Technical Memorandum

To: Jeff Uhlmeyer

From: Lauren Gardner, Gonzalo Rada, Kevin Senn and Gary Elkins

cc: Mustafa Mohamedali

Date: May 29, 2020

Re. Forensic Desktop Study Report: South Carolina LTPP Test Section 45_1024

The Long-Term Pavement Performance (LTPP) General Pavement Study (GPS-1) test section 45_1024[1] was nominated for a desktop study under TPF-5(332) "LTPP Forensic Evaluations." The pavement at this test section was constructed in 1985, and the pavement structure consists of 1.6 inches of asphalt concrete (AC) on 4.8 inches of granular base over coarse grained soil. After 35 years since the section's construction, and 33 years since its inclusion into the LTPP program, the test section is still active despite a very thin pavement structure and no maintenance or rehabilitation applications. Moreover, prior to 2015, other than the presence of some cracking, the test section was performing well – latest measured IRI at 98 inches/mile and maximum rutting at 0.2 inches – despite being in an area subjected to high precipitation. In light of the performance of this section, this test section is being recommended for forensic investigation in order to (1) investigate the long-term performance of the pavement structure in terms of cracking, rutting and IRI, (2) assess performance of pavement in the absence of traffic, (3) explore the initiation and propagation of the various crack types, and (4) identify those factors most responsible for the performance of the pavement.

SITE DESCRIPTION

LTPP test section 45_1024 is located on State Route 1623, eastbound, in Lexington County, South Carolina. State Route 1623 is an urban collector with one lane in each direction of traffic. It is classified as being in a Wet, No Freeze climate zone with an average annual precipitation ranging between 29.54 inches (2001) and 65.30 inches (2015). The test section has an average annual freezing index ranging between 0 deg-F deg-days (multiple years) and 40 deg-F deg-days (1985) during the performance period. The coordinates (in degrees) of the test section are 34.01269, -81.14397. Photograph 1 shows the test section at Station 5+00 looking westbound in 2014, while Map 1 shows the geographical location of the test sections relative to Columbia, South Carolina.

[1] First two digits in test section number represent the State Code [45 = South Carolina]. The final four digits are unique within each State/Province and were assigned at the time the test section was accepted into the LTPP program.

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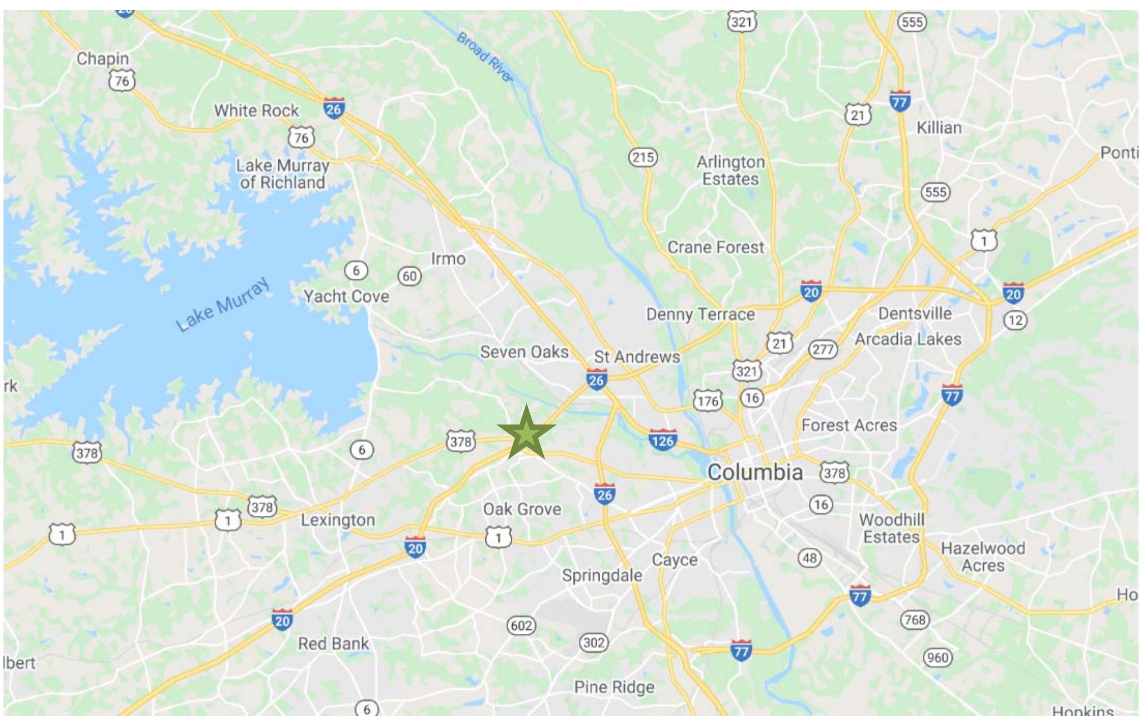
Photograph 1. LTPP Section 45_1024 at Station 5+00 looking westbound in 2014.



Map 1. Geographical location of test section relative to Columbia, South Carolina.

BASELINE PAVEMENT HISTORY

This section of the document presents historical data on the pavement structure and its structural capacity, climate, traffic and pavement distresses.

Pavement Structure and Construction History

The test section was constructed in 1985 and incorporated into the LTPP program in January 1987 as part of the GPS-1 (Asphalt Concrete on Granular Base) Experiment. The pavement structure at the time of its incorporation into LTPP consisted of 1.6 inches of hot mixed, dense graded Asphalt Concrete (AC) on 4.8 inches of unbound granular base over a coarse-grained subgrade. The pavement structure for the test section in 1987 is summarized in Table 1; this information corresponds to CONSTRUCTION_NO = 1 (CN = 1) in the LTPP database. According to the LTPP database, no further construction events have taken place following the initial construction.

Table 1. Pavement structure for CN =1

Layer Number	Layer Type	Thickness (in.)	Material Code Description
1	Subgrade (untreated)		Coarse-Grained Soil: Clayey Sand with Gravel
2	Unbound (granular) base	4.8	Soil-Aggregate Mixture (Predominantly Coarse-Grained)
3	Asphalt Concrete (AC) Layer	1.6	Hot Mixed, Hot Laid AC, Dense Graded

Figure 1 shows the average Falling Weight Deflectometer (FWD) deflection under the nominal 9,000-pound load plate over time. The deflection of the sensor located in the center of 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 moisture. As depicted in Figure 1, the deflections observed on the site have remained relatively constant, with values ranging between 14.1 mils (2012) to 23.7 mils (1995).

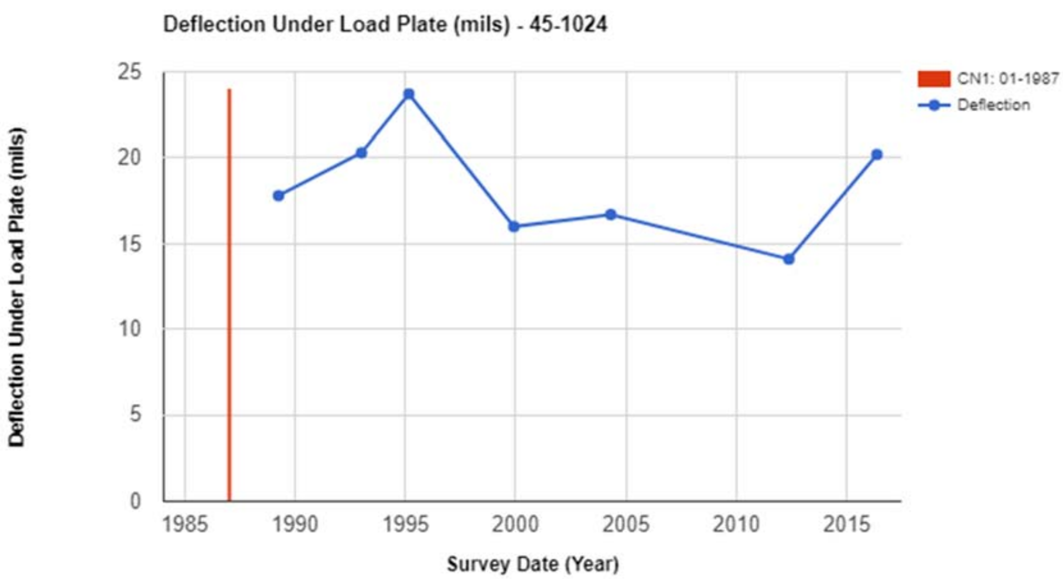


Figure 1. Average deflections over time.

Table 2 shows the layer moduli backcalculated (using EVERCALC 5.0 software) from the deflection data measured in April 1989, January 1993, March 1995, December 1999, and May 2012 (five rounds of FWD testing), which were available in the LTPP database. The pavement structure was modeled as a 1.6-inch AC layer over 4.8 inches of granular base on top of a semi-infinite layer of coarse-grained subgrade.

Table 2. Backcalculated average modulus over time.

Layer No.	Date	Average Monthly Temperature (deg F)	Average Modulus (ksi)
Layer 1—Asphalt	04/06/1989	52.3	2421
	01/07/1993	50	2847
	03/02/1995	47.7	2114
	12/02/1999	40.8	3621
	05/18/2012	67.8	3431
Layer 2—Base	04/06/1989	52.3	33
	01/07/1993	50	24
	03/02/1995	47.7	23
	12/02/1999	40.8	27
	05/18/2012	67.8	32
Layer 3—Subgrade	04/06/1989	52.3	59
	01/07/1993	50	50
	03/02/1995	47.7	46
	12/02/1999	40.8	60
	05/18/2012	67.8	64

As depicted in the table above, the average backcalculated moduli reported (at Record Status E), for the AC surface layer are higher than expected, while the moduli for the base and subgrade layers appear more reasonable. It is hypothesized the high AC moduli are the result of the layer being so thin, and consequently only the geophone immediately under the load plate center was able to capture the response of that layer – i.e., the deflections captured by the remaining geophones were mostly due to deformations that took place in subgrade. It is also possible there were compensating layer moduli effects as a result of the thin AC layer thickness; e.g., the AC moduli are higher than anticipated because moduli of the granular base layer were underestimated by the backcalculation software.

Climate History

The time history for average annual precipitation (from the virtual weather station (VWS) for the site) since 1985 is shown in Figure 2. In 2015, the amount of precipitation appears to be a local high (65 inches), while the low (30 inches) was recorded in 2001. The mean precipitation recorded at the site was 46 inches for the period shown in Figure 2. While some variation in precipitation is expected, the amount of precipitation reported in 2015 is notable. The increase in precipitation in 2015 on the test site is likely related to flooding event that occurred in South Carolina in early October of 2015. The severe flooding, which was caused in part by Hurricane Joaquin, resulted in more than 20 inches of rainfall in nearby Columbia, SC[2]. As discussed in the sections to follow, the high amount of precipitation observed in 2015 is likely the cause of the increased cracking and the sand deposits observed on the test section in 2016.

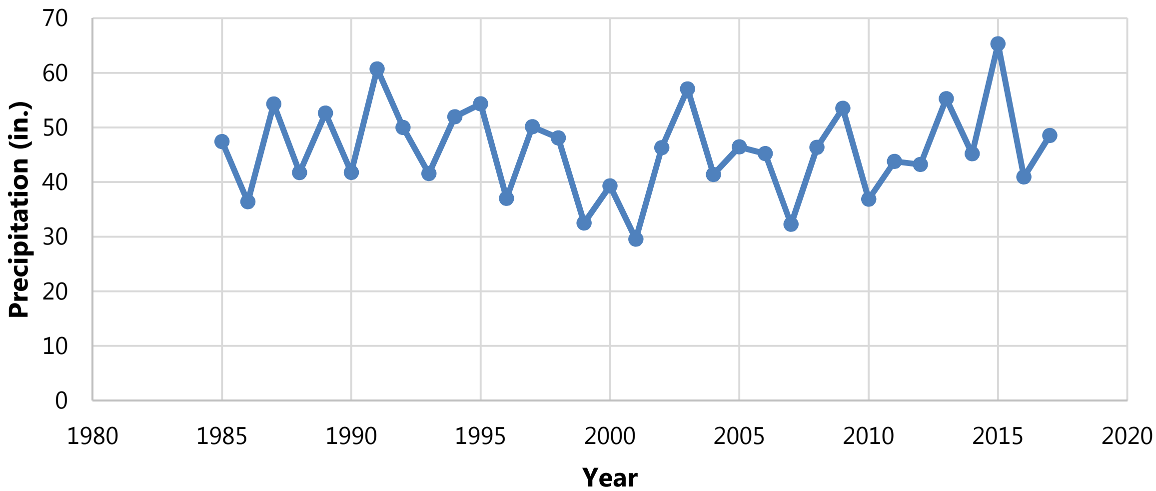


Figure 2. Average annual precipitation over time.

Figure 3 shows the time history of the average annual freezing index (from the VWS) for the test site. The freezing index is the summation of the difference between freezing temperature and the average air temperature when it is less than freezing 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. As depicted in Figure 3, the freezing index values ranged from 0 (multiple years) to 40 (in 1985)—which is well below the 150 deg F deg days used to classify a freeze region—indicating it is not a likely factor affecting the performance of the test section.

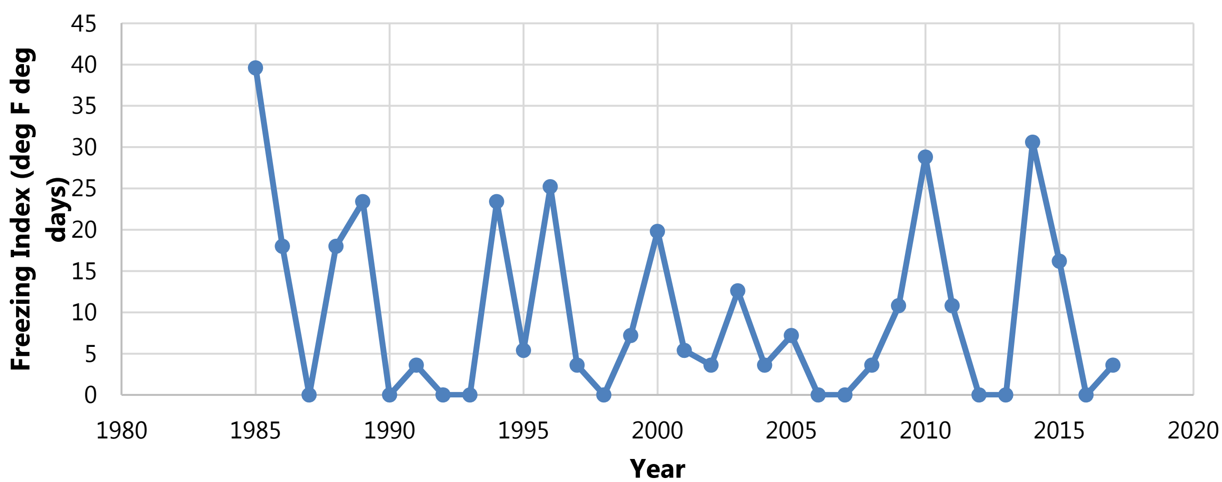


Figure 3. Average annual air temperature freezing index over time.

[2] National Oceanic and Atmospheric Administration (2016). *The Historic South Carolina Floods of October 1-5, 2015.* U.S. Department of Commerce. Silver Spring, Maryland.

Truck Volume History

Figure 4 shows the average annual daily truck traffic data in the LTPP test lane by year. In 1985, when the section was constructed, the average daily truck traffic reported was 4. By 2017, the average daily truck traffic increased to 19. The number of 18-kip ESALS increased from 1 in 1985 to 3 in 2008. While a slight increase in the traffic and loading is observed over time, the total amount of traffic and loading is still extremely low (close to 0) and therefore, the performance of the pavement may be similar to the performance of a pavement in the absence of traffic loading.

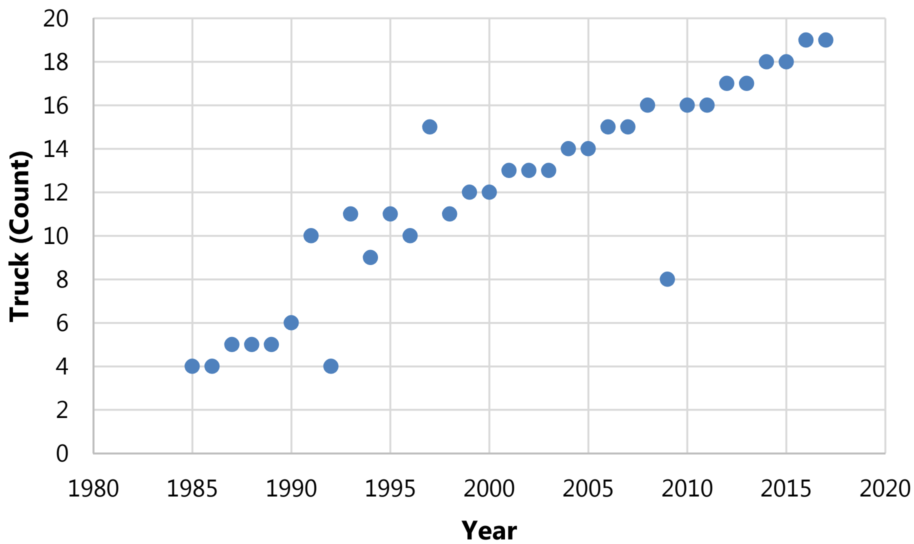


Figure 4. Average annual daily truck traffic history.

The slight increase in truck traffic and ESALs reported, while minimal, may be the result of the change in land use along this roadway over time. Between 1994 and 2002, the corporate office for Southeastern Freight Lines was constructed just north of the test site. The construction of the office may have contributed to an increase in both traffic due to construction as well as deliveries. The increase in the number of ESALs may be related to the increased loads from FWD testing on the roadway. Regardless, the amount of truck traffic and ESALs observed on this roadway remains relatively low and therefore, likely plays a limited role in the performance of the pavement over time.

Pavement Distress History

The following section summarizes the distresses observed on the test section between the time the section was constructed and 2019, which is when the last manual distress survey was performed on the test section. Fatigue cracking, longitudinal cracking (inside and outside the wheel path), transverse cracking, IRI, and rutting were assessed. No block cracking and minimal patching (3 ft^2) was observed[3].

Fatigue Cracking

Figure 5 shows the total area of fatigue related cracking observed on the sections. As the cracking observed on the section is limited to the wheel paths, it is hypothesized that it is the result of bottom-up cracking. For the test section, the area of roadway where fatigue cracking was observed increased over

[3] Please note that the patching observed on the site is over a core hole approximately 84 meters from sta. 0+00. The coring (which was subsequently patched) at this location is in violation of the standing LTPP policy that pavement in the test section should not be disturbed. A Data Analysis/Operations Feedback Process (DAOFR) will be prepared to make note of this violation as well as to add associated CN event to the LTPP database.

time. Fatigue cracking was first observed on the section in June 1997, almost 12 years after the initial construction of the site, when 25 ft^2 of fatigue cracking was observed. Once the cracking had initiated, it propagated at an average rate of 18 ft^2/year over the next 22 years. By 2019, 427 ft^2 of fatigue cracking was observed.

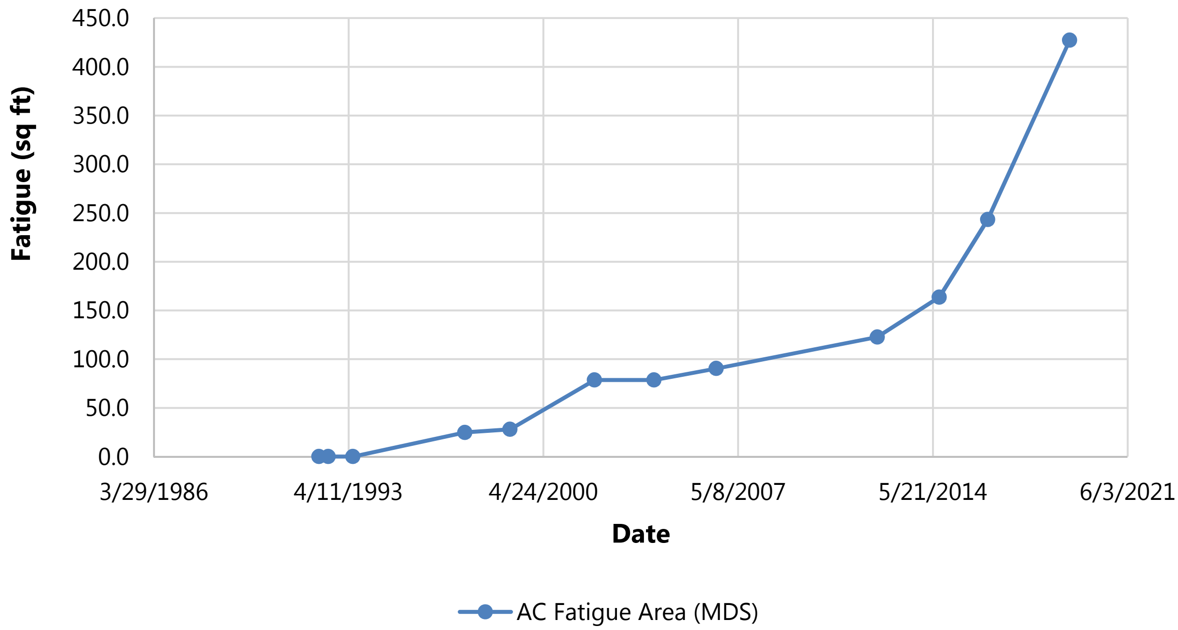


Figure 5. Time history of the area of fatigue cracks.

While an increase in fatigue cracking as the pavement ages is expected, a notable (80 ft^2) increase is observed between 2014 and 2016, or prior to and following the 2015 flood event. As discussed previously, the increase in fatigue cracking in 2016 and subsequent years is likely a result in the increased average annual precipitation observed in 2015. As water infiltrates the pavement layers, the base and subgrade tend to weaken (especially when reaching saturation conditions) causing the increase in fatigue cracking observed. This is further exacerbated as both the base and AC layers are thin.

Longitudinal Cracking

Figure 6 shows the total length of non-wheel path (NWP) longitudinal cracking observed on the section. The length of NWP longitudinal cracking was observed to increase over time. NWP longitudinal cracking was first observed on the section in June 1997, almost 12 years after initial construction, when 9 ft of NWP longitudinal cracking was observed. Once the cracking had initiated, it propagated at a rate of 2 ft/year, over the next 22 years. By 2019, 272ft of NWP longitudinal cracking was observed. The NWP longitudinal cracking was predominantly found along the centerline and edge of the lane. Similar to the fatigue cracking observed on the section, there was a notable increase in the amount of NWP longitudinal cracking observed between 2014 and 2016, before and after the 2015 flood event, which is likely a result of the increased average annual precipitation observed in 2015.

Figure 7 shows the total length of wheel path (WP) longitudinal cracking observed on the section. For the pavement section, little to no WP longitudinal cracking was observed over time. WP longitudinal cracking was first observed on the section in June 1993, 8 years after the construction of the pavement structure, when 7 ft of WP longitudinal cracking was observed. WP longitudinal cracking was also observed in June

1997. Both these reported values may be attributed to WP longitudinal cracking that evolved into fatigue cracking by 1999.

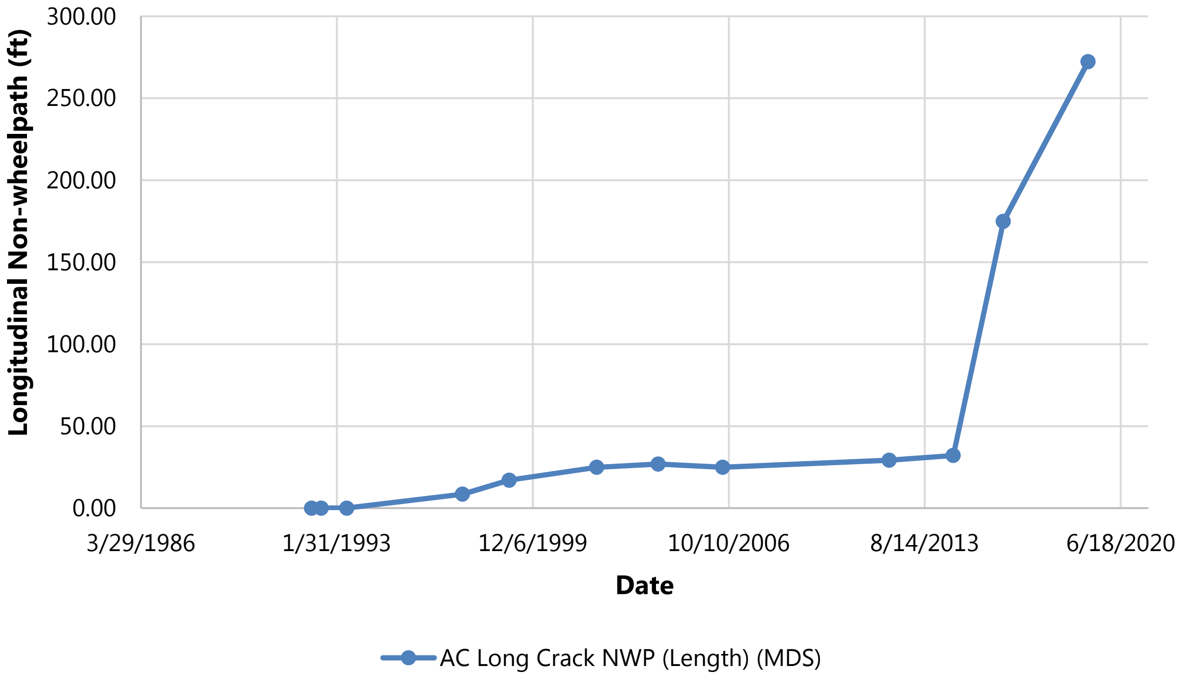


Figure 6. Time history of the length of NWP longitudinal cracks.

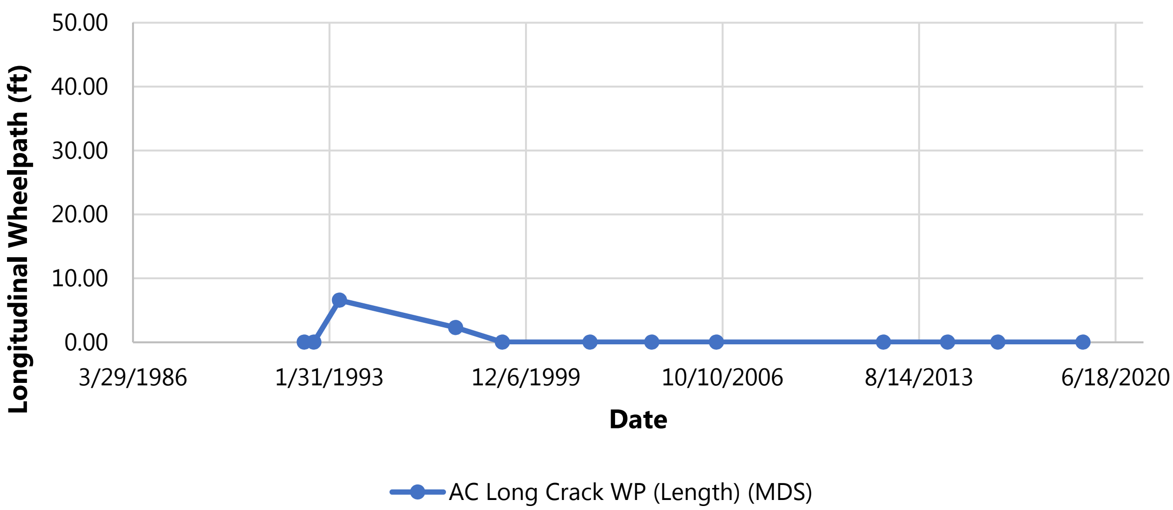


Figure 7. Time history of the length of WP longitudinal cracks.

Transverse Cracking

Figures 8 and 9 show the total count and length of transverse cracking observed on the section. Transverse cracking was first observed on the section in June 1993, nearly 8 years after construction, when 5 ft (3 cracks) of transverse cracking was observed. Once the cracking had initiated, it propagated at a rate of 3 ft/year over the next 26 years. By 2019, 81 ft (23 cracks) of transverse cracking was observed. The transverse cracks observed were mostly low severity and located near patches, non-functioning AVC loops within the pavement structure, and at random intervals along the edge or centerline of the pavement; the cracks observed were not the full width of the lane. In some cases, the transverse cracks observed continued into the westbound lane of the roadway.

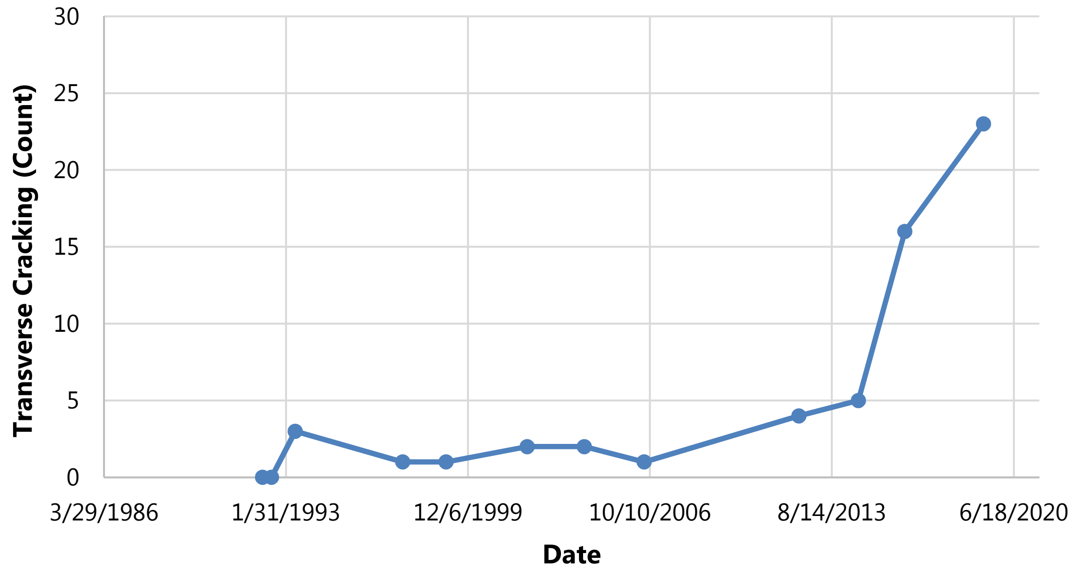


Figure 8. Time history of the number of transverse cracks (count).

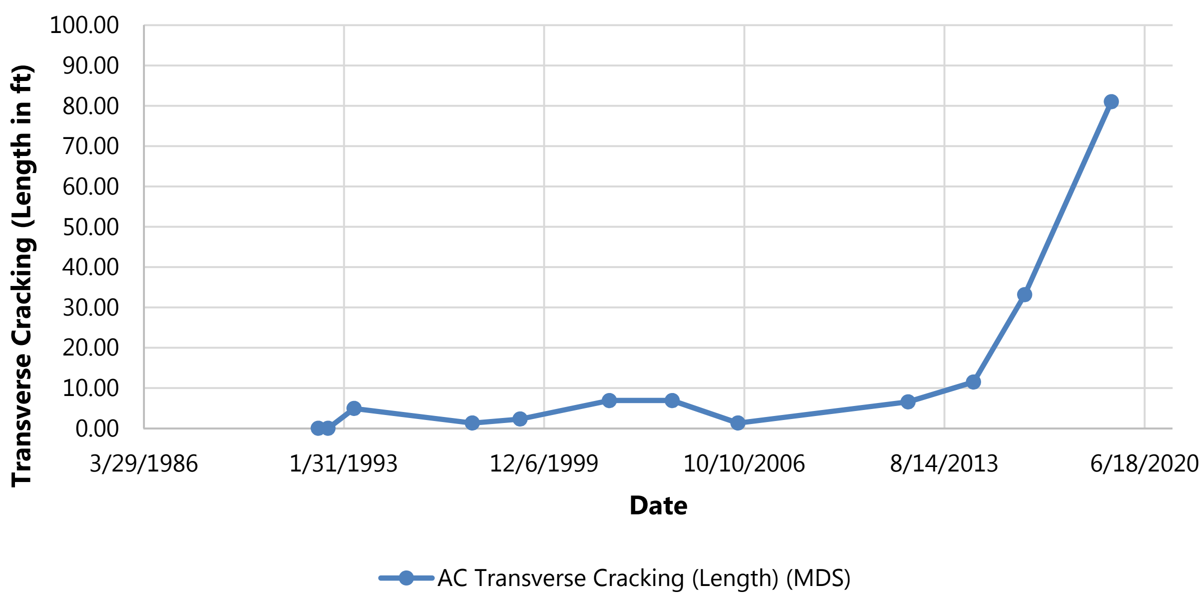


Figure 9. Time history of the length of transverse cracking (length).

As depicted in Figure 9, a notable increase in the transverse cracking observed on the test site occurs between 2015 and 2019. The increase in transverse cracking in 2016 is likely a result in the increased average annual precipitation observed in 2015 and material degradation due to pavement aging. Material degradation along the section is also evidenced by the 982 ft^2 of raveling that is first reported on the pavement section in 2019.

IRI

The average IRI measurements for the section over time is shown in Figure 10. The IRI of the test section slightly increased over time. The section's IRI increased from 88 in/mile in 1990 to 98 in/mile in 2019. There was a gradual increase in roughness over time, 0.34 in/mi/yr. The pavement's IRI performance is classified as "Fair" based on FHWA performance definitions.

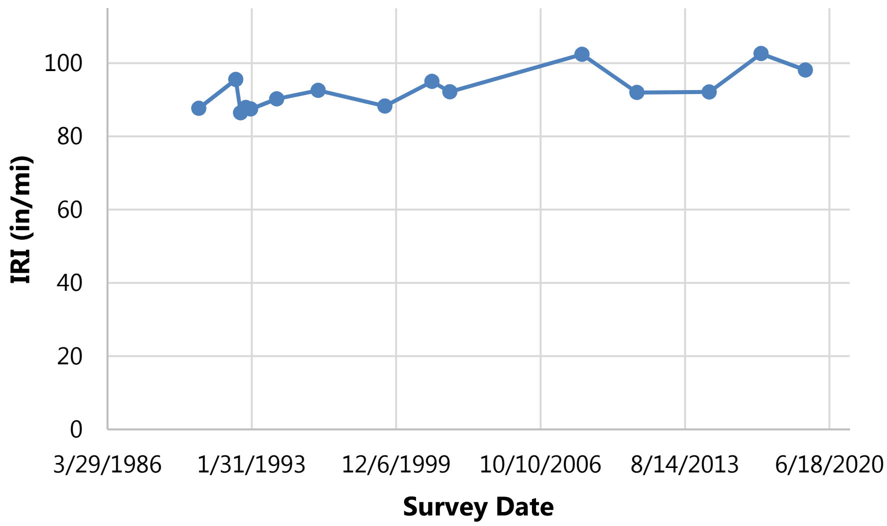


Figure 10. Time history plot of pavement roughness.

Rutting

The last distress observed was rutting, and the rutting trend over time is shown in Figure 11. The rut depths are considered steady over time with 0.16 inches of rutting observed in 1990 and 0.24 inches in 2016. There was consistent rut depth measurements between 2003 and 2016 (0.16 in).The median of the rutting measurements was 0.16 inches. The lack of rutting is likely related to the low traffic volumes observed on this site.

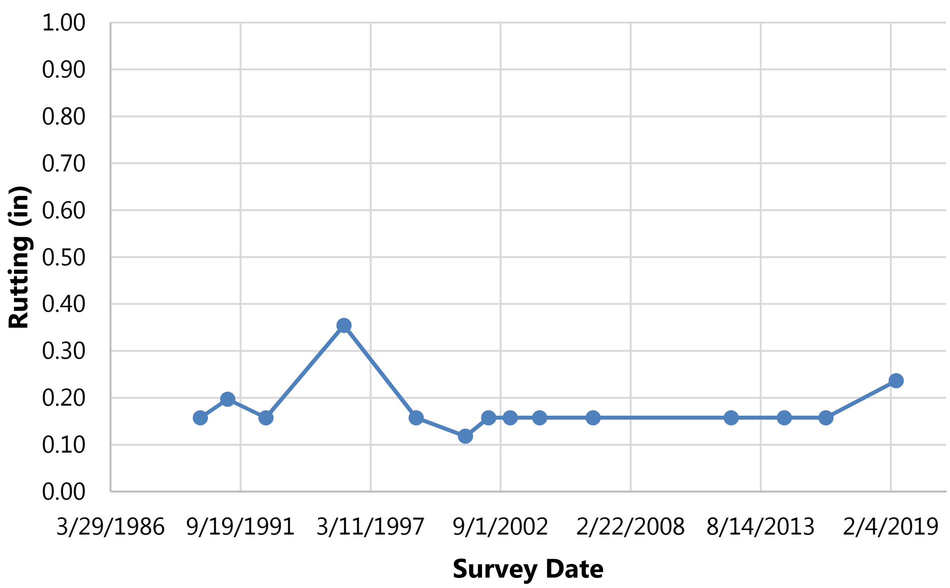


Figure 11. Time history of average rut depth.

SUMMARY OF FINDINGS

LTPP test section 45_1024 is located on State Route 1623, eastbound, in Lexington County, South Carolina. State Route 1623 is an urban collector with one lane in each direction of traffic. The test section was constructed in 1985 and incorporated into the LTPP program in January 1987 as part of the GPS-1 (Asphalt Concrete on Granular Base) Experiment. The pavement structure at the time of its incorporation into the LTPP program consisted of 1.6 inches of hot mixed, dense graded Asphalt Concrete (AC) on 4.8 inches of unbound granular base over a coarse-grained subgrade. Despite the test site having both a thin AC and base layer, the pavement performed well prior to 2015 with low levels of cracking and rutting, "Fair" IRI based on FHWA performance definitions, and consistent FWD deflections. This is likely attributed to the low levels of traffic observed on the section. However, following 2015, when there was a reported increase in the average annual precipitation (65 inches), likely due to a flooding event in early October of 2015, the performance of the pavement began to deteriorate more rapidly. The following is a summary of the performance of the pavement over time:

- ***Fatigue Cracking****:* Fatigue cracking was first observed on the section in June 1997, almost 12 years after the initial construction of the site, when 25 ft^2 of fatigue cracking was observed. Once the cracking had initiated, it propagated at an average rate of 18 ft^2/year over the next 22 years. The increase in fatigue cracking in 2016 is likely a result of the increased average annual precipitation observed in 2015, exacerbated by the pavement layer thicknesses.
- ***NWP Longitudinal Cracking****:* NWP longitudinal cracking was first observed on the section in June 1997, almost 12 years since initial construction. Once the cracking had initiated, it propagated at a rate of 12 ft/year, over the next 22 years. The NWP longitudinal cracking was predominantly found along the centerline and edge of the lane. Like the fatigue cracking observed on the section, there was a notable increase in the amount of NWP longitudinal cracking observed between 2014 and 2016, which is likely a result of the increased average annual precipitation observed in 2015.
- ***WP Longitudinal Cracking****:* For the pavement section, the minimal WP longitudinal cracking that was observed on the section evolved into fatigue cracking by 1998.
- ***Transverse Cracking****:* Transverse cracking was first observed on the section in June 1993, nearly 8 years after the construction of the pavement structure. Once the cracking initiated, it propagated at a rate of 3 ft/year over the next 26 years. The transverse cracks observed were mostly low severity and located near patches, non-functioning AVC loops within the pavement structure, and at random intervals along the edge or centerline of the pavement. The increase in transverse cracking is likely a result in the increased average annual precipitation observed in 2015 and material degradation due to pavement aging. Material degradation along the section is also evidenced by the 982 ft^2 of raveling that is first reported on the pavement section in 2019.
- ***IRI****:* The IRI of the test section slightly increased over time. The section's IRI increased from 88 in/mile in 1990 to 98 in/mile in 2019. The pavement's IRI performance over the history of the section is classified as "Fair" based on FHWA performance definitions.
- ***Rutting****:* The rut depths are considered steady over time with 0.16 inches of rutting observed in 1990 and 0.24 inches in 2016. There was consistent rut depth measurements between 2003 and 2016 (0.16 in). The median of the rutting measurements was 0.16 inches. The lack of rutting is likely related to the low traffic volumes observed on this site.

In conclusion, it appears that the data contained in the LTPP database is sufficient to adequately explain the excellent performance of the test section. After 35 years, however, the test section appears to be showing increased signs of deterioration, especially in terms of fatigue, NWP and transverse cracking.

FORENSIC EVALUATION RECOMMENDATIONS

Based on the information gathered and analyzed in the above sections, only close-out monitoring and coring is recommended at this time. The coring will be used to confirm that the test section thicknesses match those reported when the test section was incorporated into the LTPP program. It is important to point out, however, that after completion of the desktop study it was found that the test section in question has been moved to the LTPP "long life" test section list, meaning it is not scheduled for close-out monitoring at this time. The next round of measurements is tentatively scheduled for 2021, but given the current deterioration rate, the pooled fund study team believes this may be the final round of measurements (i.e., close-out monitoring) on the test section.