Technical Memorandum

To: Jeff Uhlmeyer

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

cc: Mustafa Mohamedali

Date: June 16, 2020

Re. Forensic Desktop Study Report: Georgia LTPP Test Section 13_7028

The Long-Term Pavement Performance GPS 7A Existing AC Overlay of PCC, and subsequently, GPS 7S Existing AC Overlay of PCC (with structural milling of AC overlay) experiment, test section 13_7028[1] was nominated for a desktop study under TPF-5(332) "LTPP Forensic Evaluations." This test section is being recommended for forensic investigation in order to: (1) pursue information concerning the JPCP layer, including steel reinforcement, if any, (2) confirm the transverse and NWP longitudinal cracking is reflection cracking, (3) investigate why the IRI has remained so low despite the presence of cracking (e.g., Is most of the cracking low severity? Is it related to steel reinforcement?), and (4) explore and clarify the reason for the small quantity (19 feet) of wheel-path (WP) longitudinal cracking observed in the 2014 and 2016 distress surveys.

SITE DESCRIPTION

LTPP test section 13_7028 is located on Interstate 85, northbound, in Franklin County, Georgia. Interstate 85 is a rural interstate, principal arterial with two lanes in the direction of traffic. It is classified as being in a Wet, No Freeze climate zone with an average annual precipitation ranging between 29 inches (2016) and 72 inches (2013). The test section has an annual average air freezing index ranging between 0 deg-F deg-days (2013) and 97 deg-F deg-days (2010) during the performance period in question. The coordinates (in degrees) of the test section are 34.36843, -83.27832. Photograph 1 shows the test section at Station 0+00 looking northbound in 2016, while Map 1 shows the geographical location of the test section relative to Atlanta, Georgia.

[1] First two digits in test section number represent the State Code [13 = Georgia]. 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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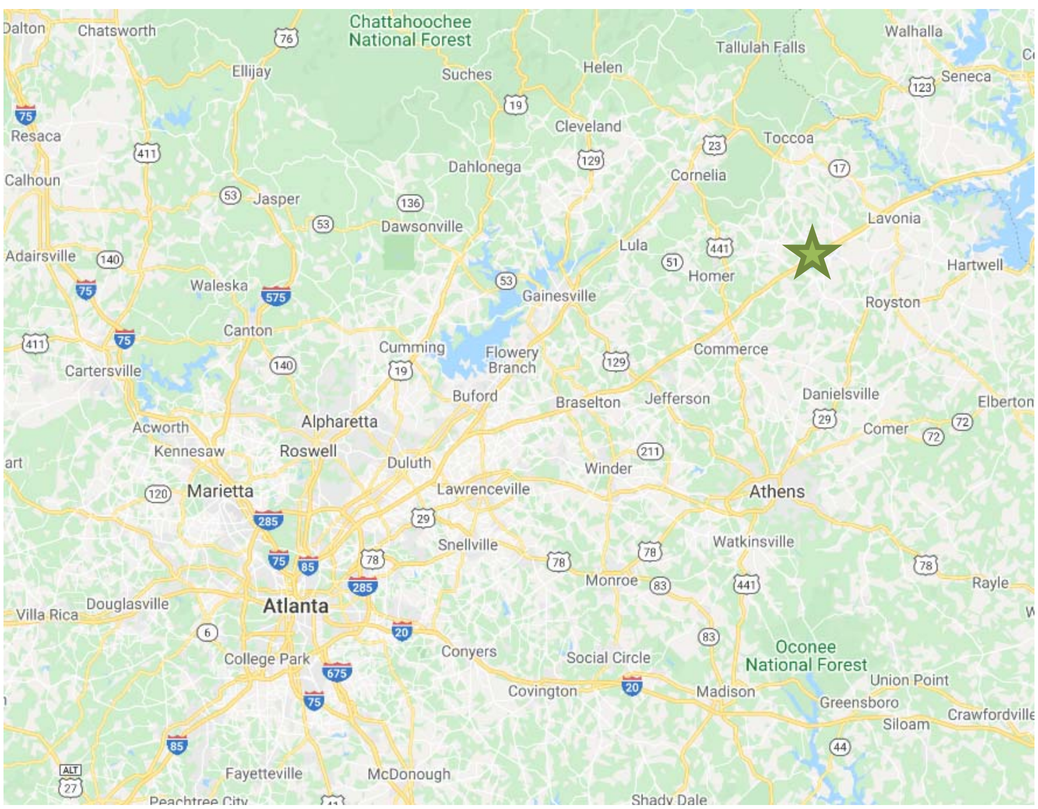
Photograph 1. LTPP Section 13_7028 at Station 0+00 looking northbound in 2016.



Map 1. Geographical location of test section relative to Atlanta, Georgia.

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

This section of I-85 was initially constructed in 1966 and was designed as 9 inches of plain Portland cement concrete (PCC) over 3 inches of premixed bituminous stabilized aggregate subbase and 5 inches of premixed soil aggregate subbase as depicted in Figure 1. The PCC has sawed transverse joints that are spaced 30 feet apart and are undoweled. A lab test of a core taken in 1990 determined the compressive strength, modulus of elasticity, Poisson's ratio, and coefficient of thermal expansion of the PCC layer was 5,980 psi, 3,350,000 psi, 0.16, and 0 in/in/deg F, respectively. The primary aggregate type used for the PCC layer was crushed stone (igneous plutonic, granite). It is unknown whether any additional maintenance or construction events occurred between the section's initial construction (1966) and the application of an asphalt concrete (AC) overlay in November 1986. The test section was incorporated into the LTPP program in January 1987 as part of the GPS 7A Existing AC Overlay of PCC experiment.

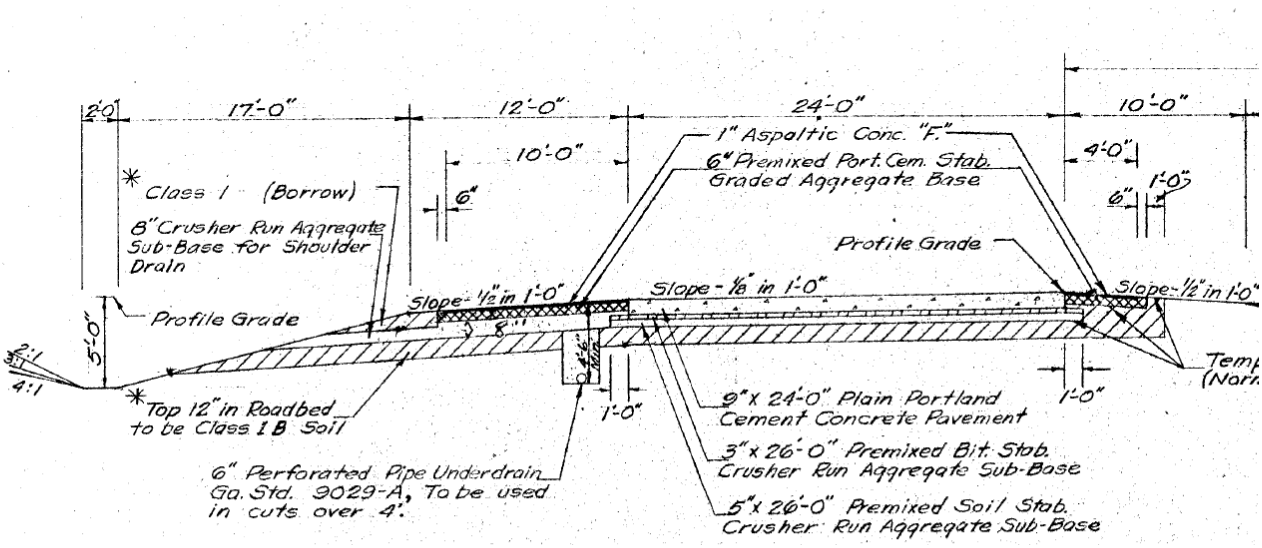


Figure 1. Typical cross-section of 1961 design of section.[2]

The pavement structure at the time of its incorporation into the LTPP program consisted of 6 inches of hot mixed, dense graded Asphalt Concrete (AC) (two layers separated by a 0.1 inch slurry seal[3]) over 9.1 inches of jointed plain concrete pavement (JPCP), 3.1 inches of bound base, and 3.9 inches of unbound granular base over a clayey sand subgrade. The original pavement structure for the test section at the time of its incorporation into the LTPP program is summarized in Table 1; this information corresponds to CONSTRUCTION_NO = 1 (CN = 1) in the LTPP database. The next construction event occurred in 1996, when crack sealing was applied to the test section (CN=2). In July 1998, the section received a mill and 2.5-inch AC overlay, moving the test section to the GPS 7S experiment: Existing AC Overlay of PCC (with structural milling of AC overlay). The pavement structure of the test section following the overlay corresponds to CN=3 and is depicted in Table 2.

[2] http://www.dot.ga.gov/applications/geopi/Pages/Dashboard.aspx?ProjectId=H000319

[3] While the 0.1-inch layer is identified as a slurry seal in the LTPP database, it is suspected that this layer is a tack coat.

Table 1. Pavement structure for CN =1 and CN=2

Layer Number	Layer Type	Thickness (in.)	Material Code Description
1	Subgrade (untreated)	Semi-infinite	Coarse-Grained Soil: Clayey Sand
2	Unbound (granular) subbase	3.9	Other
3	Bound (treated) base	3.1	Asphalt Treated Mixture
4	Portland cement concrete layer	9.1	Portland Cement Concrete (JPCP)
5	Asphalt Concrete (AC) Layer	2.6	Hot Mixed, Hot Laid AC, Dense Graded
6	Asphalt Concrete (AC) Layer	0.1	Slurry Seal[4]
7	Asphalt Concrete (AC) Layer	3.4	Hot Mixed, Hot Laid AC, Dense Graded

Table 2. Pavement structure for CN =3

Layer Number	Layer Type	Thickness (in.)	Material Code Description
1	Subgrade (untreated)	Semi-infinite	Coarse-Grained Soil: Clayey Sand
2	Unbound (granular) subbase	3.9	Other
3	Bound (treated) base	3.1	Asphalt Treated Mixture
4	Portland cement concrete layer	9.1	Portland Cement Concrete (JPCP)
5	Asphalt Concrete (AC) Layer	2.6	Hot Mixed, Hot Laid AC, Dense Graded
6	Asphalt Concrete (AC) Layer	0.1	Slurry Seal[4]
7	Asphalt Concrete (AC) Layer	1.9	Hot Mixed, Hot Laid AC, Dense Graded
8	Asphalt Concrete (AC) Layer	2.5	Hot Mixed, Hot Laid AC, Dense Graded

Pavement Structural Properties

Figure 2 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 2, the deflections observed on the site fluctuate over time. The reported deflections over the load plate are greatest in June 1991 (3.9 mils) and July 1998 (4.8 mils; this was also the last set of deflection measurements before 1998 mill and overlay, so there could be some impact related to the deterioration of the existing AC layer), which correspond to high temperature collection dates as depicted in Table 3. However, overall, the deflections reported are low, ranging between 2 and 5 mils.

Layer moduli were backcalculated (using EVERCALC 5.0 and MODCOMP software) from the deflection data measured on March 1989, June 1991, September 1992, March 1995, July 1998, February 2001, October 2003, and May 2012 (eight rounds of FWD testing), which were available in the LTPP database. The pavement structure was modeled as a 6-inch AC layer (Layer 1) over 9.1 inches of Portland Cement

[4] While the 0.1-inch layer is identified as a slurry seal in the LTPP database, it is suspected that this layer is a tack coat.

Concrete (Layer 2) and 7 inches of a combination of a typical granular subbase and asphalt treated base (Layer 3) on top of coarse subgrade (Layer 4) and bedrock (Layer 5) prior to CN=3. After CN=3, the pavement structure was modeled as a 7-inch AC layer (Layer 1) over 9.1 inches of Portland Cement Concrete (Layer 2) and 7 inches of a combination of a typical granular subbase and asphalt treated base (Layer 3) on top of coarse subgrade (Layer 4) and bedrock (Layer 5). The resulting backcalculated layer moduli are summarized in Table 4.

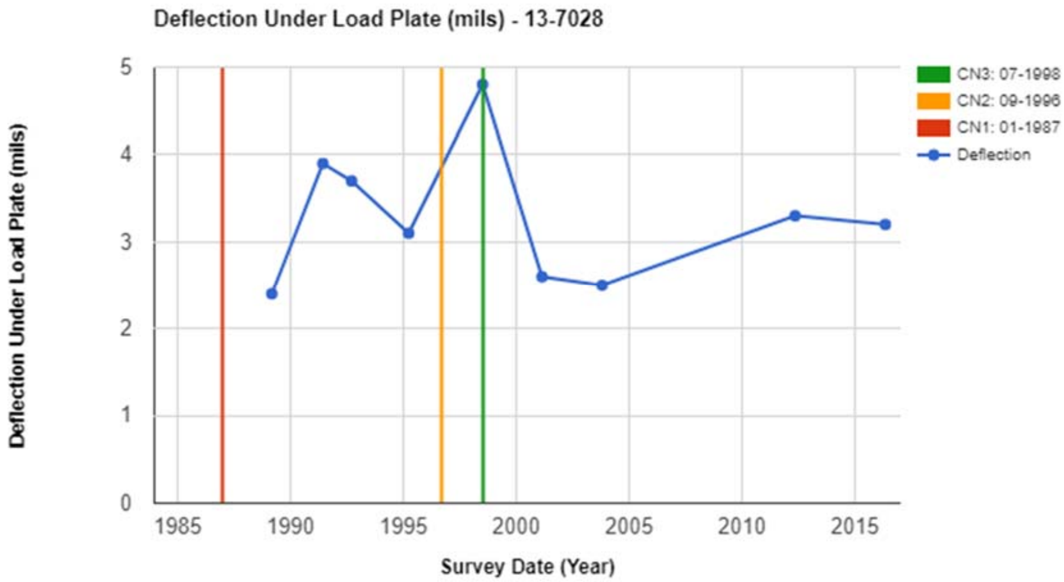


Figure 2. Time history of average deflection for the sensor located in the load plate normalized to 9,000 lb. drop load.

Table 3. Average air temperature during deflection testing

Date	Air temperature during FWD testing (deg F)	Daily Average Air Temperature (from VWS) (deg F)
03/07/1989	47	42
06/11/1991	73	72
09/17/1992	72	72
03/30/1995	64	61
07/07/1998	84	79
02/23/2001	45	39
10/24/2003	62	59
05/11/2012	75	62
05/10/2016	80	71

Table 4. Average Backcalculated Layer Moduli

Test Date	Average Modulus (ksi)				
	Layer 1-AC	Layer 2-PCC	Layer 3- Granular Subbase/Asphalt Treated Base	Layer 4- Coarse subgrade	Layer 5- Bedrock
03/07/1989	1865	5400	145	36	500
06/11/1991	538	3717	552	32	500
09/17/1992	748	3700	307	31	500
03/30/1995	1204	4595	168	38	500
07/07/1998	351	3662	418	31	500
02/23/2001	2090	3048	385	26	500
10/24/2003	1736	3205	504	24	500
05/11/2012	766	3266	664	20	500

As shown in Table 4, some of the resulting layer moduli do not appear reasonable, which is not surprising given the pavement structure. The modulus of the asphalt layer in 1989, 2001 and 2003, for example, are considered high even when taking temperature into consideration. However, it is difficult to backcalculate reasonable layer moduli when the modulus of the top layer is significantly lower than the one for the layer below (i.e., AC layer over PCC layer). In the case of EVERCALC, this condition violates the theory of elasticity upon which the program is based. Backcalculating layer moduli for five distinct layers is also a challenge, and hence may have contributed to some of the poor results.

Climate History

The time history for average annual precipitation (from MERRA) since 1986 is shown in Figure 3. In 2015, the amount of precipitation appears to be a local high (72 inches), while the low (29 inches) was recorded in 2016. The mean precipitation recorded at the site is 52 inches for the period shown in Figure 3. The high amounts of precipitation reported on this section may be attributed flooding events such as those that occurred in this region in February 2009 and December 2015, as well as hurricanes and tropical storms that occurred in October 1990 (Tropical Storm Marco), July 1994 (Tropical Storm Alberto), June 1995 (Hurricane Allison), August 1995 (Tropical Storm Jerry), October 1995 (Hurricane Opal), September 2004 (Hurricane Frances), July 2005 (Hurricane Dennis), October 2005 (Tropical Storm Tammy), and August 2008 (Tropical Storm Fay).

Figure 4 shows the time history of the average annual freezing index (from the MERRA) 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 8, the freezing index values ranged from 0 (2013) to 97 (in 2010)—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.

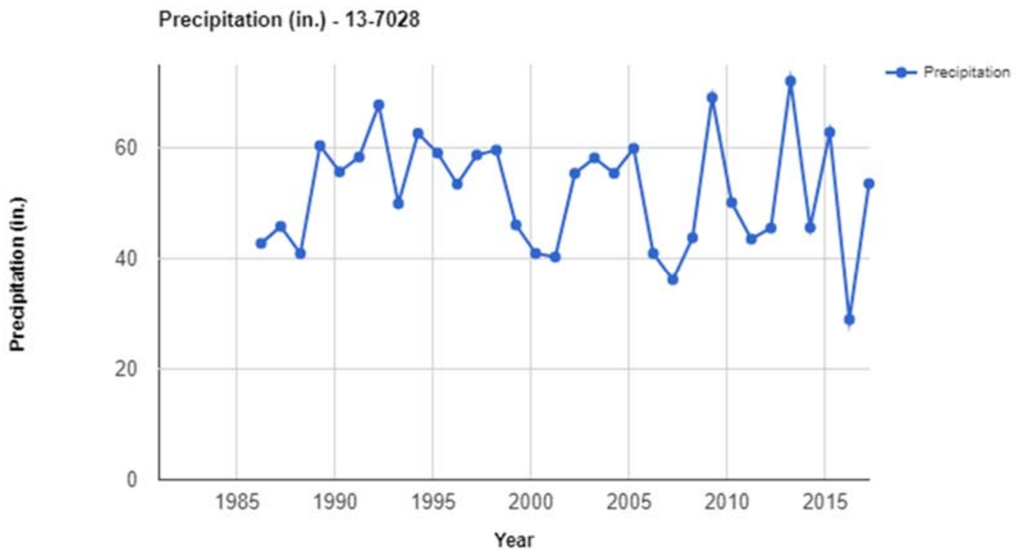


Figure 3. Average yearly precipitation over time.

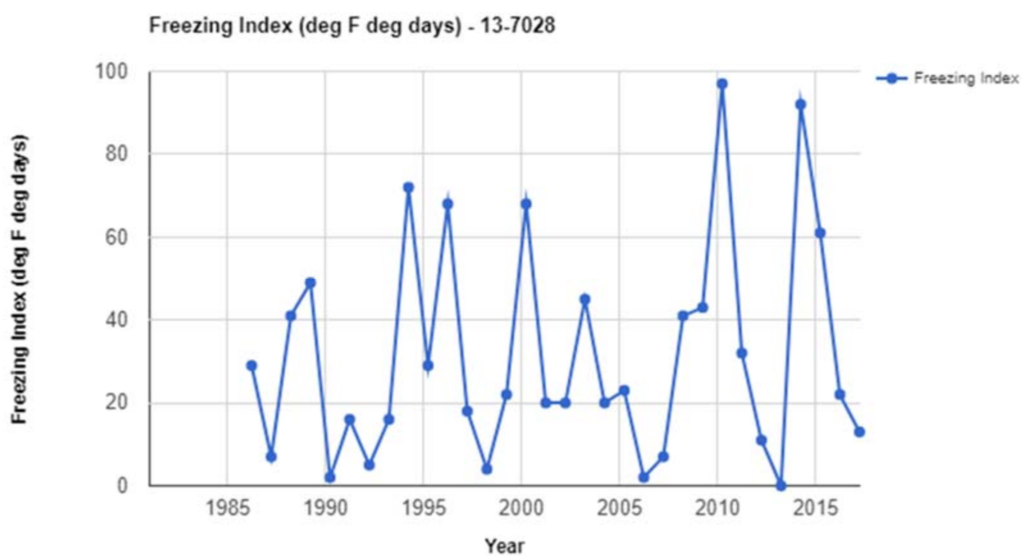


Figure 4. Average annual freezing index over time.

Truck Volume History

Figure 5 shows the annual average daily truck volume data in the LTPP test lane by year. The annual truck traffic counts increase from 2,785 in 1986 to 5,307 in 2017, or approximately 81 additional annual trucks per year. While there is a consistent increase in truck traffic along this section, a spike in truck traffic is observed in 1996. This spike may be related to the 1996 Summer Olympics which were held in Atlanta and surrounding areas (including Lake Lanier just southwest of the test section). The annual number of equivalent single axle loads (ESALs) reported on this section also increased over time. The number of ESALS increased from 1,570,934 in 1981 to 2,994,069 in 2017, or approximately 39,532 ESALs per year as depicted in Figure 6.

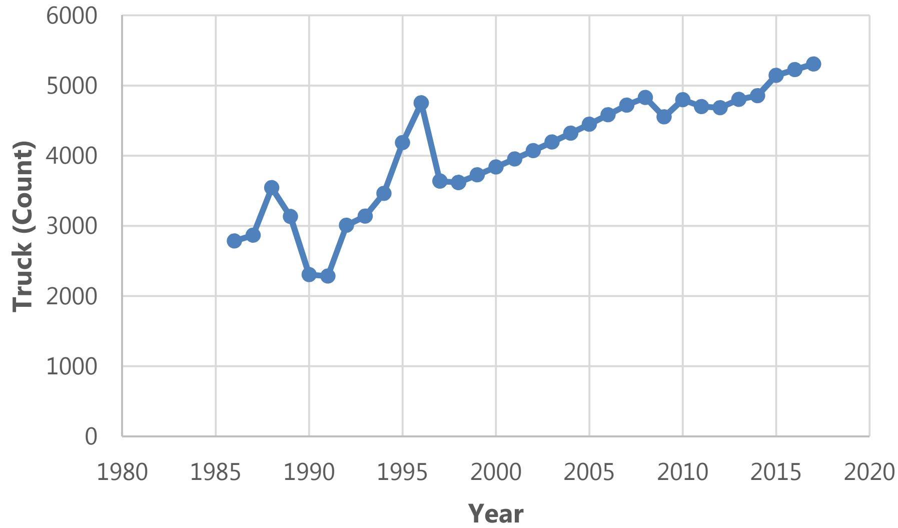


Figure 5. Average annual daily truck traffic (AADTT) history.

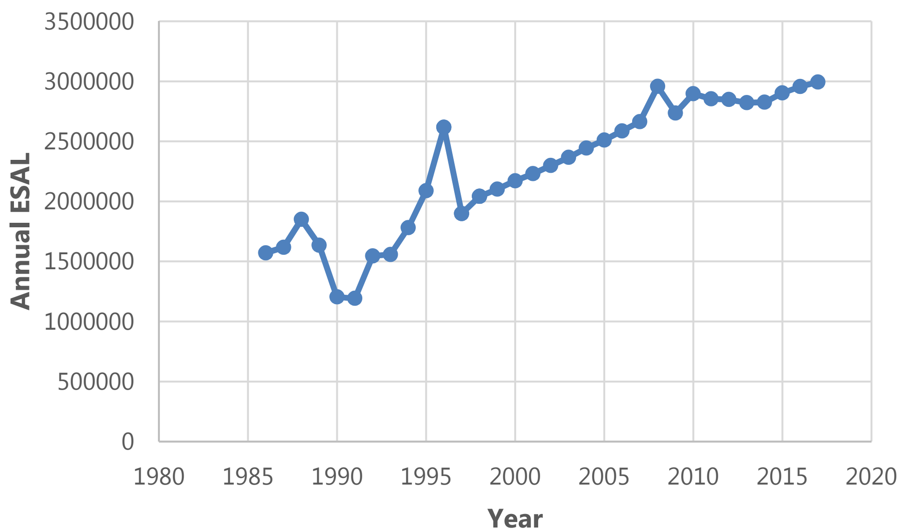


Figure 6. Estimated annual ESAL for vehicle classes 4-13 over time.

Pavement Distress History

The following section summarizes the distresses observed on the test section between the time the section was constructed and when the last manual distress survey was performed on the test sections. Longitudinal cracking (inside and outside the wheel path), transverse cracking, IRI, and rutting were assessed. No fatigue cracking, block cracking, or patching was observed.

Longitudinal Cracking

Data on longitudinal cracking, inside and outside the wheel paths of the test section, was collected between 1994 and 2016 as shown in Figures 7 and 8. Non-wheel path longitudinal cracking (NWP) was reported the first year a manual distress survey (MDS) was conducted. In 1994, 506 feet of NWP was reported, 8 years after CN=1. The NWP longitudinal cracking continued to increase at a rate of 58 feet/year over the next four years or at rate of 61 feet/year between 1986 and 1998 (assuming there was no NWP longitudinal cracking on the test section after it received an AC overlay in 1986). Following the overlay event in July of 1998, the NWP longitudinal cracking observed on the section dropped to zero. NWP longitudinal cracking was not reported again until 2007 (9 years after the AC overlay) when 217 feet of NWP longitudinal cracking was observed. Once cracking was initiated, it propagated at a rate of 34 feet/year between 2007 and 2016, approximately half the rate of propagation reported prior to the AC overlay in 1998. A comparison of the distress maps before and after the overlay in 1998 shows the NWP longitudinal cracking appears in similar locations along the section (at the edge and along the longitudinal joint of the test section) as depicted in Figure 9. This indicates the NWP longitudinal cracking observed after the application of the overlay in 1998 is likely a reflection of the NWP longitudinal cracking observed before the overlay.

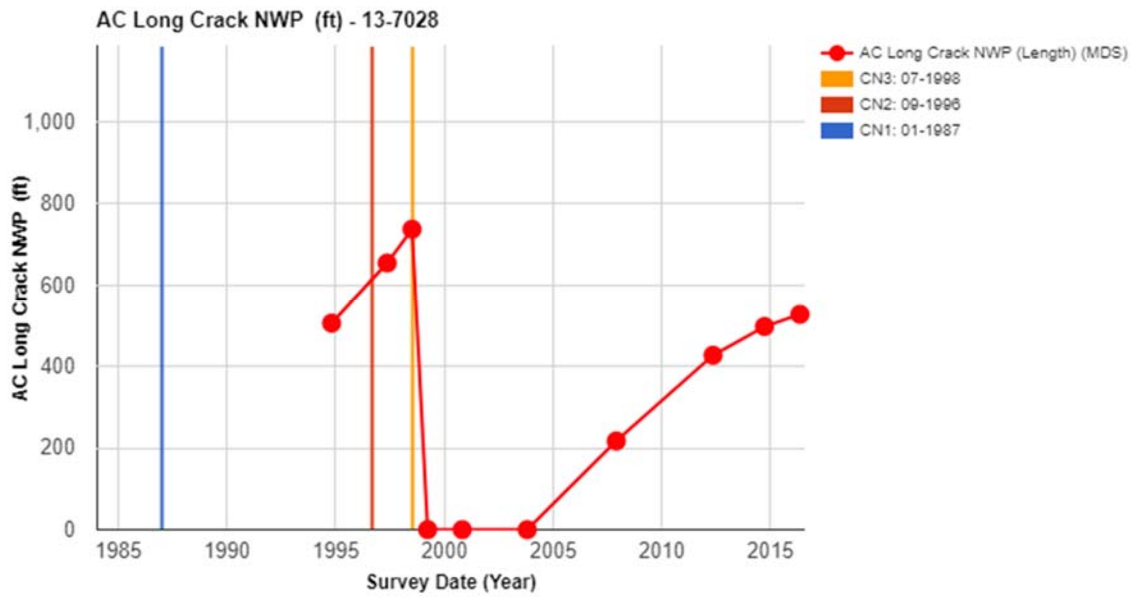


Figure 7. Time history of the length of NWP longitudinal cracking.

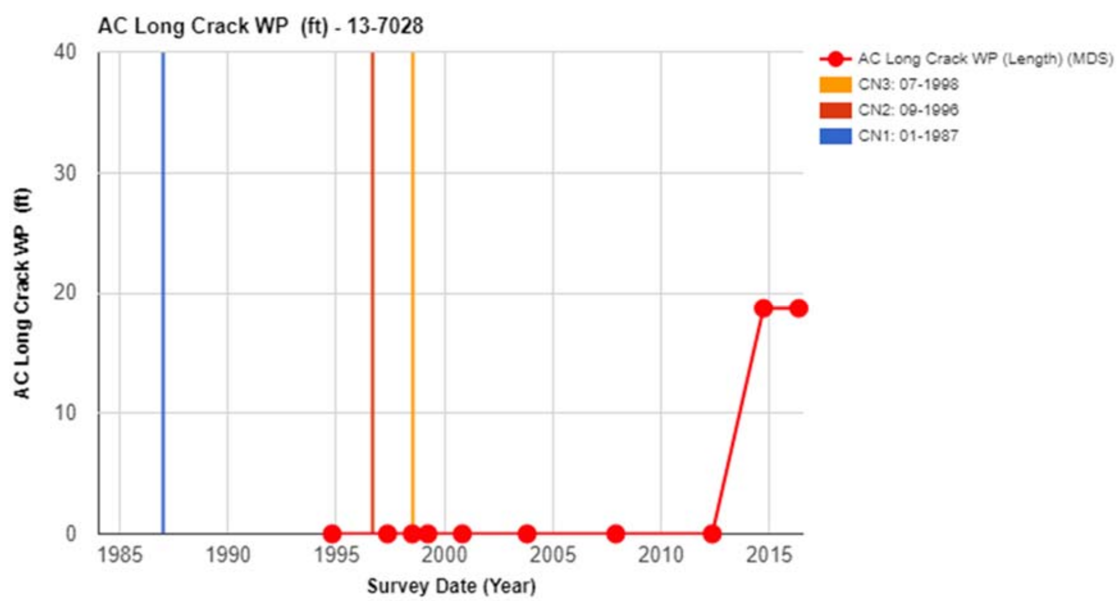


Figure 8. Time history of the length of WP longitudinal cracking.

Longitudinal cracking in the wheel path does not appear on the pavement section until 2014, 16 years after the application of the AC overlay, when 19 feet of low severity, sealed longitudinal cracking in the wheel path was observed. As indicated on the 2014 manual distress survey and as shown in Figure 9, the "longitudinal cracking" on the WP is a result of a rim gouge rather a typical distress mechanism, which is technically correct given LTPP rating procedures. Therefore, no increase in WP longitudinal cracking is reported in 2016.

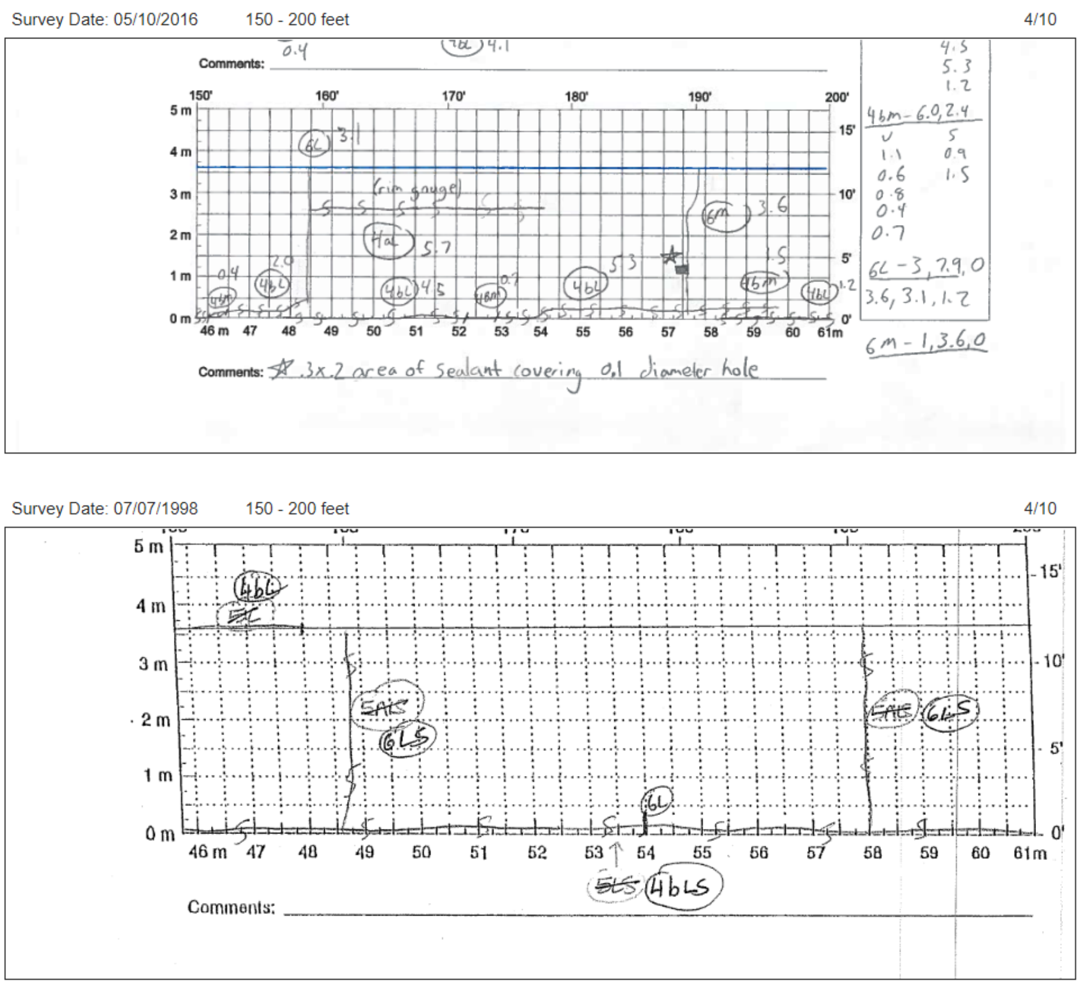


Figure 9. Distress survey map between sta 01+50 and 02+00 in 2016 (top) and 1998 (bottom).

Transverse Cracking

Data on transverse cracking was collected between 1994 and 2016 as shown in Figures 10 and 11. Transverse cracking was reported the first year the manual distress survey (MDS) was conducted. In 1994, 210 feet (21 cracks) of transverse cracking was reported, 8 years after the construction of the test section. The transverse cracking continued to increase at a rate of 4.5 feet/year from 1994 to 1998 (or at a rate of 19 feet/year between 1986 and 1998 assuming there was no transverse cracking on the test section after it received an AC overlay in 1986). Following the overlay in July of 1998, the transverse cracking observed on the section dropped to zero. Transverse cracking was not reported again until 2003 when 15 feet (5 cracks) of transverse cracking was observed, 5 years after the AC overlay. Once cracking was initiated, it propagated at a rate of 15 feet/year between 2003 and 2016, which is slightly less than the rate of propagation reported prior to the AC overlay in 1998. A comparison of the distress maps before and after the overlay event in 1998 shows that the transverse cracking appears in similar locations along the section.

This indicates that the transverse cracking observed after the application of the overlay in 1998 is likely a reflection of the transverse cracking observed before the overlay. As depicted in Figure 9, the transverse cracks appear approximately every 30 feet, which likely corresponds to the contraction joint spacing of the PCC layer.

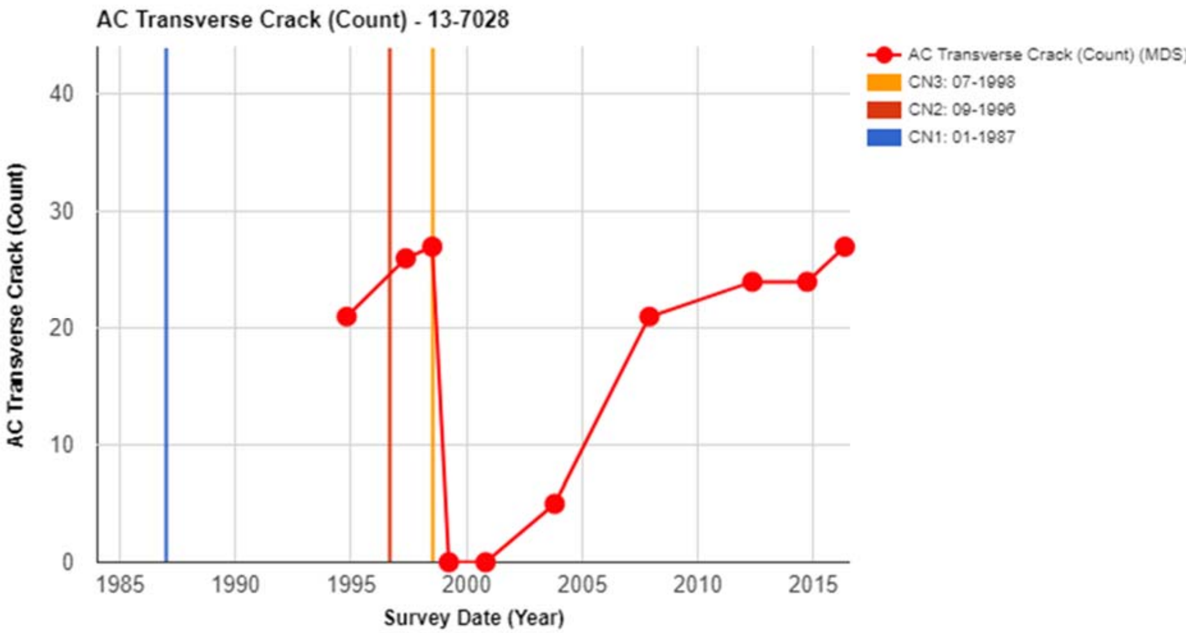


Figure 10. Time history of the number of transverse cracks.

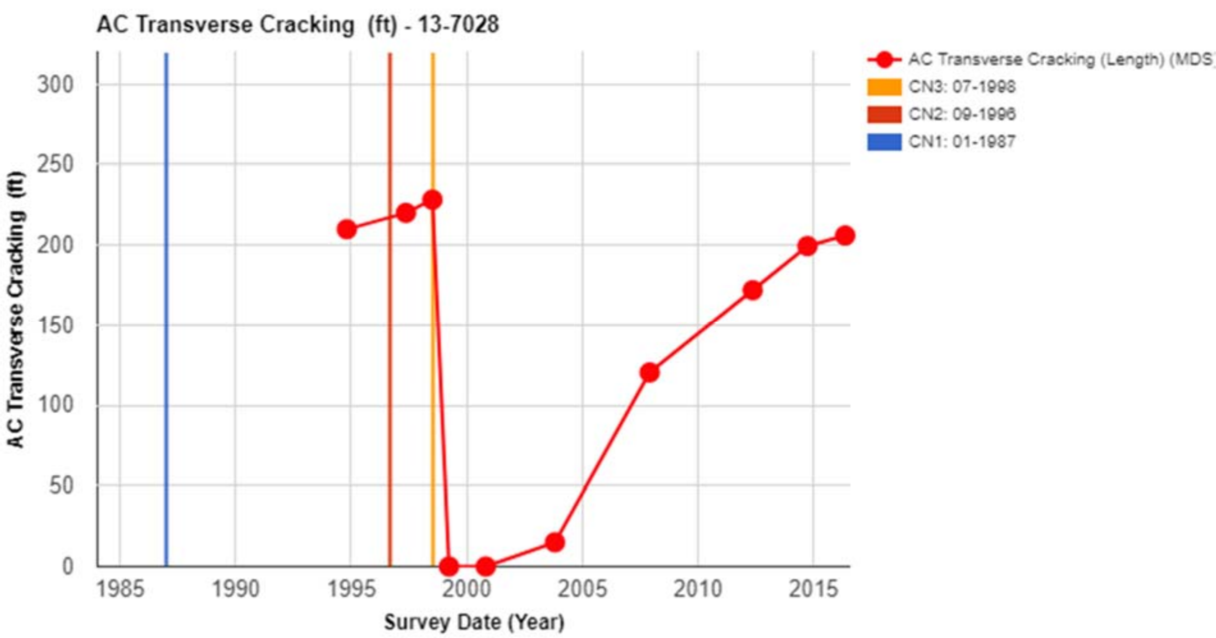


Figure 11. Time history of the length of transverse cracking.

IRI

The average IRI measurements for the section over time are shown in Figure 12. Prior to the AC overlay in 1998, the IRI reported on the test section slightly increases from 64 in/mile in 1990 to 71 in/mile in 1998, at a rate of 0.9 in/mile/year, which is extremely low and indicative of how smooth the pavement has been throughout its life. Following the AC overlay in 1998, the IRI on the section drops to 30 in/mile in 2000. The IRI reported increases to 54 in/mile in 2017, increasing at a rate of 1.4 in/mile over the next 17 years. The pavement's IRI performance is classified as "Good" based on FHWA performance definitions.

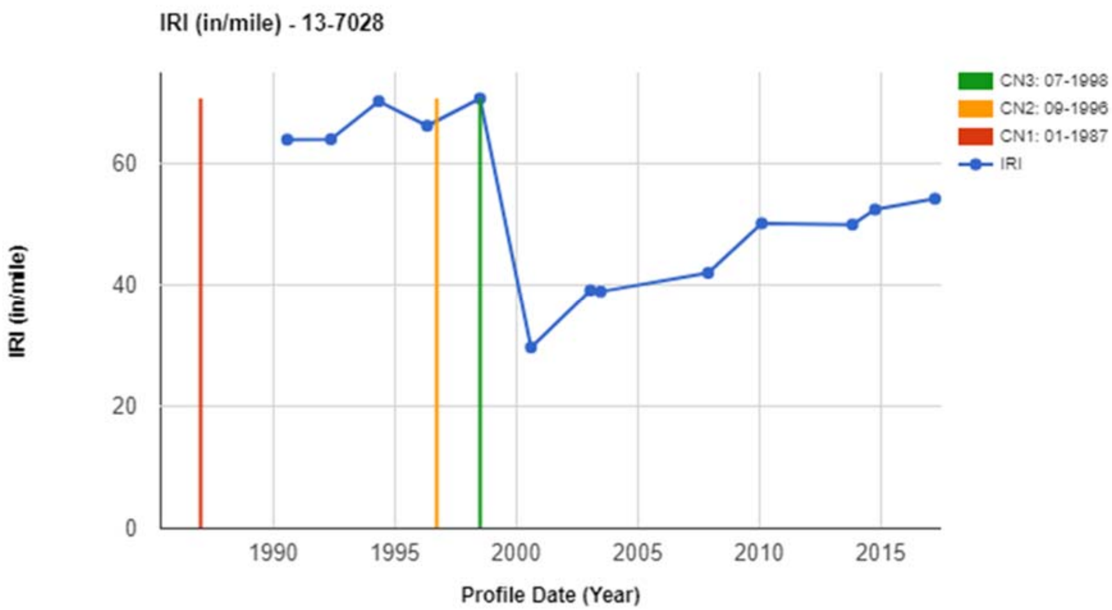


Figure 12. Time history plot of pavement roughness.

Despite the amount of cracking observed on the section before and after the overlay in 1998, the IRI reported on the section remains relatively low. This is likely due to the type of cracking reported on the test section. Prior to the overlay, all cracking observed on the section is low severity. Following the overlay, the cracking observed on the section is low and medium severity cracking with most of the cracking observed being low severity. Additionally, the cracking most affecting the IRI of the test section is predominantly transverse cracking, which has reflected to the surface from the transverse joints of the PCC layer. Furthermore, it is hypothesized that the underlying PCC layer has contributed significantly to the smoothness of the pavement over time.

Rutting

The rutting observed over time on the test section is shown in Figure 13. Prior to the 1998 overlay, the rut depths observed on the overlay are consistent, with the average reported rut depth being 0.29 inches. Following the overly in 1998, the rutting observed on the section decreases to 0.08 inches in 2000. The rutting observed increases slightly between 2000 and 2016 when a rut depth of 0.2 inches is reported on the test section. The lower levels of rutting after the 1998 AC overlay can be attributed to the stiffness of the AC layer applied in 1998 overlay.

SUMMARY OF FINDINGS

LTPP test section 13_7028 is located on Interstate 85, northbound, in Franklin County, Georgia. Interstate 85 is a rural interstate, principal arterial with two lanes in the direction of traffic. This section of I-85 was initially constructed in 1966 and was designed as 9 inches of plain Portland cement concrete over 3 inches of premixed bituminous stabilized aggregate subbase and 5 inches of premixed soil aggregate subbase. It is unknown whether any additional maintenance or construction events occurred between the section's initial construction (1966) and the application of an asphalt concrete (AC) overlay in 1986; however, because the section has a PCC layer, no additional events are suspected to have occurred in that time period. The test section received an AC overlay in November 1986 and was incorporated into the LTPP program in January 1987 as part of the GPS 7A Existing experiment: AC Overlay of PCC. The pavement structure at the time of its incorporation into the LTPP program consisted of 6 inches of hot mixed, dense graded Asphalt Concrete (AC) (two layers separated by a 0.1 inch slurry seal[5]) over 9.1 inches of jointed plain concrete pavement (JPCP), 3.1 inches of bound base, and 3.9 inches of unbound granular base over a clayey sand subgrade. The next construction event occurred in 1996 when crack sealing was applied to the test section (CN=2). In July 1998, the section received a mill and 2.5-inch AC overlay, moving the test section to the GPS 7S experiment: Existing AC Overlay of PCC (with structural milling of AC overlay).

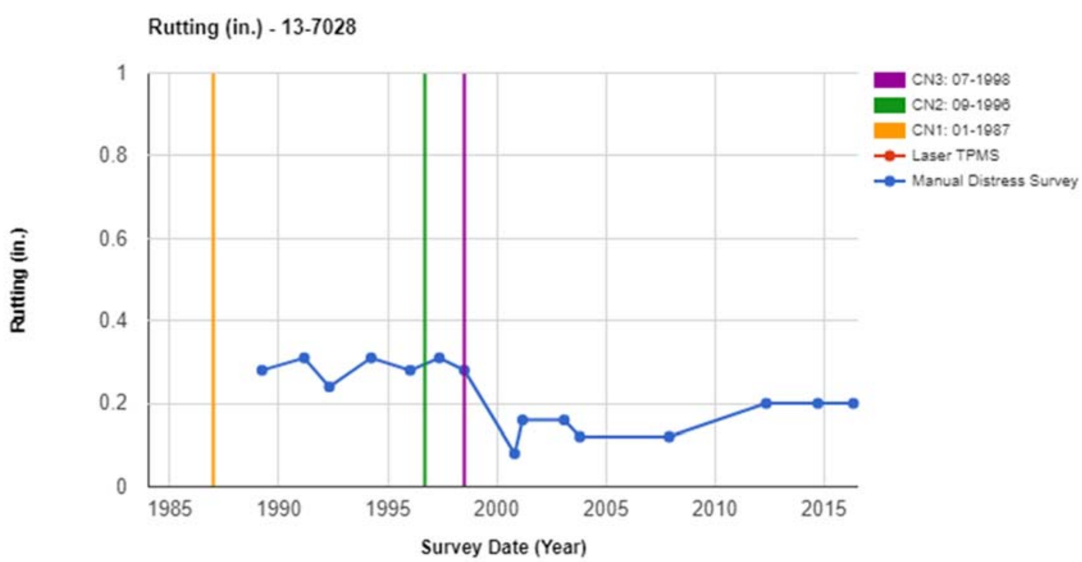


Figure 13. Time history plot of average rut depth computations.

The memorandum was focused on the following:

1. **Pursuing information concerning the JPCP layer, including steel reinforcement.** The PCC has sawed transverse joint that are spaced 30 feet apart and is undoweled; no steel reinforcement was used. A lab test of a core taken in 1990 determined the compressive strength, modulus of elasticity, Poisson's ratio, and coefficient of thermal expansion of the PCC layer was 5,980 psi, 3,350,000 psi, 0.16, and 0 in/in/deg F, respectively. The primary aggregate type used for the PCC layer was crushed stone (igneous plutonic, granite).
2. **Confirming the transverse and NWP longitudinal cracking is reflection cracking**. A comparison of the distress maps before and after the AC overlay in 1998 shows that the transverse and NWP longitudinal cracking appears in similar locations along the test section (approximately every 30 feet and at the edge and along the longitudinal joint of the test section, respectively).

[5] While the 0.1-inch layer is identified as a slurry seal in the LTPP database, it is suspected that this layer is a tack coat.

This indicates that the transverse cracking and NWP longitudinal cracking observed after the application of the overlay in 1998 is likely a reflection of the cracking observed before the overlay.

3. **Investigating why the IRI has remained so low despite the presence of cracking.** The IRI reported on the section remained relatively low throughout the history of the test section. This is likely due to the type of cracking reported on the test section. Prior to and following the overlay, most of the cracking observed on the test section is low severity. Additionally, the cracking most affecting the IRI of the test section is predominantly transverse cracking. Furthermore, as indicated earlier, it is hypothesized that the underlying PCC layer has contributed significantly to the smoothness of the pavement over time.
4. **Exploring and clarifying the reason for the small quantity (19 feet) of wheel-path (WP) longitudinal cracking observed in the 2014 and 2016 distress surveys.** Longitudinal cracking on the wheel path does not appear on the pavement section until 2014, 16 years after the application of the AC overlay, when 19 feet of low severity, sealed longitudinal cracking in the wheel path is observed. As indicated on the 2014 manual distress survey, the "longitudinal cracking" on the WP is a result of a rim gouge rather a typical distress mechanism. Therefore, no increase in WP longitudinal cracking is reported in 2016.

FORENSIC EVALUATION RECOMMENDATIONS

Based on the information gathered and analyzed in the above sections, only close-out monitoring (not including FWD testing) and coring is recommended at this time. The coring will be used to confirm that the test section thicknesses (including the PCC layer) match those reported when the test section was incorporated into the LTPP program and that the transverse and NWP longitudinal cracking reported is being reflected from the PCC joints.