomplish this, the GPS coordinates of each problem joint were reported and a photo of each location provided. One of these locations is shown in Figure 2.17. As stated, just over 100 of these locations were identified. This thin overlay project has been let and construction will be underway in the fall of 2014. The entire project consists of localized joint repair, hot rubber under-seal, 1 inch of thin overlay mix, and then a saw and seal operation over the identified problematic joints.

Figure 2.17: One Joint with High Deflection Scheduled for a Saw and Seal Operation

However, one real problem area was identified in the short section from Bissonett Road to South Gessner in the northbound direction. The very high deflections in this location are shown in Figure 2.18, where the deflections are over 20 mils at points along the section. These very high deflections are on either side of a bayou, and it was reported that TxDOT had already completed some void filling projects at this location. The bayou is represented in Figure 2.18 as the gap in the deflection plot, as no deflection data was collected over the bridge deck. Just after the bridge is a section of very low deflection; after that is what appears to be additional voided areas.

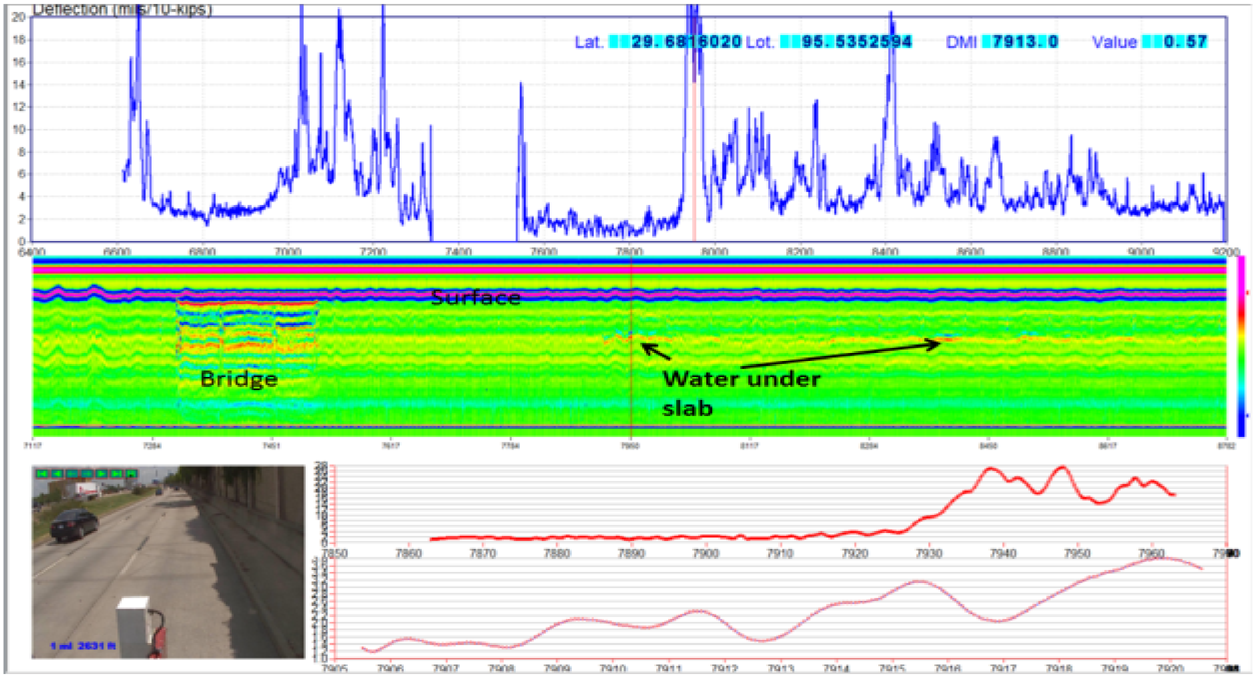


Figure 2.18: TPAD Data from Bissonett to South Gessner, Problematic Section

In total, six locations were identified to the Area Office as areas that need to be investigated prior to placing a thin overlay on this section. This work is currently underway.

2.8 Case 7: US 59 in the Atlanta District in January 2014

The TPAD was used to inspect a short section of US 59 that was still under construction in the Atlanta District. The District suspected that the fill material placed over the newly installed culvert had settled, resulting in a void being formed under the newly placed CRCP pavement. The location of the problem is shown in Figure 2.19.

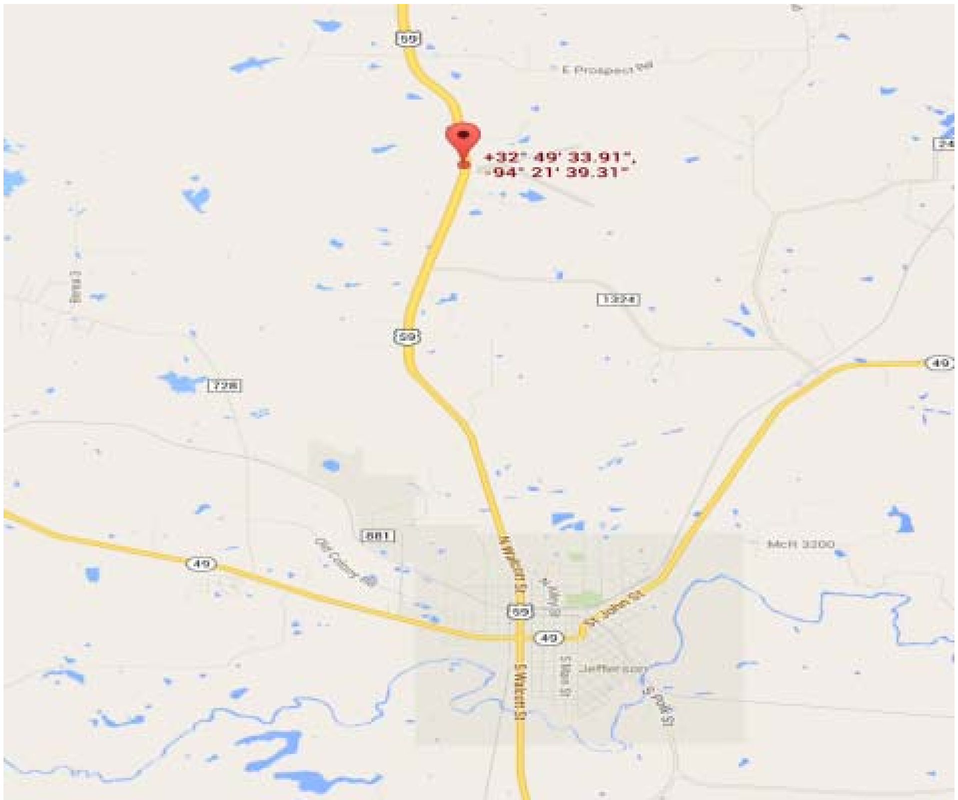


Figure 2.19: Test Location of Suspected Void (4.7 Miles North of Jefferson)

The data collected with the TPAD over this suspect location is shown in Figure 2.20. As with other new CRCP pavements, the measured deflections are very low—in the 1 to 2 mils range. However, over the suspect location, measurements from all three TPAD sensors increased substantially. In the middle of the voided area, an access hole was drilled; the researchers found that the material had indeed settled. Directly under the slab was a 2-inch void, then 3 inches of hot mix asphalt (HMA); below that was another 6-inch air void. The total width of the suspect area was estimated to be 35 feet.

This section was repaired by the contractor, the concrete was removed, the fill material was re-compacted, and the slab was replaced.

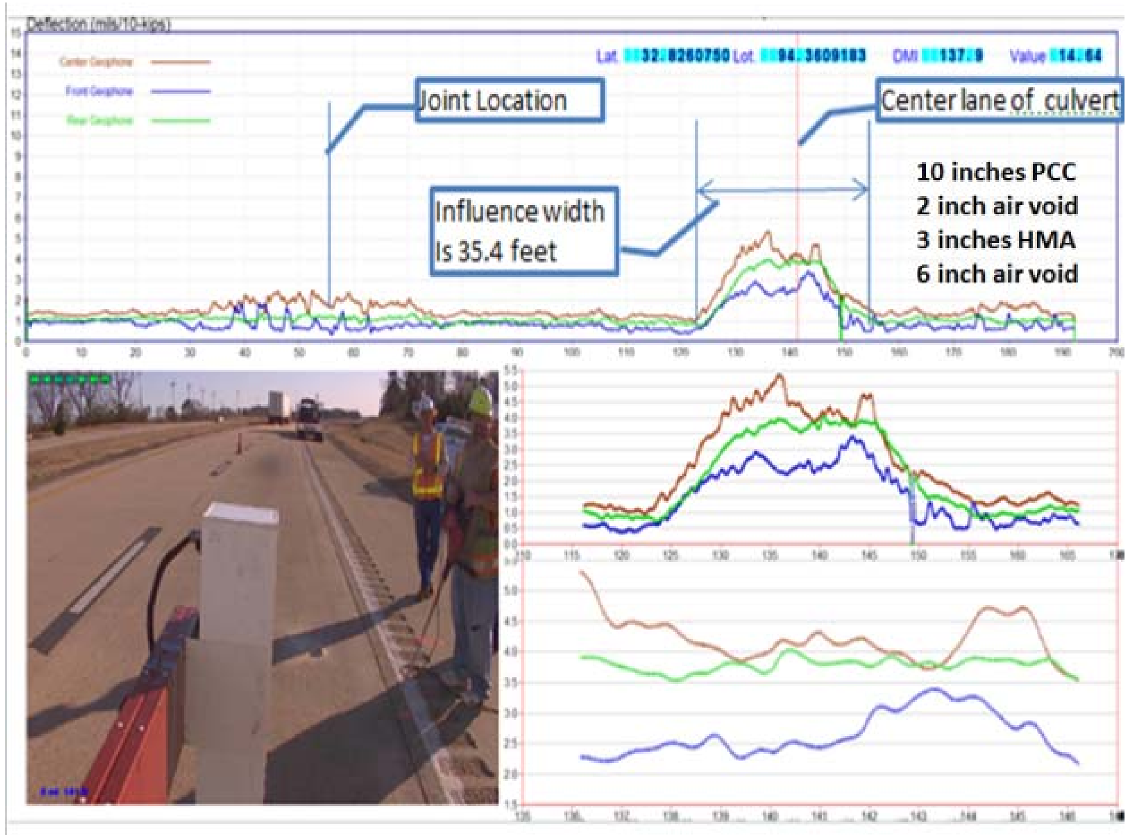


Figure 2.20: TPAD Deflection Data Collected over a Section with Suspected Voids beneath the Concrete

2.9 Case 8: SH 6 in the Childress District in March 2014

TTI performed analysis of SH 6 from US 287 to 6.1 miles south to explore rehab options for this pavement. The investigation included deflection testing, GPR survey, and digital video with the TPAD, and a follow-up site visit consisting of coring and dynamic cone penetrometer (DCP) tests. Analysis of the results focused on whether rubblization would offer a feasible rehab option for this pavement section.

Rubblization has been problematic in the Childress District in the past. Localized wet spots beneath the slab can cause inadequate slab breakage; in one case, major failures occurred under the asphalt laydown machine caused by slab rotation. To be a good candidate for rubblization, the amount and severity of weak areas need to be defined. The TPAD was used to test the entire project and locate areas of high deflection. Figure 2.21 shows representative TPAD data. The pavement has 3 to 4 inches of HMA with a 9-6-9 jointed concrete slab. The brown plot in Figure 2.21 is the maximum deflection profile under the normalized 10,000 lb. load.

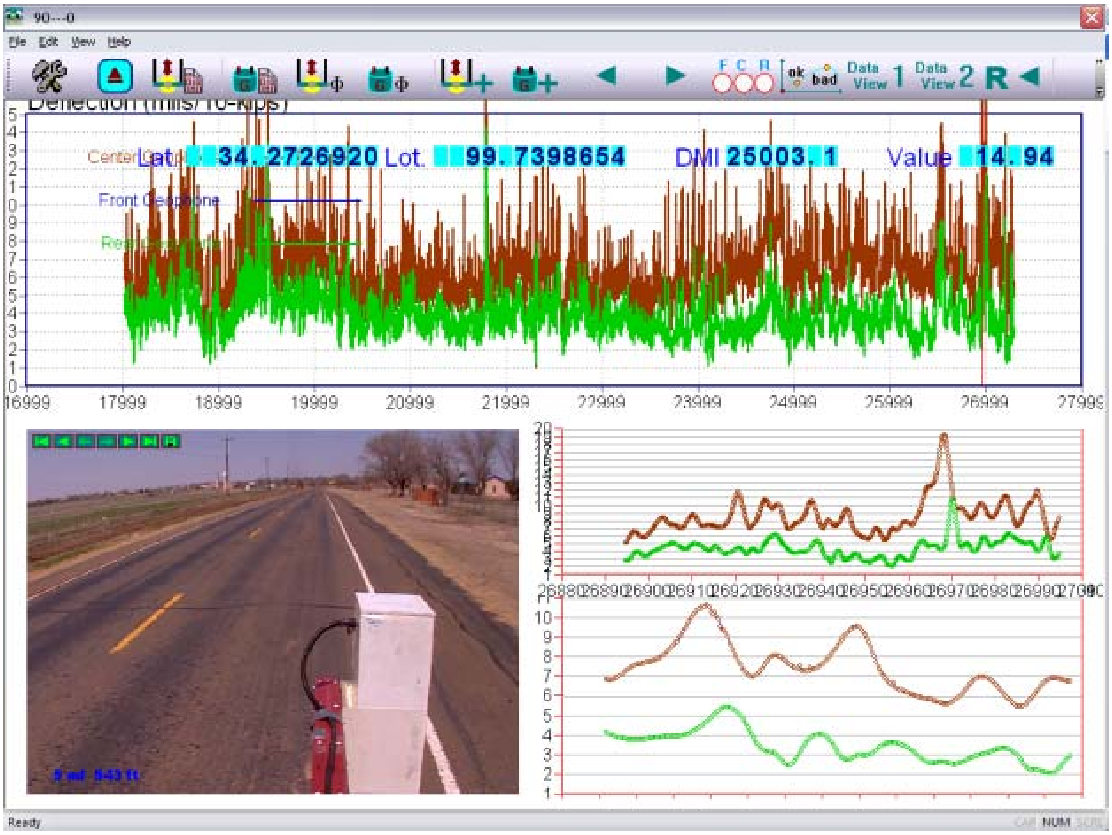


Figure 2.21: Representative TPAD Data for SH 6

Based on the TPAD data, six locations were selected for field investigation. Locations 1 and 2 were measured to have moderate deflections. The other four areas had either high deflections or suspect load transfer efficiencies. Table 2.1 and Figure 2.22 present the summary information from the focused field tests with the DCP, which is used to assess the risk level associated with rubblization. Analysis of the data shows that rubblization may not be the best option for this pavement due to marginal support conditions under the slab and substantial weak support, particularly at the transverse joints. The data suggest that the District may have decent success (~ 70%) rubblizing most of the slab area; however, each instance of testing near the joint showed extremely poor support in the vicinity. The data suggest that many localized full-depth repairs surrounding the joints would be necessary.

Based on the results generated in this study, the District decided not to pursue the rubblization option, instead opting to remove the existing HMA and place a flexible base overlay with a two-course surface treatment.

Table 2.1: DCP Summary Results – SH6, Hardeman County

DCP Test Location	Concrete Thickness (in.)	Base Thickness (in.)	CBR Values	
			Base	Subgrade
1	6.5	6.8	42.1	16.3
2	6.5	5.5	28.8	11.6
3	6.8	8	3	1.7
3 (joint)	6.8	6.8	5.9	3.0
4	6.5	6.3	14.6	9.3
4 (joint)	6.5	4.4	3.6	1.8

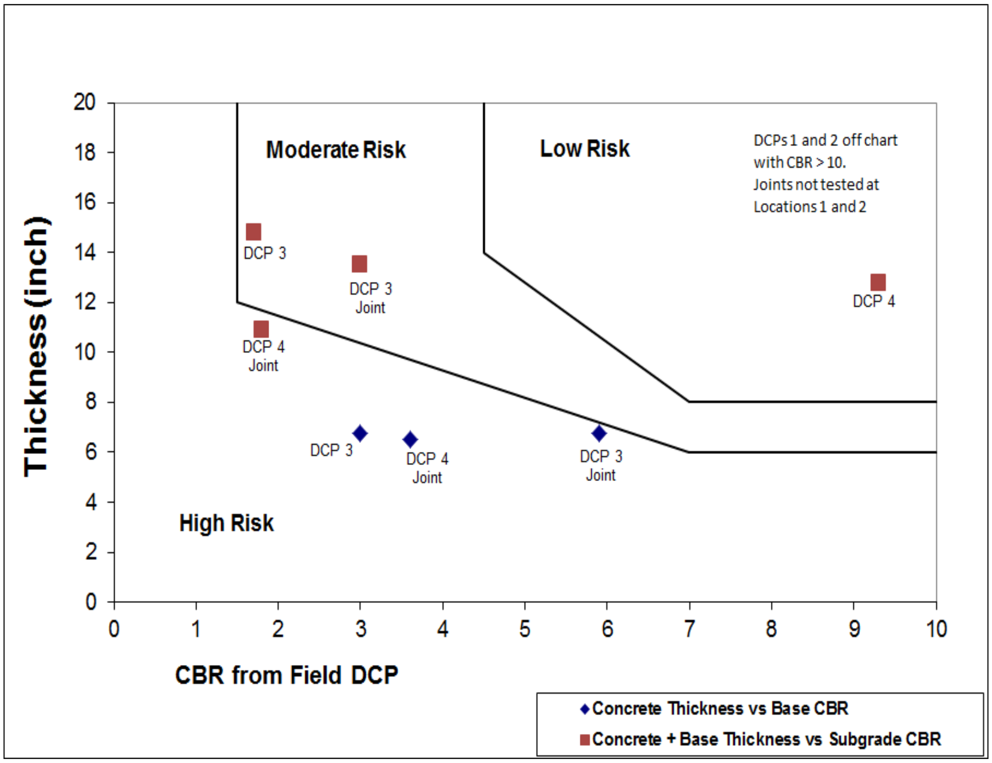


Figure 2.22: Risk Assessment of Rubblization on SH 6

2.10 Case 9: IH 27 in Lubbock and US 287 in Quanah in May 2014

The TPAD testing on IH 27 in Lubbock was performed as a joint effort with Dr. Moon Won and his research team at Texas Tech University (TTU). The pavement type on IH 27 in Lubbock is a CRCP. The TPAD testing was performed on the outside lane of the pavement to investigate current structural conditions. Detailed interpretations by Dr. Moon Won were presented separately to TxDOT personnel. As an example of the work, two representative deflection profiles are shown in this document. The first deflection profile is the one that was collected on the stiffer section of IH 27. This profile is shown in Figure 2.23. Since this pavement is a CRCP, cracks with a range in spacings are shown in the profile by peaks at different irregular spacings. Mid-slab deflections are low (generally less than 2.5 mils), which are typical deflections of CRCP exhibiting good performance. The deflection profile collected on a somewhat less stiff section is shown in Figure 2.24. In this section, it is interesting to see the different deflection patterns before and after the bridge. According to TTU personnel, the pavement was constructed over the same time period but by different contractors. More studies and evaluations are being performed by TTU personnel.

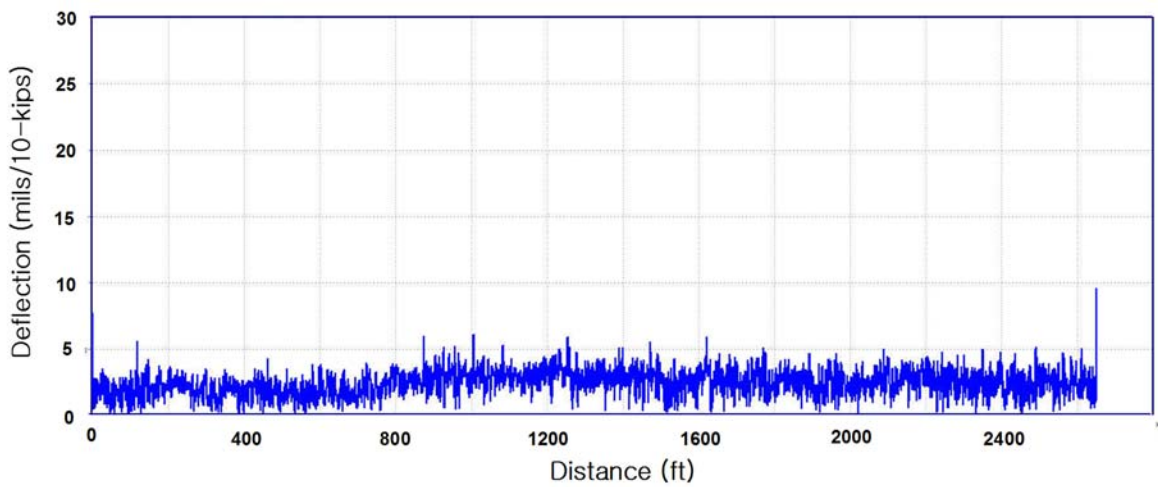


Figure 2.23: Deflection Profile Collected on a Good Section on IH 27 in Lubbock, TX

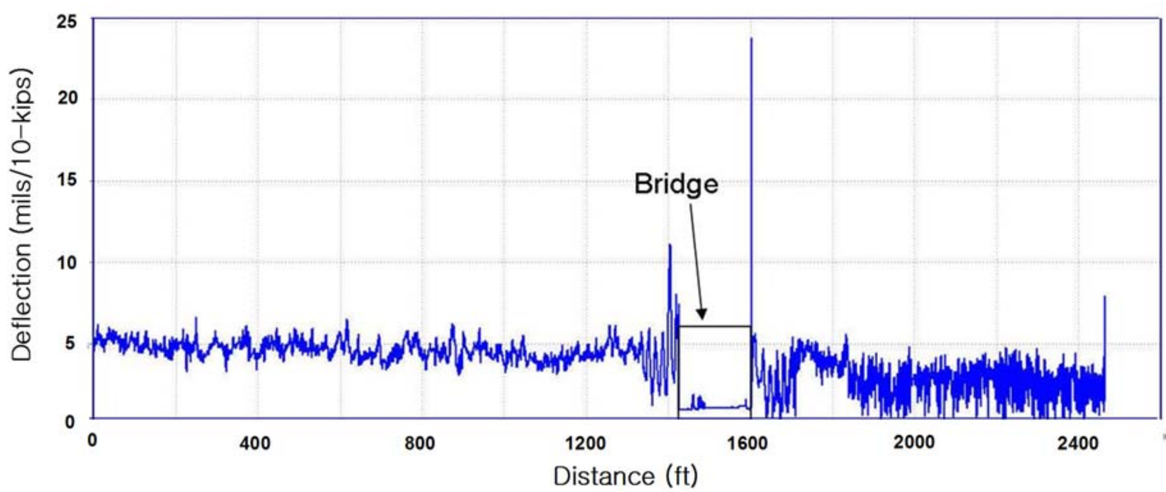


Figure 2.24: Deflection Profile Collected on a Section with Somewhat Larger Slab Movements along IH 27 in Lubbock, TX

During the same week in May, a 2-mile section of pavement on US 287 in Quanah was also tested. This pavement is a JCP. The TPAD testing was performed along this section in the eastbound and westbound outside lanes. Figure 2.25 shows the deflection profile for a section of the westbound lane of US 287, a 2-mile profiling distance that exhibits high deflections. Relatively higher peak deflections with regular spacings were concentrated at a distance between 600 and 2800 ft. These high peak deflections result from transverse joints with severe faulting problems in this area. After the distance of 2800 ft, several high peaks were also found but not regularly spaced. In a visual survey, a severe faulting problem was not found after the distance of 2800 ft. It seems that this area has transverse joint problems. Figure 2.26 shows the severity of the faulting at the transverse joints.

In Figure 2.27, the portion of the deflection profile collected on the eastbound lane of US 287 is shown. Significant peak deflections occur in this profile after 7000 ft, which corresponds to the location on the westbound lane (the westbound from 600 to 2800 ft) where severe faulting exists. Several high peaks before the distance of 7000 ft also occurred due to deteriorated transverse joints. The mid-slab deflections on the westbound and eastbound lanes seem to be low for a JCP (about 3 mils/10 kips in average). It was concluded that this area has severe problems associated with transverse joints. Further evaluation will be necessary to determine the source of these problems and a viable rehabilitation option.

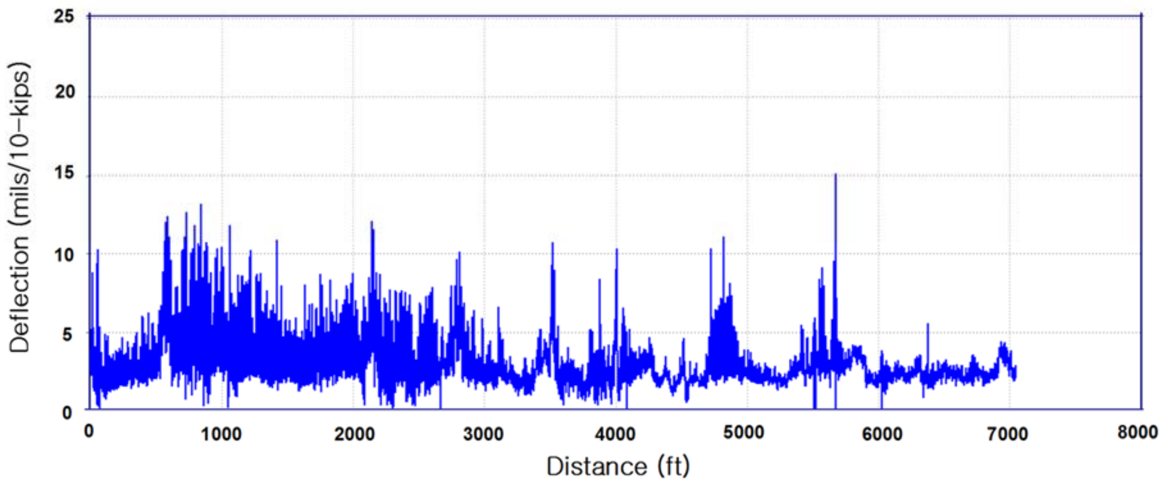


Figure 2.25: Deflection Profile Collected on Westbound Lane of US 287 in Quanah, TX

Figure 2.26: Transverse Joints Showing Faulting on Westbound Lane of US 287 in Quanah, TX

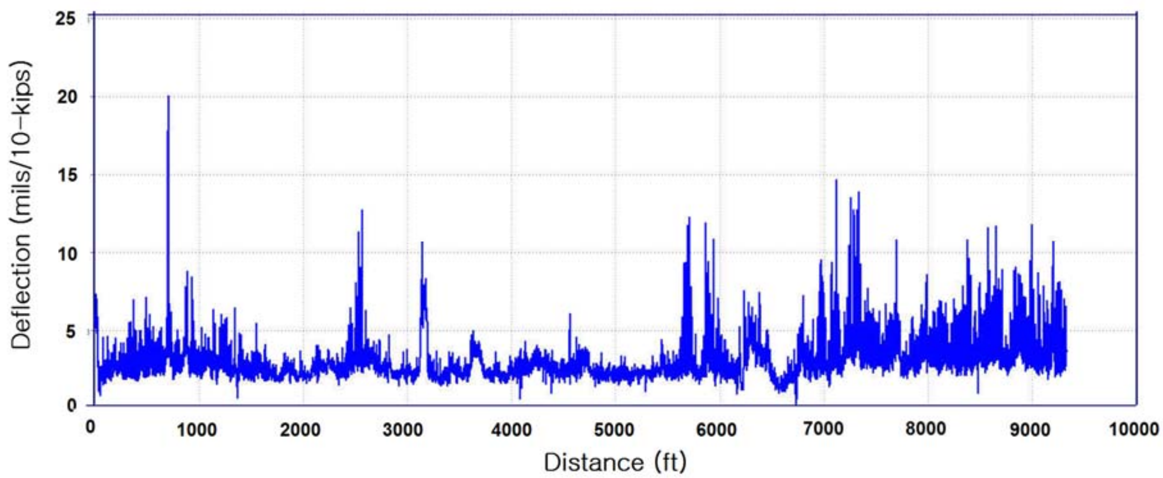


Figure 2.27: Deflection Profile Collected on Eastbound Lane of US 287 in Quanah, TX

2.11 Case 10: SH 288 in Houston in June 2014

The Houston District made a request for field testing and evaluation of the existing pavement condition on SH 288 (Choi and Won, 2014). TPAD testing was performed on both the northbound and southbound sections in the middle and outside lanes. The testing section was about 10 miles long and extended from Cleburne Road just south of US 59 to Clear Creek just south of Beltway 8. The pavement types are CRCP-only and CRCP with asphalt concrete (AC) overlay over both directions. The testing location and pavement types along the testing section are shown in Figure 2.28.

Figure 2.28: TPAD Testing Location and Pavement Types on SH 288 in Houston, TX

Some examples of deflection profiles collected on the section are presented in Figures 2.29 through 2.33. Possible poor support conditions are shown in Figure 2.29; this area has sudden increased deflections. Other peaks are from the bridge approach slabs. The section shown in Figure

2.30 exhibits overall good and uniform support conditions, except for one peak caused by surface distresses and one area with deteriorated AC overlay. Figure 2.31 depicts two large peak deflections. One is from the transition area between AC overlay and CRCP and another one is from the full-depth repair joint. A large deflection from the area with a deteriorated AC and a large deflection due to the change in AC material quality are shown in Figures 2.32 and 2.33, respectively.

Analysis of the deflection profiles indicates that the current pavement structural conditions are quite good in both directions, with some exceptions such as possible poor support conditions, bridge approach slab areas, construction joints, and areas with deteriorated overlaid AC. It was commonly found that deflections on the bridge approach slabs are larger.

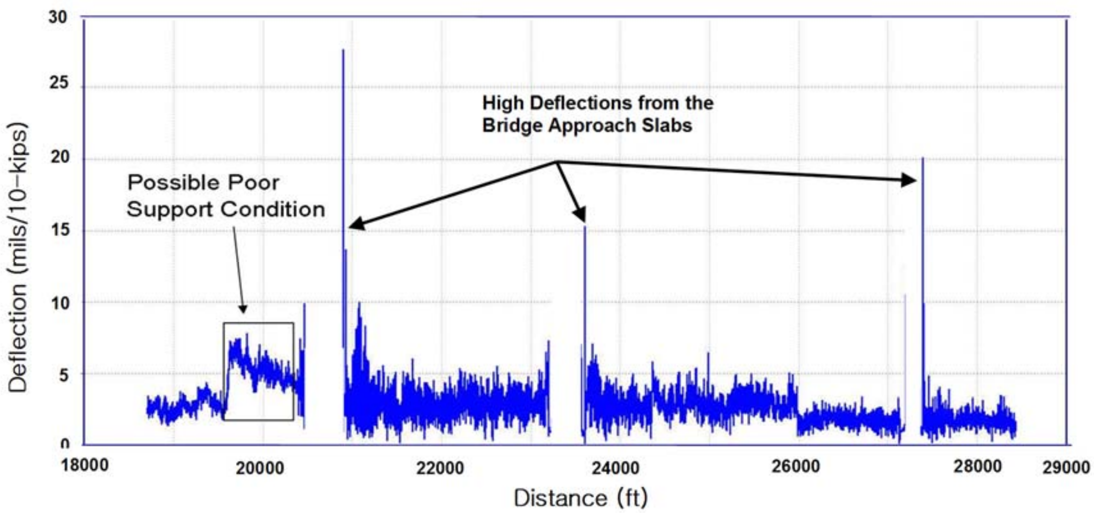


Figure 2.29: Deflection Profile Showing Possible Poor Support Condition on Middle Lane of Southbound SH 288

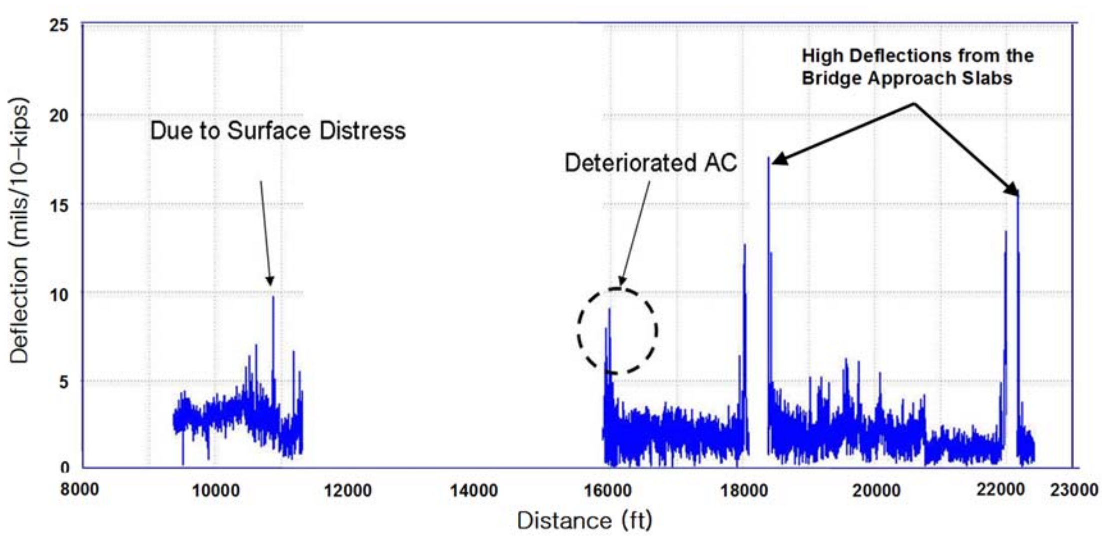


Figure 2.30: Deflection Profile Showing High Deflections due to Surface Distress and Deteriorated AC on Outside Lane of Southbound SH 288

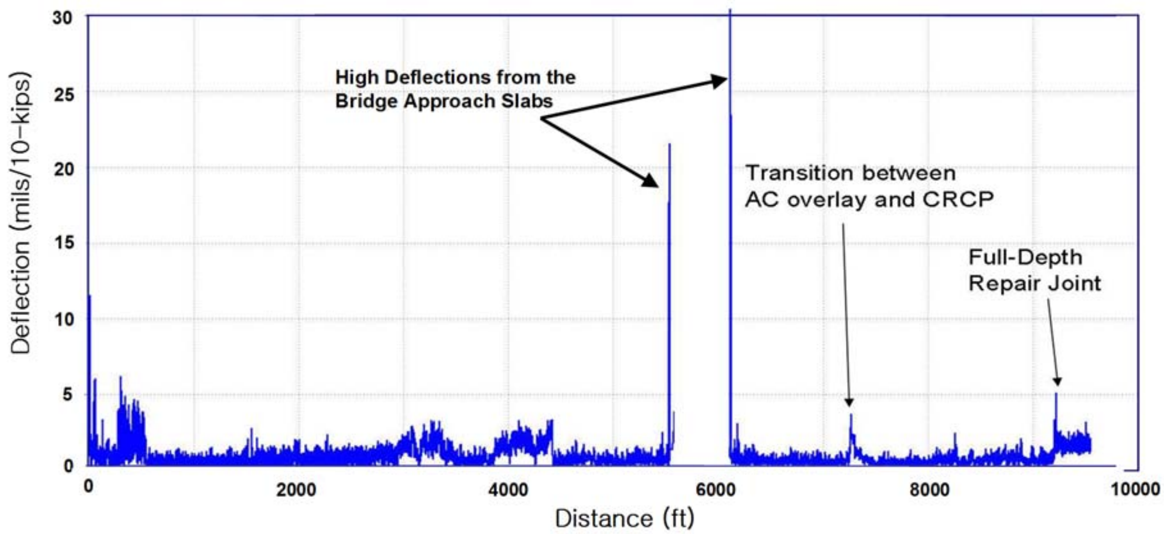


Figure 2.31: Deflection Profile Showing High Deflections due to Transition between AC Overlay and CRCP and Full-Depth Joint Repair on Outside Lane of Southbound SH 288

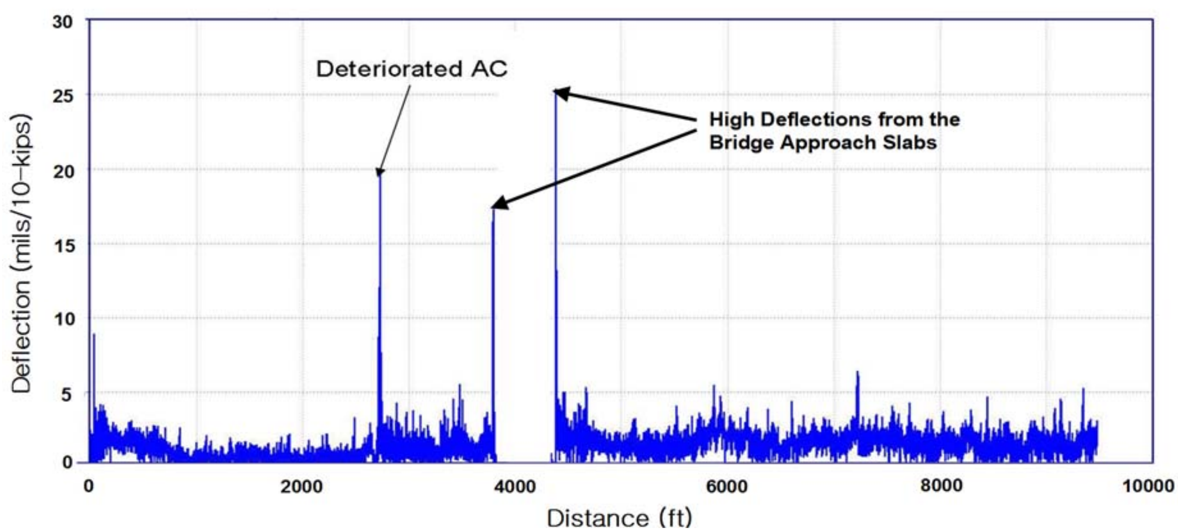


Figure 2.32: Deflection Profile Showing High Deflections due to Deteriorated AC Overlay on Middle Lane of Northbound SH 288

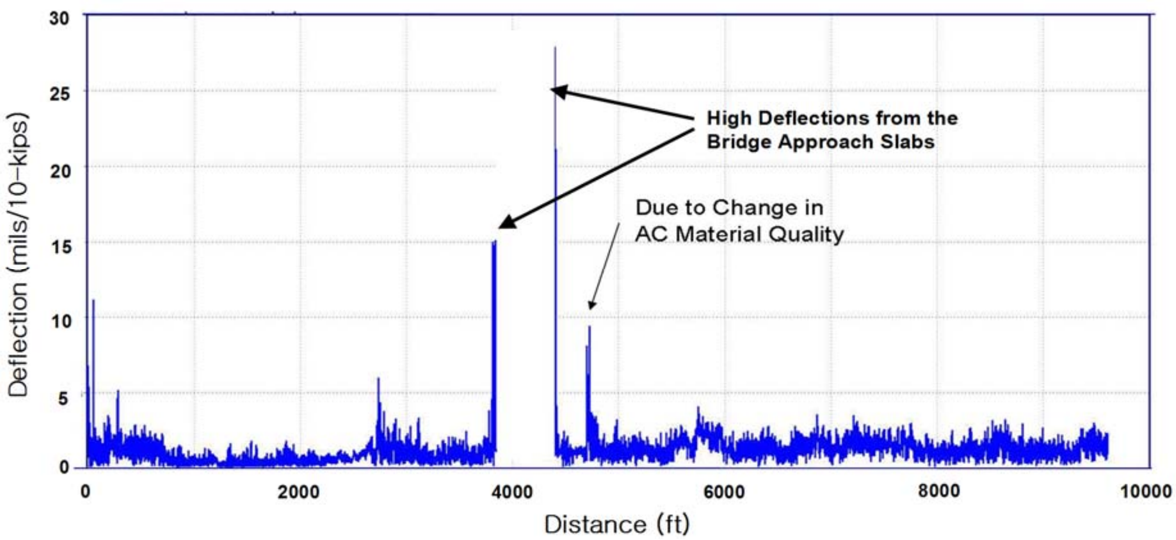


Figure 2.33: Deflection Profile Showing High Deflections due to AC Quality Change on Outside Lane of Northbound SH 288

2.12 Summary

The TPAD was successfully employed in pavement condition evaluations at various Texas sites from January 2013 to August 2014. In these pavement evaluations, the TPAD performed well in testing a range of pavement types, including HMA, JCP, CRCP, and composite pavements.

Chapter 3. Improvements to the RDD Functionality

3.1 Introduction

During the 20-month period of this project, TPAD testing was performed on multiple projects. This testing was also helpful in identifying modifications and improvements that were needed to improve the functionality and robustness of the RDD system on the TPAD. In this chapter, improvements made by the CTR team to improve the RDD functionality are briefly discussed.

3.2 Improvements Made to the RDD Functionality

The first improvement to the RDD system was to improve the air-pressure control system used to load the rolling sensors. Each rolling sensor has two air bladders to apply a hold-down force. During RDD testing, air pressure needs to be applied to the air bladders to keep contact between the rolling sensors and the pavement. Originally, one air-pressure control system was used to regulate the hold-down force. This single air-pressure control system sometimes did not regulate the air pressure to all three rolling sensors as well as intended. Therefore, the CTR team replaced the single air-pressure regulating system with three separate pressure control systems, one for each rolling sensor, for more stable air-pressure regulation. In addition, air-pressure supply cables and connectors were also replaced with more reliable supply cables and connectors.

The second set of improvements concerned the towing frame. The towing frame is used to position the rolling sensors during testing and to raise/lower the rolling sensors in combination with the loading frame. The design of the RDD system has an array of three rolling sensors that are positioned along the longitudinal centerline of the TPAD. When the TPAD was moved from TTI to CTR in April 2014, the CTR team found scratches on the loading frame, which were evidence of contact between loading frame and towing frame during testing. Such contact can adversely affect the motions monitored by the rolling sensors because it will have the same frequency as applied to the pavement. In addition to this problem, the left towing arm was bent downward, one of four turnbuckles was broken, and two were bent. The CTR team decided to work together with Center for Electromechanics at UT Austin to make improvements to the towing frame for positioning the towing frame properly with respect to the loading frame. These final improvements were completed: (1) reinforcement of the towing arms with angle iron gusset plates to the towing arms, (2) stronger turnbuckles, and (3) vertical rubber bumpers on all four corners to prevent the towing frame from rubbing the loading frame. Much of this work was paid by Prof. Kenneth Stokoe out of non-TxDOT funds. The iron gusset plate, stronger turnbuckle, and vertical bumper installed on the right front side of the towing frame are shown in Figure 3.1.

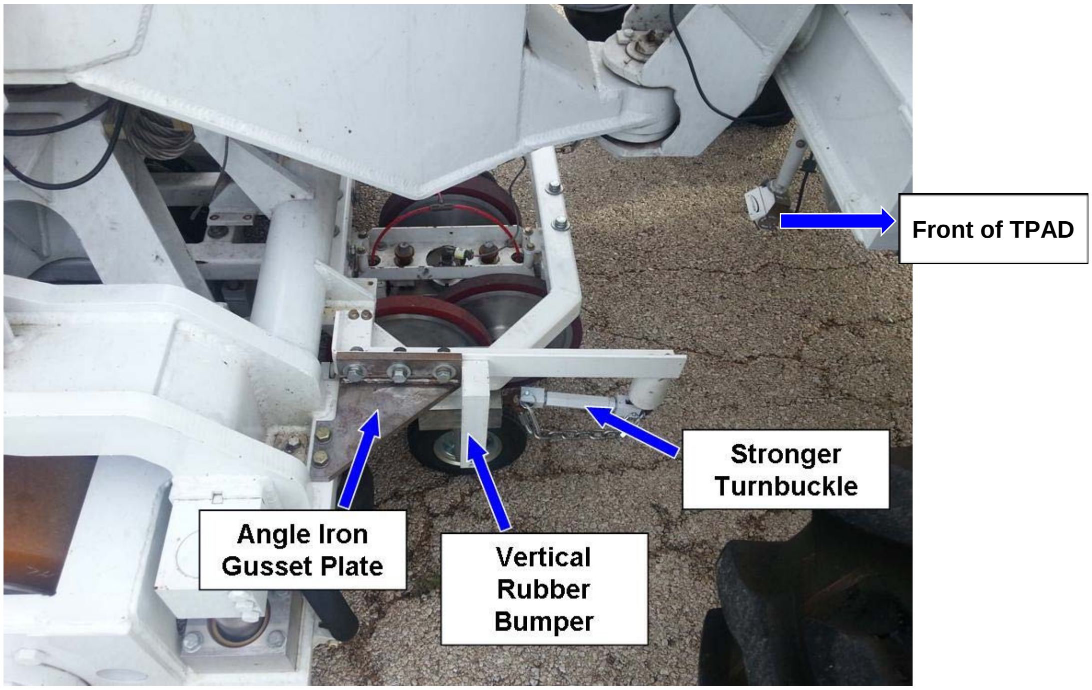


Figure 3.1: Improvements Made to the TPAD Towing Frame on Right Front Side: (1) Angle Iron Gusset, (2) Strong Turnbuckle, and (3) Vertical Bumper

3.3 Summary

RDD deflection measurements are one of the most important testing functions of the TPAD. To perform more reliable and accurate deflection measurements, four modifications and improvements were made to the RDD portion of the TPAD: (1) replacement of the single air-pressure regulating system used by all three rolling sensors with three separate air-pressure control systems, one for each rolling sensor, for more stable air-pressure regulation, (2) installation of angle iron gusset plates to reinforce each of the four towing arms, (3) replacement of normal-strength turnbuckles with reinforced turnbuckles, and (4) installation of vertical rubber bumpers to prevent contact between the loading frame and the towing frame.

Chapter 4. Conclusions

Project No. 5-6005-01, *Statewide Implementation of the Total Pavement Acceptance Device (TPAD)*, was completed on August 31, 2014. The TPAD was successfully used on eleven project-level studies in eight districts to evaluate in-service pavement structural conditions. The TPAD was used in various pavement evaluations, including the following assessment activities:

(1) evaluating the current structural conditions of highway and runway pavements,

(2) helping to select the optimum rehabilitation strategies for a corridor study involving the pavement on IH 10 in El Paso,

(3) detecting delaminations and voids underneath JCP slabs,

(4) identifying joints that need to be repaired prior to placing the new overlay,

(5) evaluating frontage road conditions for a future thin overlay construction,

(6) evaluating structural conditions of CRCP sections with suspected void areas, and

(7) investigating areas to identify good candidates for rubblization.

The TPAD has been successfully used to evaluate the remaining life of current pavement, help district engineers select optimum rehabilitation schemes, and identify problematic areas over a wide range of pavements such as HMA, JCP, CRCP, and composite structures.

The RDD functionality was improved during Project 5-6005-01 by replacing the one air-pressure control system used for the rolling sensors with three separate air-pressure control systems, one for each of the three rolling sensors. In addition, the towing frame used to position and raise/lower the rolling sensors was modified and improved. The towing frame improvements included (1) reinforcement of the towing arms with angle iron gusset plates, (2) stronger turnbuckles, and (3) vertical rubber bumpers on all four corners of the loading frame to prevent the towing frame from rubbing the loading frame.

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Choi, P.G. and Won, M. (2014) “Evaluation of the Existing Pavement Condition on SH 288,” Technical Memorandum, Tech Memo No.: 12-4XXIA028-4, Center for Multidisciplinary Research in Transportation, Texas Tech University.

Stokoe, II, K. H., Lee, J–S, Nam, B. H., Lewis, M., Hayes, R., Scullion, T., and Liu, W. (2011) “Developing a Testing Device for Total Pavement Acceptance-Third Year Report,” Publication Report No. FHWA/TX-11/0-6005-4, FHWA/Texas Department of Transportation, Center for Transportation Research and Texas Transportation Institute.

Stokoe, K. H., Lee, J-S, Nam, B. H., Scullion, T., Liu, W., Leidy, J., and Claros, G. (2013) “Development and Initial Testing of the Total Pavement Acceptance Device (TPAD).” Transportation Research Board 92nd Annual Meeting, TRB, Jan. 14, 2013, Washington D.C.