Technical Memorandum

To: Jeff Uhlmeyer

From: Gonzalo Rada, Nick Weitzel, Kevin Sen, and Gary Elkins

cc: Mustafa Mohamedali

Date: August 15, 2019 (original), June 30, 2020 (revised)

Re. Forensic Desktop Study Report: LTPP Test Section 48_1111

The Long-Term Pavement Performance (LTPP) General Pavement Studies (GPS) test section 48_1111[1] was nominated for a desktop study under TPF-5(332) “LTPP Forensic Evaluations” because of its excellent performance. The test section received a 2.6 in overlay (over a 0.1 in geo-fabric) in 1999 and after 20 years of service and only the application of a 0.5 in chip seal in 2011, the test section is still performing well. The purpose of this document is to review the test section history, examine distress manifestations, and make recommendations on the need for forensic evaluation related work to explain the excellent performance of the test section over time.

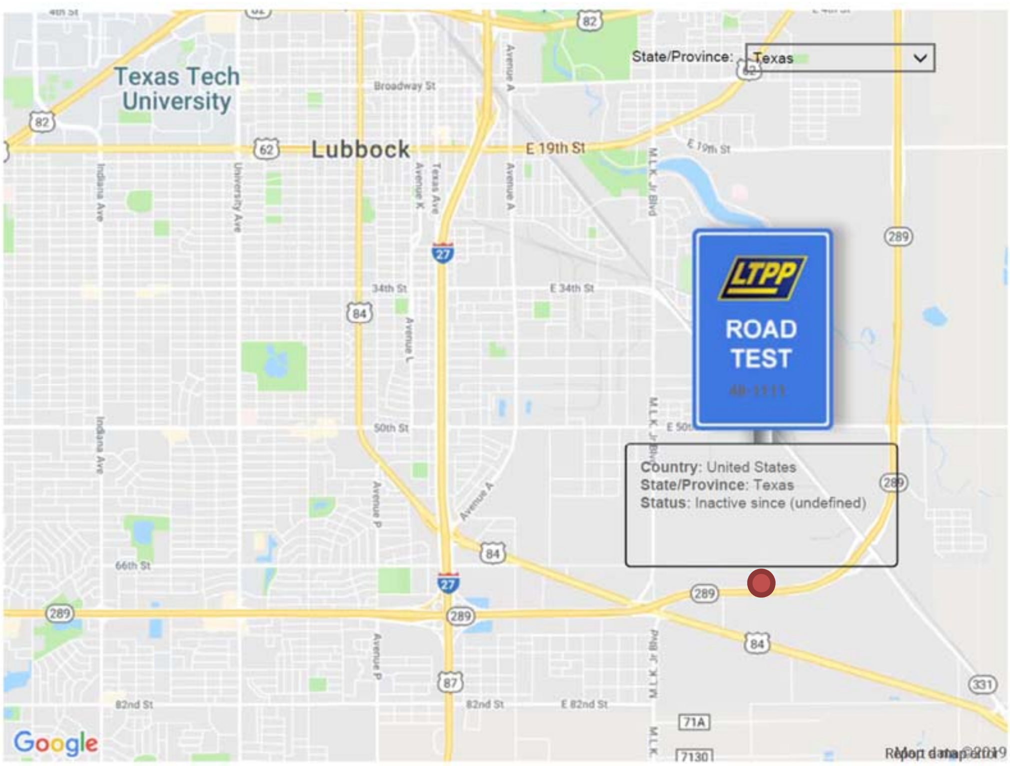
SITE DESCRIPTION

LTPP test section 48_1111 is located on State Route (SR) 289, eastbound at milepost 6.4 in Lubbock County, Texas. SR-289 is a rural principal arterial ring road around the city of Lubbock Texas with two separate lanes in each direction of traffic. It is classified as being in a Dry-No Freeze climate zone with an average annual precipitation ranging between 6.3 inches (2011) and 37.4 inches (2004) and an annual average air freezing index ranging between 14 Deg-F degree-days (1999) and 338 Deg-F degree-days (1983) during the period of 1972 to 2017. The coordinates of the test section are 33.53144, -101.80471. Photograph 1 shows the test section in 2013, while Map 1 shows the geographical location of the test section relative to the City of Lubbock within the State of Texas.

[1] First two digits in test section number represent the State Code [48 = Texas]. For LTPP GPS test sections, the final four digits are unique within each State/Province and they were assigned at the time the test section was accepted into the LTPP program. For LTPP Specific Pavement Studies (SPS) test sections, the second set of two numbers indicates the Project Code (e.g., 02 = SPS-2) and the final set of two numbers represents the test section number on that project (e.g., 13).

Wood Environment & Infrastructure Solutions, Inc.
12000 Indian Creek Ct, Suite F
Beltsville, MD 20705
+1 301-210-5105
www.woodplc.com

Photograph 1. Picture of test section 48_1111 in 2014 (from start of section looking west).



Map 1. Geographical location of test section relative to the City of Lubbock in Texas.

BASE-LINE PAVEMENT HISTORY

The information included in this portion of the document presents the baseline data on history of pavement structure, climate, traffic and pavement distresses, roughness and deflection.

Pavement Structure and Construction history

The initial pavement structure was constructed in 1972. The pavement layer structure when the test section entered the LTPP program in 1987 is detailed in Table 1. This corresponds to CONSRTUCTION_NO = 1 (CN = 1). The two non-structural chip seals shown in this table were already part of the pavement structure when the test section entered the program.

Table 1. Pavement structure from 1972 to 1999.

Layer Number	Layer Type	Thickness (in.)	Material Code Description
1	Subgrade (untreated)		216-Coarse-Grained Soil: Clayey Sand
2	Unbound (granular) base	8.4	308-Soil Aggregate Mixture (Predominantly Coarse-Grained)
3	Asphalt concrete (AC) layer	5.7	1-Hot Mixed, Hot Laid AC, Dense Graded
4	AC layer	1.2	1-Hot Mixed, Hot Laid AC, Dense Graded
5	AC layer	0.2	71-Chip Seal
6	AC layer	0.3	71-Chip Seal

In August 1999, the test section was overlaid with a 2.6-inch dense graded asphalt concrete mixture on top of a 0.1 inch geo-fabric. No milling was performed. This corresponds to CN = 2. The resulting pavement structure is detailed in Table 2.

Table 2. Pavement Structure from 1999 to 2011

Layer Number	Layer Type	Thickness (in.)	Material Code Description
1	Subgrade (untreated)		216-Coarse-Grained Soil: Clayey Sand
2	Unbound (granular) base	8.4	308-Soil Aggregate Mixture (Predominantly Coarse-Grained)
3	AC layer	5.7	1-Hot Mixed, Hot Laid AC, Dense Graded
4	AC layer	1.2	1-Hot Mixed, Hot Laid AC, Dense Graded
5	AC layer	0.2	71-Chip Seal
6	AC layer	0.3	71-Chip Seal
7	Engineering fabric	0.1	74-Woven Geotextile
8	AC layer	2.6	1-Hot Mixed, Hot Laid AC, Dense Graded

In June 2011, a 0.5 inch chip seal was placed. This corresponds to CN = 3. The resulting pavement structure is detailed in Table 3. There are no further recorded construction events after CN =3.

Table 3. Pavement Structure from 2011 to Date

Layer Number	Layer Type	Thickness (in.)	Material Code Description
1	Subgrade (untreated)		216-Coarse-Grained Soil: Clayey Sand
2	Unbound (granular) base	8.4	308-Soil Aggregate Mixture (Predominantly Coarse-Grained)
3	AC layer	5.7	1-Hot Mixed, Hot Laid AC, Dense Graded
4	AC layer	1.2	1-Hot Mixed, Hot Laid AC, Dense Graded
5	AC layer	0.2	71-Chip Seal
6	AC layer	0.3	71-Chip Seal
7	Engineering fabric	0.1	74-Woven Geotextile
8	AC layer	2.6	1-Hot Mixed, Hot Laid AC, Dense Graded
9	AC layer	0.5	71-Chip Seal

Pavement Structural Properties

Figure 1 shows the time history average FWD deflection plot under the nominal 9,000 lb. load from the sensor position in the load plate. The deflection of the sensor located in the load plate is a general indication of the total “strength” or response of all layers in the pavement structure to a vertically applied load. This deflection can be influenced by pavement temperature at the time of testing, precipitation, and changes in pavement structure. As shown, deflections have remained relatively constant between 10 and 15 mils, over the life of the pavement, with the exception of the ~20 mil measurement in 1997. The 1999 overlay appears to have provided added structural capacity as reflected by the smaller deflections in 2002, and to a lesser degree the 2011 chip seal. Overall, the center sensor (under the load plate) deflection time history magnitudes are judged to be relatively consistent with respect to natural variations in FWD measurements and low for a rural principal arterial AC pavement. This indicates a “strong” pavement structure.

Table 4 shows layer moduli backcalculated from the FWD deflection data collected at the test section. As shown, seven rounds of FWD testing have been performed between 1989 and 2012 – four under CN = 1, two under CN = 2 and one under CN = 3. As also shown, the test section was modeled as a three-layer pavement structure, consisting of an AC layer (6.9 inches during CN =1 and 9.5 inches during CN = 2 and 3) on an unbound granular layer made up of the granular base and top portion of the subgrade (total thickness of 24 inches for all CN values) over the remainder of the subgrade layer, which has been modeled as separate semi-infinite layer. The backcalculated layer moduli values shown in the table appear reasonable for the material types in questions and, in the case of the two unbound granular layers, the results are indicative of a strong, high-quality granular base and subgrade.

Figure 2 shows the laboratory measured average total resilient modulus - temperature relationship for the 2.6-inch overlay layer placed in 1999. This is the only AC pavement layer for which laboratory resilient modulus results are available. While the results in this plot only come from the top 2.3 inches of the total 9.5 inch AC layer thickness, they are consistent with the layer moduli backcalculated from the field FWD deflection data, which ranged between 200 and 750 ksi.

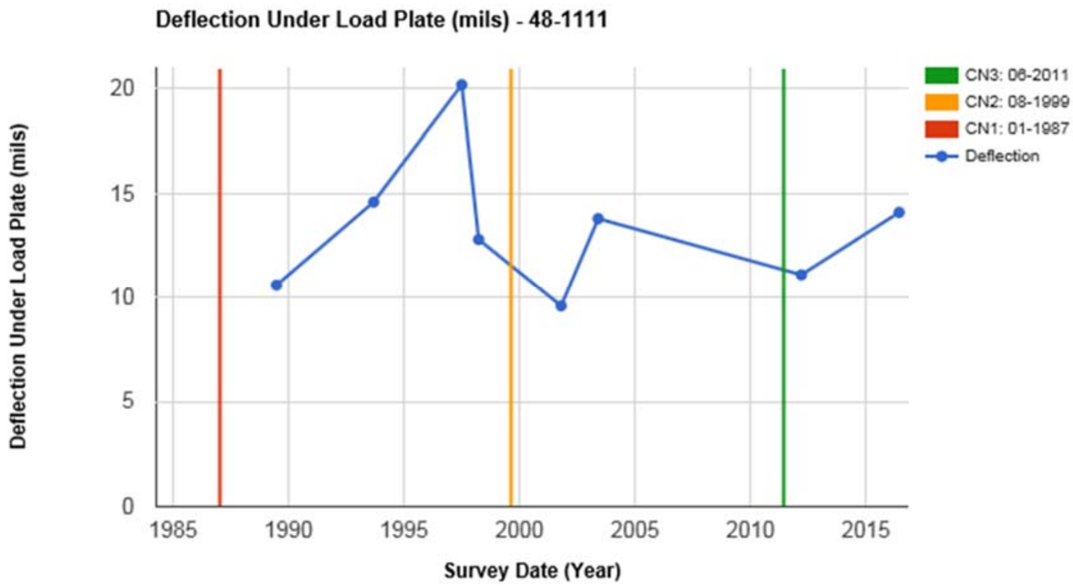


Figure 1. Time history of average deflection for the sensor located in the load plate normalized to 9,000 lb. drop load.

Table 4. Backcalculated layer moduli over time.

Date	CN	Layer	Thick. (inches)	Mod (ksi)	Layer	Thick. (inches)	Mod (ksi)	Layer	Thick (inches)	Mod (ksi)
06/23/89	1	AC	6.9	642	GB/SG	24	26	SG	Semi-inf	29
09/07/93	1	AC	6.9	486	GB/SG	24	21	SG	Semi-inf	27
07/01/97	1	AC	6.9	201	GB/SG	24	20	SG	Semi-inf	27
03/25/98	1	AC	6.9	724	GB/SG	24	20	SG	Semi-inf	27
10/19/01	2	AC	9.5	554	GB/SG	24	25	SG	Semi-inf	29
05/28/03	2	AC	9.5	221	GB/SG	24	25	SG	Semi-inf	28
03/04/12	3	AC	9.5	422	GB/SG	24	26	SG	Semi-inf	28

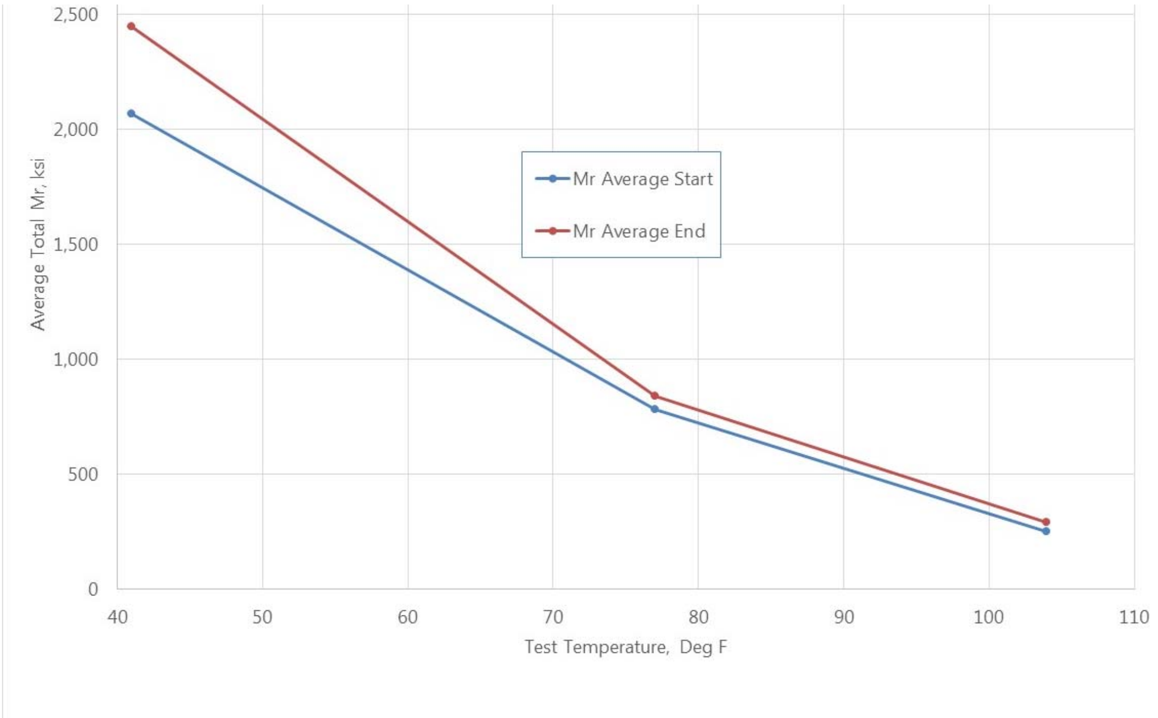


Figure 2. Average total resilient modulus versus test temperature from laboratory tests on samples of the overlay placed in 1999 from the start and end of the test section.

Climate History

The time history for annual average precipitation since 1972 is shown in Figure 3. In 2004, the amount of precipitation appears to be a local high (37.4 inches) at the site, while the low (6.3 inches) was recorded in 2011. Neither of these measurements are considered to drastically deviate from the mean at the site (19.6 inches for time period in question), nor do they appear to have resulted in drastic changes in pavement distresses or pavement response.

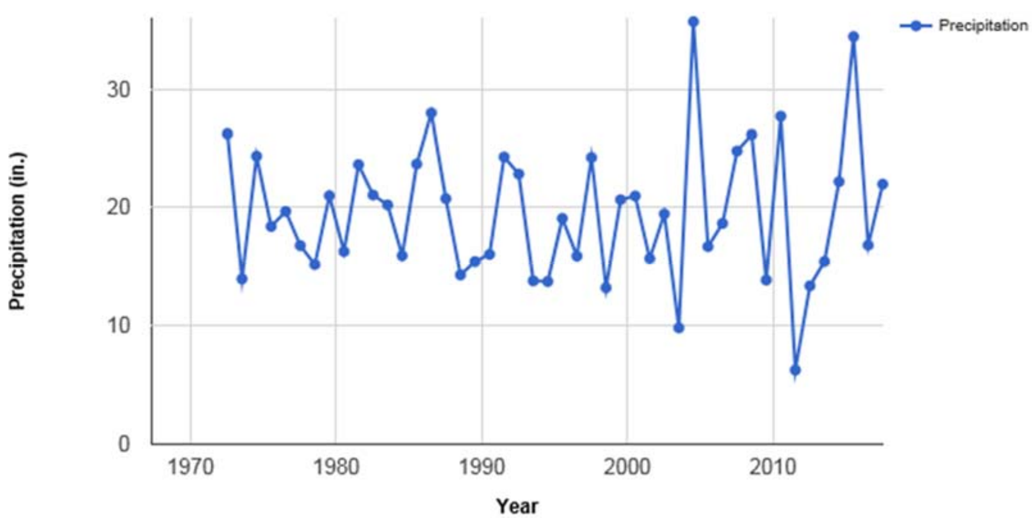


Figure 3. History of annual precipitation starting in 1973.

Figure 4 shows the time history of the annual freezing index over the history of this test section. The freezing index is the sum of the difference between 32 degrees F and when the average air temperature is less than freezing and 32 degrees F for each day, which is summed over a year's time. This index is an indicator of the harshness of the winter season relative to issues such as ground frost and low temperature cracking in pavements. A large spike in extreme low temperatures can be observed in 1983, well before the test section was incorporated into the LTPP program; however, there does not appear to be any significant impacts on the performance of the pavement.

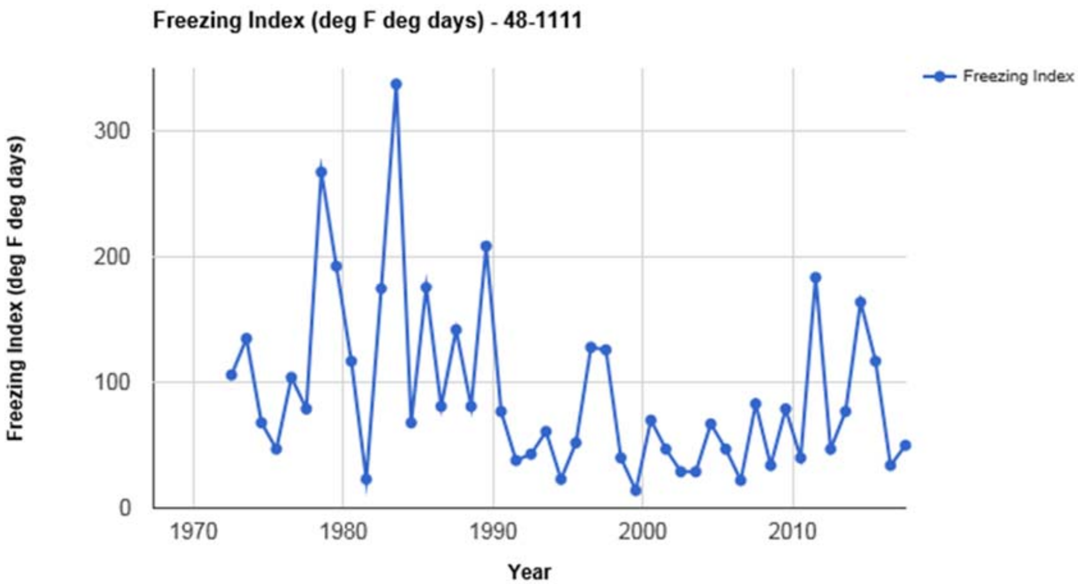


Figure 4. Time history of annual air temperature freezing index.

Truck Volume History

Figure 5 shows the annual truck volume data in the LTPP test lane by year. The red triangles are data provided by the Texas DOT (TxDOT) from historical records. The blue diamonds are truck counts based on monitoring data reported to LTPP by TxDOT. While not perfect, there appears to be agreement between the estimated and monitored counts. The figure also shows that there has been a gradual annual increase in truck volumes.

Pavement Distress History

While there are no significant distresses on this test section, the following paragraphs address those distresses observed at the test section between 1991and 2016. Figures 6 and 7 show the time history of the number and length of transverse cracks, respectively, on the pavement. In this figure, the construction events are shown with vertical lines – the period this investigation focuses on goes from the start of CN = 2 in 1999 to date, which captures the performance of the asphalt concrete overlay. The distress data shown are from manual distress surveys. As shown in these two figures, the number and length of transverse cracking steadily increased when the test section was first introduced into the LTPP program, but then dropped to zero after the 1999 AC overlay, and it remained at a that level until around 2010, when it again began to steadily increase.

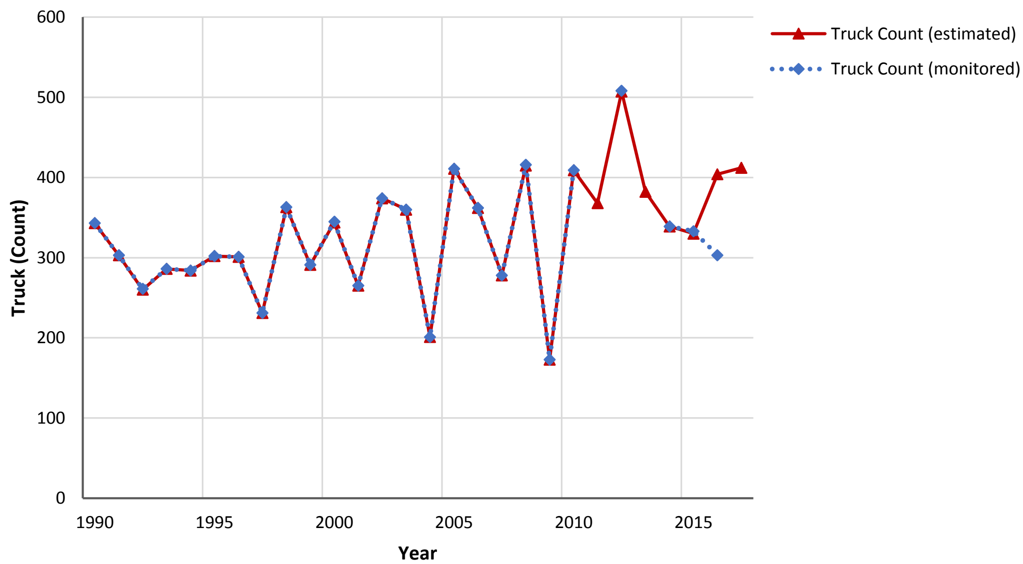


Figure 5. Average annual daily truck traffic on test section 531005 based on state supplied estimates and monitoring measurements.

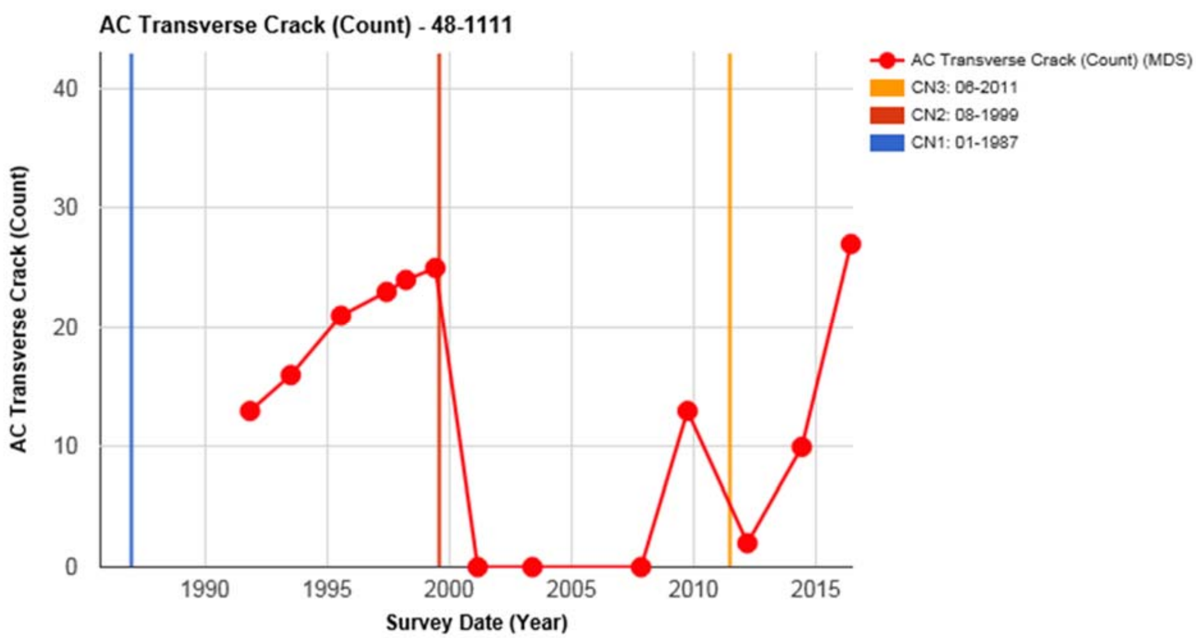


Figure 6. Time history of the number of transverse cracks.

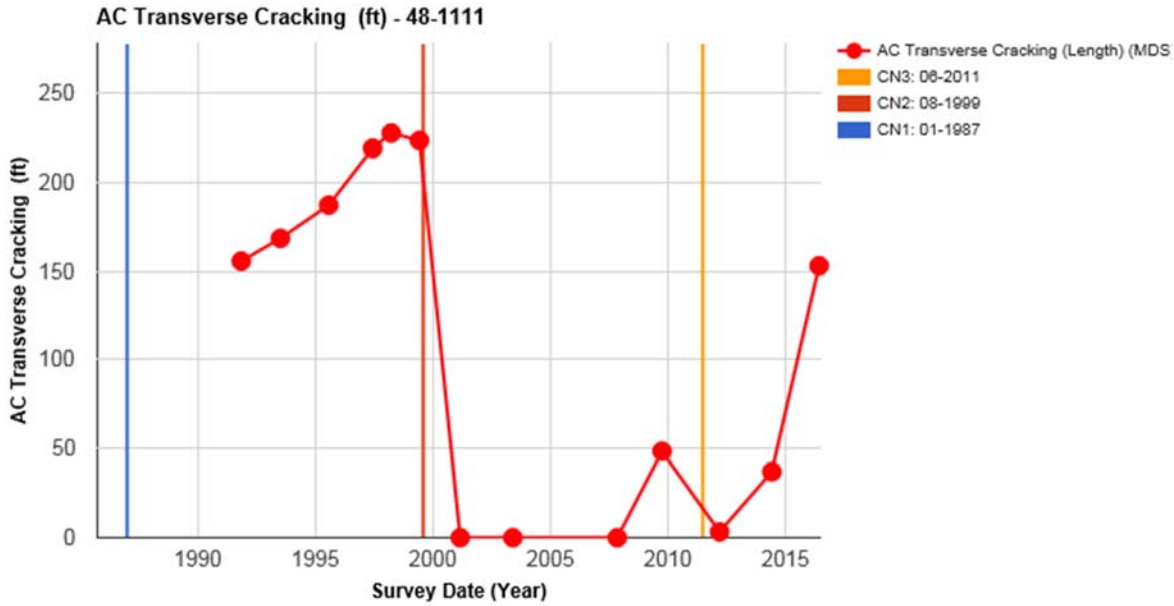


Figure 7. Time history of length of transverse cracks.

Figure 8 shows the time history plot of alligator cracking data on LTPP test section 48_1111. While the plot is labeled fatigue cracking, in the LTPP distress rating system, this is alligator cracking that is not limited to the wheel path. As shown, the amounts of alligator cracking on this test section are relatively low. Figure 8 also shows that the chip seal placed in 2011 reduced the amount of alligator cracking and appears to have helped keep it low for the next several years. However, it is noted on the distress survey form that the reason for the drop in area of alligator cracking from 2014 to 2016 was due to apparent healing of the surface, i.e. excess asphalt intrusion into the previous cracks. Bleeding was also noted in the wheel paths where this alligator cracking occurred.

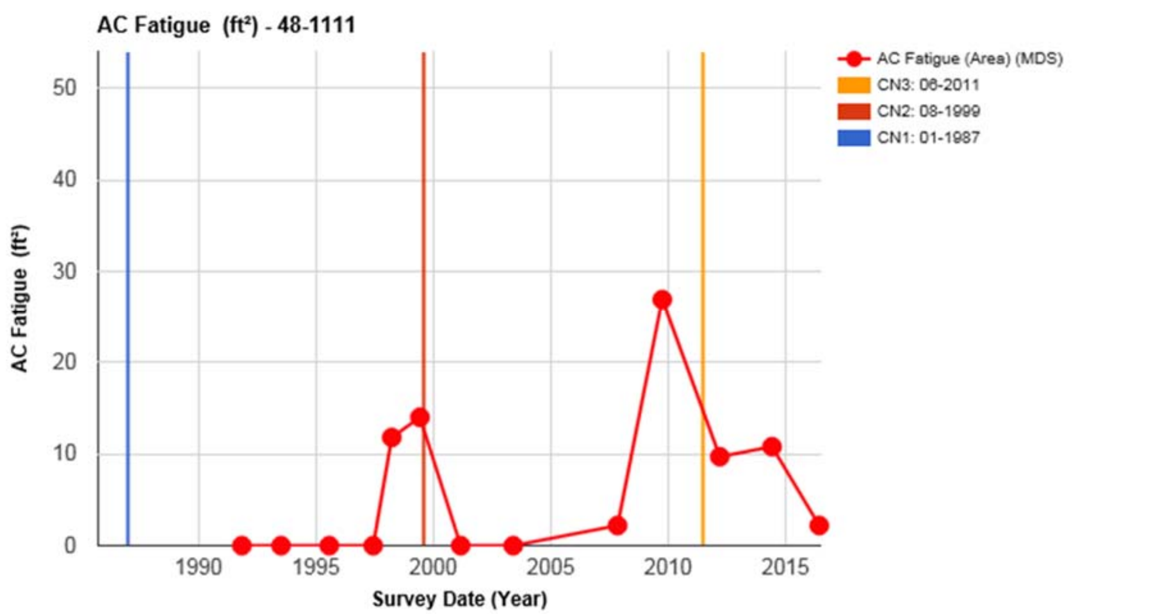


Figure 8. Time history of area of alligator cracking.

Figure 9 shows the time history plot of longitudinal cracking in the wheel path (WP), which can be considered as an indicator of fatigue cracking on a pavement, while Figure 10 shows the time history plot of longitudinal cracking not in the wheel path (NWP). As shown in Figure 9, WP longitudinal cracking after the 1999 overlay was non-existent until the 2016 distress survey. Figure 10, on the other hand, shows that NWP longitudinal cracking was eliminated after the AC overlay, but resurfaced in 2008 and remained constant until after application of the 2011 chip seal, which eliminated the cracking until 2014. In 2016, NWP longitudinal cracking, which is located at the longitudinal joint between the lanes, re-appeared.

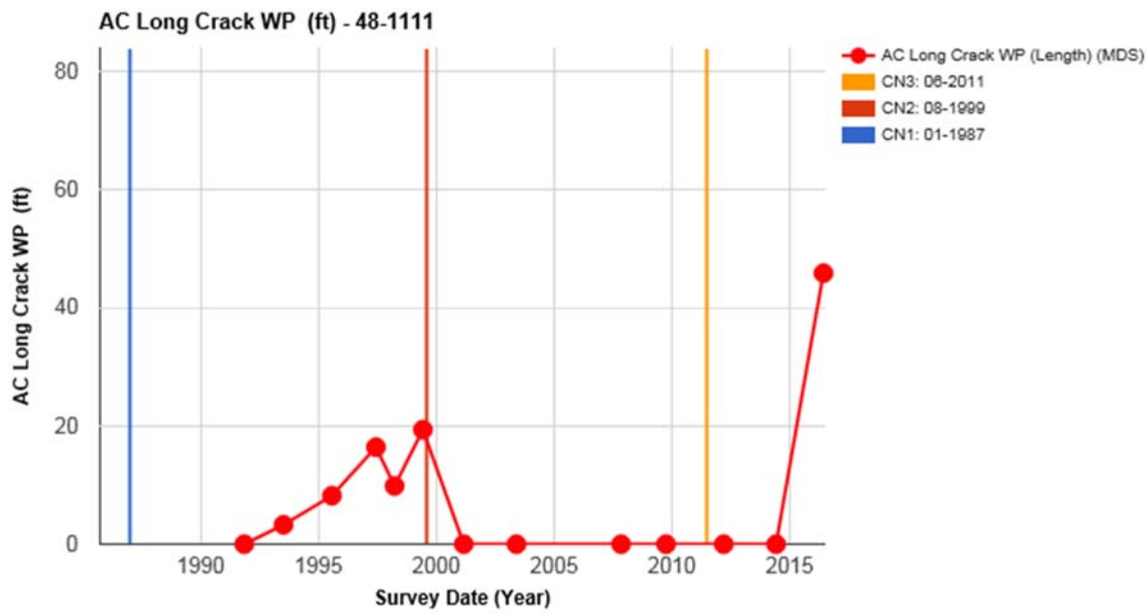


Figure 9. Time history of longitudinal cracking in the wheel path.

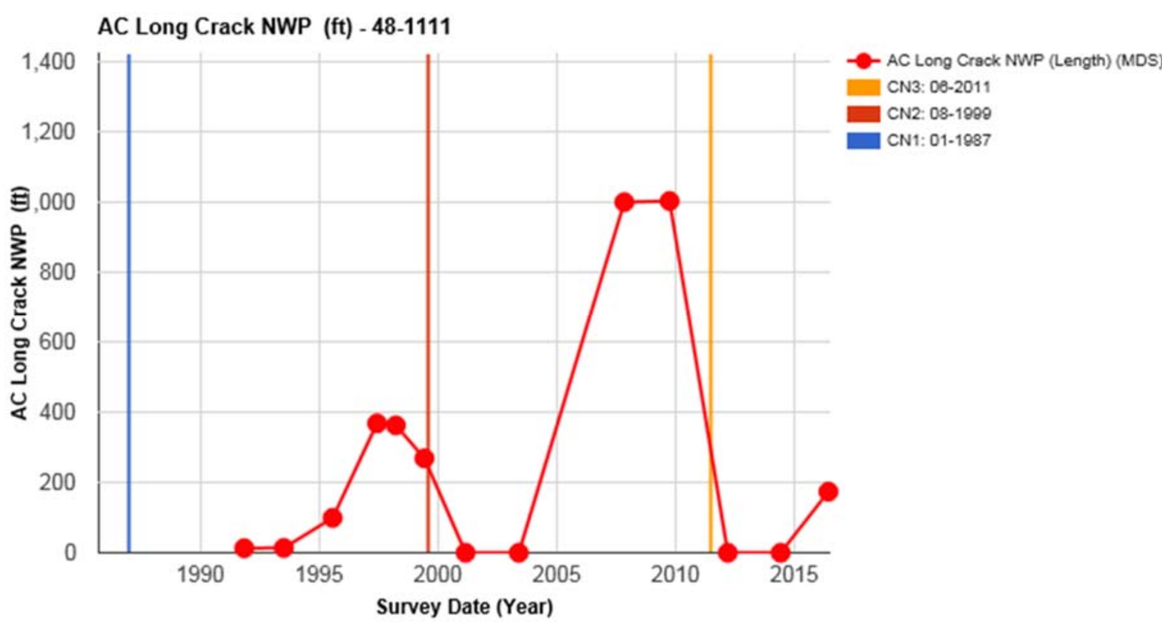


Figure 10. Time history of longitudinal cracking not in the wheel path.

The time history plot of rutting on the test section is shown in Figure 11. As shown, rutting of the pavement test sections has remained under 0.2 inches throughout the life of the pavement and close to 0.1 inches since the application of the 2.6 inch AC overlay in 1999.

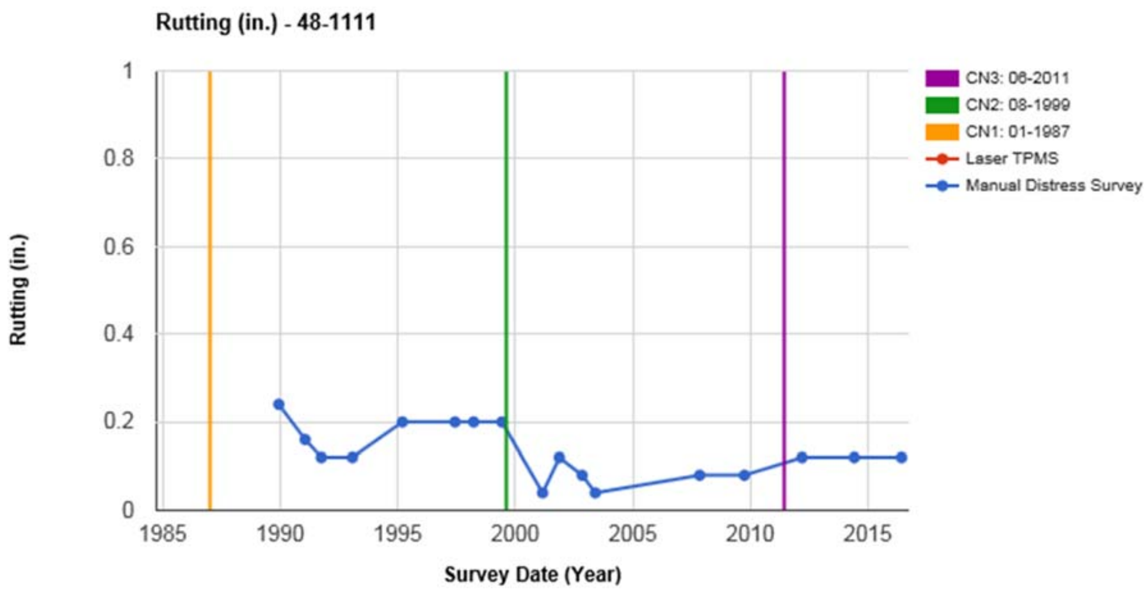


Figure 11. Time history plot of average rut depth computations.

Similarly, the time history of roughness measurements is shown in Figure 12. As shown, after placement of the AC overlay in 1999, the IRI of the pavement test section dropped to around 52 inches/mile and it has only increased 17 inches/mile to 69 inches/mile by 2015, which is the date of the last survey – a fairly constant increase of ~1 inch/mile per year. Another interesting fact is that the IRI before and after the 2011 chip seal is nearly identical.

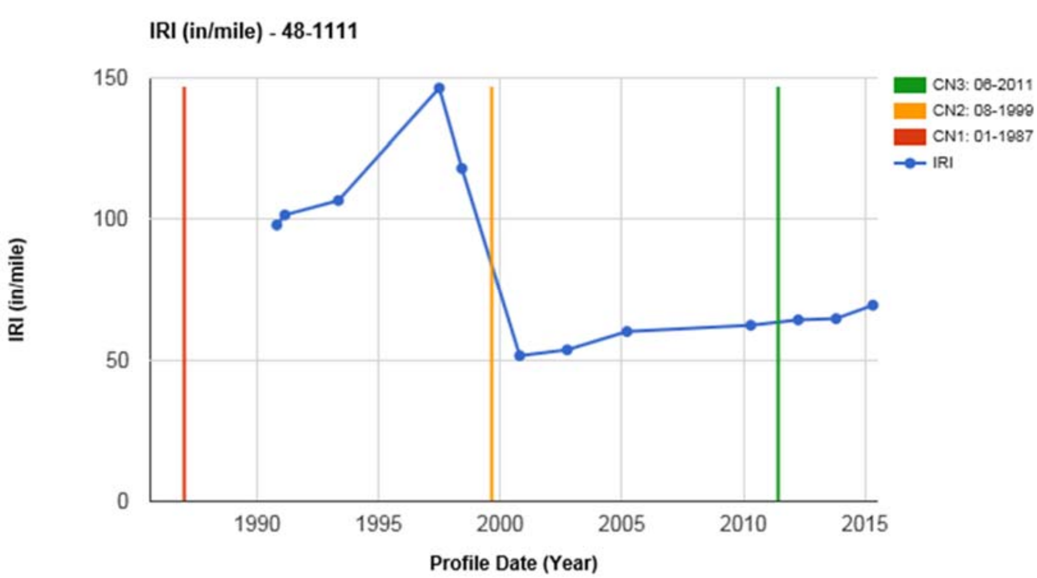


Figure 12. Time history plot of pavement roughness.

SUMMARY OF FINDINGS

In this review of information concerning the performance history of test section 48_1111, the following information was presented:

The test section was originally constructed in 1972 and included in the LTPP program in 1987, consisting of 6.9 inches of AC and 8.4 inches of unbound granular over a clayey sand subgrade. It was included in the LTPP program that same year as part of the GPS-1 experiment. In 1999, a 2.6-inch AC overlay over a woven geotextile fabric was placed on the test section, and through the last field measurements performed in 2016, the test section had performed quite well through 17 years of service (1999 to 2016) with only the application of a 0.5 inch chip seal in 2011.

- The pavement has exhibited excellent performance subsequent to the application of the AC overlay in 1999. Table 5 summarizes the condition of the pavement immediately prior to the 1999 AC overlay, immediately after the 1999 AC overlay and through to the latest survey. As shown in the table:
    - Transverse and longitudinal (non-wheel path) cracking along with IRI appear to have been the drivers of the 1999 AC overlay, 27 years after the pavement was constructed.
    - Other than the above referenced distresses, the pavement test section prior to application of the 1999 AC overlay appears to have been in good condition.
    - Application of the AC overlay and geo fabric in 1999 not only improved all condition metrics, but it appears to have also reduced the deterioration rate for all condition metrics.
- The layer modulus backcalculated from FWD measurements exhibited very stiff base and subgrade layers. This indicates an exceeding good/strong pavement foundation.
- While this test section is classified in a Dry-No Freeze climate zone, it is borderline. The dry climate is defined as average annual precipitation less than 20 inches, however, there are many years when the annual precipitation exceeded 20 inches. In 2005 and 2016 the annual precipitation exceeded 30 inches. The no-freeze zone is defined as have an annual average freeze index less than 150 Deg-F degree-days. In the late 1970's and early 1980's there are freezing indices in excess of 200 and even 300 Deg-F degree-days. However there did not appear to be a detectable trend between these climate extremes and pavement distress manifestations. Although truck volumes in the LTPP lane have almost doubled from 1999 to 2017, this increased truck traffic does not appear to have unduly affected the performance of the test section.

In summary, this pavement test section has performed well over the 1987 to 2016 (last field measurements) time period with just a 2.6 inch AC overlay with geotextile placed in 1999, and a 0.5 inch chip seal in 2011. The function of the use of geotextile fabrics in pavements has long been a subject of debate. It appears in this application the geotextile fabric may have had a positive impact on performance as part of the 1999 AC overlay. Another factor that may have contributed to the performance is the quality of the materials as reflected by the field- and laboratory-derived layer moduli.

Table 5. Pavement Test Section 48_1111 Condition History

Pavement Condition Metric	Condition Prior to AC Overlay	Condition After AC Overlay	Latest Condition
Transverse Crack Count	25	0	0 until 2012 and increased to 28 by 2016
Transverse Crack Length	225 ft	0 ft	0 ft until 2012 and increased to 150 ft by 2016
Alligator Cracking	14 ft^2	0 ft^2	Less than 11 ft^2 through 2016, except for unexplained 28 ft^2 spike in 2010
Longitudinal Cracking Wheel Path	20 ft	0 ft	0 ft until 2015 and increased to 46 ft in 2016
Longitudinal Cracking NWP	260 ft	O ft	Less than 200 ft through 2016 except for unexplained 1,000 ft spike in 2008-2009.
Rutting	0.2 inches	0.1 inches	Has remained less than 0.15 inches through 2016
IRI	118 inches/mile	51 inches/mile	Has remained less than 70 inches/mile through 2015
Normalized Maximum Deflection	12.8 mils	9.6 miles	Has remained below 14.1 mils through 2016

FURTHER EVALUATION RECOMMENDATIONS

It is recommended that the desktop study be extended to further investigate the following:

- Performance expectations are defined during design, but actual performance is driven by construction. As such, it would be beneficial to obtain design information from TxDOT for the original pavement structure as well as for the AC overlay. Information to be pursued includes:
    - Traffic – it is possible, for example, that the pavement was designed for more traffic than it has received, which should lead to improved performance.
    - Material strengths – it is possible, for example, that lower structural layer coefficients were assumed in the design to characterize the AC and granular pavement layers, but the as-constructed coefficients were higher (which the field- and laboratory-derived layer moduli support), then the pavement would have been over-designed leading to improved performance.
    - Layer thicknesses – it is possible, for example, that the pavement layers were constructed thicker than designed, which would mean the pavement was over-designed and hence would have improved performance.

   - Drainage or other features that could have affected the performance of the pavement test section.

  As part of this information gathering effort, it is also recommended that interviews of TxDOT staff familiar with test section be conducted, if possible, to gather their thoughts as to why it has performed so well.

- It is apparent from the performance of the test section that the AC overlay and underlying AC layers are well bonded to each other and are acting monolithically, as reflected by the field-derived backcalculated layer moduli. However, it would be beneficial, and hence it is recommended, that the bonding between the referenced AC layers be confirmed.
- It is suggested that the influence of the woven geotextile on the performance of the pavement test section be investigated. A possible way of doing this is to do transverse cracking coring to see if the cracks on surface are reflection cracks from previous transverse cracks, which would support the idea that the fabric retarded reflection cracking for an extended period of time.
- Since the last field measurements were performed in 2016, it is recommended that another round of distress and IRI surveys be conducted to confirm the performance of the pavement through 2019. Additional FWD testing would also be beneficial in order to confirm the current structural soundness of the pavement, but this is not considered as critical.
- Given the apparent lack of material layer characterization data, it is suggested that MRL material samples for the test section be used to address current material data gaps. If the material is not available, then it is recommended that coring and boring be performed to obtain the required material.

ATTACHMENT A: FOLLOW-UP FIELD INVESTIGATIONS

The follow-up field investigations were performed:

- FWD testing was performed in early afternoon on November 14, 2019 following standard LTPP FWD protocols.
- Coring was also performed on November 14, 2019 whereby eight cores were obtained from within the monitoring section.
- Longitudinal profile measurements were performed on November 14, 2019 using the LTPP High Speed Survey vehicle and following standard LTPP profiling protocols.

SUMMARY OF CURRENT CONDITION

During the November 2019 field visit, a visual distress survey was performed to quantify the level of surface distress present within the section. The number of transverse cracks has surpassed the pre-overlay number, but the total length of transverse cracking has remained small. The alligator cracking is similar to the amount recorded between 2010 and 2015, indicating that no further alligator cracking has formed since 2015. There was no longitudinal cracking in the wheel path, which has historically been the case since the AC overlay. Non-wheel path longitudinal cracking remains at a very low value of only 54 feet. The calculated IRI value of 64 inches/mile is similar to historical IRI values that show a slow increase since the AC overlay was constructed. Lastly, the average load-normalized maximum deflections on the section are nearly identical to those recorded just after overlay construction.

Table 6. Pavement Test Section 48_1111 Condition History

Pavement Condition Metric	Condition Prior to AC Overlay	Condition After AC Overlay	Latest Condition- November 2019
Transverse Crack Count	25	0	31
Transverse Crack Length	225 ft	0 ft	58.1 ft
Alligator Cracking	14 ft2	0 ft2	10.3 ft2
Longitudinal Cracking Wheel Path	20 ft	0 ft	0 ft
Longitudinal Cracking NWP	260 ft	0 ft	53.7 ft
IRI	118 inches/mile	51 inches/mile	64 inches/mile
Normalized Maximum Deflection	12.8 mils	9.6 mils	9.8 mils

ORIGINAL CONSTRUCTION PLANS

During an extensive review of documents available from the project, some of the original construction plans from 1971 were recovered. The plan sheets show that at least some portions of the pavement near the test section could include soil stabilization with lime. The plan sheets also show the existing frontage road contained some lime stabilization and it is possible that some soil stabilizations were utilized on the mainline pavement near and possibly including the test section.

Further exploration of the available records on the Infopave™ website led to the discovery of a test pit being dug in Section 48_1111 on June 23, 1989. The test pit clearly shows approximately 9 inches of aggregate base which is placed on top of a dark, fine-grained soil. This photo is shown in Figure 13. This shows that there is most likely no subgrade stabilization beneath the aggregate base.

Figure 13. Test pit dug in section 48_1111.

CORE SUMMARY

Eight core samples were obtained from Section 48_1111. Two additional cores were planned between stations 381 and 500 but, due to time constraints and equipment problems, were not obtained. The cores show that the chip seal and AC overlay are relatively uniform in thickness, ranging from a combined 2.2 inches to 2.4 inches. There is some layer variation in the lower AC layers, which show a wider range of thicknesses. The total thickness of the AC section on top of the aggregate base varies from 5.3 inches up to 8.4 inches. The core measurements are summarized in Table 7 and total AC thickness shown in Figure 14.

Table 7. Summary of Cores Obtained from Within Section 48_1111

Core Number	Station (ft)	Offset from Fogline (ft)	Layer Thickness (in)							Total AC Thickness (in)
			L9- Chip Seal	L8-AC Overlay	L7- Eng. Fabric	L6- Seal Coat	L5- Seal Coat	L4-AC Surface	L3-AC Binder	
CA01	11.8	5.2	0.1	2.2	0.1	0.0	0.0	0.9	5.1	8.4
CA02	42.3	6.6	0.1	2.1	0.1	0.0	0.0	0.8	4.7	7.8
CA03	96.8	6.6	0.1	2.1	0.1	0.0	0.0	0.6	2.4	5.3
CA04	197.5	4.9	0.1	2.1	0.1	0.0	0.0	0.9	5.0	8.2
CA05	240.8	7.2	0.2	2.0	0.1	0.0	0.0	0.6	4.7	7.6
CA06	277.6	7.2	0.1	2.1	0.1	0.0	0.0	0.6	4.4	7.3
CA07	332.0	3.9	0.1	2.3	0.1	0.0	0.0	0.7	4.4	7.6
CA08	381.2	3.3	0.2	2.2	0.1	0.0	0.0	0.7	4.7	7.9

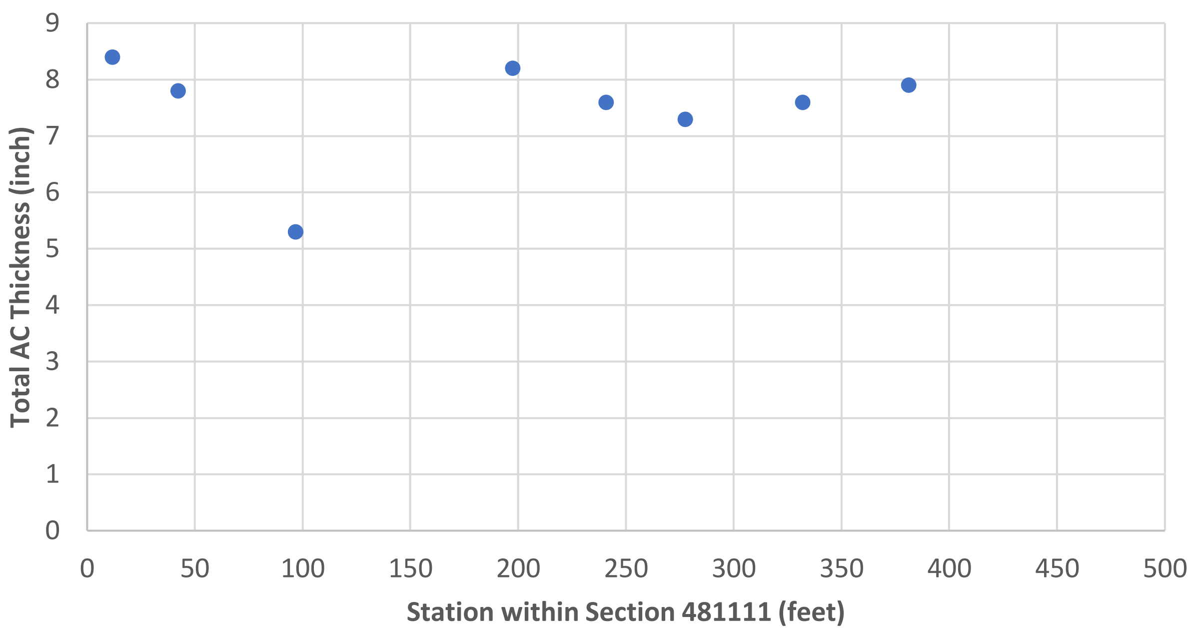


Figure 14. Plotted total AC thicknesses from cores obtained within section 48_1111.

Several of the cores were obtained on top of cracks to determine the depth of cracking and whether to crack was a top-down or bottom-up crack. The condition of the underlying AC (layers L4 and L3) was mostly in poor condition with several cores showing extensive cracking in these layers. Core CA06 was taken at a location where cracking existed before the overlay, and no surface cracking was observed. The observed cores are summarized in Table 8. Seven of the eight cores recovered from the section showed the surface cracks had reflected into the overlay and through the geosynthetic fabric placed underneath the overlay. In cores where the integrity of Layer 4 is best, reflective cracking is minimized. The geosynthetic fabric could have played a role in slowing down crack propagation into the AC overlay as well. Core photographs are shown in Attachment B.

Table 8. Summary of Visual Observations of 48111 Cores

Core Number	Station (ft)	Visual Condition and Cracking Notes	Crack Reflected through Fabric?
CA01	11.8	ENTIRE CORE SPLIT IN HALF. TOP LAYER BROKE OFF. Split Through.	Yes
CA02	42.3	ONLY CAPTURED PART OF THE KNOWN CRACK WITHIN THE LOWER LAYERS (REF 1999 MDS). Reflected through Top.	Yes
CA03	96.8	CORE BROKE OFF. SHORT. Split Through.	Yes
CA04	197.5	CRACK AT AN ANGLE. Reflected through Top.	Most Likely Yes
CA05	240.8	CRACK ALL THE WAY THROUGH. Split through.	Yes
CA06	277.6	BARELY CAUGHT CRACK UNDERNEITH. Bottom Up not Through.	No
CA07	332.0	CRACK ONLY SEEN ON TOP 2 LAYERS (5 & 6). Reflected through Top.	Yes
CA08	381.2	CRACK GOES THROUGH. Split Through.	Yes

* Cores with **bold** font have good integrity with regards to Layer 4

ADDITIONAL TEXAS DOT TRAFFIC DATA

The desktop study discusses the historical traffic volumes in the LTPP test lane as determined by TxDOT, which is illustrated in Figure 5. The results show that up until 2010 the estimated average daily truck traffic on the LTPP section was around 400 trucks per day. The data then indicates a substantial increase of up to 300 trucks per day after 2010.

The TxDOT's Traffic Count Database System (TCDS) showed a traffic count station in the immediate vicinity of Section 48_1111. The traffic counts from this traffic station are broken down by lane and summarized in Table 9. The results show the actual AADTT in the 2010's was actually less than the approximate 400 trucks per day shown in Figure 5 in the year 2010. Furthermore, this shows a decline in truck traffic compared to the historical trend of yearly increases that stretches back to the 1990's.

Table 9. Traffic Data from TxDOT TCDS Database for Count Station near 48_1111

EB Outside Lane (LTPP Lane)				EB Inside Lane			
Year	AADT	Percent Trucks	AADTT	Year	AADT	Percent Trucks	AADTT
2018	4,196	--	--	2018	991	--	--
2017	2,943	--	--	2017	1,044	--	--
2016	3,838	8%	291	2016	1,014	1%	12
2015	3,518	8%	293	2015	1,016	2%	16
2014	3,814	--	--	2014	864	--	--
2013	3,781	8%	286	2013	858	2%	16

FWD DATA ANALYSIS

FWD data was collected on section 48_1111 following standard LTPP protocols. Table 4 illustrates the backcalculated moduli values from historical FWD data. The pavement model used to analyze these results includes 9.5 inches of AC on top of 24 inches of Base/SG on top of a third semi-infinite layer representing the subgrade. Moduli values obtained through backcalculation are dependent on the model used to represent the pavement structure. In this case, combining the 8.4 inches of aggregate base with 15.6 inches of subgrade will impact the moduli values for all three layers compared to a pavement model that modeled the 8.4 aggregate base separately from the subgrade soil. The EVERCALC software was used to backcalculate moduli values from the FWD data. Two pavement models were used, the first representing the same model discussed in Table 4, the second representing the actual pavement thicknesses where the base and subgrade were not combined in the middle layer. The backaclulated moduli values for each pavement model are summarized in Table 10 and Figures 15 to 17.

The results show the subgrade modulus is nearly identical regardless of the pavement model used. This makes sense as the outer sensors are used to determine subgrade modulus, which would not be influenced by the thickness used for layer 2. The AC modulus values are also very similar, the model using the 24-inch base layer produced AC moduli that were roughly 7% higher than the standard model. The largest discrepancy occurs in the modulus of layer 2. In the 24-inch model, the base moduli values are very similar to that of the subgrade, which is to be expected as this layer contains 15.6 inches of subgrade compared to only 8.4 inches of aggregate base. The standard model uses 8.4 inches of aggregate base, so the moduli values for this layer are more representative and realistic of the in-situ base layer.

Table 10. Summary of Backcalculated Moduli Values from EVERCALC

24-inch Pavement Model		"Standard" Pavement Model	
Layer Number/Type	Layer Thickness (inch)	Layer Number/Type	Layer Thickness (inch)
1-AC	9.5	1-AC	7.8
2-Base & SG	24	2-Base	8.4
3-SG	Semi-Infinite	3-SG	Semi-Infinite

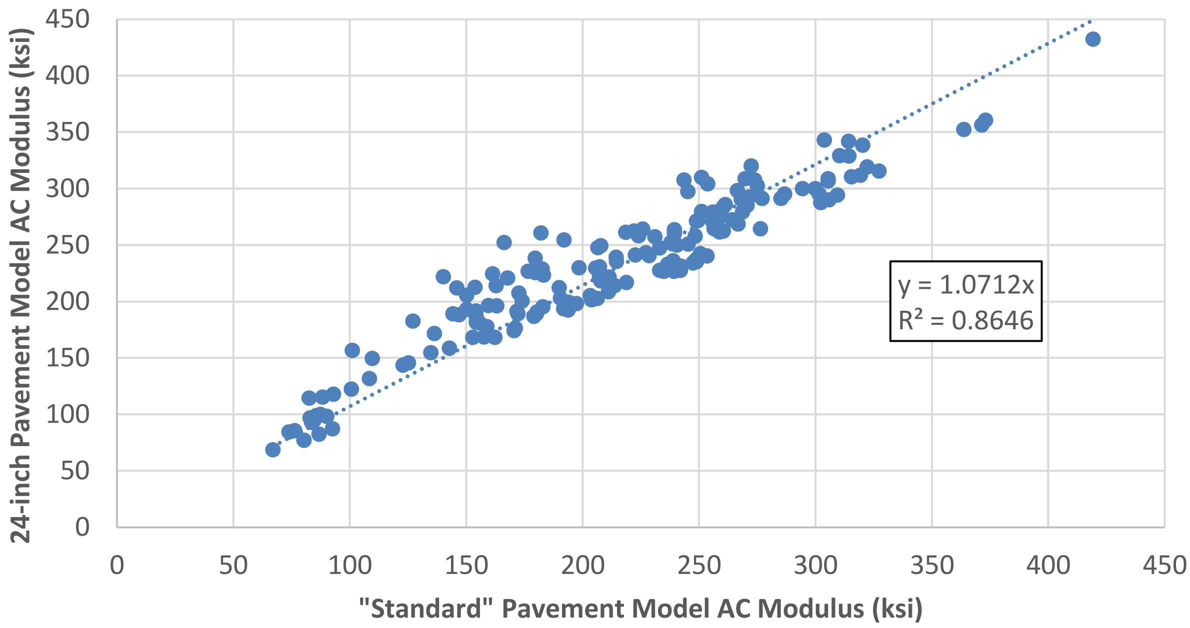


Figure 15. Plotted AC moduli values from standard pavement model compared to 24-inch pavement model.

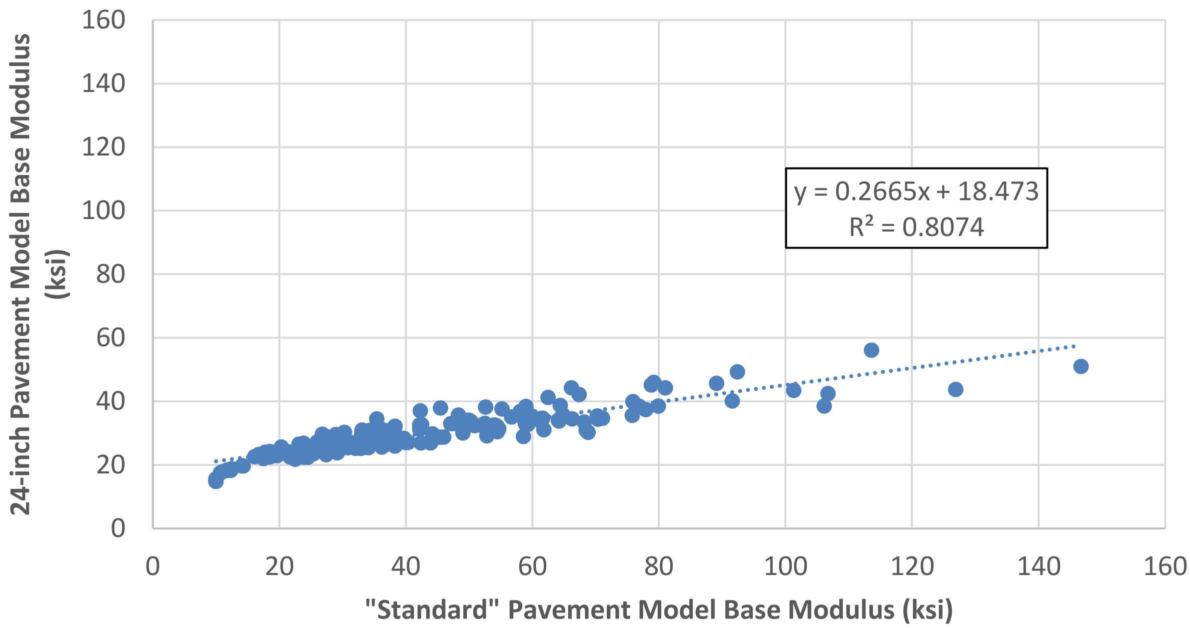


Figure 16. Plotted aggregate base moduli values from standard pavement model compared to 24-inch pavement model.

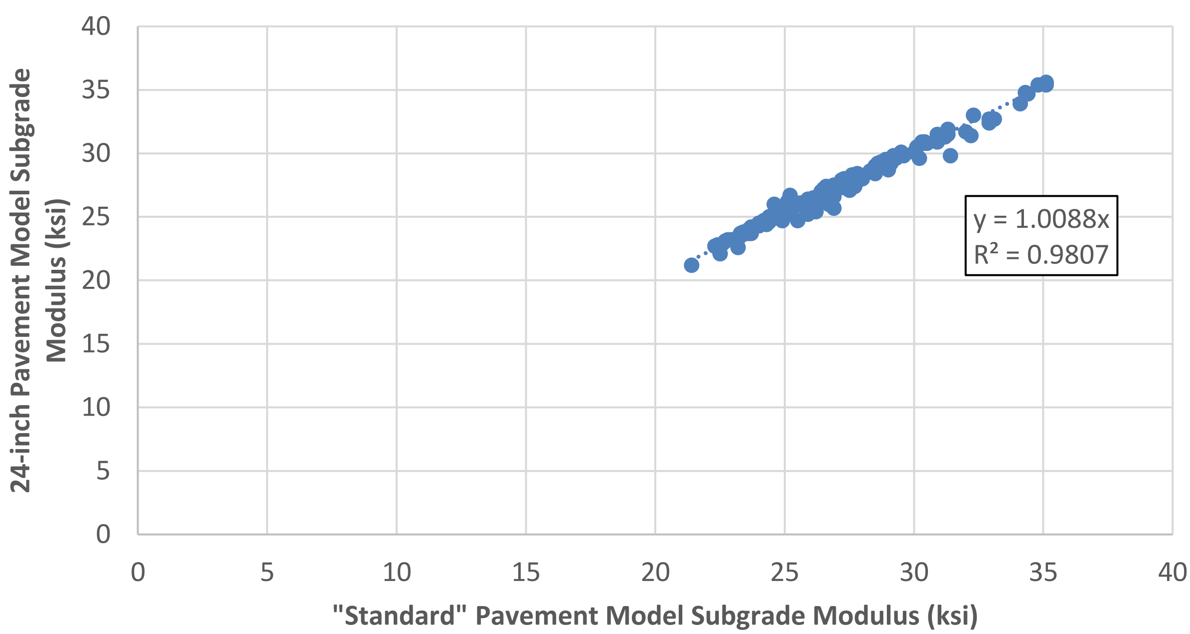


Figure 17. Plotted subgrade moduli values from standard pavement model compared to 24-inch pavement model.

In addition, the AASHTO 1993 Guide for Design of Pavement Structures included a chapter discussing AC overlay thickness designs. The Guide presents a closed form backcalculation procedure that can be used to determine the structural number of an existing pavement from FWD test data. This effective structural number (SN_{eff}) can be used to estimate the number of ESALs the pavement can withstand before reaching failure, defined as reaching a PSI values of 2.5. In addition to the recently collected 2019 FWD data, all of the FWD data from section 48_111 was obtained from the Infopave™ website and analyzed according to this backcalculation procedure. The results are summarized in Table 11 and illustrated in Figure 18.

Table 11. Summary of Remaining Life Values from FWD Data over life of section 48_1111

FWD Test Date	Average Remaining ESALs
6/23/1989	1,895,754
9/7/1993	1,290,865
7/1/1997	1,986,030
3/25/1998	1,291,464
10/19/2001	2,851,487
5/28/2003	1,266,391
3/14/2012	3,622,138
6/7/2016	1,233,180
11/14/2019	1,778,088

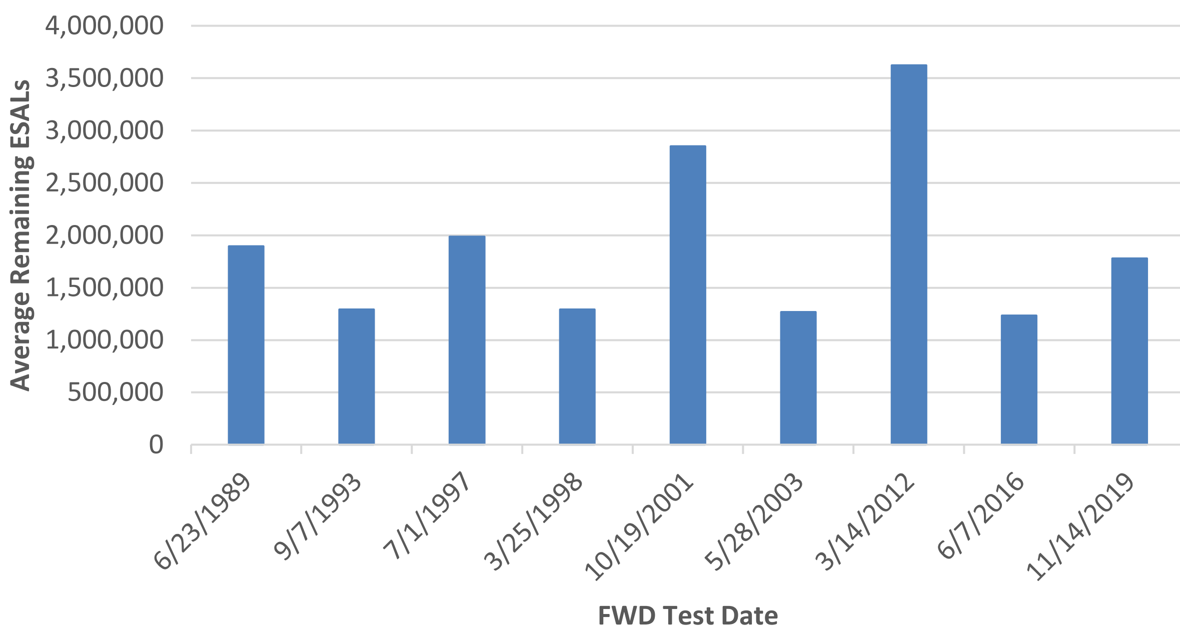


Figure 18. Plotted average remaining ESALs values from FWD data over life of section 48111.

The remaining ESAL values show the existing pavement could withstand between 1.3 and 2 million ESALs prior to the overlay construction in August of 1999. Analysis of the FWD data collected since overlay constructed showed the remaining ESAL values ranged between 1.2 and 3.6 million ESALs. While the numbers do not show a clear trend, it is interesting how the values from 1993 and 1998 compare favorably to the values from 2003 and 2016. The remaining ESALs is based on the AC structural design equation; but instead of starting with a design ESAL value and determining structural number, the FWD determines the structural number and the "design" ESAL value is calculated. The AASHTO 1993 design methodology is based on stiffness, a stiffer pavement section will give a higher structural number and can accommodate a higher number of ESALs. The failure criteria is based on reaching a terminal pavement serviceability index of 2.5, which is a function of surface cracking.

The fact that the remaining ESAL values for these four years ('93, '98, '03, '16) are similar would indicate the pavement's overall stiffness has remained relatively constant. If that is the case, surface cracks should begin to form as the pavement is subjected to additional truck loadings. However, the surface distresses have not manifested as quickly as the remaining ESAL values would indicate. This could be due to the truck traffic consisting of under-loaded trucks, resulting in a low ESAL-per-truck number and a low number of ESALs the pavement carries per year. However, it must be noted the ASHTO 93 design guide was developed without assessing the impact of geosynthetics, such as the one placed between the existing pavement and 1999 overlay on section 48_1111.

The impact of the geosynthetic can't be explicitly accounted for in the AASHTO design guide, except for artificially increasing the AC layer coefficient. The design equations are based on un-reinforced pavement sections, so a pavement with a certain structural number is expected to deteriorate and have surface distresses occur at a certain rate. The pavement in section 48111, with the inter-layer geosynthetic, will not behave like an unreinforced pavement with the same structural number. The remaining ESAL values do not always decrease over time, due to a significant number of factors, but the numbers here suggest that the geosynthetic has slowed the progression of the cracks in bottom AC layers from reflecting into the overlay.

SUMMARY OF OBSERVATIONS AND CONCLUDING REMARKS

The following observations are based on the follow-up investigations on the Texas 1111 test section:

- FWD Analysis
    - Load normalized deflections of the 2019 FWD data fall in line with historical deflections, which show that the pavement has not experienced any significant structural deterioration.
    - Backcalculation performed using EVERCALC highlighted the impact of the pavement model used on the modulus values. The AC, base, and subgrade all had similar moduli values compared to the historical backcalculated moduli values. However, when the backcalculation model was adjusted, the base modulus increased by approximately 50%; the AC and subgrade moduli values experienced a less significant increase.
    - The FWD remaining life analysis showed that the average remaining ESALs for each FWD test date, while variable, do not show a decrease over time as would be expected. The remaining ESALs represents the number of ESALs the pavement can withstand before reaching failure, where surface cracks are widespread through the test section.
        - This could indicate the paving fabric has made a significantly positive impact on the manifestation of reflective cracks from the underlying AC into the overlay. The remaining ESALs values indicate these reflective cracks should have already occurred, likely several years ago.
- Surface Distress
    - Total number of transverse cracks has surpassed the number of transverse cracks observed pre-overlay. However, the total crack length is significantly less in 2019 compared to pre-overlay conditions.

    - There is almost no alligator cracking nor longitudinal cracking in the wheel path. This is somewhat surprising when considering the level of degradation of the AC material beneath the fabric.
    - Rutting data were not available at the time of the follow-up investigations; however it is not expected that rutting values will differ substantially from historical values. Over the life of section 48_1111, wheel path rutting has not been an issue. Nonetheless, it is recommended that once the rutting data are available in the LTPP database that a more in-depth analysis be undertaken, including an analysis of the data to the determine the predominant layer where plastic deformation is occurring in accordance with the method developed in NCHRP 01-34a, which is published in NCHRP Report No. 468: Contributions of Pavement Structural Layers to Rutting of Hot Mix Asphalt Pavements. National Cooperative Highway Program, Washington D.C., 2002.
- Roughness
    - The IRI of the test section in 2019 indicate the test section is still very smooth, and the IRI has only increased by 13 in/mile over the nearly 20 years since the overlay was placed.
- Coring
    - The cores obtained from within the section in 2019 show how the total thickness of AC varies slightly along the length of the test section. With the exception of core CA03, the total AC thickness ranged from between 7.3 and 8.4 inches.
    - Visual observations showed that at least 6, possibly 7, of these 8 cores had cracks which had reflected from below the fabric into the AC overlay. Despite this, the amount of surface distress observed in 2019 does not indicate this is a widespread problem throughout the section.
    - The degree of deterioration in Layer 4 appears to correlate strongly with reflective cracking.
- Traffic Data
    - The LTPP traffic data does not line up with TxDOT truck traffic counts. While the LTPP traffic data show estimated average daily truck traffic ranging from around 325 to 400 trucks per day since 2013, the TxDOT truck traffic counts stay consistently lower at around 300 trucks per day since 2013.

Overall, the 1999 overlay of test section 48_1111 performed extremely well. The degree of contribution of the geotextile fabric to this outcome is uncertain, but it does appear to have been a positive influence on performance. Whether future treatment options are impacted in having to deal with the fabric interlayer is yet to be determined. In some locations the bonding between layers was excellent, while it had deteriorated in others, and the cracking locations were linked to the latter. Pavement smoothness was not impacted significantly regardless of the bonding condition. The pavement design conditions were not radically different than the as-built structure and subsequent traffic loading—acknowledging that LTPP and TxDOT traffic data show some variance—so overdesign of the pavement does not appear to be a reason for the excellent performance.

ATTACHMENT B. CORE PHOTOGRAPHS


State Code: 48
SHRP ID: 1111
Sample Location: C02
Sample Number: CA02
Area Number: 3
Date: (Day/Month/Year) 14-Nov-19
Field Set: 3


State Code: 48
SHRP ID: 1111
Sample Location: C02
Sample Number: CA02
Area Number: 3
Date: (Day/Month/Year) 14-Nov-19
Field Set: 3


State Code: 48
SHRP ID: 1111
Sample Location: C03
Sample Number: CA03
Area Number: 3
Date: (Day/Month/Year) 14-Nov-19
Field Set: 3


State Code: 48
SHRP ID: 1111
C04
CA04
3
14-Nov-19
Field Set: 3


State Code: 48
SHRP ID: 1111
Sample Location: C05
Sample Number: CA05
Area Number: 3
Date: (Day/Month/Year) 14-Nov-19
Field Set: 3


State Code: 48
SHRP ID: 1111
Sample Location: C06
Sample Number: CA06
Area Number: 3
Date: (Day/Month/Year) 14-Nov-19
Field Set: 3


State Code: 48
SHRP ID: 1111
Sample Location: C07
Sample Number: CA07
Area Number: 3
Date: (Day/Month/Year) 14-Nov-19
Field Set: 3
Lufkin


State Code: 48
SHRP ID: 1111
Sample Location: C08
Sample Number: CA08
Area Number: 3
Date: (Day/Month/Year) 14-Nov-19
Field Set: 3
Lufkin