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Use of Surface Treatments to Extend Pavement Life: A Case Study on US 301, Sussex County, Virginia

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Three years after the treatment application, a visual survey complemented by automated distress data from VDOT's Pavement Management System showed that the section with FiberMat and microsurfacing performed well with very little reflective cracking. The chip seal with microsurfacing (i.e., regular cape seal) also performed well, but reflective cracking was higher compared to the fiber-reinforced section. The control section (microsurfacing only) showed extensive cracking after 3 years. This study showed that pavement preservation activities such as the use of fiber-reinforced chip seal with microsurfacing and modified single seal with microsurfacing improved both the pavement condition and the surface characteristics in a very cost-effective manner. Based on this study, the unit cost of fiber-reinforced cape seal was \$5.95/yd^2 and that of conventional cape seal was \$3.99/yd^2. In comparison, the average cost of a 2-in mill and fill corrective maintenance treatment with a conventional asphalt plant mixture in VDOT's Hampton Roads District was \$10.35/yd^2.

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FINAL REPORT

USE OF SURFACE TREATMENTS TO EXTEND PAVEMENT LIFE: A CASE STUDY ON US 301, SUSSEX COUNTY, VIRGINIA

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ABSTRACT

Typical maintenance activities by the Virginia Department of Transportation (VDOT) for existing asphalt pavements involving a periodic placement of a 1.5-in to 2-in layer of asphalt concrete are becoming increasingly costly. When applied at the right time, pavement preservation treatments can restore a smooth, safe driving surface while saving money on future rehabilitation costs. The purpose of this study was to evaluate the performance of three preventive maintenance treatments applied to US 301 in Sussex County, Virginia, to extend pavement life. This report documents the installation of a cape seal application of FiberMat (i.e., FiberMat with microsurfacing on top) over an existing asphalt pavement. FiberMat is designed to act as a crack-resistant membrane and incorporates two applications of polymer-modified asphalt emulsion with a layer of fiberglass strands between them. The study also included a performance comparison with more conventional VDOT surface treatment options: regular cape seal (chip seal with microsurfacing), and microsurfacing without a chip seal.

Three years after the treatment application, a visual survey complemented by automated distress data from VDOT's Pavement Management System showed that the section with FiberMat and microsurfacing performed well with very little reflective cracking. The chip seal with microsurfacing (i.e., regular cape seal) also performed well, but reflective cracking was higher compared to the fiber-reinforced section. The control section (microsurfacing only) showed extensive cracking after 3 years. This study showed that pavement preservation activities such as the use of fiber-reinforced chip seal with microsurfacing and modified single seal with microsurfacing improved both the pavement condition and the surface characteristics in a very cost-effective manner. Based on this study, the unit cost of fiber-reinforced cape seal was \$5.95/yd^2 and that of conventional cape seal was \$3.99/yd^2. In comparison, the average cost of a 2-in mill and fill corrective maintenance treatment with a conventional asphalt plant mixture in VDOT's Hampton Roads District was \$10.35/yd^2.

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INTRODUCTION

The Virginia Department of Transportation (VDOT) maintains and operates the third largest network of state-maintained highways in the United States. Of the 128,770 lane-mile state-maintained system, 5,540 lane-miles are interstate, 21,997 are primary, 100,577 are secondary (local connector or county roads), and 656 are frontage roads. Overall, interstate and primary road pavement conditions have improved in recent years. However, with limited budgets, it remains a challenge to maintain good conditions on secondary roads. Moreover, traditional maintenance resurfacing activities involving a periodic placement of a 1.5-in to 2-in layer of asphalt concrete are becoming increasingly costly. Regular maintenance involving surface treatments can improve and extend the life span, but any trade-offs between cost and performance are unknown.

When applied at the right time, pavement preservation treatments can maintain a smooth, safe driving surface while saving money on future rehabilitation costs and are critical to a cost-effective pavement infrastructure. Preservation treatments typically used in Virginia include crack sealing, chip seals (modified single seal or modified double seal), slurry seals, microsurfacing (latex-modified slurry seals), cape seals (application of a chip seal surface covered by a slurry seal or microsurfacing), thin-lift hot mix asphalt overlays (sometimes combined with milling of the existing surface), and ultrathin bonded wearing courses (aka, Novachip). Crack sealing is the lowest cost preservation treatment and is most effective when applied as soon as cracks develop. Chip seals are mainly used for rural secondary routes, where they often serve as the permanent wearing surface. Slurry seals are a blend of crushed aggregate (No. 10 stone) and asphalt emulsion and are suitable for lower volume roads in fair condition with good cross section. Microsurfacing, which can be used to fill minor ruts, is appropriate for higher volume facilities. Cape seals are usually placed on pavements with more distresses than typical slurry seal pavement candidates. Thin lifts of dense-graded asphalt (0.5 in to 1 in thick) using SM 4.75 or SM 9.0 mixtures are good for low-speed routes (e.g., subdivisions) where a very refined surface is desired. An ultrathin bonded wearing course, a gap-graded plant-produced mixture with good texture, is a better option for higher speed, higher volume routes.

Combination treatments (e.g., cape seal) have performed well in a series of test sections near the National Center for Asphalt Technology test track (Jalali et al., 2019). Further study by the National Center for Asphalt Technology has shown that cape seals are demonstrating excellent performance after 6 years in service with minimum damage. Despite the good anecdotal local experience and more formally reported experience from elsewhere, Virginia lacks documented experience with combination preservation treatments.

One method for modifying what is often the first component of these combination treatment is a product known commercially as FiberMat. FiberMat is a highly modified chip seal that is designed to act as a crack-resistant membrane. It incorporates two applications of polymer-modified asphalt emulsion with a layer of fiberglass strands between them. A layer of aggregate is then spread and rolled into the fiberglass-reinforced emulsion. As with a normal cape seal, the fiber-modified chip seal can be covered with either the conventional slurry or microsurfacing within a couple of weeks to provide a refined wearing surface suitable for higher volumes and speeds.

PURPOSE AND SCOPE

The purpose of this study was to assess the performance of pavement preservation treatments through a highly controlled field trial on US 301 in Sussex County, Virginia. This report documents the installation of a microsurfacing application, a cape seal with a conventional modified single chip seal base, and a cape seal that incorporates a fiber-reinforced (i.e., FiberMat) chip seal base.

Three sections were included in the study:

Section 1: fiber-reinforced cape seal (chip seal [FiberMat]) with microsurfacing, ~3.6 mi, Milepost (MP) 9.94 to 12.12 and MP 12.72 to 14.39

Section 2: cape seal with a conventional modified single chip seal base (modified single chip seal [CRS-2 emulsion and No. 8NP stone]) with microsurfacing, 0.3 mi, MP 12.42 to 12.72

Section 3: microsurfacing (VDOT latex, Type C), 0.3 mi, MP 12.12 to 12.42.

The evaluation included documentation of field installation followed by periodic field evaluations to support a performance and cost comparison.

METHODS

Evaluation of Existing Pavement

Distress data for the existing pavement (i.e., prior to the application of the surface treatments) were collected from VDOT's Pavement Management System (PMS). The asphalt pavement distresses that are collected for VDOT's PMS include transverse cracking, longitudinal cracking, reflective transverse cracking, reflective longitudinal cracking, alligator cracking, longitudinal joint cracking, patching, potholes, delamination, bleeding, and rutting. VDOT uses three condition indices to rate pavement distresses. The first is the Load Related Distress Rating (LDR), which measures pavement distresses caused by traffic loading. The second is the Non-Load Related Distress Rating (NDR), which measures pavement distresses that are not load related, such as those caused by environmental or climatic conditions. These two condition indices are rated on a scale of 0 to 100, where 100 signifies a pavement having no distresses. The third is the Critical Condition Index (CCI), which is the lower of the LDR and the NDR. In addition to storing the individual distress data, VDOT's PMS calculates and stores the LDR, the NDR, the CCI, and the International Roughness Index (IRI) for all sections.

In addition to an on-site visual evaluation of existing conditions, falling weight deflectometer (FWD) testing was conducted in accordance with ASTM D4694-09, Standard Test Method for Deflections With a Falling-Weight-Type Impulse Load Device, to assess structural capacity (ASTM International [ASTM], 2013). Deflection testing was conducted at four load levels (6,000; 9,000; 12,000; and 16,000 lbf) using a 300-ft spacing. Following two unrecorded seating drops, four deflection basins were recorded at each load level.

Installation of Treatments

Fiber-Reinforced Chip Seal (FiberMat)

Figure 1 shows the equipment used to apply the FiberMat. It consists of a truck with an emulsion tank and a fiber storage unit. The equipment uses two spray bars with nozzles to spray the emulsion. It also has cutting units between the spray bars, which cut and distribute the glass fibers on the initial emulsion layer (FiberMat, n.d.). The second layer of emulsion encapsulates the fibers into a single membrane layer. Figure 2 illustrates the process of spraying polymer-modified asphalt emulsion and glass fibers on the existing pavement using rows of spray nozzles. Figure 3 depicts the fibers used for the process. The asphalt emulsion used provides the waterproofing membrane, and the glass fiber strands increase its ability to withstand stresses and enhance the tensile properties. Fibers are applied at a nominal rate of 2 to 3 oz/yd^2, depending on the severity of the cracking. The asphalt emulsion is applied in two simultaneous applications that total 0.4 to 0.6 gal/yd^2 (Midland Asphalt Materials Inc., n.d.).

The final step in the process includes the application of an aggregate layer. Figures 4 through 6 show the intermediate application of emulsion with fibers, final surface aggregate spreading, and static compaction using steel rollers, respectively. A typical aggregate application rate of 17 to 25 lb/yd^2 was used (FiberMat, n.d.).

Figure 1. FiberMat Placing Equipment


Figure 2. Placement of Fibers and Emulsion

Figure 3. Placement Showing Fibers at Beginning of Section

Figure 4. Emulsion With Fibers in Between

Figure 5. Aggregate Spreading

Figure 6. Compaction Using Steel Rollers

Modified Chip Seal Placement

The modified chip seal placement (Section 2) included an application of asphalt emulsion (0.17 gal/yd^2), a layer of stone (No. 8P at 15 lb/yd^2), and an additional layer of asphalt emulsion (0.15 gal/yd^2). The placement was finished with the application of a layer of sand (10 lb/yd^2) on top.

Microsurfacing Placement

Two weeks after the FiberMat and modified chip seal placement, microsurfacing was applied over the entire pavement test section, providing a consistent final wearing surface for all three subsections. As mentioned earlier, the 0.3-mi section (Section 3, MP 12.12 to 12.42) received only a microsurfacing treatment with no underlying chip seal. Figures 7 and 8 show the microsurfacing placement.

Post-Treatment Core Testing

After the final wearing surface was installed, cores were taken for further evaluation and for determination of the relative permeability of the completed treatments. Permeability testing was performed in accordance with Virginia Test Method 120, Method of Test for Measurement of Permeability of Bituminous Paving Mixtures Using a Flexible Wall Permeameter (VDOT, 2014).

Figure 7. Microsurfacing Placement

Figure 8. Microsurfacing Before Opening to Traffic

Performance Evaluation

Performance evaluation of the installed treatments was conducted through periodic site visits and the use of distress data from VDOT's PMS. The following non-destructive testing was also conducted.

Skid Testing

Skid numbers (SNs) were collected in general accordance with ASTM E274, Test Method for Skid Resistance of Paved Surfaces Using a Full-Scale Tire, using a consultant's skid unit. Measurements were obtained using a smooth tire test (ASTM E524). The factors that primarily influence pavement friction forces are pavement surface characteristics, vehicle operational parameters, tire properties, and environmental factors. Pavement friction is reported as an SN or a friction number. The reporting values range from 0 to 100, with 0 representing no friction and 100 representing full friction.

Ride Quality Testing

Pavement ride quality data were collected using a VDOT pavement profiler (South Dakota type) in accordance with Virginia Test Method 106, Determining Pavement Roughness and Rut Depth Using an Accelerometer Established Inertial Profile Referencing System.

Mean Profile Depth

The mean profile depth (MPD) is a measure of macrotexture that can be calculated from a pavement profile in accordance with ASTM E1845 (Flintsch et al., 2003). The MPD is defined as the difference in height between the profile and a horizontal line through the top of the highest peak. The MPD typically ranges from 400 to 2,500 microns (0.4 to 2.5 mm) for asphalt pavement surfaces. High values for the MPD generally indicate a higher percentage of aggregate with positive texture (Rada et al., 2013). Pavement surface texture influences many different pavement tire interactions. Good skid resistance results from controlling the microtexture and macrotexture of a pavement surface.

FWD Testing

FWD testing to assess structural capacity was performed in accordance with ASTM D4694-09. Deflection testing was conducted at four load levels (6,000; 9,000; 12,000; and 16,000 lbf) using variable spacing (300 ft in general with occasional 500 ft). Following two unrecorded seating drops, four deflection basins were recorded at each load level.

Ground Penetrating Radar (GPR) Testing

GPR testing was conducted with a 2 GHz horn antenna and an SIR-30 computer manufactured by GSSI. The vehicle was equipped with an electronic distance measuring instrument mounted to the rear wheel, providing synchronous distance data as the GPR data were collected, and a GPS unit, providing high-resolution, differentially corrected geospatial information. The data collection and recording were controlled by the SIR-30 GPR system operated from within the survey vehicle. The data were collected at a rate of 1 scan per foot of travel. GPR data were processed with RADAN 7 software.

RESULTS AND DISCUSSION

Pre-Treatment Pavement Evaluation

Visual Evaluation

A visual distress evaluation was conducted before treatments. Figures 9 through 11 show the existing pavement surface with different levels of cracking. The majority of the cracks were transverse cracks, longitudinal cracks (both on the wheel path and outside the wheel path), and some localized alligator cracks.


Figure 9. Section With Large Amount of Cracking


Figure 10. Section With Moderate Amount of Cracking

Figure 11. Section With Lower Amount of Cracking

Automated Condition Assessment (VDOT's PMS)

Figure 12 shows CCI and IRI values for the entire section before treatments. In general, IRI values were less than 75 in/mi, indicating relatively smooth pavement. CCI values varied considerably along the entire section. Some sections had values less than 50 (ranging from 20 to 50), and other sections had values in the range of 60 to 80. The majority of the distress identified included alligator cracking and transverse cracking. The average rut depth before treatment was 0.09 in.

In general, for secondary routes, CCI values of 45 to 65 tend to trigger a recommendation of corrective maintenance (1.5-in to 2-in mill and fill); CCI values less than 45 would call for restorative maintenance. Sections with CCI values of 65 to 85 can be considered for preventive maintenance (Izeppi et al., 2015). Sections recommended for microsurfacing and regular cape seal (modified chip seal with microsurfacing) applications usually have CCI values higher than 60.

For the majority of sections, the last rehabilitation was done in year 2003 using an SM 9.5 D mixture (1.5 in thick).

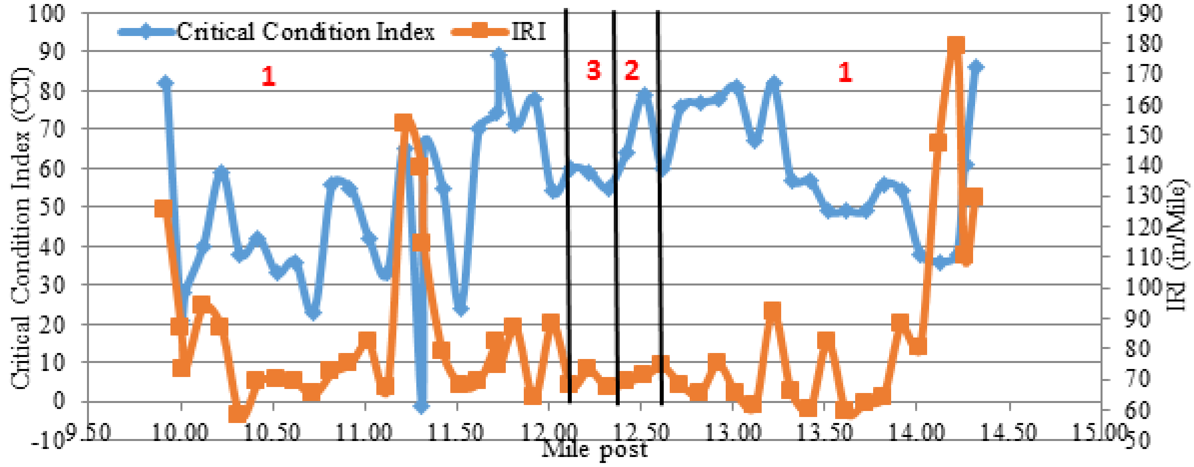

Figure 12. Distress Data Before Treatments. Section 1 = fiber-reinforced cape seal; Section 2 = conventional cape seal; Section 3 - microsurfacing.

FWD Testing (Before Treatments)

FWD deflection data for the first sensor (D0) and the last sensor (D72) for different load levels are shown in Figures 13 and 14. D0 denotes the deflection at the loading plate, and D72 denotes the deflection at a distance of 72 in from the loading plate. The D0 parameter is an indicator of the overall structural capacity of the pavement system, whereas the D72 parameter is an indicator of the quality of the pavement foundation (subgrade).

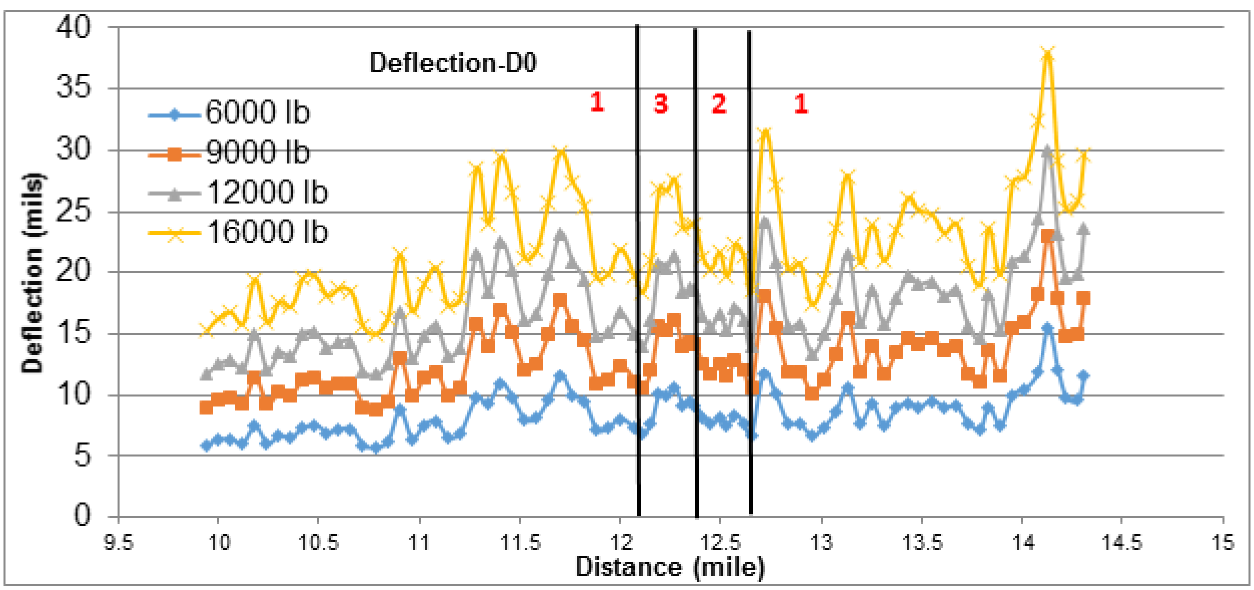

Figure 13. Deflection Results From FWD Testing. FWD = falling weight deflectometer; D0 = deflection at loading plate; Section 1 = fiber-reinforced cape seal; Section 2 = conventional cape seal; Section 3 = microsurfacing.

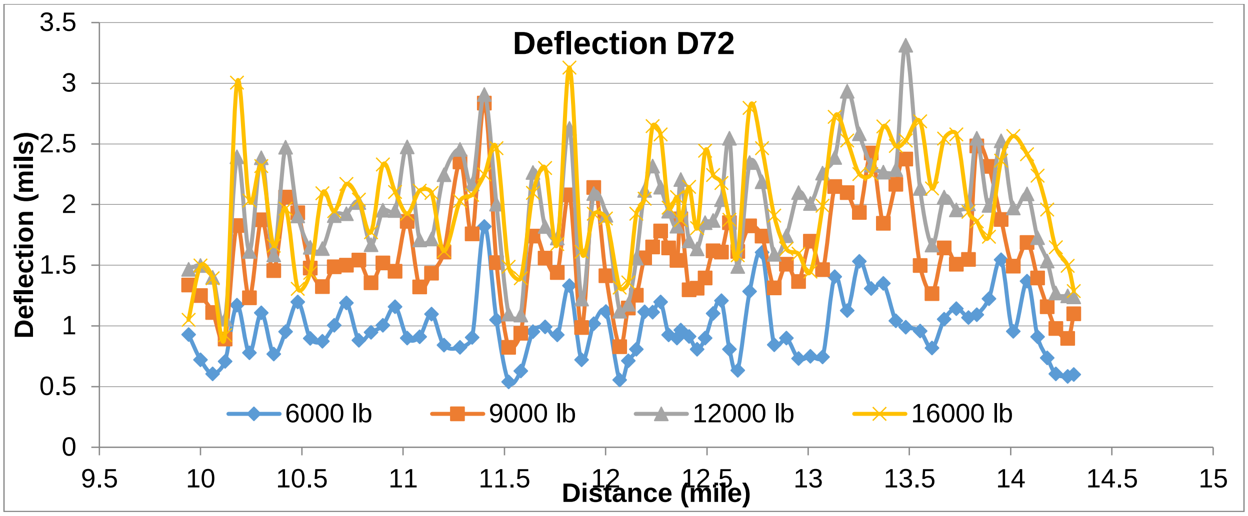

Figure 14. Deflection Results From FWD Testing. FWD = falling weight deflectometer; D72 = deflection at 72 in from loading plate.

The results in Figure 13 also show the deflection of D0 to be uniform from Station 0 to approximately Station 1.2, with an average of approximately 10 mils (using a 9,000-lb load level), and a bit higher from approximately Station 1.2 to Station 4.4, with an average of approximately 13 mils. Earlier studies showed that these deflection values indicate a strong structural pavement (Diefenderfer et al., 2019; Pierce et al., 2017). Station 4.2 showed high deflection compared to others (23 mils), showing a weaker pavement structure compared to the rest of the pavement. The results in Figure 14 show the pavement foundation to be stiff and uniform with a deflection of approximately 2.2 mils when 9,000-lb loading was used.

Post-Treatment Evaluation

Pavement Core Evaluation and Permeability Testing

Figures 15 through 17 show cores obtained from fiber-reinforced cape seal, regular cape seal, and microsurfacing sections, respectively. From Figure 15, a clear interface is seen between the existing top asphalt surface and the FiberMat because of thicker emulsion with fibers. Figure 18 shows a surface picture of microsurfacing treatment after curing. Four full-depth cores were collected from the north end of the section, and Figure 19 shows a full-depth asphalt core. Full-depth cores had an average asphalt thickness of 7 in. All full-depth cores were intact (no delamination).

Figure 15. Core Showing FiberMat + Microsurfacing Surface Above Existing Asphalt Top Surface

Figure 16. Core Showing Chip Seal + Microsurfacing Above Existing Asphalt Top Surface

Figure 17. Core Showing Microsurfacing Above Existing Asphalt Top Surface

Figure 18. Final Pavement Surface With Microsurfacing

Figure 19. Full-depth Core

Permeability testing was conducted on all cores. All sections had very low permeability values; the average values for each section are shown in Table 1.

Table 1. Average Permeability From Cores

Section No.	Treatment	Average Permeability, cm/sec
1	Microsurfacing alone	4×10^{-5}
2	Regular cape seal	2.5×10^{-5}
3	Fiber-reinforced cape seal	1×10^{-5}

Performance Evaluation

General Visual Assessment

Several visual evaluations were conducted over the first 3 years in service. The annual average daily traffic for US 301, Sussex County, was 612 in the southbound direction and 715 in the northbound direction. Overall, the fiber-reinforced cape seal section (Section 1) is performing well with very little reflective cracking (mostly transverse cracks). Figure 20 shows the fiber-reinforced cape seal surface after 3 years. Figure 21 shows a close-up view of the surface texture of the fiber-reinforced section.

Figure 20. FiberMat With Microsurfacing After 3 Years

Figure 21. Surface Texture of FiberMat With Microsurfacing After 3 Years

The regular cape seal section (Section 2) was also performing well, but reflective cracking was higher compared to the fiber-reinforced cape seal section (Section 1). Figure 22 shows the modified single seal with microsurfacing after 3 years.

The section with microsurfacing alone showed the largest amount of reflective cracking. Delamination of the microsurfacing was also found in several places. Figure 23 shows the microsurfacing section (Section 3) with considerable cracking.

Figure 22. Modified Single Seal With Microsurfacing After 3 Years

Figure 23. Microsurfacing Section After 3 Years

Localized Failure

Four months after the treatments, a segment near the end of the northbound FiberMat cape seal section (200 ft long, approximately at MP 14.2) began to exhibit early cracking. FWD testing showed higher deflections in this segment, and a forensic investigation revealed moisture damage and delamination in the underlying asphalt layer, as shown in Figure 24. If subsurface drainage of the pavement is inadequate, moisture and/or moisture vapor can move upward because of capillary action and saturate the asphalt courses. An impermeable layer on top (such as a microsurfacing treatment) can accelerate the existing moisture damage. The damaged section was removed and patched with new asphalt concrete.

Figure 24. Core Showing Moisture Damage and Delamination

VDOT's PMS Distress Evaluation

Distress data were collected from VDOT's PMS for 3 years; CCI values are plotted in Figure 25 (2016 data reflect condition state before treatment). It can be seen that, overall, the fiber-reinforced cape seal was performing well, with CCI values above 85 (based on 2019 data). It can also be seen that the CCI for the section with microsurfacing alone had dropped below 80 based on 2019 data. Average rut depth for all sections in 2019 was 0.15 in, and most of the cracks were transverse reflective cracking.

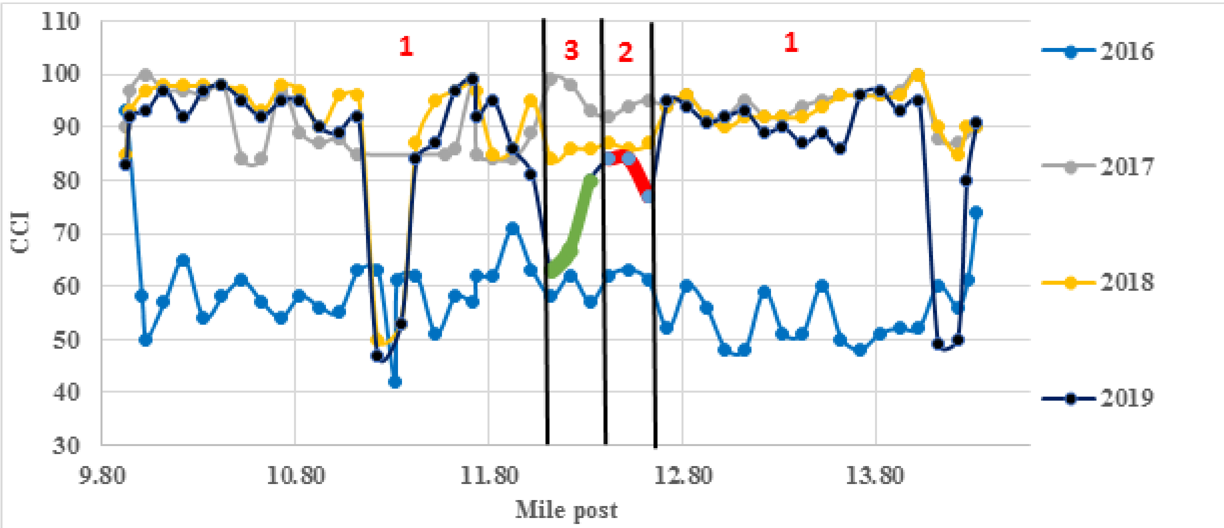

Figure 25. VDOT's PMS Distress Data. Green color in 2019 data indicates microsurfacing-only section, and red color indicates regular cape seal section. Section 1 = fiber-reinforced cape seal; Section 2 = conventional cape seal; Section 3 = microsurfacing.

Table 2 shows detailed normalized distress data. From Table 2 it can be seen that the FiberMat cape seal section had a lower percentage of cracking compared to the other two sections. Transverse reflective cracking and longitudinal cracking were also lower for the FiberMat cape seal section.

Table 2. Distress Data From VDOT's PMS

Treatment	Length (mi)	CCI Before Treatments	CCI (Avg.) After 3 Yr	Rut Depth (Avg.), in	Normalized Total Transverse Cracking (Severity 1), ft	Normalized Total Transverse Cracking (Severity 2), ft	Normalized Longitudinal Cracking (Severity 1), ft	Normalized Total Alligator Cracking (Severity 1), % Cracking
FiberMat cape seal	3.87	57	88	0.14	771	7.5	40	0.66%
Regular cape seal	0.3	62	82	0.18	2640	0	286	3.36%
Microsurfacing alone	0.3	60	70	0.15	6700	40	1393	7.31%

PMS = Pavement Management System; CCI = Critical Condition Index.

GPR Testing

The primary objective of the GPR testing was to measure the thickness of the pavement layers. The layer thickness was summarized by using the average of the data taken at 0.01-mi (52.8-ft) intervals. The data represented by each point is 0.005 mi on either side of the testing point. Multiple layers were observed in the RADAN 7 images. The layer interface at the bottom of the scan image was marked. An example of the processed image with multiple layers was shown in Figure 26.

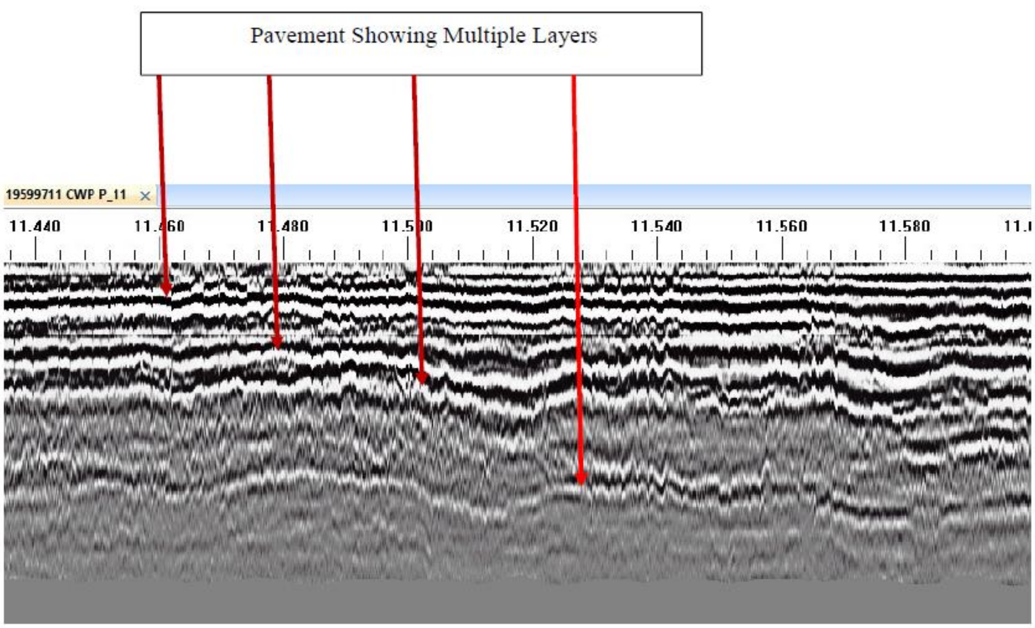

Figure 26. Sample of GPR Images With Different Layers in Processed RADAN 7 Images. GPR = ground penetrating radar.

Multiple layers were observed in processed RADAN 7 images, and only two layers were marked for this analysis. Layer 1 was assumed to be the bottom of the asphalt concrete, and Layer 2 was assumed to be the bottom of the base (aggregate layer based on construction history). The pavement thickness graphs for 0.01-mi sections were plotted in Figures 27 and 28 for the northbound and southbound sections. On average, the asphalt thickness was 12 in, with an aggregate layer 6 to 7 in thick. As mentioned earlier, limited full-depth cores showed an average asphalt thickness of 7 in; hence, further coring is needed to confirm the thickness.

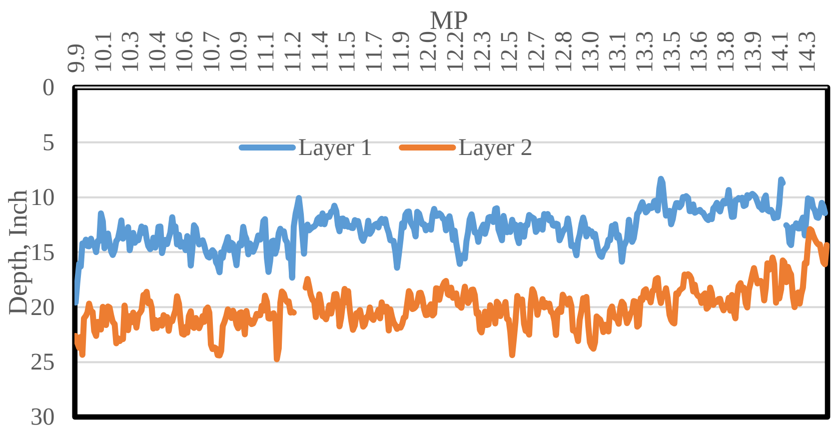

Figure 27. US 301 Northbound Center Line Pavement Thickness Plot

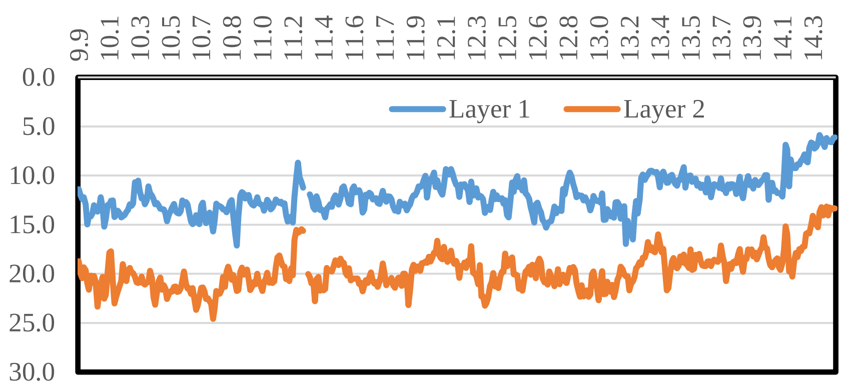

Figure 28. US 301 Southbound Center Line Pavement Thickness Plot

FWD Testing

FWD testing was conducted 3 years after treatments. Figure 29 shows D0 deflections before treatment and 3 years after treatment for the sections using the 9,000-lb load. In general, the deflection values were less than 15 mils. When compared to D0 values before treatment, changes in deflection values were not large, indicating the structurally strong section remains in a similar condition as previously tested.

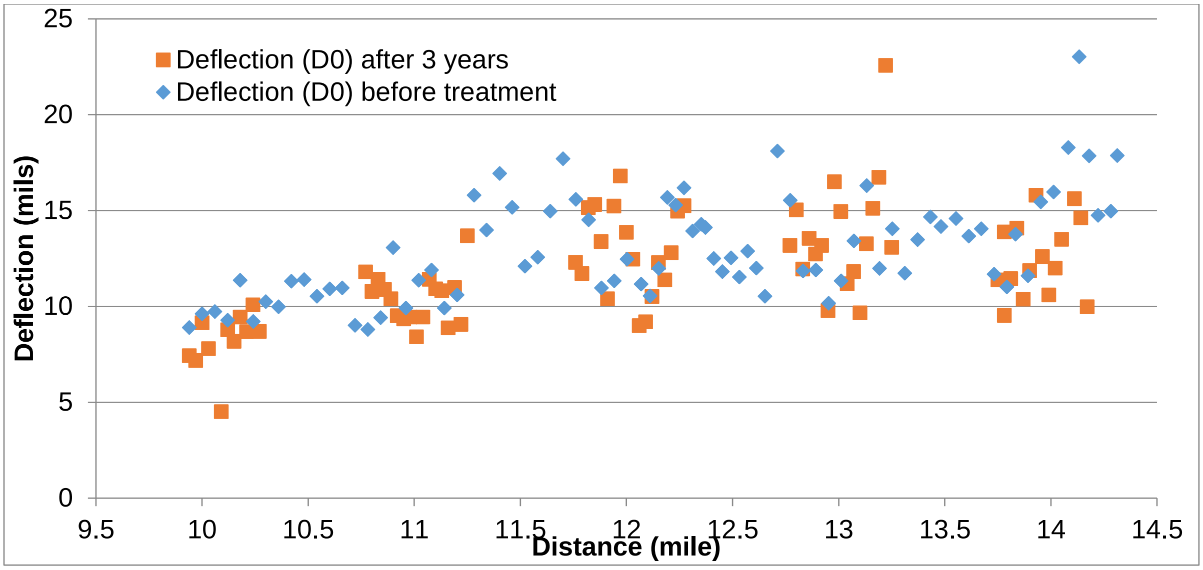

Figure 29. FWD D0 Deflection Data (9,000-lb Load) Before Treatment and 3 Years After Treatment. FWD = falling weight deflectometer.

Skid Testing

Skid testing results after 3 years are shown in Figure 30. In general, values ranged from 40 to 55. In Virginia, when SNs are less than or equal to 20, measures are usually taken to improve friction. The values were higher than 20, indicating good friction.

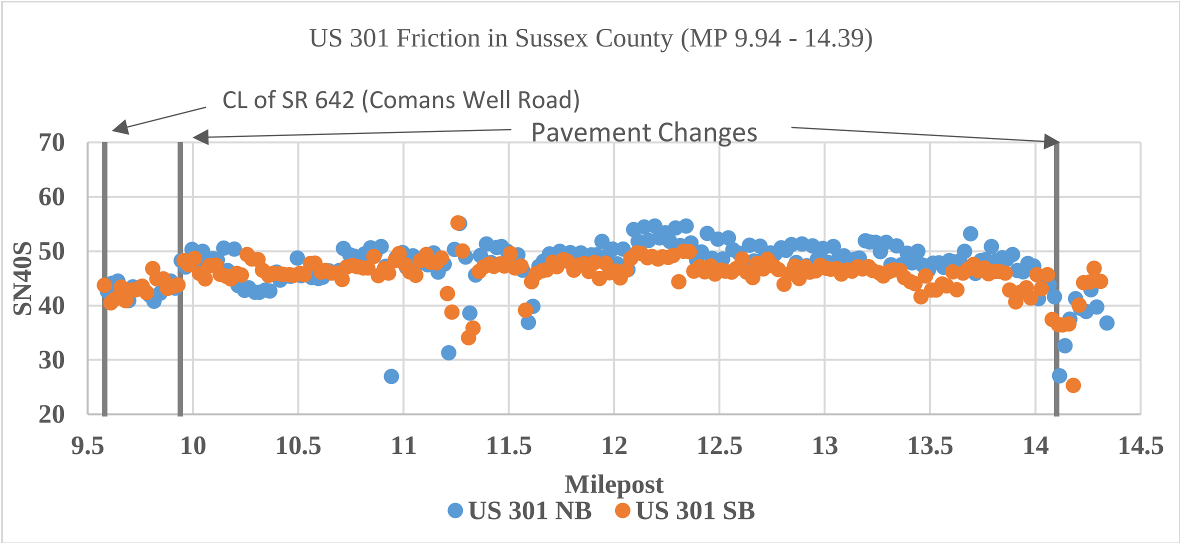

Figure 30. Skid Testing Results. SN = skid number; CL = closing line; NB = northbound; SB = southbound.

MPD Testing

MPD values relate to macrotexture; testing results after 3 years are shown in Figure 31. In general, average MPD values of 1 mm were observed, which is comparable to typical values for asphalt pavement surfaces. The higher SNs obtained were consistent with the adequate macrotexture, as indicated by these MPD values.

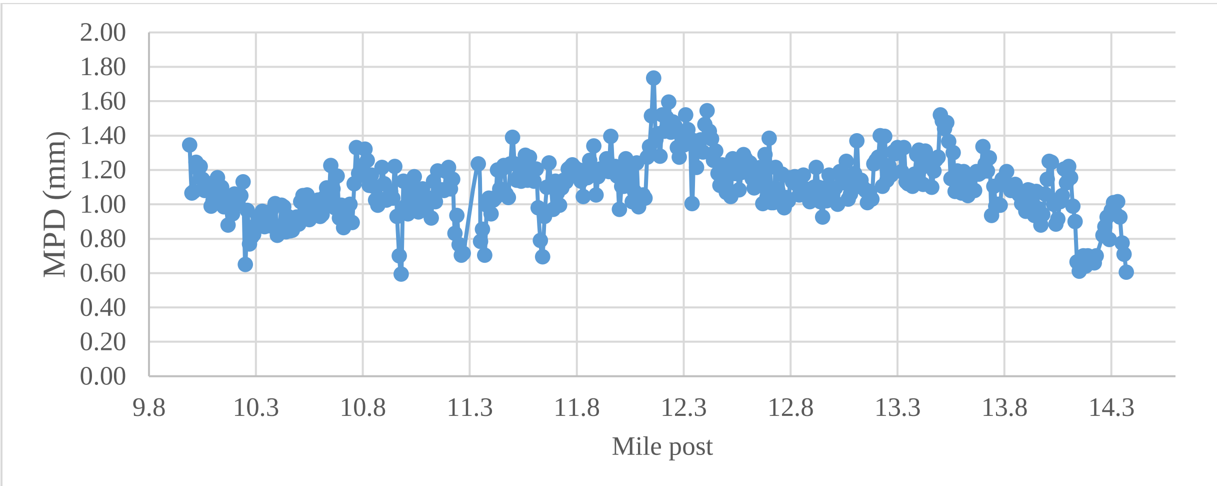

Figure 31. MPD Testing Results. MPD = mean profile depth.

Ride Testing Results

Figure 32 shows ride test results after 3 years. The average IRI value was 70 in/mi. In general, IRI values less than 70 in/mi indicate smoother pavement. The IRI values did not increase after the surface treatments. The higher ride value for Section 11.37 was due to the concrete bridge deck.

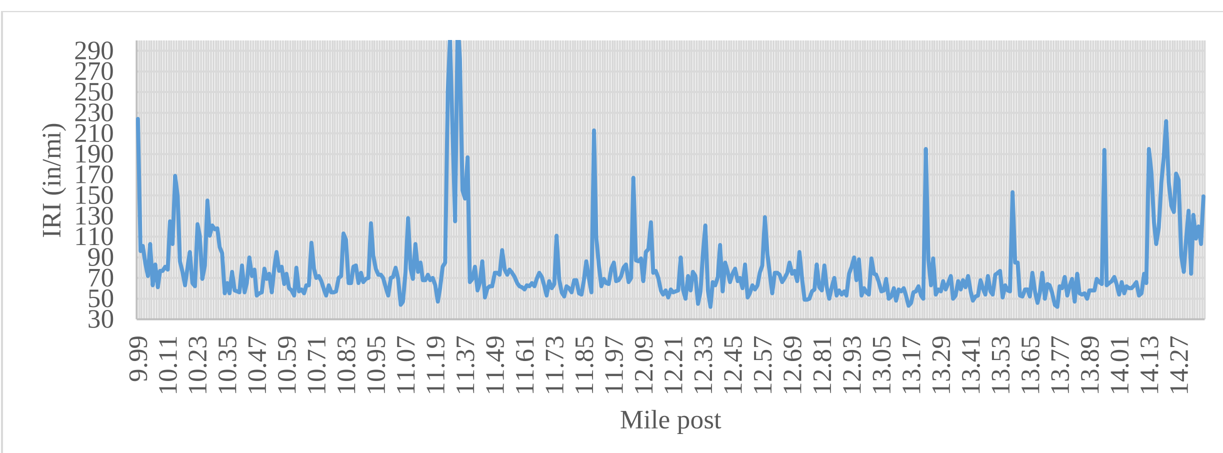

Figure 32. IRI Testing Results (at every 52.8 ft). IRI = International Roughness Index.

Cost Data From US 301 Project

The unit costs of a modified single seal and the Type C microsurfacing used in this project were \$1.54/yd^2 and \$2.45/yd^2, respectively. The unit cost of a fiber-reinforced chip seal for the project was around \$3.50/yd^2. Hence, the unit cost of fiber-reinforced cape seal was \$5.95/yd^2 and that of conventional cape seal was \$3.99/yd^2. In comparison, the average cost of a 2-in mill and fill corrective maintenance treatment with a conventional asphalt plant mixture in VDOT's Hampton Roads District is \$10.35/yd^2.

Summary of Findings

- The visual survey and VDOT's PMS data showed that the majority of the cracks found on the pre-treatment pavement were transverse cracks and longitudinal cracks (both on and outside the wheel path). Alligator cracking was also present in certain areas.
- Before-treatment CCI values varied considerably along the entire section. Some sections had values less than 50 (that ranged from 20 to 50), and some sections had values that ranged from 60 to 80. Sections selected for conventional cape seal and microsurfacing alone had relatively higher CCI values compared to the rest of the project.
- No rutting distresses were found on pre-treatment pavement.
- In general, the majority of IRI values were less than 75 in/mi, indicating relatively smooth existing pavement prior to treatments.
- FWD deflection data indicated structurally strong pavement and a uniform and stiff subgrade for the pre-treatment pavement.
- All sections showed very low permeability after treatments. The value for fiber-reinforced cape seal was $1 * 10^{-5}$ cm/sec, for regular cape seal was $2.5 * 10^{-5}$ cm/sec, and for microsurfacing alone was $4 * 10^{-5}$ cm/sec. In comparison to surface asphalt mixtures, VDOT's specifications require an average permeability not higher than 150×10^{-5} cm/sec.
- A 3-year visual survey showed that the fiber-reinforced cape seal section performed well, with very little reflective cracking. The regular cape seal section also performed well, but reflective cracking was higher compared to the fiber-reinforced cape seal section. The microsurfacing-only control section showed considerable cracking after 3 years.
- Based on VDOT's PMS data, the fiber-reinforced cape seal section performed well, with CCI values above 85 (based on 2019 data). The CCI for the microsurfacing section dropped to below 80, based on 2019 data.
- Based on GPR testing, average asphalt thickness was 12 in and aggregate layer thickness was 6 to 7 in.

- FWD testing 3 years after treatment showed that deflection values were comparable to those before treatments, indicating that surface treatments protected the pavement structure.

- The SNs of the sections ranged from 40 to 55. In general, these values were well above VDOT's minimum requirements.

- In general, MPD values (average of 1 mm) consistent with well-textured asphalt pavement surface were obtained. Higher SNs were complemented by good MPD values.

- The different surface treatments used in this study did not negatively affect the smoothness of the pavement.

CONCLUSIONS

- *Existing pavement condition and past performance should be considered when the type of surface treatment is selected. Existing pavement should be structurally adequate. A project-level pavement investigation using FWD and GPR can identify damages in the existing pavement.*

- *Surface treatments can provide an impermeable surface.*

- *Surface treatments such as fiber-reinforced cape seal and regular cape seal were crack inhibiting, and improved pavement condition ratings were obtained.*

- *Microsurfacing alone is not effective when the existing pavement has more than 10% cracking or a CCI < 65.*

- *Surface treatments used in this study provided good surface characteristics such as friction, MPD, and ride values.*

- *Pavement preservation treatments can extend pavement life in a cost-effective manner.*

RECOMMENDATIONS

1. *The Virginia Transportation Research Council (VTRC) should continue to monitor the performance of the US 301 sections to evaluate the long-term cost-effectiveness of each treatment.*

2. *VDOT pavement managers should consider the use of fiber-reinforced cape seal along with regular cape seal to extend pavement life.*

3. *Microsurfacing alone should not be used on existing pavements with a large amount of cracking (more than 8% to 10% cracking or a CCI < 70).*

IMPLEMENTATION AND BENEFITS

Implementation

For Recommendation 1, VTRC will monitor the performance of the US 301 sections for the next 3 to 6 years.

For Recommendations 2 and 3, VTRC will work with VDOT district pavement managers to develop site selection guidelines to apply cape seal treatments and microsurfacing. VTRC will also work with VDOT's Maintenance Division to update VDOT's *Asphalt Pavement Preventive Maintenance Guide* by September 30, 2020.

Benefits

Based on the unit cost from this particular project, if the FiberMat cape seal option is determined to be an appropriate treatment, the initial project cost for 4.45 lane-miles will be $372,800 as compared to a cost for conventional corrective maintenance of $648,500. The initial cost of a regular cape seal option will be $250,000. However, long-term performance data are needed to evaluate the benefit/cost ratio for each treatment.

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