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A Follow-up Evaluation of the Concrete Pavements (U.S. 58) Rehabilitated in 2012

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FINAL REPORT

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In Cooperation with the U.S. Department of Transportation
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Virginia Transportation Research Council
(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)

Charlottesville, Virginia

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ABSTRACT

The Virginia Department of Transportation usually rehabilitates old concrete pavements with an asphalt overlay, making them composite pavements. In 2012, a portion of U.S. Route 58 west in Southampton, Virginia, received two additional treatment options: a bonded concrete overlay and an unbonded concrete overlay. Around the same time, the eastbound lanes of the same area received the traditional treatment of asphalt overlay. This rehabilitation provided an opportunity to compare the performance of all three treatment options.

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INTRODUCTION

In 2012, the Virginia Department of Transportation (VDOT) rehabilitated a section of U.S. Route 58 (hereafter, US 58) in Southampton County in the Hampton Roads District using different options: bonded concrete overlay, unbonded concrete overlay, and asphalt overlay. The four-lane divided primary highway was built in 1988 with an 8-inch-thick continuously reinforced concrete pavement (CRCP) placed over a 6-inch-thick cement-treated aggregate layer. In 2012, this section of highway was in very poor condition. Three rehabilitation techniques were used:

- Bonded—Patching and placing a 4-inch bonded concrete overlay.
- Unbonded—Minimal repairing of the existing surface, placing a 1-inch asphalt separation layer and a 7-inch unbounded concrete overlay.
- Asphalt—Patching and placing a 5-inch asphalt overlay.

A 2.6-mile section of westbound lanes was rehabilitated using a 4-inch-thick bonded concrete overlay with sandblasting to prepare the surface for proper bonding. Another 2.2-mile section of westbound lanes was rehabilitated using a 7-inch-thick unbonded concrete overlay with a 1-inch asphalt separation layer. Saw cutting was used to form joints at 6-by-6-foot panels for the unbonded overlay, and tie bars were used along the centerline of the pavement and along both shoulders. A concrete overlay was placed on the shoulders of the unbonded overlay, and asphalt was placed on the shoulders of the bonded overlay. A nearby 9.75-mile section of the eastbound lane of US 58 was rehabilitated using two layers of stone matrix asphalt (SMA) with a total thickness of 5 inches. Using asphalt overlay is a common practice in VDOT for rehabilitating CRCP.

The concrete overlay construction and initial performance were documented in Virginia Transportation Research Council (VTRC) report 14-R16 (Sprinkel et al., 2014). A relative cost comparison was also provided in the report for all three sections.

A followup study or evaluation of the performance of these sections after 12 years of traffic and construction is proposed. This evaluation should be useful for VDOT in comparing the three rehabilitation strategies for concrete pavement. VDOT pavement management system (PMS) data, falling weight deflectometer (FWD) measurements, and ride quality measurements were used for this evaluation.

PURPOSE AND SCOPE

The purpose of this study was to document the field performance of the rehabilitation techniques used to repair deteriorating CRCP. The study is focused on a section of the roadway on US 58 in the Hampton Roads District of VDOT. It included visual surveys, a review of district maintenance records, VDOT PMS condition rating, and FWD and ride quality testing.

METHODS

Overview

The following tasks were performed to achieve the study objectives:

1. Literature Review—A literature survey was conducted to find the field application of overlay techniques for concrete pavement in other departments of transportation (DOTs). Their success stories, challenges, and appropriateness of application were documented.

2. Project Details—Relevant project details for all three overlay options and construction information were gathered from VTRC report 14-R16 (Sprinkel et al., 2014), the Materials Division pavement evaluation record, the district maintenance record, and construction contracts or documents.

3. In-Service Data (Maintenance, Traffic, and Weather)—A pavement section is usually designed to withstand traffic loading and environmental factors for the length of its design life, but most sections need regular maintenance at certain intervals. The research team gathered traffic information and weather data, such as temperature and precipitation, as well as maintenance records.

4. Pavement Condition and Surface Distress—A detailed analysis of pavement performance was conducted using VDOT PMS data to explore the change in distress rating and ride quality. The analysis was supplemented by a site visit to document the existing surface condition.

5. Pavement Condition and Structural Assessment—FWD data, a nondestructive testing, were collected right before construction and after 12 years of service for comparison.

6. Performance of Treatment Options—The performance of three overlay techniques and their respective challenges were observed. AASHTOWare Pavement ME software was used to predict the performance, and it was compared with PMS data.

Literature Review

The literature regarding the use of overlay as rehabilitation strategies for pavement was identified using the resources of the VDOT Research Library and the University of Virginia Library. Online databases searched included the Transportation Research International Documentation, an integrated database of the Transportation Research Board; the Engineering Index (EI Compendex); Transport; and WorldCat, among others.

Project Details and Construction Information

In 2012, VDOT used three overlay techniques to rehabilitate a portion of US 58 in Southampton County. As mentioned previously, the existing pavement was a CRCP built in 1988. VTRC documented the design, construction, and lessons learned in VTRC report 14-R16 for two of the options with concrete overlay (Sprinkel et al., 2014). Some of the information on asphalt overlay was available from the contract document and in a pavement condition evaluation report from the Materials Division (Wells and Tate, 2007).

In-Service Data (Traffic, Weather, and Maintenance)

The research team met with district materials and pavement managers to capture their experiences regarding the maintenance and rehabilitation of these sections during the past 12 years. The traffic loading for the past 12 years was gathered from a VDOT published traffic volume report (VDOT, 2025). Annual precipitation and temperature data were collected from the Weather Underground (wunderground.com) for a nearby weather station. The bonded concrete overlay section had some maintenance done right after overlay construction, and VTRC collected information during the repair work

Pavement Condition—Surface Distresses

Pavement surface condition was explored to assess the condition of the overlays after 12 years of traffic. Researchers visited the site to document the condition as evident from the surface. An in-depth analysis was conducted using VDOT PMS data to explore the change in distress rating and ride quality. PMS data include the video images of the entire section to provide a detailed count of distresses.

Pavement Condition—Structure

To assess the structural condition of the pavement sections, FWD testing was conducted in the fall of 2024. In addition to basin testing at 9 kip drop loads for all three sections, load transfer efficiencies (LTEs) were measured at several joints on the unbonded section and at major cracks (and patch joints) on the bonded section. The VDOT Materials Division used ModTag, a back-calculation software, to process the data.

Performance of Treatment Options

The overall performances of all three overlay techniques were observed, and the major challenges were identified. The construction of these sections was well documented, providing an opportunity to model with AASHTOWare Pavement ME (version 2.2). The predicted performance from Pavement ME was compared with PMS data.

RESULTS AND DISCUSSION

Literature Review

Using overlays to rehabilitate distressed pavement is a common practice. The Federal Highway Administration's (FHWA) Every Day Counts program identified overlay as one of the technologies for implementation and initiated a program known as Targeted Overlay Pavement Solutions. The program is designed to promote innovative overlay techniques into practices that can extend pavement life, improve safety, and reduce the cost of pavement ownership by restoring pavement performance (FHWA, 2023). Documented performance would facilitate successful implementation of these technologies in future projects. Two types of overlays can repair CRCP:

1. **Asphalt Overlay**—Often used to restore the ride quality and prevent CRCP from further deterioration. It provides a moisture and temperature barrier and reduces the effect of dynamic loading, hence slowing down the pavement deterioration. This overlay acts as a composite pavement. In general, it could be installed faster than a concrete option with minimal traffic disruption. A reflection of cracks from the underlaying layer, debonding, stripping, and rutting are the major distresses for asphalt overlay. Usually, a thinner (structurally deficient) overlay and higher temperature exhibit rutting problems in the asphalt layer (Trevino et al., 2004).

2. **Concrete Overlay**—Many state DOTs have successfully used concrete overlays to rehabilitate their aged CRCP pavement systems. Overlays can provide both structural capacity and functional enhancements, hence extending the service life. Concrete overlays are ideal for high truck traffic and extreme temperature fluctuation with reduced (i.e., no) chance of rutting compared with asphalt overlays. A properly constructed concrete overlay could provide long-term durability. These overlays could be either bonded or unbonded, depending on the existing pavement condition and desired performance (Cackler et al., 2021).

    A. *Unbonded Concrete Overlay*—These overlays consist of jointed concrete pavement with a separator layer underneath to prevent cracks from reflecting through. Both asphalt and geosynthetics are used as separator layers. Slabs 8 inches or thicker usually have doweled joints, but thinner slabs perform adequately for load transfer with aggregate interlock.

B. *Bonded Concrete Overlay*—These concrete overlays are placed directly over CRCP to strengthen the pavement. Good bonding is critical for the success of these overlays and requires special attention to the surface preparation and repair of damaged concrete before overlay.

The Minnesota DOT published a synthesis on design and performance of unbonded concrete overlays on concrete pavement for eight member states of the National Road Research Alliance (Korzilius et al., 2020). The member states include California, Illinois, Iowa, Michigan, Minnesota, Missouri, North Dakota, and Wisconsin. The synthesis focused on state design practices, performance, and specification. Both jointed plain concrete pavement with dowel bars and CRCP were considered as unbonded concrete overlay options. Overall, good performance of unbonded concrete overlay was reported based on the experiences of state DOTs, and some DOTs mentioned service life of more than 20 years with minimal maintenance or treatment.

In 2020, Grogg et al. (2020) conducted a performance evaluation for both bonded and unbonded concrete overlays throughout Missouri. This study included a review of: (1) performance histories of concrete overlays obtained from the Transportation Management System database and (2) the latest year of video from Automatic Road Analyzer and documentation of visible cracking, along with patching and maintenance performed on the pavement. As documented, the typical thickness of unbonded concrete overlay was 8 inches with an asphalt or geotextile interlayer, and the panel size was 15 feet long and approximately 12 to 14 feet wide. In the case of bonded concrete overlay, the typical thickness was 4 inches with a 4-foot by 4-foot panel size. All bonded overlay was over asphalt pavement. It was reported that both types performed well, and the unbonded concrete overlays exhibited superiority in terms of ride quality. A geotextile separator layer and concrete shoulder in unbonded overlay showed less cracking compared with an asphalt interlayer and asphalt shoulder.

The National Concrete Pavement Technology Center has evaluated the effectiveness of nonwoven geotextile materials as a separation layer for unbonded concrete overlays on existing pavements in the United States (Cackler et al., 2018). Since 2008, 10 states have successfully used a geotextile separator layer over 10 million square yards of concrete overlays. Minnesota has widely adopted this method. Geotextiles can reduce material costs and improve drainage compared with asphalt separation layers. They eliminate the risk of interlayer stripping, which can cause overlay failures. Proper installation of geotextile separation materials is essential for optimal performance—6- to 10-inch overlap for splicing, extending the layer beyond the pavement edge to ensure drainage, cleaning the surface before placement of geotextile, avoiding any wrinkles during placement, and ensuring no traffic on the fabric.

The National Concrete Pavement Technology Center has recently summarized design, construction, and performance information for different types of concrete overlays, including both concrete over asphalt and concrete over concrete with bonded and unbonded options (Griss, 2023). The study presented 17 case histories with examples of successful performance of concrete overlay projects in different geographical locations, overlay types, and roadway functional classifications.

Project Details and Construction Information

Location

The project is in Southampton County, Virginia, under the jurisdiction of the VDOT Hampton Roads District. US 58 is a four-lane divided primary highway, running east-west through the southern part of the state, carrying 15,000 vehicles per day with 22% truck traffic according to average annual daily traffic from VDOT 2022 data. Although total vehicles per day varied between 13,000 and 16,000, truck traffic increased significantly from 12 to 23% in the past 20 years. The selected test section was 4.8 miles of two westbound lanes slightly east of Capron between Capron and Courtland for the concrete overlay. Another 9.8-mile section on the eastbound lanes just west of Capron was overlaid with asphalt. Figure 1 shows the project location on a Google map. Three repair options were used:

- Asphalt overlay: 9.8 miles (County milepost [MP] 6.8 to MP 16.6)—eastbound lanes.
- Bonded overlay: 2.6 miles (County MP 20.9 to MP 18.3)—westbound lanes.
- Unbonded overlay: 2.2 miles (County MP 18.3 to MP 16.1)—westbound lanes.

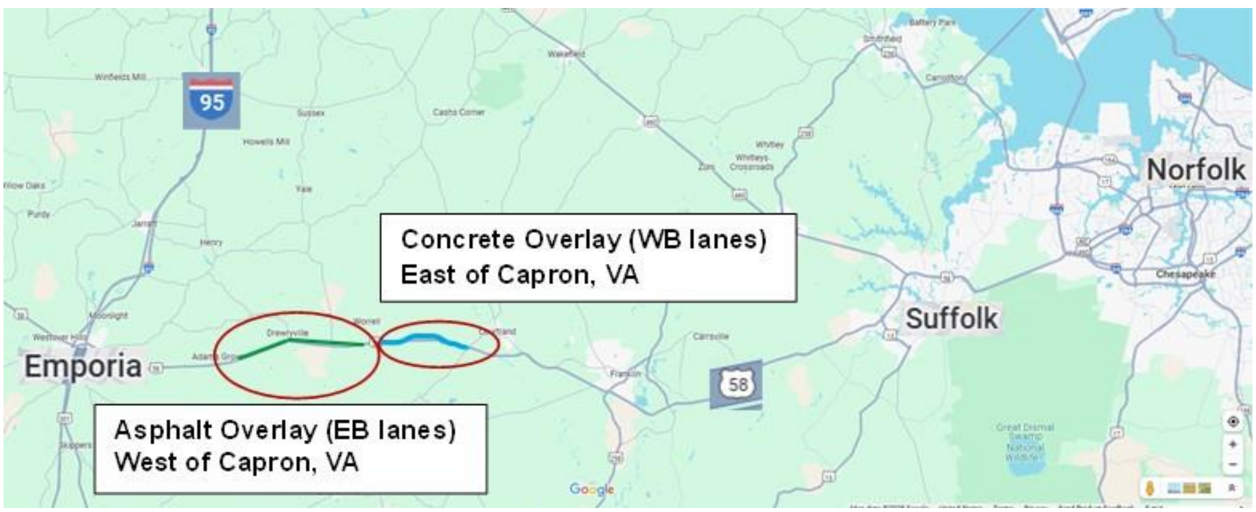


Figure 1. Location of Overlay Project in Southampton, Virginia. Courtesy of Google Maps. EB = eastbound; WB = westbound.

The existing pavement for overlays was 8-inch CRCP over a 6-inch cement-treated aggregate base. The subgrade soil is mostly clayey in this area. CRCP was reinforced with #5 steel bar with 6-inch center-to-center spacing (0.64% steel) according to VDOT specifications. The compressive strengths from cores for the old (original) concrete were 6500 to 7500 psi, and cement-treated aggregate base were 1500 to 2000 psi.

Some drainage issues were obvious within 5 years after initial construction, with the manifestation of early distresses, such as punchout in the concrete pavement. A drainage retrofit was performed with a VDOT underdrain system in 1997. Although the underdrain system was able to move some of the water out of the pavement area, it continued to deteriorate because many drainage outlets were clogged. This deterioration necessitated the patching of a few areas each year. The pavement was eventually rehabilitated in 2012 with asphalt and concrete overlays.

Pavement Condition Before Overlay

The researcher visually assessed the pavement condition from field visits, in addition to the distress data from the VDOT PMS. VDOT's Maintenance Division rates the pavement annually through a video logging and automated condition survey. A pavement condition rating is calculated with a deduct value distress rating scale from 0 to 100, with a higher number indicating better pavement condition. Two distress ratings are calculated for CRCP—concrete distress rating and concrete punchout rating—and one slab distress rating for jointed concrete pavement. On the other hand, asphalt pavement has two different distress ratings—the load-related distress rating, composed of pavement distresses considered to be primarily due to traffic, and the nonload-related distress rating, composed of distresses considered to be primarily nonload-related (i.e., climate, materials, or construction issues). The lower of these ratings is considered a critical condition index (CCI) for a particular section. VDOT considers pavement conditions to be excellent when the CCI rating score is 90 and higher and very poor when the score is 49 and lower. In addition to surface distress rating, pavement is also evaluated by its ride quality. International roughness index (IRI) values are measured for ride quality, also as a part of VDOT PMS data collection. A value of less than 60 inches/mile is considered excellent, whereas 200 inches/mile or more is considered very poor. Table 1 shows the general guidelines for pavement conditions based on either CCI or IRI as used by VDOT.

Table 1. Pavement Qualitative Rating, VDOT Practice (VDOT, 2019)

International Roughness Index Range (inch/mile)	Qualitative Pavement Rating	Critical Condition Index Rating
60 and lower	Excellent	90 and higher
60–99	Good	70–89
100–139	Fair	60–69
140–199	Poor	50–59
200 and higher	Very Poor	49 and lower

Visually, the unbonded section was more distressed than the bonded section (Figure 2). The design was based on these observations by selecting the highly distressed areas for the unbonded section.

Distress condition from visual observation through video log showed some variation along both eastbound and westbound sections. Table 2 summarizes the major distresses in the test sections. The average pavement condition rating from VDOT PMS for the unbonded section was 31, whereas the bonded section was 46 in 2012, right before the overlay. The average IRI values for the bonded and unbonded sections were 113 and 154 inches/mile, respectively. The asphalt section CCI was 39, and IRI was 145 inches/mile. To facilitate the overlay design, these sections were further evaluated using cores and FWD testing (Sprinkel et al., 2014; Wells and Tate, 2007).

Figure 2. Distresses before Overlay, Travel (Outside) Lane: (a) Bonded and (b) Unbonded

Table 2. Major Distresses on CRCP before Overlay (per 0.1-Mile Section)

Distress Type	**Distress Measure**	**Asphalt Overlay**	**Bonded Overlay**	**Unbonded Overlay**
Transverse Crack[a]	Severity 1 (LF)	216	589	438
	Severity 2 (LF)	436	146	257
	Severity 3 (LF)	5	0	1
	Total number of cracks	56	67	64
	Average spacing (feet)	9	8	7
Longitudinal Crack[b]	Severity 1 (LF)	43	19	42
	Severity 2 (LF)	39	30	50
	Severity 3 (LF)	1	0	0
Cluster Crack[c]	Severity 1 (SF)	429	645	727
	Severity 2 (SF)	76	135	183
Punchout and Y-Crack[d]	Count	2	5	10
	Area (SF)	72	60	149
Asphalt Patch	Area (SF)	77	56	92
PCC Patch Condition[e]	Severity 1 (SF)	147	7	12
	Severity 2 (SF)	415	233	45
	Severity 3 (SF)	282	247	297
Average rating for the whole test section				
Pavement Condition Index	Concrete distress rating	47	69	59
	Concrete punchout rating	59	51	34
Average IRI (inches/mile)	Ride quality	145	110	150

CRCP = continuously reinforced concrete pavement; IRI = international roughness index; LF = linear feet; PCC = Portland cement concrete; SF = square feet. [a]Transverse Crack—Severity 1: < 1/4-inch wide, no spalling; Severity 2: > 1/4-inch wide, no spalling; Severity 3: > 1/4-inch, with spalling. [b]Longitudinal Crack—Severity 1: no spalling; Severity 2: 1/4 of the length or less, with spalling; Severity 3: more than 1/4 of the length, with spalling. [c]Cluster Crack (closely spaced transverse cracks)—Severity 1: 1–2-foot spacing; Severity 2: less than 1-foot spacing. [d]Punchout and Y-crack—Broken slab by two or more cracks. [e]PCC Patch Condition—Severity 1: no distress; Severity 2: Severity 1 CRCP distress; Severity 3: Severity 2 CRCP distress.

Concrete Overlay Construction History

As Figure 3 shows, these overlay sections were constructed during the second one-half of 2012: (1) 2.2 miles of 7-inch unbonded and (2) 2.6 miles of 4-inch bonded. In addition, 0.3 mile of jointed plain concrete pavement reconstruction was present. The bonded section had an asphalt shoulder, and the unbonded section had a concrete shoulder. The pavement was designed using an AASHTOWare Pavement ME 1993 pavement design guide for 30 years of design life. Traffic was diverted to the eastbound lanes in each phase, with full lane closure for that section. Head-to-head traffic on the eastbound lanes needed concrete barriers. Installation (bolted) and removal of these concrete barriers and temporary crossovers added a significant cost to the project. VTRC report 14-R16 summarizes the construction practices and lessons learned (Sprinkel et al., 2014). The following is a brief discussion.

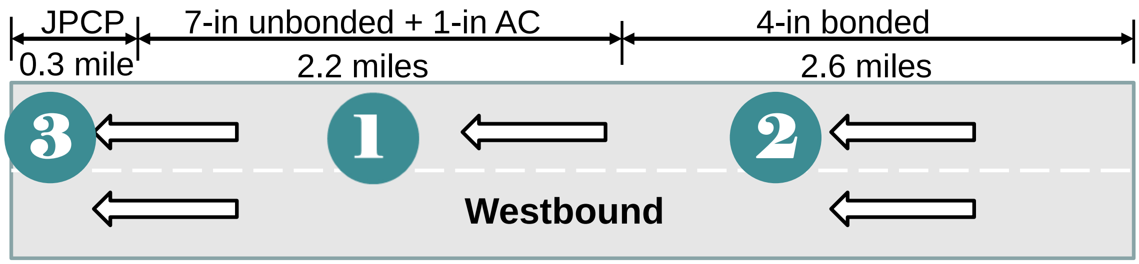


Figure 3. Construction Sequence (Sprinkel et al., 2014). AC = asphalt concrete; JPCP = jointed plain concrete pavement.

Surface Preparation

Prior to the bonded overlay placement, the deteriorating areas were repaired with full- or partial-depth concrete patches, whereas the unbonded section had no need for any extensive repairs, and only minor asphalt patches were placed. A 1-inch hot mix asphalt (HMA) was used under unbonded concrete as a separator layer to prevent crack reflection. This asphalt mixture was a porous friction course (PFC), which is open-graded and supposed to facilitate drainage. The surface of the bonded section was shot blasted and wetted before the placement of a 4-inch bonded overlay to ensure proper bonding. Several surface tensile strength tests were conducted according to ASTM C1583 (ASTM, 2013), and the bond strength varied between 193 and 608 psi, indicating a good bond.

Concrete Materials

According to the VDOT specification, a 3,000-psi concrete with 0 to 3 inches of slump was required for the project. The total cementitious material was 596 pounds/yard^3 with type I and II cement and 25% Class F fly ash. The water-cementitious materials ratio (w/cm) of 0.43 and 0.45 was used to ensure the desired properties in the concrete, with a specified flexural strength of 650 psi. Fresh and hardened concretes were tested for quality control and quality assurance. Table 3 summarizes the test results.

Table 3. Fresh and Hardened Concrete Properties (Sprinkel et al., 2014)

Concrete Property	Number of Samples	Maximum	Minimum	Average	Standard Deviation
Density (pounds/feet^3)	50	142.9	137.9	139.8	1.3
Air Content (%)	71	8.0	4.0	6.5	0.9
Slump (inches)	71	5.0	1.0	2.0	0.6
Compressive Strength, psi (28 days)	71	5750	3790	4878	418
Permeability (coulombs)	70	1239	325	596	189

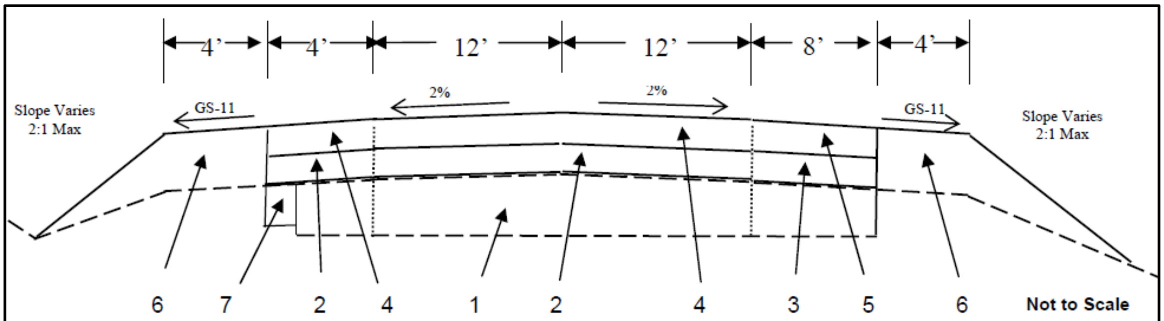
Paving Operation

A Global Positioning System-enabled laser guidance system was used for this stringless paving operation. A two-track paver behind the spreader was used without any major issues except some stop-and-go operations in the bonded section due to rain. Figure 4 shows the paving operations. The unbonded section used tie bars (#4, 30 inches long) along the longitudinal joints between the two lanes, as well as between the lane and the concrete shoulders. The unbonded overlay was sawed into 6-foot squares as soon as possible without causing raveling. All joints on the unbonded overlay were un-doweled because the thickness was less than 8 inches. The width and depth of the saw cut were approximately 1/8 inch and 1/3 of the overlay thickness, respectively. These 1/8-inch joints were sealed with hot-pour asphalt.

Figure 4. Paving Operation: (a) Trucks Dumping Concrete in Front of Spreader; (b) Side Discharge; (c) Two-Track Paver; (d) Global Positioning System-Enabled Laser Guidance System (Sprinkel et al., 2014)

Asphalt Overlay Construction History

The eastbound lanes were overlaid with asphalt mixtures during the second one-half of 2012. The 5-inch asphalt overlay was a SMA consisting of two layers: 2-inch SMA 12.5 (76-22) over 3-inch SMA 19.0 (76-22). The distressed areas of the CRCP surface were patched full depth with hydraulic cement concrete for an area of approximately 13% before asphalt overlay (Sprinkel et al., 2014). Figure 5 shows a typical section.



1. Existing hydraulic cement concrete with asphalt shoulders, all patching will be in accordance with the 2007 edition of the VDOT Road and Bridge Specifications and the attached Special Provision for patching hydraulic cement concrete pavement.

2. Place one 3 inch lift of asphalt over CRCP pavement and 4 foot wide left shoulder with Type SMA-19.0 (76-22) asphalt. Existing pavement to receive a tack coat of CRS-2 @ 0.05 gal.per sq. yd. diluted with 50% water prior to placement of SMA-19.0 base asphalt.

3. Place one 3 inch lift of asphalt over 8 foot wide right shoulder with Type IM-19.A asphalt.

4. Place one 2 inch lift of asphalt over the CRCP pavement and 4 foot wide left shoulder with Type SMA-12.5 (76-22)

5. Place one 2 inch lift of asphalt over 8 foot wide right shoulder with Type SM-12.5 asphalt.

6. Unpaved shoulders to be raised to grade using borrow material within two days of constructing each phase, with the final 2" of fill being Class A Topsoil, failure to comply will result in paving operations being halted until this condition is met. Payment for this phase of work shall be included in the lump sum grading item. Restoration of the shoulder is to be paid for under the seed, fertilizer and lime pay items.

7. Trench widening of existing paved left shoulder 1 foot wide & 6 inches deep using BM-25.0A. See attached widening details.

Figure 5. Typical Section for Asphalt Overlay (VDOT contract document UPC 98787, 2011). CRCP = continuously reinforced concrete pavement; SMA = stone matrix asphalt.

The asphalt mixtures SMA 12.5 and SMA 19.0 have nominal maximum aggregate sizes of 1/2 inch and 3/4 inch, respectively. The 5-inch SMA overlay used polymer-modified asphalt binder with 15% reclaimed asphalt pavement and approximately 75% coarse aggregate. A large amount of coarse aggregate is supposed to provide better rut resistance through a stone-on-stone contact. SMA is the most common gap-graded mixture used in Virginia and comprises a gap-graded aggregate that is intended to maximize rutting resistance and durability with a stable stone-on-stone skeleton held together by a rich mixture of asphalt binder, mineral filler, and cellulose fibers. This stable skeleton is achieved by establishing the voids in coarse aggregate (VCA) fraction. VCA is measured twice: (1) with only the coarse aggregate fraction rodded dry (designated as VCA_{drc}) and (2) by measuring the VCA of the compacted SMA mixture (designated VCA_{mix}). To ensure stone-on-stone contact, VCA_{mix} has to be less than VCA_{drc}. If VCA_{mix} is greater than VCA_{drc}, the fine aggregate fraction and asphalt in the mixture pushes the coarse aggregate particles apart and creates extra voids above VCA_{drc}. Table 4 presents the quality control and quality assurance properties, along with the design values. Although the VCA_{mix} values are less than the VCA_{drc} values, as required by the design, they are very close to each other, indicating the possibility of loss of stone-on-stone contact. Moreover, VCA_{drc} was not measured on the actual field samples. They are the design values.

Table 4. SMA Mixture Properties during Construction

Asphalt Mixture Properties	SMA 12.5 (76-22)		SMA 19.0 (76-22)	
	Design JMF	Production Average (of 14)	Design JMF	Production Average (of 9)
AC (%)	6.80	6.64	6.00	6.01
VTM (%)	3.0	3.21	3.0	2.51
VMA (%)	18.4	18.2	17.0	16.3
VCA (drc)	42.8	—	43.9	—
VCA (mix)	38.3	39.0 (range: 36.3–40.7)	35.1	36.9 (range: 34.6–38.9)

— = not available; AC = asphalt content; drc = dry rodded coarse aggregate; JMF = job mix formula; SMA = stone matrix asphalt; VCA = voids in coarse aggregates; VMA = voids in mineral aggregates; VTM = voids in total mix.

In-Service Data (Traffic, Weather, and Maintenance)

This section of roadway has seen a significant increase in truck traffic, according to VDOT published traffic data (VDOT, 2025). Although the average annual daily traffic has not increased appreciably, the percentage of trucks has increased, the increase is noticeable right after the overlay in 2012, from 13 to 20%. Figure 6 shows traffic distribution from 2001 to 2023. The average annual daily traffic varies from 13,000 to 16,000 vehicles per day, and the truck traffic has increased from 13 to 23%. As Figure 6 shows, no definitive trend is apparent in the increase in truck traffic. Therefore, the average annual daily traffic could be assumed at 15,000 vehicles per day with 22% truck traffic.

In addition to the traffic loading, the weather also affects pavement performance, specifically temperature and precipitation. High and low temperatures, as well as daily temperature cycles, influence the pavement performance. On the other hand, precipitation could compromise foundation support if not drained properly. The annual average rainfall varied from 35 to 70 inches, with a slight increasing trend. The daily temperature cycles were mostly between 15 and 25°F with a range from 0 to 40°F. The high temperature was around the 90s (°F), and the low temperature was around the 20s (°F). The daily average temperature varied from 5°F to 100°F during the past 12 years.

The unbonded concrete and asphalt overlay sections did not receive any major maintenance work because the overlaid but bonded concrete overlay section needed some repair. A few wide transverse cracks showed within 6 months after construction (Figure 7), pictures taken in January 2013. One crack was 0.75 inch wide, and others varied from 0.1 inch to 0.4 inch, and some were clustered together. Subsequent coring, as seen in Figure 8, revealed that all the cracks reflected from the underlaying old concrete layer and were affected by the shrinkage of the bonded overlay concrete on the surface. Severely distressed old concrete occurred at the bottom but was not apparent at the surface. From the cores, moisture damage was evident by the corrosion of steel and severely broken concrete at the bottom.

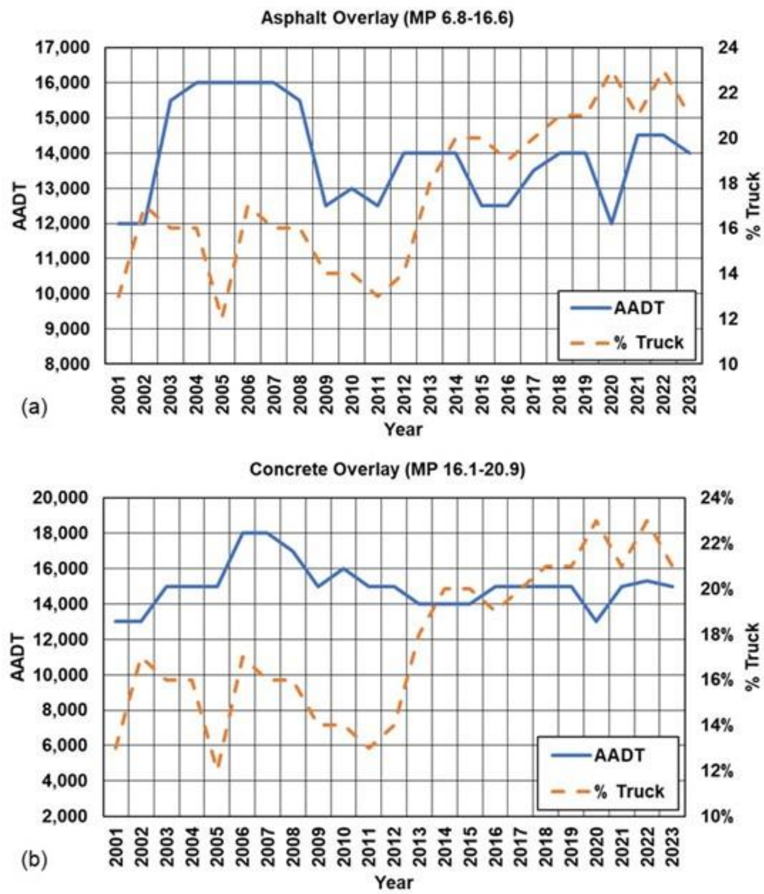


Figure 6. Traffic Distribution for U.S. Route 58: (a) Asphalt Overlay Area and (b) Concrete Overlay Area. AADT = annual average daily traffic; MP = milepost.

Figure 7. Bonded Concrete Surface—Wide Cracks, January 2013

Figure 8. Cores from the Distressed Area of the Bonded Overlay Section

These distressed areas were repaired with concrete patches in 2014. Sixteen patches were installed: 14 on the travel lane and 2 on the passing lane within 2 years after the overlay placement. A few more patches have been done in recent years since the overlay, but no major repair has been done.

Pavement Condition—Surface Distresses

Surface distress data were collected from the VDOT PMS for both eastbound and westbound US 58 in Southampton County, Virginia. In addition, researchers visited the section for a visual assessment. Although all sections were CRCP before overlay, their classification has changed after overlay. The bonded section is CRCP, the same as before, but the unbonded section is rated as jointed plain concrete pavement. On the other hand, the asphalt overlay section is now a composite section with an asphalt surface. Therefore, the surface distresses cannot be compared directly with the pre-overlay conditions because the major distress categories have changed. Overall pavement conditions were compared in terms of pavement CCI and IRI ride quality, shown in Figures 9 and 10, respectively. The following section discusses the individual section's surface distresses.

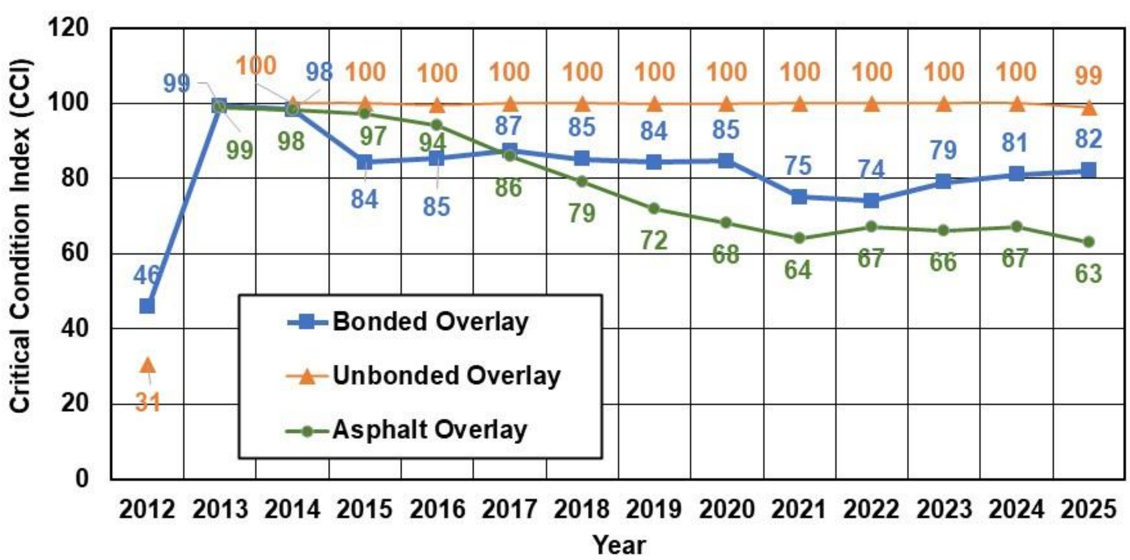


Figure 9. Pavement Condition Index for Three Overlay Sections

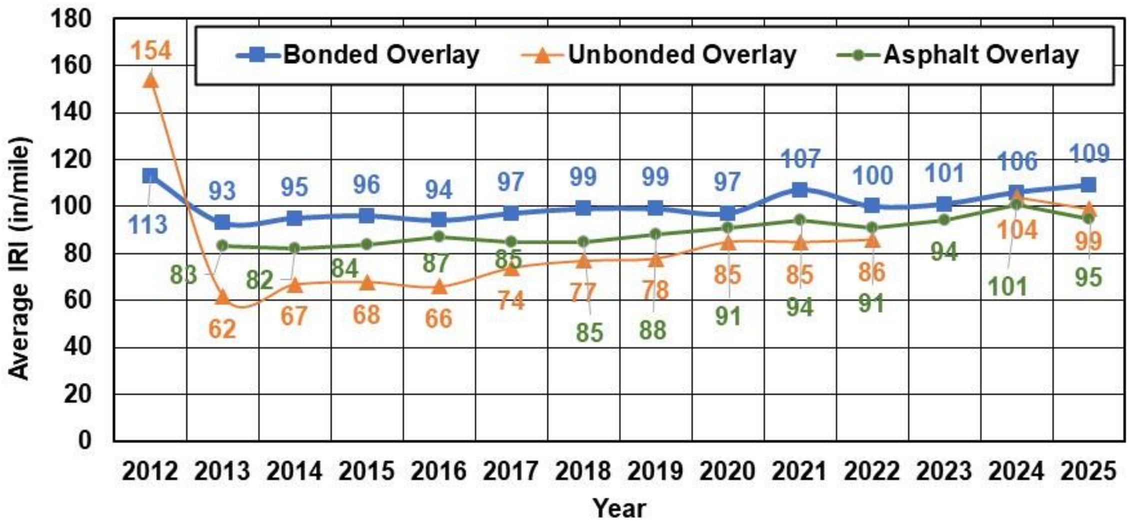


Figure 10. Ride Quality as Measured by IRI for Three Overlay Sections. IRI = international roughness index.

Bonded Overlay Section

Table 5 summarizes the major distresses in the year 2024. Most types of distresses have not reached the level of pre-overlay, except punchout, which is a major distress type for CRCP. Although the average punchout determined per 0.1-mile section is 4.2 punchouts compared with 5 for pre-overlay, the most punchouts are within 0.3 mile of the west-end section, closer to the unbonded overlay, with as many as 17 to 24 punchouts per 0.1-mile section. Although this bonded overlay is in good condition, as indicated by the pavement condition rating value of 85, a few concentrated punchouts, cracks, and patches are evident (Figure 11). The total punchout and patched areas, including both Portland cement concrete and asphalt, for the whole 2.2-mile section were approximately 1% in 2024 compared with 9% in 2012, before overlay placement. These patches were done within 2 years of overlay construction. Patching mixes usually use high cement factors because they need high early strength due to the traffic closure limitations. High cement factor directly relates to higher paste content and high shrinkage, resulting in cracks. A field visit revealed similar observation (Figure 12). During the field visit, the polished concrete surface at wheel paths was observed (Figure 13). However, the skid testing using full-scale smooth tires on a locked wheel device, according to ASTM E274 (ASTM, 2024), revealed adequate friction with a skid number (SN40S) of 40 and above; skid numbers were corrected for a test speed of 40mph and monthly climate according to VTM-122 (VDOT, 2023). VDOT uses a minimum threshold value of 20 for skid number (SN40S). Appendix A shows the skid results.

Table 5. Summary of Major Distresses on U.S. Route 58 Bonded Overlays in 2024

Distress Type	Distress Measure	Bonded Overlay	
		Condition before Overlay (2012)	**Present Condition after Overlay (2024[a])**
Transverse Crack	Severity 1 (LF)	589	446
	Severity 2 (LF)	146	322
	Severity 3 (LF)	0	6
	Total number of cracks	67	69
	Average spacing (feet)	8	7
Longitudinal Crack	Severity 1 (LF)	19	8
	Severity 2 (LF)	30	4
	Severity 3 (LF)	0	0
Cluster Crack	Severity 1 (SF)	645	27
	Severity 2 (SF)	135	0
Punchout & Y-Crack[b]	Count	5	4.2
	Area (SF)	60	24.5
Asphalt Patch	Area (SF)	56	1.75
PCC Patch condition	Severity 1 (SF)	7	40.1
	Severity 2 (SF)	233	0
	Severity 3 (SF)	247	0
Average rating for the whole test section			
Pavement Condition Index	Concrete distress rating	69	86
	Concrete punchout rating	51	88
Average IRI (inches/mile)	Ride quality	110	104

IRI = international roughness index; LF = linear feet. PCC = Portland cement concrete; SF = square feet. [a]Rated November 27, 2024. [b]Although the average number of punchouts per 0.1-mile section is approximately the same before and after overlay, the average does not represent the current condition because most of the punchouts are concentrated between mileposts 18.45 and 19.15.

Figure 11. Surface Distresses on Bonded Section in 2025

Figure 12. Map Cracks on the Patches

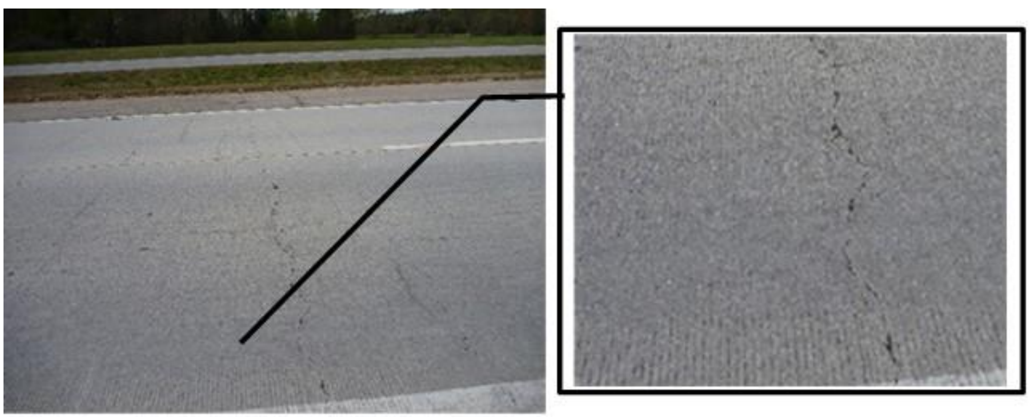


Figure 13. Polished Surface on the Concrete Overlay in 2025

Unbonded Overlay Section

The unbonded concrete overlay is performing satisfactorily after 12 years of service, with minor distresses on the surface, such as low-severity faulting, some joint sealant loss, and a few corner breaks. Figure 14 shows some of the distressed areas. Corner breaks are mostly associated with the settlement of the slab. One of the probable causes of settlement might be the underlaying asphalt separation layer, which might have settled or disintegrated. The separation layer was PFC, which is an open-graded asphalt layer. A few joints are missing sealants, and moisture could easily enter the system and damage the PFC through asphalt striping. Although the low-severity faulting was consistent across all the joints, the amount of faulting is very low at only 0.03 inches. It may also be attributed to the PFC separation layer. It is also important to note that these joints do not have any dowels. Overall, the pavement condition is excellent, with CCI of 99. The ride quality is between good and fair, with a value from 99 to 100 inches/mile. Like bonded concrete, this section also showed some polishing on the wheel path (Figure 14), but the average skid number (SN40S) was above 40.

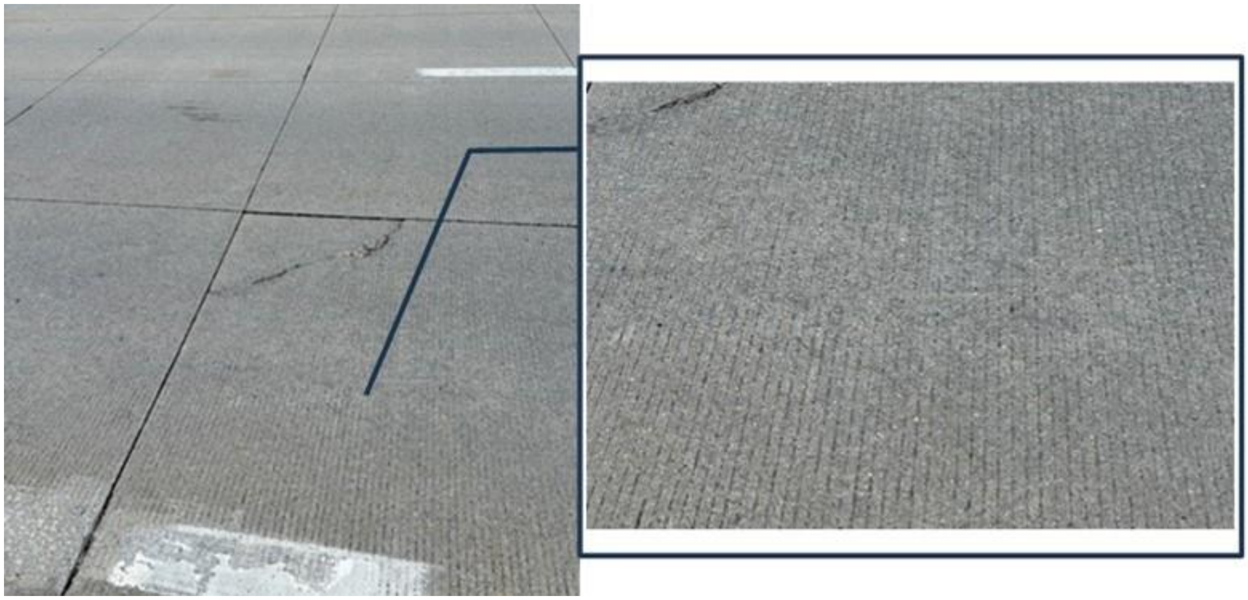


Figure 14. Pavement Surface Condition for Unbonded Concrete Overlay in 2025

Asphalt Overlay Section

After 12 years of service, the asphalt overlay surface has no major distresses except for significant rutting of approximately 0.35 inch (Figure 15). Figure 16 shows the progression of rutting during the years. Along with the current surface condition in 2025, it appears to be dual wheel rutting, indicating ruts only in the asphalt layer. The asphalt layer is also placed directly on top of the rigid concrete, which usually does not rut. Rutting had increased until 2021 and then stayed around 0.35 inches for the past few years. Because of this high rutting value, the pavement condition index dropped to 66. Rutting has a significant effect on the VDOT load-related distress rating. For example, just the average rut depth of 0.3, 0.4, and 0.5 inches would result in a deduction of 22, 42, and 60 points out of 100 in load-related distress rating, respectively. It is obvious from the traffic data in Figure 6 that the percentage of truck traffic has increased from 12 to 20% right after the overlay construction and might have contributed to rutting. No indication of polishing is present, and the measured skid resistance (SN40S) is around 40, indicating adequate friction like a concrete overlay surface in the westbound lanes.

Figure 15. Asphalt Overlay Surface Condition in 2025

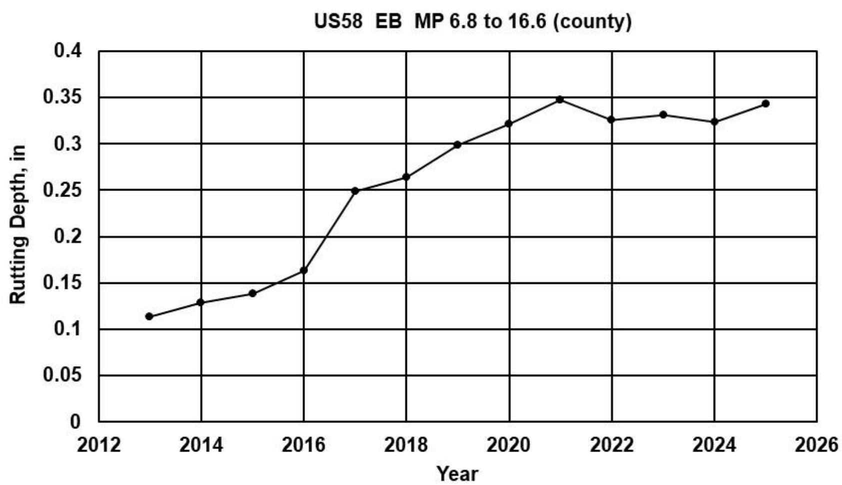


Figure 16. Progression of Rutting on Asphalt Overlay. EB = eastbound; MP = milepost.

Pavement Condition—Structural Assessment

To assess the structural condition of the pavement sections, FWD testing was conducted in the fall of 2024. In addition to basin testing at 9-kip drop-load for all three sections, LTEs were measured at several joints on the unbonded section and at major cracks (and patch joints) on the bonded section. ModTag software was used to process data to calculate the subgrade modulus. Table 6 presents a summary of the data. The deflection values (D_0) under 9-kip drop-load are low, indicating adequate pavement structure. D_0 denotes the deflection at the loading plate, and D_9 denotes the deflection at a distance of 72 inches from the loading plate. The D_0 parameter is an indicator of the overall structural capacity of the pavement system, and the D_9 parameter is an indicator of the quality of the pavement foundation (subgrade).

Table 6. Falling Weight Deflectometer Test Results for 2024 and 2012 Measurements

Property	Lane	Asphalt		Bonded		Unbonded	
		2024	2012	2024	2012	2024	2012
		Measurement Statistics: Average (COV, %)					
Effective Subgrade Modulus, psi	Travel (1)	9179 (23)	—	15733 (21)	—	17978 (28)	—
	Passing (2)	—	—	—	—	—	—
Deflection under 9 kip load, D_0 (mils)	Travel (1)	4.4 (19)	—	2.9 (30)	3.8 (25)	3.0 (32)	5.7 (61)
	Passing (2)	6.5 (15)	—	—	4.7 (24)	—	5.3 (45)
Deflection at the far end, D_9 (mils)	Travel (1)	1.1 (24)		1.2 (22)	1.1 (28)	1.0 (39)	1.5 (37)
	Passing (2)	1.2 (21)	—	—	1.1 (28)	—	1.6 (32)

— = not available; COV = coefficient of variation; D_0 = deflection directly under the loading plate measured with the first sensor; D_9 = deflection measured with the last sensor at 72 inches from the loading plate.

LTEs in the unbonded overlay section were measured on the joints at every 500 feet, and most of them have more than 75% LTE. Although these joints do not have any dowels, the smaller slab size helped maintain aggregate interlock. Twenty-four joints were measured, and only two (8%) joints showed a low value of approximately 50 to 60% LTE. Only one joint had more than 100% LTE, indicating measurement error or some slab instability or settlement. A similar trend was observed for both 9- and 16-kip loads.

LTEs on the bonded overlay section were measured on the visible cracks and patch boundaries. Thirty-seven joints or cracks were measured with both 9- and 16-kip drop loads. Only the slab technique was used. Thirty measurements had good LTEs of greater than 75%. Approximately five joints have more than 100% LTE, indicating error or instability of the slab. Four joints had less than 75% LTE.

Performance of Treatment Options

The performances of concrete and asphalt overlays were assessed based on visual observation, surface distresses from VDOT PMS data, ride quality, and skid measurements. In general, all three sections are performing satisfactorily, with some of the distresses needing attention.

Maintenance Need

These overlays have been in service for approximately 12 years, and the need for some sort of maintenance is common. The following sections discuss some of the maintenance strategies.

Unbonded Concrete Overlay

No major distress was observed in the unbonded concrete overlay. Some of the distresses from PMS were as follows:

- 100% of slabs showing severity level 1 faulting.
- Average Faulting: Left wheel path 0.03 inch and right wheel path 0.03 inch.

- Transverse Joint Spalled: Total seven slabs.
- Longitudinal Joint Spalled: Only one slab.
- Corner Breaks Severity 2: Only one slab (three observed during field visit on April 2, 2025).

The measured faulting was only 0.03 inch, and good load transfer was observed across the joints. More than 90% of the joints have LTE of 75% or more. The low-level faulting might have affected the ride quality, and the average IRI in 2025 was 99 inches/mile. Some corner breaks were present that could be attributed to the moisture damage or the settlement of the separation layer (PFC). Joint seals were missing in a few places, which can cause moisture intrusion and subsequent stripping of the asphalt separation layer, hence loss of support and corner break. Maintenance suggestions to extend the life of the overlay include:

- Patch corner breaks.
- Monitor and seal joints.
- Grinding to improve IRI if deemed necessary.

Bonded Concrete Overlay

This bonded section had a few visibly distressed areas. Table 5 summarizes the distresses for a 0.1-mile section. The bonded section had wide transverse cracks and localized punchouts. Here are the highlights of the distresses from PMS for the whole 2.6-mile section:

- Average Spacing of Transverse Cracks: 7.76 feet.
  - Severity 1: 56%; and severity 2: 44%.
- Longitudinal Cracks.
  - Severity 1: 254 feet.
  - Severity 2: 180 feet.
  - Severity 3: 11 feet.
- Clustered Cracking Severity 1.
  - 18 clusters with a total area of 714 square feet.
- Longitudinal Joint Spalling.
  - 98 linear feet.
- Punchouts and Spalled Y-cracks—most of which are within a 0.3-mile section.
  - 126 punchouts totaling 787 square feet.
- PCC Patch—Severity 1: 962 square feet.
- Asphalt Patching—91 square feet.

Longitudinal and transverse cracks and spalled areas can be sealed with Mastic One (a hot-applied, pourable, self-adhesive patching material used for filling wide cracks and joints), and smaller width cracks can be repaired by applying hot asphalt binder. Some areas of high punchouts are present around county milepost 19, which need to be patched full depth with good-quality concrete. Other options of overlay (such as unbonded or asphalt) could also be considered if damage becomes significant.

Asphalt Overlay

As discussed previously, the only major distress on the asphalt overlay was rutting. The following is a summary of the distresses in the 2025 PMS data:

- No transverse or longitudinal cracks.
- Longitudinal Lane Joint—Severity 1: 374 feet (whole 9.8-mile section).
- Reflective Transverse Cracking—whole 9.8-mile section.
  - Severity 1: 953 linear feet.
  - Severity 2: 341 linear feet.
- Reflective Longitudinal Cracking—whole 9.8-mile section.
  - Severity 1: 16 linear feet.
- Alligator Cracking—whole 9.8-mile section.
  - Severity 1: 424 square feet.
  - Severity 2: 3 square feet.
- Patching Area—whole 9.8-mile section.
  - Wheel path: 12,273 square feet (1% of whole section).
  - Non-wheel path: 7,148 square feet (0.5% of whole section).
- Average rut depth.
  - Straight-edge: 0.34 inches.
  - Wire method: 0.36 inches.

This asphalt overlay was SMA, which is supposed to be a rut resistance mixture. The 5-inch SMA overlay also used polymer-modified asphalt binder. Although the production mix results in Table 4 showed that VCA_{mix} was less than VCA_{drc}, they were very close to each other and may have resulted in questionable stone-on-stone contact. This contact, along with higher traffic (22%), resulted in an increased rutting of this section at 0.35 inches. The actual cause of rutting was not confirmed; further investigation is suggested. Mill and fill could be an option pending further investigation.

Mechanistic-Empirical Pavement Design Guide Performance Prediction

Results of AASHTOWare Pavement ME were compared with the performance measured in VDOT PMS.

Unbonded Concrete Overlay

In AASHTOWare Pavement ME, no option was available to simulate 6-by-6-foot panels for 7-inch unbonded concrete overlay. Therefore, 6-foot joint spacing without dowels was used to simulate the overlay structure, resulting in a higher predicted joint faulting of 0.93 inch for 30 years and 0.3 inch for 12 years. The predicted jointed plain concrete pavement transverse cracking was low (2.46%) for a 30-year design life, showing adequate thickness. Further simulations were performed using the same 6-foot joint spacing with dowel bars to provide adequate load transfer, and predicted mean joint faulting came out to be 0.04 inch (0.03 inch for 12 years). The measured faulting from PMS is also 0.03 inch for 12 years, indicating that 6-by-

6-foot panels are showing good aggregate interlock and load transfer, which is also confirmed by FWD testing results.

University of Pittsburgh's mechanistic-empirical design and analysis procedure for unbonded concrete overlays (https://pavements.pitt.edu/Products/UNOL.aspx) was also used to further analyze the section, without dowel bars (PITT, n.d.). Results showed that a 7-inch overlay thickness was adequate, and predicted faulting at 95% reliability was 0.041 inch, which is close to the actual faulting.

Bonded Concrete Overlay

The Pavement ME software predicted no punchouts for 4-inch bonded concrete over 8-inch existing CRCP, indicating that design thickness was adequate. It should be noted that the software assumes that all existing punchouts and distress were corrected before the overlay, which was not the case for this project. The Pavement ME software predicted IRI of 120 inches/mile for 12 years compared with the measured value of 109 inches/mile.

Asphalt Overlay

Appendix B presents the Pavement ME design distress prediction summary. The summary shows that the composite section on US 58 met all VDOT distress criteria for punchouts for a new CRCP and rutting criteria for asphalt concrete pavements, and Pavement ME design default criteria for some of the other distresses for the design life of 30 years (VDOT, 2017; Smith and Nair, 2016). Distress predictions for punchouts are very low for the 30-year design period. Asphalt concrete bottom-up cracking is also not a concern for composite pavements. It does not usually initiate at the bottom of the HMA layer for composite pavements because the HMA is almost always in compression unless a loss of friction occurs between the HMA and concrete layers. Composite pavement can develop fatigue-related distress in the form of punchouts, which should be an important design consideration. Punchouts are also the main distress criterion for CRCP. Moreover, the concrete layer is the primary load-carrying component of the composite pavement system (asphalt concrete over CRCP). When a heavy load is applied and repeated on a composite pavement, the HMA layer may undergo some permanent deformation, which is an important design criterion. The thickness of the HMA layer will affect rutting potential. The predicted rutting was 0.2 inch (VDOT criteria is 0.26 inch for 15 years (Smith and Nair, 2016)), indicating a 5-inch thickness was adequate. However, measured rutting was 0.35 inch, which confirms the need for further investigation.

CONCLUSIONS

- *Ride quality is good for all three overlay sections on US 58, with respective IRIs of 95, 99, and 109 inches/mile for asphalt, unbonded concrete, and bonded concrete sections in 2025.*

- *All three overlay techniques—bonded concrete, unbonded concrete, and asphalt overlays—are performing adequately after 12 years of traffic*. All three options provided an extension of service life with some maintenance. Both bonded concrete and asphalt overlay needed some patching, whereas unbonded did not need any maintenance during the past 12 years of service. The bonded concrete section needed full- or partial-depth hydraulic cement concrete patches within 2 years, mainly because of failure to identify and address all the distressed areas prior to the placement of the bonded overlay.

- *The unbonded overlay is a desirable option because it needed very little repair or surface preparation during construction.* Prior to the overlay placement, both the asphalt overlay and the bonded overlay needed hydraulic cement concrete patches, which were expensive. Many times, patching requirements were hard to detect and accomplish. Both asphalt and bonded concrete overlays also required proper bonding to the existing concrete.

- *The unbonded section outperformed the other two techniques, with an excellent critical condition rating of 99, and needed no maintenance in the past 12 years.* Pavement condition survey in 2025 showed a few corner breaks and associated slab settlements in a very limited area. All joints showed a minor faulting of 0.03 inch. Loss of joint sealants was also observed in a few places. The asphalt separation layer may have started to settle or disintegrate (strip). Based on the literature review, geotextile fabric is an option for a separator layer. Geotextile was used as a separation layer by 10 states and exhibited comparable or better performance and was less expensive than an asphalt interlayer.

- *The bonded section has maintained a pavement condition rating of around 80, and only less than 1.5% of the area has some distress in addition to transverse cracks spaced at 7 to 8 feet apart, which is common for CRCP*. This section received a substantial amount of patching right after the overlay construction within 2 years and received more patches in the past 12 years. Although small, the distressed areas would need maintenance to provide adequate services. Some cracks are wide, and many punchouts are in a concentrated area.

- *The asphalt section has been performing well except for significant rutting, which brought the pavement condition rating down to the 60s*. This section exhibited a faster rate of deterioration (rutting), indicating either poor material quality or due to an increase in truck traffic.

- *Based on the current condition survey, all three sections would require some maintenance as outlined in the report to continue extension of service life.*

- *Both concrete overlay sections showed polishing on the wheel path, but skid resistance was measured as adequate with a lock-wheel device using smooth tires*.

RECOMMENDATIONS

1. *VDOT's Materials Division and Districts should use unbonded concrete and asphalt overlays when distresses and surface characteristics adversely affect the ride quality and the structural integrity of the concrete pavement.*

2. *VDOT's Materials Division and Districts should try using geosynthetics as a separation layer when unbonded concrete overlay is used. VTRC should evaluate the performance of fabric as a separation layer.*

3. *Hampton Roads District should consider some of the suggested maintenance activities for these sections, as discussed in the report, to further extend the service life.*

4. *Bonded concrete overlay should only be used when the structural and functional conditions of the existing pavement are deemed sufficient before overlay.*

IMPLEMENTATION AND BENEFITS

Researchers and the technical review panel (listed in the Acknowledgments) for the project collaborate to craft a plan to implement the study recommendations and to determine the benefits of doing so. This process is to ensure that the implementation plan is developed and approved with the participation and support of those involved with VDOT operations. The implementation plan and the accompanying benefits are provided here.

Implementation

Recommendation 1 has already been implemented. For extending the life of existing concrete pavements, VDOT's Materials Division and districts agree to continue using asphalt overlay and exploring the use of unbonded concrete when feasible.

With regard to Recommendation 2, within 2 years of the publication of this report, VTRC, with the assistance of VDOT's Materials Division, will submit a Research Need Statement to the Research Advisory Committee to evaluate the use of geotextile as a separator layer when an unbonded overlay is used. The VDOT Hampton Roads District has recently advertised an overlay project with an option of using a fabric separator layer. VTRC will evaluate the performance if the project is awarded.

With regard to Recommendation 3, the Hampton Roads District will consider some of the suggested treatments within 3 years of the publication of this report.

With regard to Recommendation 4, the VDOT Materials Division will communicate with district pavement engineers and designers to emphasize using the Manual of Instruction for guidance on concrete pavement condition evaluation and the National Concrete Pavement Technology Center guidelines on concrete overlay selection (Fick et al., 2021). The Materials Division will share the National Concrete Pavement Technology guidebook for concrete overlay on its SharePoint site within 2 years of the publication of this report.

Benefits

Pavements undergo surface distresses due to traffic and environmental factors under normal use and could also encounter higher traffic volume and loads, adversely affecting the rideability and the load-carrying capacity, or they could simply be at the end of the design life and in need of rehabilitation. Replacement of existing pavements with new pavements is expensive, and a longer construction time is needed, resulting in work zone safety concerns, loss of service, and travel delays. Disposing of the old pavement materials may have environmental restrictions and adversely affect the sustainability goals. Instead of replacement, repair with overlays is a proven technology that improves the surface characteristics and increases the structural capacity, leading to extended service life.

The unbonded concrete overlay exhibited the best performance among the three techniques evaluated in this research. According to Sprinkel et al. (2014), the unit (bid) prices of the materials in place on the traffic lanes were \$38/yard^2, \$36/yard^2, and \$47/yard^2 for unbonded concrete, bonded concrete, and asphalt overlays, respectively. Both bonded concrete and asphalt overlay needed more than 10% of areas patched with full-depth concrete before overlaying, which added a significant cost of 30 and 40%, respectively. For a 12-foot-wide lane, the costs for a lane mile would be \$268,000, \$253,000, and \$331,000 for unbonded, bonded, and asphalt overlays, respectively. The reconstruction cost according to VDOT maintenance division's need-based analysis for Bitumen over CRCP was \$710,597 in 2024 (VDOT, 2024). The estimated overlay costs adjusted to 2024 using the National Highway Construction Cost Index would be \$544,000, \$514,000, and \$672,000 (Bureau of Transportation Statistics, n.d.). Therefore, the cost saving per lane-mile would be \$166,000, \$197,000, and \$39,000 for unbonded, bonded, and asphalt overlay, respectively. Although the overlays were designed for a 30-year life like new construction, the maintenance needs could be different in reconstruction versus overlay. The cost of the asphalt overlay used in US 58 is comparable with the reconstruction option, which is defined in the Maintenance Division Document as *break and seat plus 9 to 10 inches of asphalt overlay* opposed to US 58 overlay placed in 2012 that consisted of full-depth patching and 5-inch asphalt (VDOT, 2024).

The major contributing factor in the overall construction cost was the management of traffic. The cost of concrete overlays was much higher than that of asphalt overlay for the US 58 project in 2012: \$1.9 million versus \$240,000. Using only bolted rigid concrete barrier for concrete overlay construction added \$1.3 million to the management of traffic. The VTRC study by Sprinkel et al. (2014) had some suggestions for cost reduction in the management of traffic during concrete overlay construction.

ACKNOWLEDGMENTS

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APPENDIX A: SKID TEST RESULTS

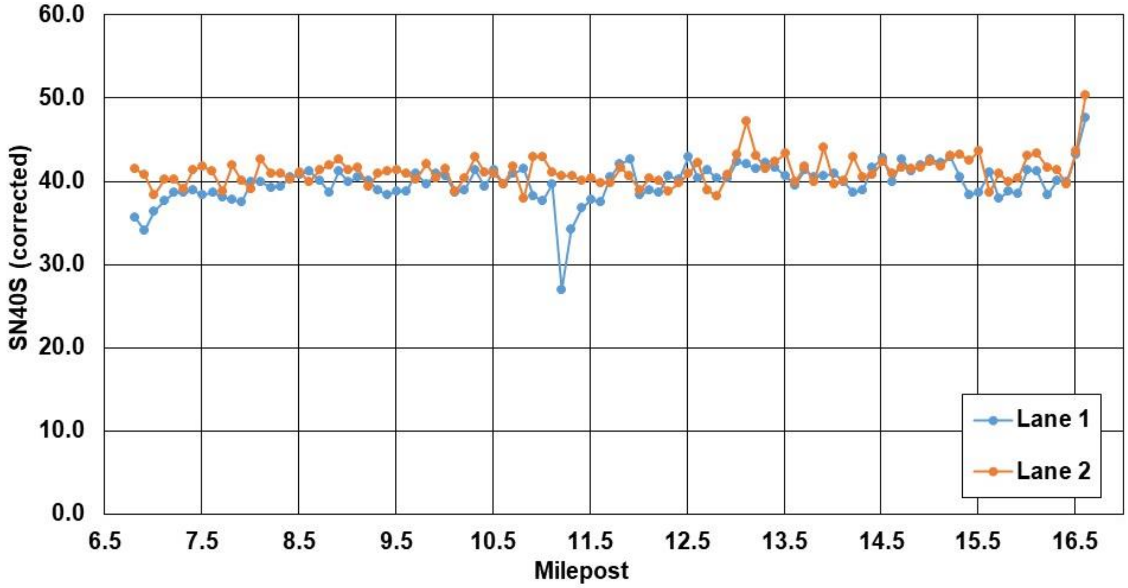

Figure A1. U.S. Route 58 East, Southampton County, Milepost 6.8–16.6. SN40S = skid number measured using smooth tire and corrected to 40 mph speed.

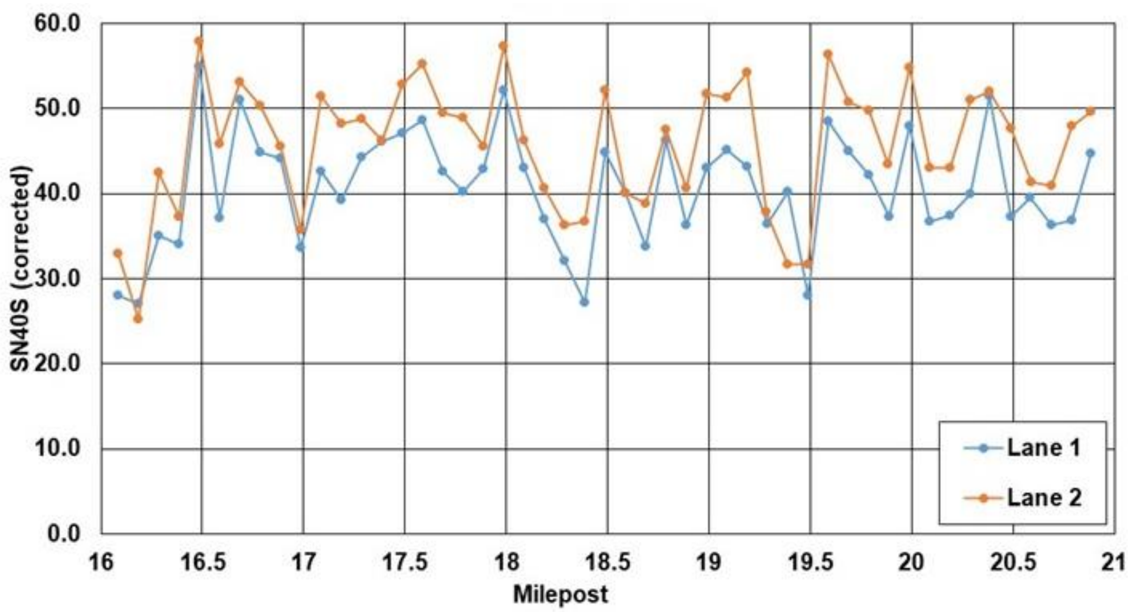

Figure A2. U.S. Route 58 West, Southampton County, Milepost 16.1–20.9. SN40S = skid number measured using smooth tire and corrected to 40 mph speed.

NOTE: Skid numbers measured at 40 mph or above were corrected for speed of 40 mph, and seasonal climate adjusted to July through August, according to Virginia Test Method-122 (VDOT, 2023).

APPENDIX B: AASHTOWARE PAVEMENT ME RESULTS

US 58 bonded 5-11

File Name: C:\Users\Harikrishnan.Nair\Desktop\final runs\US 58 bonded 5-11.dgpx

Design Inputs

Design Life: 30 years
Design Type: Bonded PCC/CRCP

Existing construction: May, 1988
Pavement construction: July, 2012
Traffic opening: September, 2012

Climate Data Sources (Lat/Lon): 37.132, -76.493

Design Structure

Layer type	Material Type	Thickness (in)
PCC	Bonded PCC Default	4.0
PCC	CRCP Default	8.0
Cement_Base	VDOT CTA	6.0
Subgrade	VA A-7-5	10.0
Subgrade	VA A-7-5	Semi-infinite

Steel Reinforcemment:	
Steel (%)	0.64
Bar diameter (in)	0.63
Steel depth (inch)	4.00

Traffic

Age (year)	Heavy Trucks (cumulative)
2012 (initial)	3,300
2027 (15 years)	8,955,810
2042 (30 years)	17,925,100

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	140.00	122.60	95.00	99.30	Pass
CRCP punchouts (1/mile)	6.00	0.00	95.00	100.00	Pass

Distress Charts

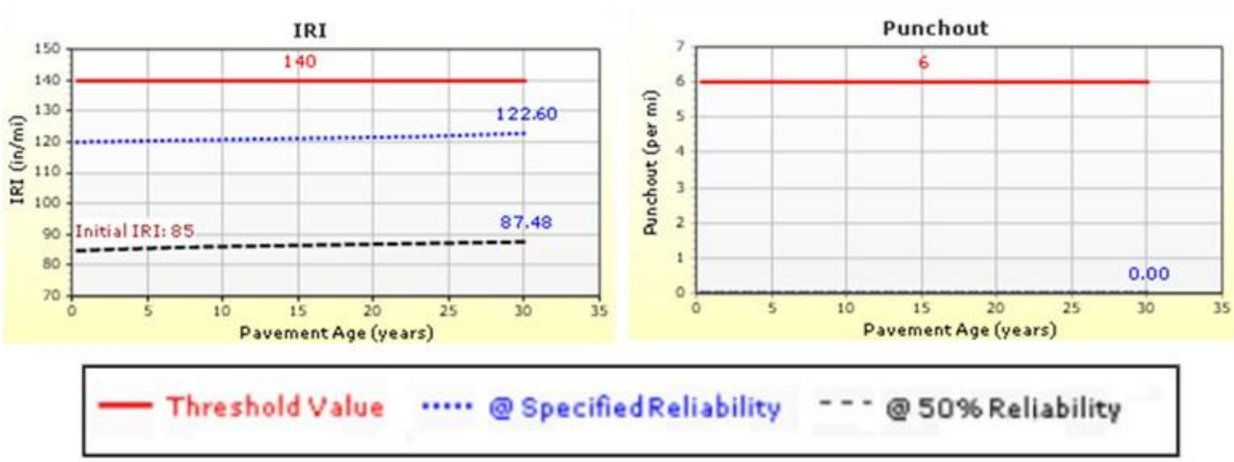

Figure B1. Bonded Concrete Overlay. CRCP = continuously reinforced concrete pavement; CTA = cement-treated aggregate; IRI = international roughness index; PCC = Portland cement concrete.

US 58 unbonded-5-11

File Name: C:\Users\Harikrishnan.Nair\Desktop\final runs\US 58 unbonded-5-11.dgpx

Design Inputs

Design Life:	30 years	Existing construction:	May, 1988	Climate Data Sources (Lat/Lon)	37.132, -76.493
Design Type:	JPCP over CRCP (unbonded)	Pavement construction:	July, 2012		
		Traffic opening:	September, 2012		

Design Structure

Layer type	Material Type	Thickness (in)
PCC	VDOT JPCP input	7.0
Flexible	VDOT Asphalt OGDL	1.0
Stabilized	Existing CRCP	8.0
Cement_Base	VDOT CTA	6.0
Subgrade	VA A-7-5	10.0
Subgrade	VA A-7-5	Semi-infinite

Joint Design:	
Joint spacing (ft)	6.0
Dowel diameter (in)	-
Slab width (ft)	12.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2012 (initial)	3,300
2027 (15 years)	8,955,810
2042 (30 years)	17,925,100

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	140.00	1362.57	95.00	0.00	Fail
Mean joint faulting (in)	0.12	0.93	95.00	0.00	Fail
JPCP transverse cracking (percent slabs)	15.00	2.46	95.00	100.00	Pass

Distress Charts

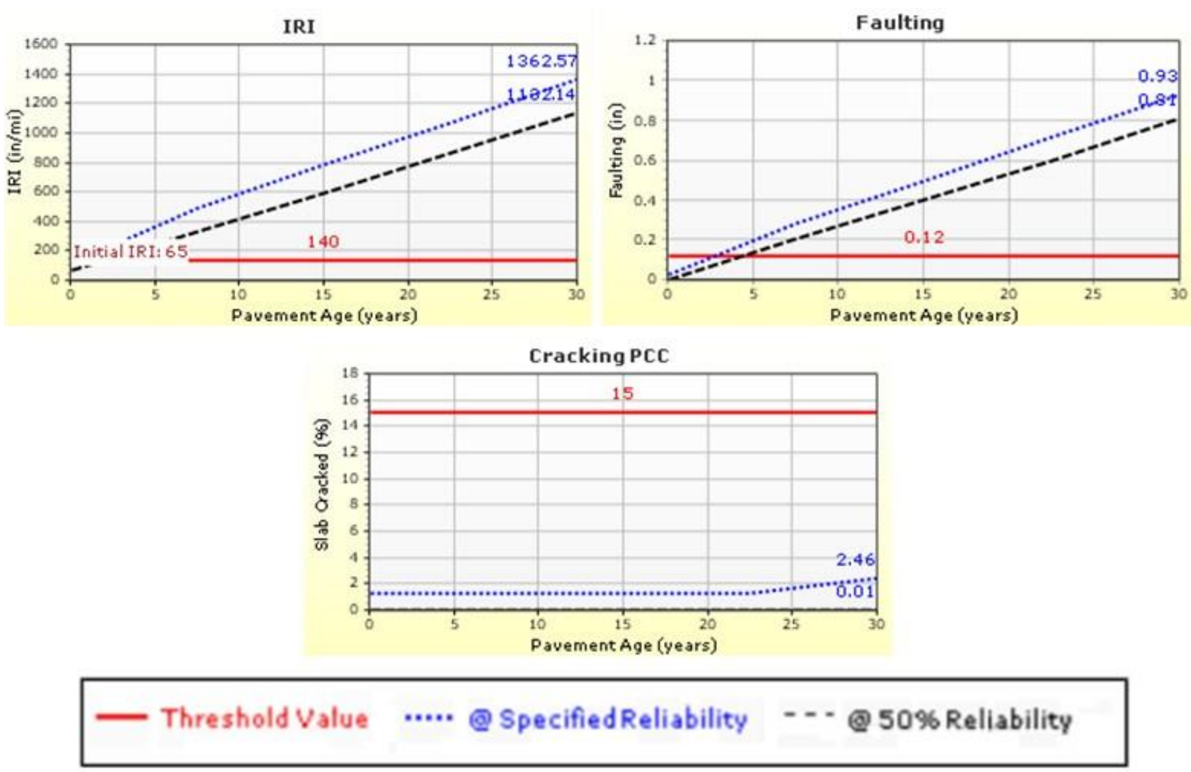

Figure B2. Unbonded Concrete Overlay (No Dowel). CRCP = continuously reinforced concrete pavement; CTA = cement-treated aggregate; IRI = international roughness index; JPCP = jointed plain concrete pavement; OGDL = open-graded drainage layer; PCC = Portland cement concrete.

US 58 unbonded-5-11dowel

File Name: C:\Users\Harikrishnan.Nair\Desktop\final runs\US 58 unbonded-5-11dowel.dgpx

Design Inputs

Design Life:	30 years	Existing construction:	May, 1988	Climate Data Sources (Lat/Lon)	37.132, -76.493
Design Type:	JPCP over CRCP (unbonded)	Pavement construction:	July, 2012		
		Traffic opening:	September, 2012		

Design Structure

Layer type	Material Type	Thickness (in)
PCC	VDOT JPCP input	7.0
Flexible	VDOT Asphalt OGDL	1.0
Stabilized	Existing CRCP	8.0
Cement_Base	VDOT CTA	6.0
Subgrade	VA A-7-5	10.0
Subgrade	VA A-7-5	Semi-infinite

Joint Design:	
Joint spacing (ft)	6.0
Dowel diameter (in)	1.50
Slab width (ft)	12.0

Traffic

Age (year)	Heavy Trucks (cumulative)
2012 (initial)	3,300
2027 (15 years)	8,955,810
2042 (30 years)	17,925,100

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	140.00	132.01	95.00	97.00	Pass
Mean joint faulting (in)	0.12	0.04	95.00	100.00	Pass
JPCP transverse cracking (percent slabs)	15.00	2.46	95.00	100.00	Pass

Distress Charts

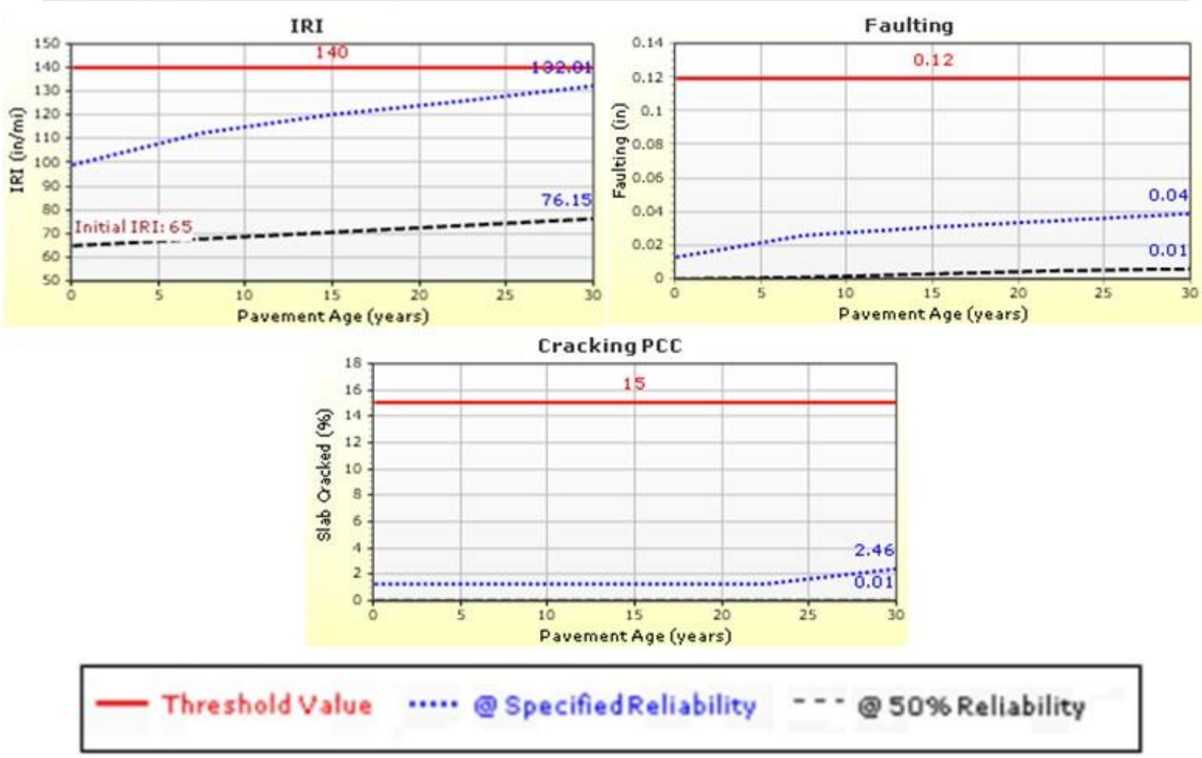

Figure B3. Unbonded Concrete Overlay (With Dowel). CRCP = continuously reinforced concrete pavement; CTA = cement-treated aggregate; IRI = international roughness index; JPCP = jointed plain concrete pavement; OGDL = open-graded drainage layer; PCC = Portland cement concrete.

US 58 asphalt overlay

File Name: C:\Users\Harikrishnan.Nair\Desktop\final runs\US 58 asphalt overlay.dgpx

Design Inputs

Design Life: 30 years
Design Type: AC over CRCP

Existing construction: May, 1988
Pavement construction: July, 2012
Traffic opening: September, 2012

Climate Data Sources (Lat/Lon): 37.132, -76.493

Design Structure

Layer type	Material Type	Thickness (in)
Flexible (OL)	VDOT SM	2.0
Flexible (OL)	VDOT IM	3.0
PCC	CRCP Default	8.0
Cement_Base	VDOT CTA	6.0
Subgrade	VA A-7-5	10.0
Subgrade	VA A-7-5	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	12.1
Air voids (%)	6.7

Traffic

Age (year)	Heavy Trucks (cumulative)
2012 (initial)	3,300
2027 (15 years)	8,955,810
2042 (30 years)	17,925,100

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (in/mile)	140.00	177.99	95.00	69.81	Fail
Permanent deformation - AC only (in)	0.26	0.28	95.00	90.26	Fail
AC bottom-up fatigue cracking (% lane area)	6.00	1.86	95.00	100.00	Pass
AC total transverse cracking: thermal + reflective (ft/mile)	2500.00	573.64	95.00	100.00	Pass
AC thermal cracking (ft/mile)	1000.00	1.00	50.00	100.00	Pass
AC top-down fatigue cracking (ft/mile)	2000.00	347.84	95.00	100.00	Pass
CRCP punchouts (1/mile)	6.00	0.00	95.00	100.00	Pass
Chemically stabilized layer - fatigue fracture (% lane area)	25.00	0.26	-	-	-

Distress Charts

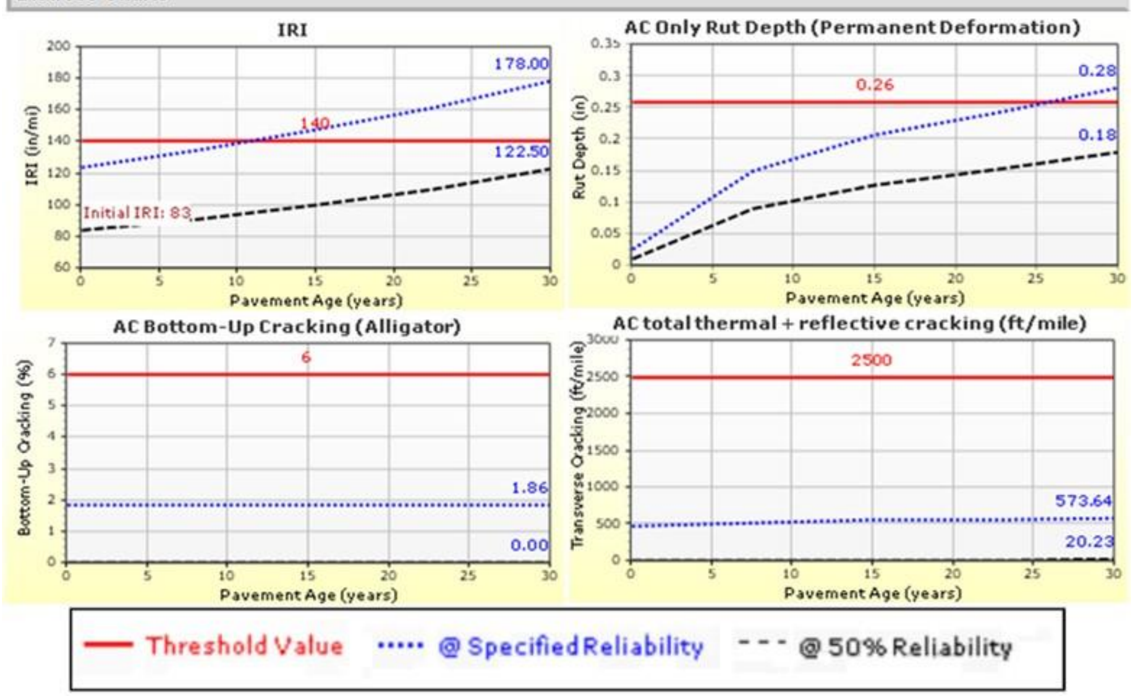

Figure B4. Asphalt Overlay. AC = asphalt concrete; CRCP = continuously reinforced concrete pavement; CTA = cement-treated aggregate; IM = intermediate mix; IRI = international roughness index; OL = overlay; PCC = Portland cement concrete; SM = surface mix.

APPENDIX C: RESULTS OF MECHANISTIC-EMPIRICAL DESIGN PROCEDURE FOR UNBONDED OVERLAYS, UNIVERSITY OF PITTSBURGH

Figure C1. Unbonded Concrete Overlay (UNOL Design, https://software.pavements.pitt.edu/UNOL). ESALs = equivalent single-axle loads; PCC = Portland cement concrete.

APPENDIX D: FALLING WEIGHT DEFLECTOMETER RESULTS

Basin Tests

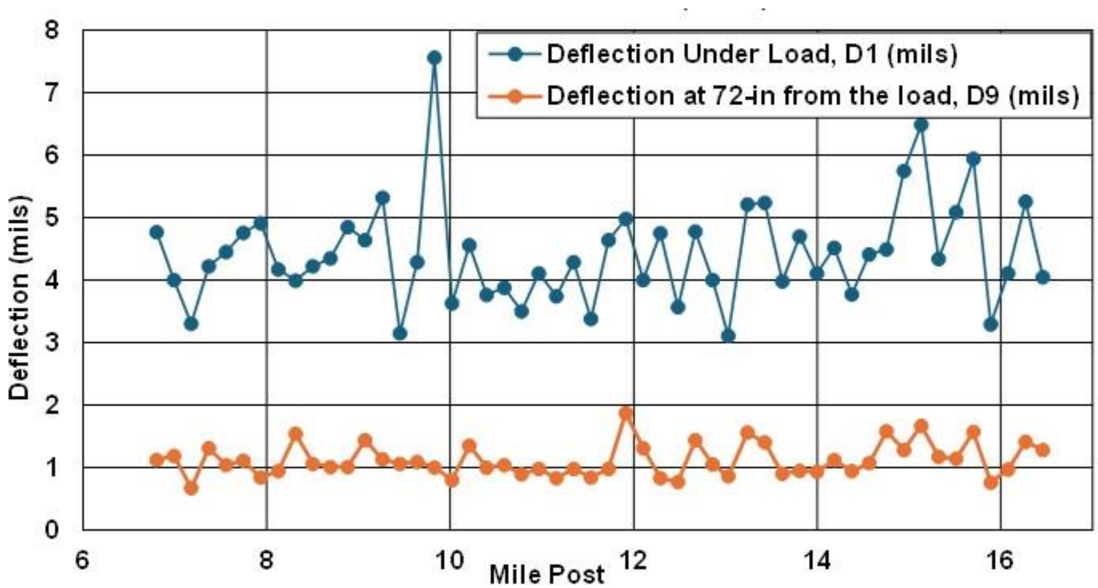

Figure D1. U.S. Route 58 Eastbound, Asphalt Overlay, Travel Lane—9,000 pounds Load (2024)

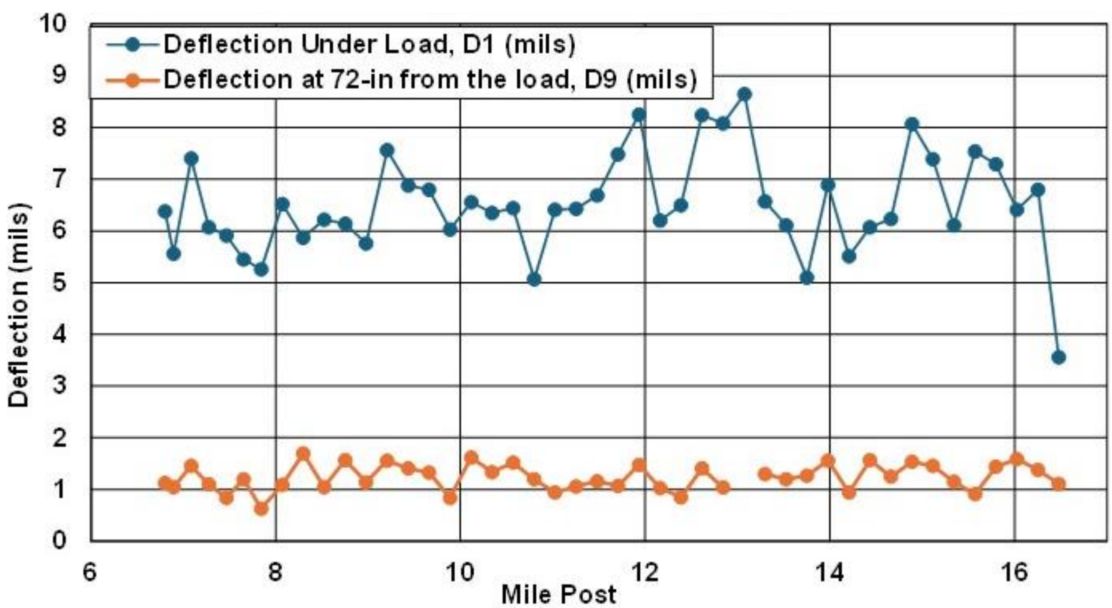

Figure D2. U.S. Route 58 Eastbound, Asphalt Overlay, Passing Lane—9,000 pounds Load (2024)

Figure D3. U.S. Route 58 Westbound, Unbonded Concrete Overlay, Travel Lane—9,000 pounds Load (2024)

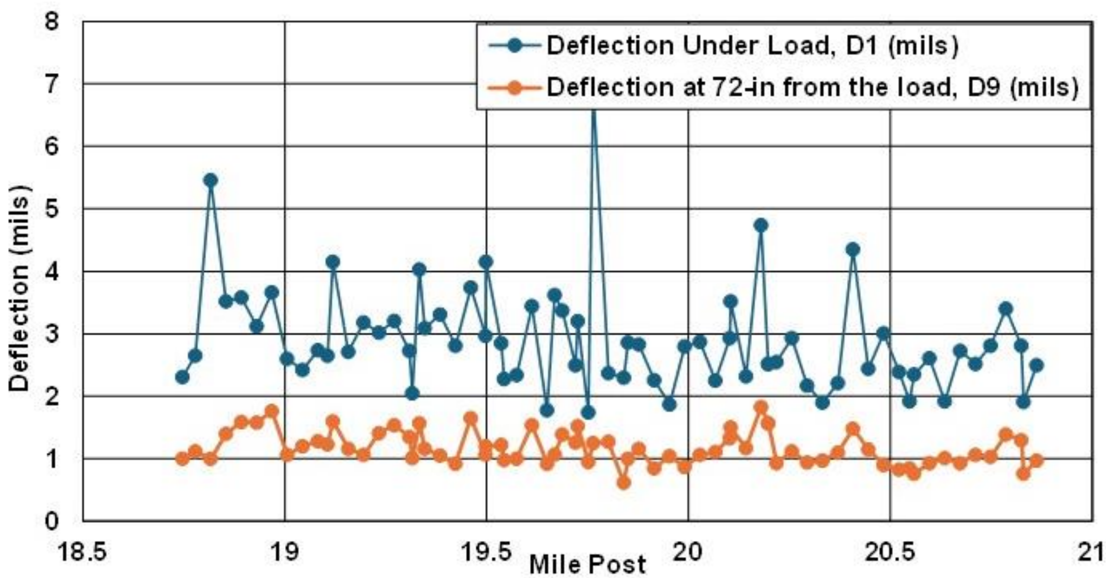

Figure D4. U.S. Route 58 Westbound, Bonded Concrete Overlay, Travel Lane—9,000 pounds Load (2024)

Load Transfer Efficiencies (Approach Side) Along Joints and Cracks

Table D1. U.S. Route 58 Westbound, Bonded Concrete Overlay (Milepost 18.3 to 20.9)—9,000-Pound Load

Milepost	Description	Deflection (mils) at 9-kip Load		LTE (%)[a]
		Under Load	Across Joint or Crack	
20.824	Patch	4.16	2.91	70.0
20.823	Crack	4.87	2.96	60.8
20.700	Crack	2.17	2.27	100.0
20.586	Crack	2.51	2.46	98.0
20.585	Crack	3.81	3.19	83.7
20.547	Patch	3.07	2.84	92.5
20.546	Patch	1.89	1.66	87.8
20.481	Crack	2.5	2.43	97.2
20.469	Crack	3.11	2.73	87.8
20.465	Crack	2.13	1.94	91.1
20.442	Crack	3.05	2.38	78.0
20.404	Crack	2.26	1.76	77.9
20.279	Construction Joint	2.37	1.88	79.3
20.209	Crack	2.44	2.38	97.5
20.197	Crack	4.78	3.77	78.9
20.195	Crack	3.1	3.58	100.0
20.118	Crack	3.02	1.97	65.2
20.1	Patch	2.81	2.7	96.1
20.1	Patch	3.26	3.05	93.6
19.857	Crack	2.88	2.24	77.8
19.848	Patch	2.89	2.76	95.5
19.848	Patch	2.82	2.31	81.9
19.749	Patch	2.46	2.06	83.7
19.749	Patch	2.48	2.17	87.5
19.665	Patch	3.21	2.33	72.6
19.665	Patch	2.95	2.78	94.2
19.665	Patch	4.09	3.86	94.4
19.665	Patch	2.93	2.48	84.6
19.54	Patch	3.02	2.76	91.4
19.54	Patch	2.46	2.21	89.8
19.494	Patch	3.57	3.49	97.8
19.494	Patch	3.07	2.81	91.5
19.324	Patch	3.61	3.49	96.7
19.324	Patch	3.87	3.14	81.1
19.315	Patch	3.16	2.47	78.2
19.314	Patch	2.48	2.31	93.1
4 Lows (less than 75%): Mileposts 20.824, 20.823, 20.118, and 19.665				
2 Highs (greater than 100%): Mileposts 20.7 and 20.195				

LTE = load transfer efficiency. [a] Most LTEs are greater than or equal to 75%.

Table D2. U.S. Route 58 Westbound, Bonded Concrete Overlay (Milepost 18.3 to 20.9)—16,000-Pound Load

Milepost	Description	Deflection (mils) at 16-kip Load		LTE (%)[a]
		Under Load	Across Joint or Crack	
20.824	Patch	7.54	5.47	72.5
20.823	Crack	8.62	5.35	62.1
20.700	Crack	4.2	4	95.2
20.586	Crack	4.61	4.25	92.2
20.585	Crack	6.15	5.24	85.2
20.547	Patch	5.16	4.78	92.6
20.546	Patch	3.13	2.85	91.1
20.481	Crack	4.54	4.24	93.4
20.469	Crack	5.28	4.64	87.9
20.465	Crack	3.62	3.31	91.4
20.442	Crack	5.28	4.03	76.3
20.404	Crack	3.92	3.13	79.8
20.279	Construction Joint	3.46	3.21	92.8
20.209	Crack	4.08	4.11	100.0
20.197	Crack	8.64	6.77	78.4
20.195	Crack	6.17	6.43	100.0
20.118	Crack	4.63	3.48	75.2
20.1	Patch	5.42	4.76	87.8
20.1	Patch	5.78	5.42	93.8
19.857	Crack	8.58	3.85	44.9
19.848	Patch	5.36	4.87	90.9
19.848	Patch	4.42	4	90.5
19.749	Patch	4.59	3.68	80.2
19.749	Patch	3.72	3.94	100.0
19.665	Patch	5.67	4.04	71.3
19.665	Patch	5.13	4.73	92.2
19.665	Patch	7.31	6.7	91.7
19.665	Patch	4.88	4.4	90.2
19.54	Patch	5.48	4.76	86.9
19.54	Patch	4.05	3.83	94.6
19.494	Patch	6.55	5.94	90.7
19.494	Patch	5.31	4.93	92.8
19.324	Patch	6.6	6.19	93.8
19.324	Patch	5.86	5.39	92.0
19.315	Patch	5.08	4.25	83.7
19.314	Patch	3.93	3.73	94.9
4 Lows (less than 75%): Mileposts 20.824, 20.823, 19.857, and 19.665				
3 Highs (greater than 100%): Milepost 20.209, 20.195, and 19.749				

LTE = load transfer efficiency. [a] Most LTEs are greater than or equal to 75%.

Table D3. U.S. Route 58 Westbound, Unbonded Concrete Overlay (Milepost 16.1 to 18.3)—9,000-Pound Load

Milepost	Description	Deflection (mils) at 9 kip Load		LTE (%)[a]
		Under Load	Across Joint or Crack	
18.301	Joint	3.14	3	95.5
18.253	Joint	3.98	3.73	93.7
18.159	Joint	6.79	3.54	52.1
18.064	Joint	2.7	2.46	91.1
17.970	Joint	3.3	3	90.9
17.876	Joint	2.95	2.83	95.9
17.780	Joint	3.15	2.81	89.2
17.686	Joint	2.22	1.7	76.6
17.591	Joint	3.24	2.52	77.8
17.543	Joint	3.76	2.91	77.4
17.496	Joint	3.81	3.11	81.6
17.402	Joint	2.78	2.33	83.8
17.308	Joint	3.4	2.75	80.9
17.212	Joint	2.85	2.13	74.7
17.118	Joint	2.35	1.6	68.1
17.023	Joint	3.23	2.94	91.0
16.929	Joint	2.27	1.69	74.4
16.833	Joint	2.66	2.31	86.8
16.738	Joint	1.93	2.35	100.0
16.643	Joint	2.12	1.8	84.9
16.548	Joint	2.72	2.31	84.9
16.454	Joint	4.75	2.67	56.2
16.360	Joint	3.77	3.22	85.4
16.264	Joint	3.86	3.35	86.8
4 Lows (less than 75%): Mileposts 18.159, 17.118, 16.929, and 16.454				
1 High (greater than 100%): Mielpost 16.738				

LTE = load transfer efficiency. [a] Most (80%) LTEs are greater than or equal to 75%.

Table D4. U.S. Route 58 Westbound, Unbonded Concrete Overlay (Milepost 16.1 to 18.3)—16,000-Pound Load

Milepost	Description	Deflection (mils) at 16-kip Load		LTE (%)[a]
		Under Load	Across Joint or Crack	
18.301	Joint	5.41	5.14	95.0
18.253	Joint	6.51	6.01	92.3
18.159	Joint	10.22	6.02	58.9
18.064	Joint	4.74	4.18	88.2
17.970	Joint	5.54	5.08	91.7
17.876	Joint	5.02	4.65	92.6
17.780	Joint	5.67	4.59	81.0
17.686	Joint	3.4	2.84	83.5
17.591	Joint	5.41	4.33	80.0
17.543	Joint	6.05	4.81	79.5
17.496	Joint	5.74	4.86	84.7
17.402	Joint	4.94	3.87	78.3
17.308	Joint	5.07	4.52	89.2
17.212	Joint	4.99	3.48	69.7
17.118	Joint	3.99	2.8	70.2
17.023	Joint	5.6	4.92	87.9
16.929	Joint	4	2.99	74.8
16.833	Joint	4.2	3.86	91.9
16.738	Joint	3.76	4.12	100.0
16.643	Joint	3.35	3.07	91.6
16.548	Joint	4.41	3.89	88.2
16.454	Joint	7.5	4.63	61.7
16.360	Joint	6.07	5.18	85.3
16.264	Joint	6.45	5.44	84.3
4 Lows (less than 75%): Milepost 18.159, 17.212, 17.118, and 16.454				
1 High (greater than 100%): Milepost 16.738				

LTE = load transfer efficiency. [a] Most (80%) LTEs are greater than or equal to 75%.

APPENDIX E: WEATHER DATA

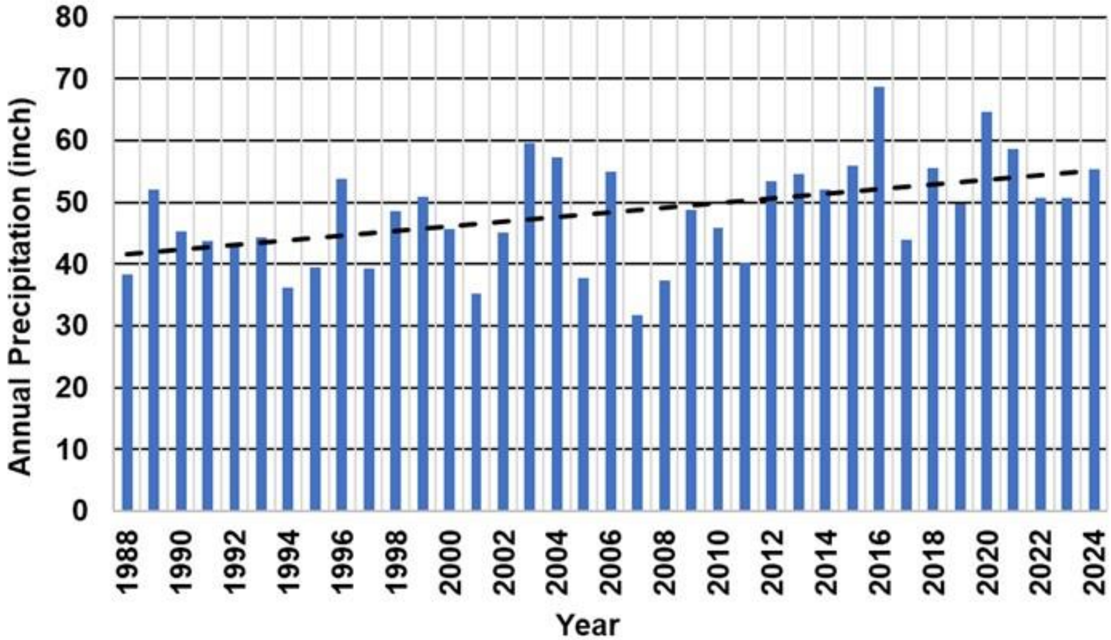

Figure E1. Weather Data from 1988 to 2024

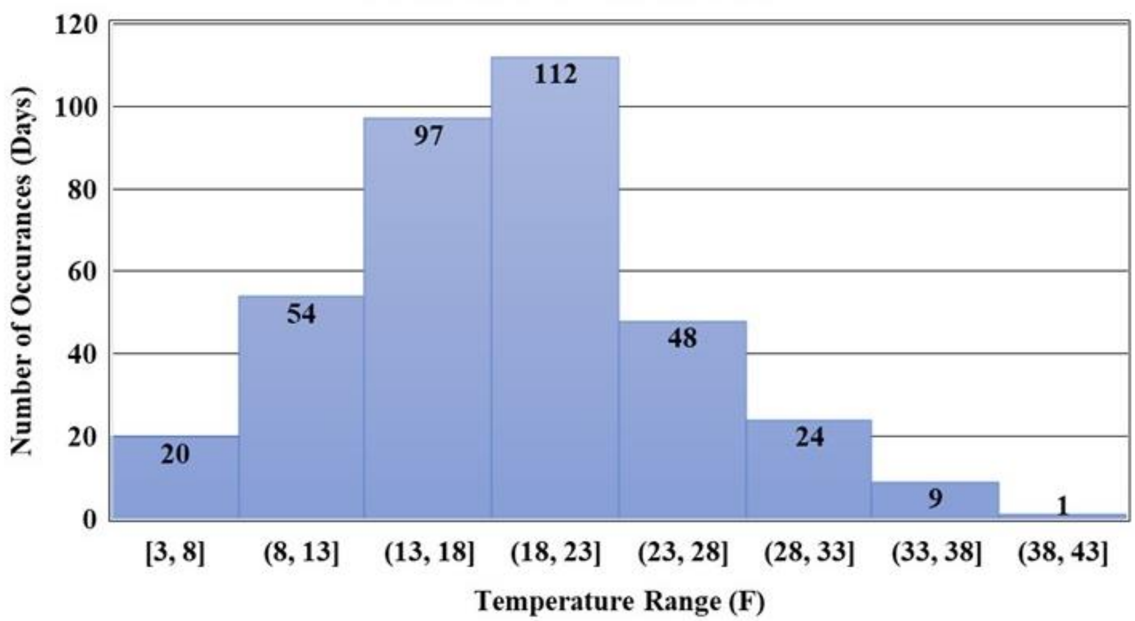

Figure E2. Frequency Plot: Delta T (2022)