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Full Depth Reclamation With Thin Surface Treatment for Low Volume Road Maintenance

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Abstract:

The Virginia Department of Transportation (VDOT) maintains more than 100,500 lane-miles of pavement on the secondary network. Of this total, more than 95% of the lane-miles have an annual average daily traffic of less than 3,500 vehicles. Pavement recycling techniques (such as full depth reclamation [FDR] and cold in-place recycling) can be used to fix many underlying issues in an existing pavement and when combined with thin surfacings, where appropriate, can help VDOT maintain low volume roads and provide significant cost and environmental savings. However, VDOT has limited experience using pavement recycling techniques (especially FDR) where pavement is overlaid with thin surfacings. The purpose of this study was to document the performance baseline for a series of FDR sections having thin surfacings on lower volume traffic routes since the performance of these types of pavements was previously unknown. This study summarized the construction and initial performance of the FDR field projects on Rte. 602 in Surry County in VDOT's Hampton Roads District and at Estates at Leeland in Spotsylvania County in VDOT's Fredericksburg District; in addition, an inventory was conducted and the performance of past VDOT FDR projects on lower traffic routes was evaluated.

The study found that the initial performance of the FDR project on Rte. 602 (having three thin surfacing treatments) and the FDR project at Estates at Leeland (having a 2-in asphalt concrete surface) was promising at early ages. However, the information gathered to date is not sufficient to make conclusions about the long-term performance of FDR with thin surfacings. In general, for the past FDR projects reviewed, based on visual surveys and data from VDOT's Pavement Management System, FDR with 2 to 4 in of asphalt concrete surface performed well at ages of 7 to 13 years after construction.

The study recommends continued performance assessment of the FDR sites surveyed in this study and additional field trials on the secondary network system using FDR with thin surfacings. Further research is also recommended to develop a framework to consider using performance data from VDOT's Pavement Management System to predict the future conditions of pavement sections on the secondary network. Being able to identify those sections that could benefit from FDR treatments in the future would allow VDOT to allocate funding proactively for those sections based on early findings from this study.

FINAL REPORT

FULL DEPTH RECLAMATION WITH THIN SURFACE TREATMENT FOR LOW VOLUME ROAD MAINTENANCE

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ABSTRACT

The Virginia Department of Transportation (VDOT) maintains more than 100,500 lane-miles of pavement on the secondary network. Of this total, more than 95% of the lane-miles have an annual average daily traffic of less than 3,500 vehicles. Pavement recycling techniques (such as full depth reclamation [FDR] and cold in-place recycling) can be used to fix many underlying issues in an existing pavement and when combined with thin surfacings, where appropriate, can help VDOT maintain low volume roads and provide significant cost and environmental savings. However, VDOT has limited experience using pavement recycling techniques (especially FDR) where pavement is overlaid with thin surfacings. The purpose of this study was to document the performance baseline for a series of FDR sections having thin surfacings on lower volume traffic routes since the performance of these types of pavements was previously unknown. This study summarized the construction and initial performance of the FDR field projects on Rte. 602 in Surry County in VDOT's Hampton Roads District and at Estates at Leeland in Spotsylvania County in VDOT's Fredericksburg District; in addition, an inventory was conducted and the performance of past VDOT FDR projects on lower traffic routes was evaluated.

The study found that the initial performance of the FDR project on Rte. 602 (having three thin surfacing treatments) and the FDR project at Estates at Leeland (having a 2-in asphalt concrete surface) was promising at early ages. However, the information gathered to date is not sufficient to make conclusions about the long-term performance of FDR with thin surfacings. In general, for the past FDR projects reviewed, based on visual surveys and data from VDOT's Pavement Management System, FDR with 2 to 4 in of asphalt concrete surface performed well at ages of 7 to 13 years after construction.

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INTRODUCTION

Traditional restorative maintenance activities for asphalt pavements employed by the Virginia Department of Transportation (VDOT) typically involve milling and replacement of one or more asphalt concrete (AC) layers. As the pavement network ages and traffic levels increase, these practices are becoming increasingly costly in that they do not often last as long as intended, especially if structural deficiencies are found deep within the pavement structure. Pavement recycling is a series of pavement rehabilitation techniques that can be used effectively to rehabilitate a deteriorated asphalt pavement (Asphalt Recycling and Reclaiming Association [ARRA], 2015). Pavement recycling treatments (such as full depth reclamation [FDR] and cold in-place recycling) are options that can have lower costs and environmental impacts than traditional approaches and have shown good service on pavements with both high and low traffic volumes (Diefenderfer and Apeagyei, 2011; 2015).

For the FDR process, a reclaimer is used to mix the bound layers and a predetermined portion of the underlying unbound layers into a homogeneous material that is often 4 to 12 in thick (ARRA, 2015). FDR may consist of simply pulverizing and remixing the roadway foundation, termed mechanical stabilization, but it most often incorporates one or several stabilizing agents. Typical FDR stabilizing agents include chemical stabilizers such as portland cement, lime, fly ash, and lime kiln dust and asphalt-based stabilizers such as emulsified and foamed asphalt. A recent survey indicated that the most commonly used chemical stabilizer was portland cement and the most commonly used asphalt-based stabilizer was foamed asphalt used in combination with cement or lime (Diefenderfer et al., 2021). Prior to construction, samples are collected from the roadway to classify the aggregate base and subgrade materials, and the results of the classification tests are used to determine the choice of stabilizing agent. Generally, lime is used for cohesive materials and cementitious or bituminous stabilizing agents (with cementitious stabilizing agents being preferred for silty materials) are used for non-cohesive materials (VDOT, 2015). The Pennsylvania Department of Transportation developed a decision table to aid in the selection of a stabilizer based on the gradation, plasticity index, and fines content of the pulverized base materials, and the California Department of Transportation selects the type of stabilization agent to be used based on the gradation of the pulverized base material, the plasticity index of the base and subgrade, and the R-value of the subgrade (Jahren, 2018).

VDOT started using FDR in trial sections constructed in 2008 to look at constructability, costs, and engineering properties. Diefenderfer and Apeagyei (2011) documented the construction and performance of these sections, and their life-cycle cost analysis showed that if a pavement rehabilitation strategy that includes FDR is applied to a preliminary candidate list of projects on VDOT's primary and secondary networks, a 50-year life-cycle cost savings of approximately $10 million and $30.5 million, respectively, is possible when compared to a traditionally used pavement rehabilitation approach. Further, if the potential cost savings were annualized, the savings to VDOT would be approximately $463,000 and $1.42 million per year for selected projects on the primary and secondary networks, respectively. During the 2011 construction season, VDOT completed an in-place pavement recycling project to rehabilitate a section of pavement on I-81 near Staunton (Diefenderfer and Apeagyei, 2015). The recycling processes on I-81 included FDR, cold in-place recycling, and cold central-plant recycling. This project marked the first time in the United States that these three recycling techniques were combined in one project on the interstate system. Starting in 2017, VDOT also used FDR on a series of lane widening and reconstruction projects on I-64 where FDR was used to stabilize materials brought to the project to construct the new lanes (termed *imported FDR*) (VDOT, n.d.). In recent years, VDOT has completed several FDR projects on primary and secondary routes; for most of the projects, cement was used as a stabilizing agent with an asphalt overlay (with a minimum asphalt thickness of 3.5 in).

VDOT maintains more than 100,500 lane-miles of secondary roads, and 95% of the secondary network has an annual average daily traffic (AADT) of less than 3,500 vehicles (VDOT, n.d.). Depending on the existing condition, pavements with low traffic volumes may simply require low-structure treatments, making the thicker surfacing used in previous VDOT FDR projects unnecessary and more costly. The application of thinner surface treatments such as chip seals, cape seals, microsurfacings, and 1-in AC courses also cover more area for less money and can be placed more rapidly provided the underlying pavement structure is in good condition. Pavement recycling techniques (such as FDR and cold in-place recycling) can be used to fix most underlying issues in an existing pavement and when combined with thin surfacings, where appropriate, can help VDOT maintain low volume roads and provide significant cost and environmental savings. However, VDOT has limited experience using FDR overlaid with thin surface treatments, and this study sought to document the experience and performance of recently constructed field projects.

PURPOSE AND SCOPE

The purpose of this study was to document the performance baseline for FDR with a thin surface treatment on lower volume traffic routes since the performance of these types of pavements is unknown. The following tasks were undertaken to achieve the study objectives:

1. Summarize the construction and initial performance of the FDR field projects on Rte. 602 in Surry County in VDOT's Hampton Roads District and Estates at Leeland in Spotsylvania County in VDOT's Fredericksburg District.

2. Inventory and evaluate the performance of past VDOT FDR projects on low traffic routes.

METHODS

Summarize FDR Construction and Surface Layers

Rte. 602, Surry County, Hampton Roads

The existing pavement structure on Rte. 602 was approximately 2.6 in of AC and 4.3 in of aggregate base. The section selected for the FDR project had medium to high severity alligator cracking, low severity longitudinal/transverse cracking, and low to high severity potholes. Figure 1 shows an example of the roadway condition on Rte. 602 just north of the project, and Figure 2 shows some of the core pictures from Rte. 602. The AADT for Rte. 602 was 130 vehicles (based on 2016 traffic data). The Hampton Roads District conducted a detailed pavement evaluation, which included a visual inspection of the functional condition, ground penetrating radar testing, pavement coring and boring, and laboratory soil testing using a consultant service. The laboratory test results revealed several different soils throughout the project, including silt, lean clay, and fat clay. Based on the distress and pavement investigation, the Hampton Roads District decided to use FDR for Rte. 602 in both directions of travel from the intersection with Oak Hill Road to the Union Baptist Church (Milepost 3.5). To study the performance of FDR surfaced with thin treatments, the treatments listed in Table 1 were placed on top of the FDR.

Figure 1. Typical Conditions of Rt. 602 Just North of FDR Project Site. FDR = full depth reclamation.

Figure 2. Core Pictures From Rte. 602, Surry County

Table 1. Treatments Applied to Rte. 602 FDR

Section	Milepost From	Milepost To	Surfacing Treatment
A	3.50	4.50	Modified Double Seal
B	4.50	5.50	Blotted Seal Coat, Type C
C	5.50	6.49	1-in SM-9.0A AC

FDR = full depth reclamation; SM-9.0A = a surface mixture having a 9.0 mm nominal maximum aggregate size using a Performance Grade 64-22 binder; AC = asphalt concrete.

The materials for Sections A and B (modified double seal and Type C blotted seal) had three applications of asphalt material: two applications of cover aggregate, and one application of blot fine aggregate. Details of these two methods can be found in VDOT's special provision (VDOT, n.d.). The SM-9.0A mixture used in Section C had 6.1% asphalt binder and 30% reclaimed asphalt pavement.

Estates at Leeland, Spotsylvania County

The original pavement structure at this section had 3 in of AC and 6 to 8 in of aggregate base. The Fredericksburg Residency decided to surface the FDR with a 2-in asphalt surface (SM-9.5A) as a repair strategy for this residential area section, which included portions of Sutter Drive (1,400 LF, cul-de-sac to cul-de-sac) and Tipton Lane (500 LF). Details of each section are shown in Table 2. For all sections at Estates at Leeland, 1.5 in of existing AC was milled prior to the FDR process.

Table 2. Locations of FDR, Estates at Leeland

Section	Road Name	Station From	Station To
A	Sutter Drive	1+00	15+00
B	Tipton Lane	0+00	5+00

FDR = full depth reclamation.

Initial Performance of Rte. 602 and Estates at Leeland

A visual performance evaluation was conducted on Rte. 602 after 1.5 years and at Estates at Leeland 1 year after placement.

Performance Summary of Older Recycled Test Sections

The performance of other recycled test sections was summarized using visual surveys (when necessary) and using condition state data from VDOT's Pavement Management System (PMS) when available. Projects were selected based on low traffic levels, which better match 95% of secondary routes (<3,500 AADT). Table 3 shows the list of projects reviewed by visual observation. Table 4 lists the projects for which performance data were extracted from VDOT's PMS.

Table 3. FDR Projects Used for Visual Survey Performance Evaluation

District	County	Route Number	FDR Year	FDR Thickness, Stabilizing Agent, Dosage Rate	AC Surface Thickness, in	Two-Way AADT, % Trucks, 2017	Project Length, lane-miles
Northern Virginia	Loudoun	Rte. 651, Hog-Back Mountain Rd.	2018	8 in with 6% cement content	Chip seal surface	140 vehicles, including 5% trucks	0.7
Richmond	Hanover	SC01131NB, Stonewall Park Rd.	2013	-	2.5	-	0.45
Richmond	Hanover	SC01366EB, Lee Park Rd.	2013	-	2.5	-	0.16

FDR = full depth reclamation; AC = asphalt concrete; AADT = annual average daily traffic; -not available.

Table 4. FDR Projects With AC Surface

District	County	Route Number	FDR Year	FDR Thickness, Stabilizing Agent, Dosage Rate	AC Surface Thickness, in	Two-Way AADT, % Trucks, 2017	Project Length, lane-miles
Salem	Franklin	40[a]	2008	8 in, emulsified asphalt, 3.5%	2 in	4,400, 4%	0.5
		40[b]	2008	8 in, foamed asphalt + cement, 2.7% + 1%	2 in	4,400, 4%	0.5
Salem	Bedford	24	2012	FDR with cement	3.5 in	2,000, 3%	3
Fredericksburg	King William	30	2014	8 in FDR with cement	4 in	4,600, 22%	4
Fredericksburg	Richmond	3	2012	8 in FDR with cement	4 in	6,000, 6%	1.5

FDR = full depth reclamation; AC = asphalt concrete; AADT = annual average daily traffic; -not available.
[a] The western half of both lanes was constructed using emulsified asphalt as the stabilizing agent.
[b] The eastern half of both lanes was constructed using foamed asphalt plus portland cement as the stabilizing agent and active filler.

RESULTS AND DISCUSSION

Construction Summary

Rte. 602, Surry County

Construction of the FDR section on Rte. 602 began with a trial section built on October 25, 2019. During the work, the application rate of cement was found not to be uniform across the lane width; more cement was found on the outside of the lane and less cement toward the middle of the lane. Visually, the mixture looked dry in some areas, as the water content was not close to optimum. Also, when the reclaimer stopped during cement application, the water added was not stopped, which resulted in puddles of water in certain locations. This, in turn, resulted in soft, pumping areas during compaction. There were also issues with the sequence of pulverizing and initial compaction. Figure 3 shows the surface of the first trial section after a few weeks.

Because of the multiple issues observed in the first FDR trial section, another trial section was placed on Rte. 602 on November 18, 2019. This trial section was successful. However, because of low temperatures on the following days, the contractor could complete the FDR on only a short section of Rte. 602. For the section completed, a SM-9.0 AC mixture was placed as the surface. The SM-9.0 mixture placement had issues indicative of cold weather paving to include segregation and raveling. Figure 4 shows the surface of the SM-9.0 mixture (which shows segregation and raveling).

Additional FDR work on Rte. 602 resumed on March 16, 2020. Using a reclaimer, the contractor pulverized the section to a depth of 8 in. Samples were collected to verify the achievable density of the FDR materials using a one-point Proctor test (AASHTO T 99). The gradation of the FDR material was also checked and found to meet VDOT's FDR special provision requirements. Following initial pulverization, the contractor added cement using a distributor truck. During cement placement, multiple tarp tests were performed to check the application rate. The application rates were also calculated based on yield calculations from each full tanker of cement. The application rates of cement generally ranged from 4% to 6% (although in some samples the cement content ranged from 6% to 9%).

Figure 3. First FDR Trial Section on Rte. 602. FDR = full depth reclamation.

Figure 4. Segregation and Raveling on SM-9.0 Mix Placed Over Second FDR Trial. FDR = full depth reclamation.

After cement placement, the contractor again used the reclaimer to mix the cement with the pulverized material. The reclaimer was connected to a water truck that supplied water for compaction. The mixture was compacted using a sheepsfoot roller and then using a 20-ton smooth drum roller.

The moisture content of the mixture was checked by the direct heating method at multiple locations; the moisture contents ranged from 5.83% to 8.92%. Nuclear density tests were performed during the compaction, and the moisture contents were used to correct the nuclear gauge readings. The depth of the FDR was checked to verify the intended 8.0 in thickness. The FDR process is shown in Figure 5.

Figure 5. FDR Process on Rte. 602. FDR = full depth reclamation.

Figure 6 shows the compressive strength of the FDR samples collected throughout the project. From Figure 6 it can be seen that all the strength values were less than the maximum allowable of 450 psi. Figure 6 also shows that more than 40% of the tests (26 of 64 tests) failed to meet the minimum strength of 250 psi. However, the lower strengths are less likely to contribute to more prominent transverse cracking in the thin surfaces.

After FDR was completed, 1 mile of double chip seal was placed, followed by 1 mile of blotted seal coat, followed by the SM-9.0 plant mixture for the remainder of the project. Figure 7 shows the blotted seal placement on the FDR layer. As mentioned previously, much (3,600 ft) of the SM-9.0A mixture was placed in December 2019, with the remainder (1,600 ft) placed in April 2020. At some locations paved in 2019, the segregated material had eroded/raveled out to a depth of approximately ¼ in below the adjacent surface. Based on the extent and severity of the surface segregation and erosion/raveling of the material, patching of the surface was performed in 2020 after completion of the project (milling and filling with an SM-9.0 mixture to a minimum of 1 in).

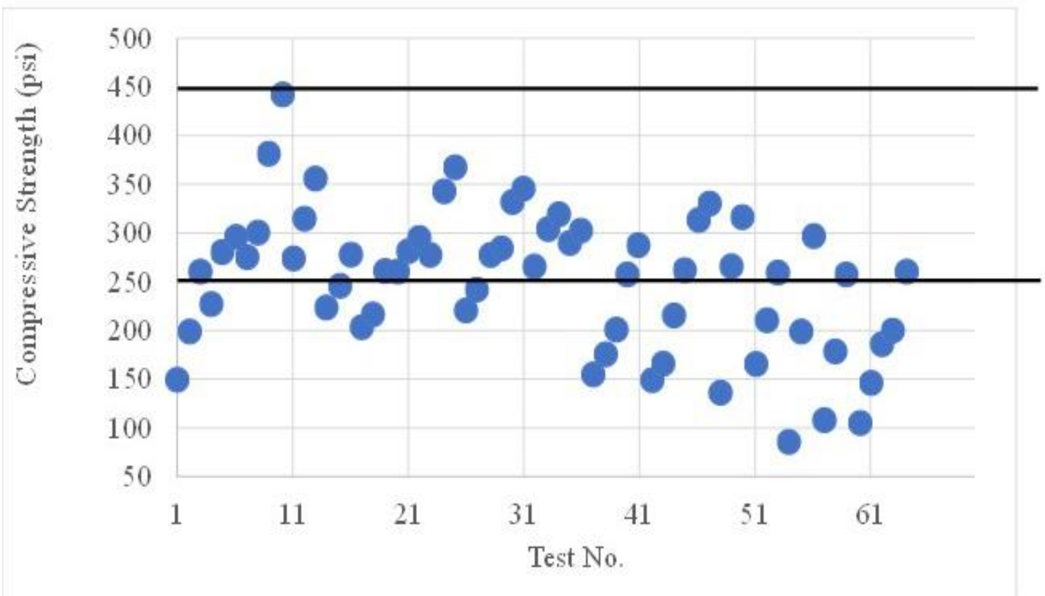

Figure 6. Compressive Strength Results for FDR Samples on Rte. 602. Horizontal lines indicate minimum and maximum acceptable values. FDR = full depth reclamation.

Estates at Leeland, Spotsylvania County

The FDR at Estates at Leeland was constructed between September 16 and 18, 2020. The process began with the reclaimer pulverizing the existing pavement to a depth of 10 in (including the existing asphalt, aggregate base, and top of subgrade). Following shaping by a motor grader, a distributor was used to add 5% (by weight) cement. A plate weight test was performed to verify the cement application rate. The added cement and water were then mixed by another pass of the reclaimer. The moisture content generally ranged from 6.8% to 8.2% (OMC was 8%); however, 8 of 21 test results were higher (9% to 10.3%). Material was then compacted using a sheepsfoot roller.

Figure 7. Blotted Seal Placement on Rte. 602 FDR. FDR = full depth reclamation.

Additional compaction was achieved using a vibratory smooth drum roller. Density testing was performed, and then additional water was sprayed on the surface to assist with curing.

Three compressive strength specimens were prepared on the first day of FDR; the compressive strengths were 500, 600, and 70 psi (specimens were kept in sealed plastic bags). However, the values were close to the maximum allowable, and tests were run at 9 days after fabrication rather than the typical 7 days. The compressive strength report showed that the lowest strength of 70 psi was due to a sample that was damaged when removed from the split mold. On September 22, 2 in of a SM-9.5A mixture was placed as a surface on the FDR layer. Figure 8 shows the different stages of the FDR process and asphalt paving at Estates at Leeland.

Initial Performance

Rte. 602, Surry County

A visual inspection of the Rte. 602 project was performed on August 17, 2021, 1.5 years after construction. The visual inspection revealed occasional transverse cracking (spacing of 15 to 35 ft, width of 0.02 to 0.04 in using a crack width scale) in the modified double seal section in the last 250 ft of the southbound lane.

Figure 8. FDR and Asphalt Paving at Estates at Leeland. FDR = full depth reclamation.

These cracks may be reflective from cracks in the FDR layer where the cement content was high (hence a higher compressive strength). Similar, but less frequent, transverse cracking was found in the double seal section in the northbound lane. Figure 9 shows the FDR with the modified double seal section. Excellent performance was observed in the FDR with a blotted seal, with very few instances of transverse cracking (Figure 10). The section having the FDR with a 1-in AC layer showed several reflective cracks and a few longitudinal cracks (Figure 11). Even though Rte. 602 sees logging truck traffic, there were no slippage cracks found on the 1-in AC layer or other surfaces (slipping cracking was a concern expressed by the VDOT district).

Estates at Leeland, Spotsylvania County

A visual inspection of the FDR placed at Estates at Leeland was conducted in September 2021. No cracks were found, and the overall performance was excellent at 1 year after construction, as shown in Figure 12.

Figure 9. FDR + Modified Double Seal Layer, 1.5 Years After Construction. FDR = full depth reclamation.

Figure 10. FDR + Blotted Seal Coat, 1.5 Years After Construction. FDR = full depth reclamation.

Figure 11. FDR + 1-in SM-9.0 AC Layer After 1.5 Years. FDR = full depth reclamation.

Figure 12. FDR + 2-in AC Surface at Estates at Leeland, Spotsylvania County, 1 Year After Construction. FDR = full depth reclamation; AC = asphalt concrete.

Performance Summary of Older Recycled Test Sections

Visual Inspection

As mentioned previously, VDOT has limited past FDR field projects with thin surface treatments such as chip seal. Hoppe and Nair (2018) conducted a technical assistance study in 2018 on Rte. 651, Hogback Mountain Road, Loudoun County, to upgrade a gravel road using a chip seal surface on top of FDR using cement as a chemical additive. Excellent field performance was observed after 3 years. Figure 13 shows the Rte. 651 FDR process and the 1-year and 3-year field conditions.

Two FDR projects were constructed in 2013 in Hanover County in the Richmond District (Stonewall Parkway and Lee Park Road); both projects used cement as the stabilizing agent (Table 1) with a 2.5-in AC surface. The AC surface consisted of a 1-in SM-9.0E mixture placed on top of a 1.5-in layer of SM-12.5E. A visual inspection of these two sections was conducted on August 17, 2021, after 8 years in service. Overall good performance with only minor reflective cracks was observed (Figures 14 and 15). The cement application rate was not available to the researchers for these two projects.

(a) FDR Process (b) Chip Seal Over FDR

(c) Section After 1 Year (d) Section After 3 Years

Figure 13. FDR + Chip Seal Surface on Rte. 651, Hogback Mountain Road. FDR = full depth reclamation. Source: Hoppe and Nair (2018).

Figure 14. FDR + 2.5-in AC Surface on Stonewall Parkway, 8 Years After Construction. FDR = full depth reclamation; AC = asphalt concrete.

Figure 15. FDR + 2.5-in AC Surface on Lee Park Road, 8 Years After Construction. FDR = full depth reclamation; AC = asphalt concrete.

VDOT's Pavement Management System

As mentioned previously, VDOT constructed several field projects with FDR beginning in 2008. Most of these projects used cement as the stabilizing agent and were surfaced with multiple lifts of AC (often more than 3.5 in). Projects were selected as shown in Table 4 based on low traffic levels, which better match 95% of secondary routes (<3,500 AADT).

Rte. 40 EB in Franklin County in the Salem District was reclaimed to a depth of approximately 8 to 10 in, and a 2-in hot mix asphalt overlay was placed as a wearing surface. Both lanes of the western half of the Rte. 40 project were reclaimed using emulsified asphalt; for the eastern half of the Rte. 40 project, foamed asphalt was used as the stabilizing agent. The binder used during the foaming process was a performance grade (PG) 64-22 binder (Diefenderfer and Apeagyei, 2011). The reclamation process on the foamed asphalt portion occurred May 13 through 15, 2008, and on the asphalt emulsion portion occurred May 19 through 22, 2008. This section has a combined AADT of approximately 4,400 (4% trucks). Figures 16, 17, and 18 show the critical condition index (CCI), cracking and rutting, and transverse cracking since construction. Condition is reported on a scale from 0 to 100, completely failed to new or like new, respectively. The overall section rating, the CCI, is the lower of two ratings that summarize the load related and non-load related distresses for a pavement. The CCI and distress data before paving are also shown. Overall good performance was observed over the years with very low cracking. An increase in transverse cracking was observed only after 8 years in service. *Excellent* is defined as a CCI of 90 and above, and good performance is the range of 70 to 89 (VDOT, 2016).

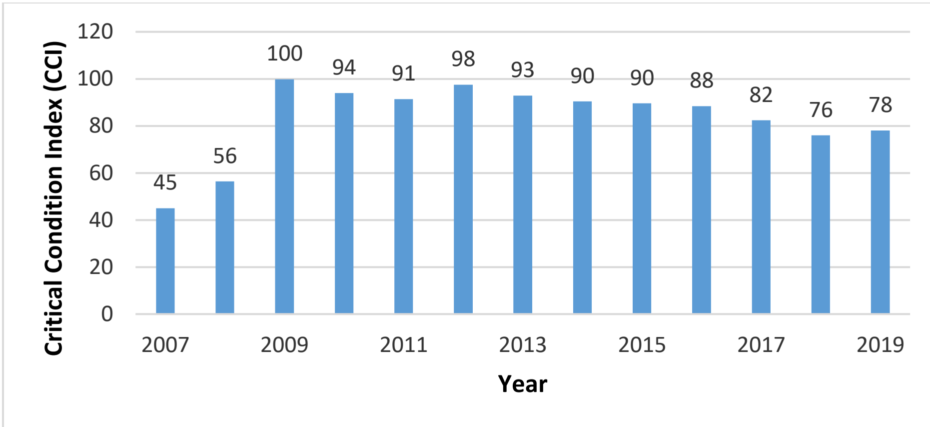

Figure 16. CCI Data for Rte. 40 EB. Full depth reclamation was completed in 2008 (after the 2008 condition survey).

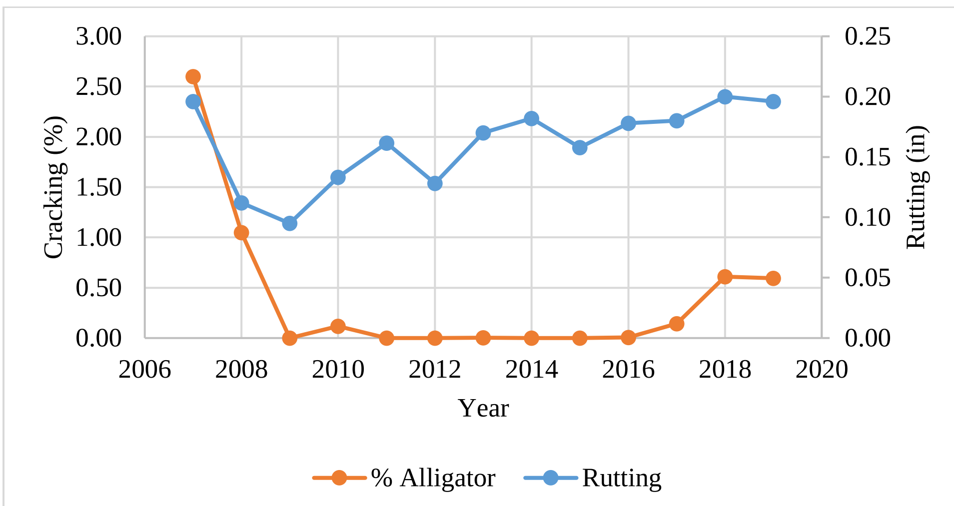

Figure 17. Rutting and Cracking Data for Rte. 40 EB. Full depth reclamation was completed in 2008 (after the 2008 condition survey).

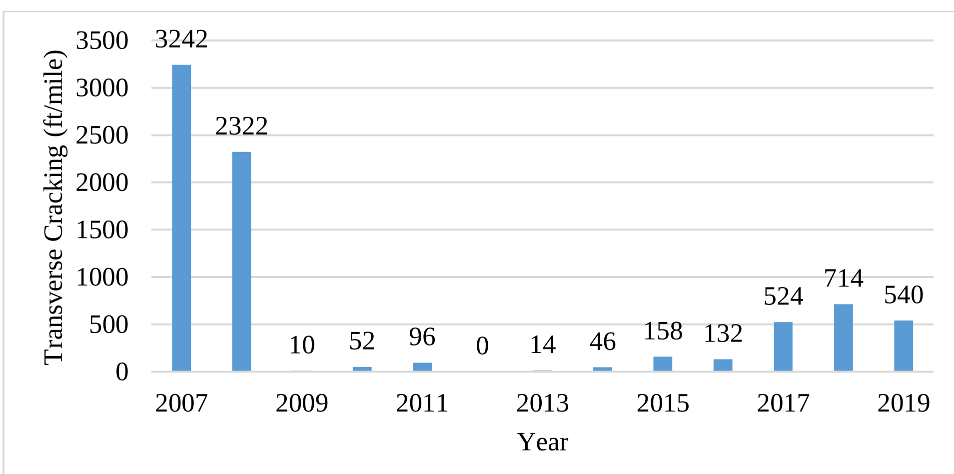

Figure 18. Transverse Cracking Data for Rte. 40 EB. Full depth reclamation was completed in 2008 (after the 2008 condition survey).

Figures 19, 20, and 21 show performance data for Rte. 24, Bedford County, in the Salem District. The FDR was conducted using cement as the stabilizing agent in 2012. The AADT for this section in 2017 was 2,000 with 3% trucks. Similar to the Rte. 40 project, excellent performance was observed with limited fatigue and transverse cracking. The CCI is still above 90 after 9 years.

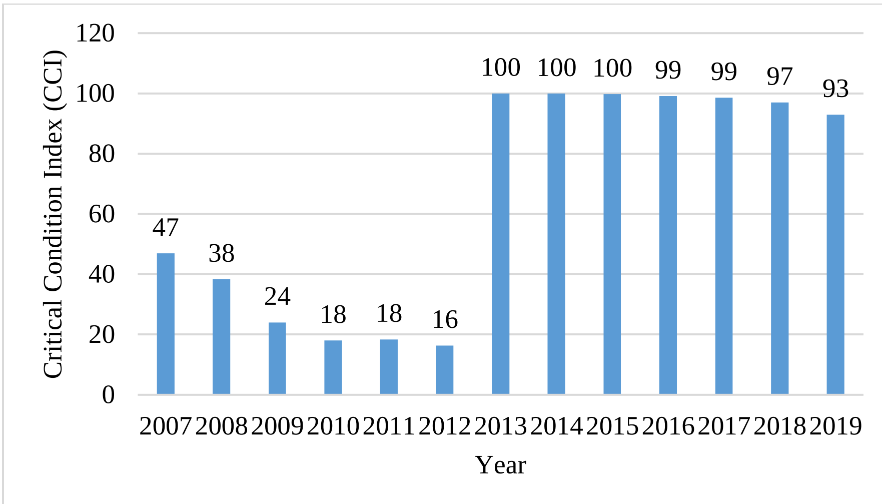

Figure 19. CCI Data for Rte. 24. Full depth reclamation was completed in 2012 (after the 2012 condition survey).

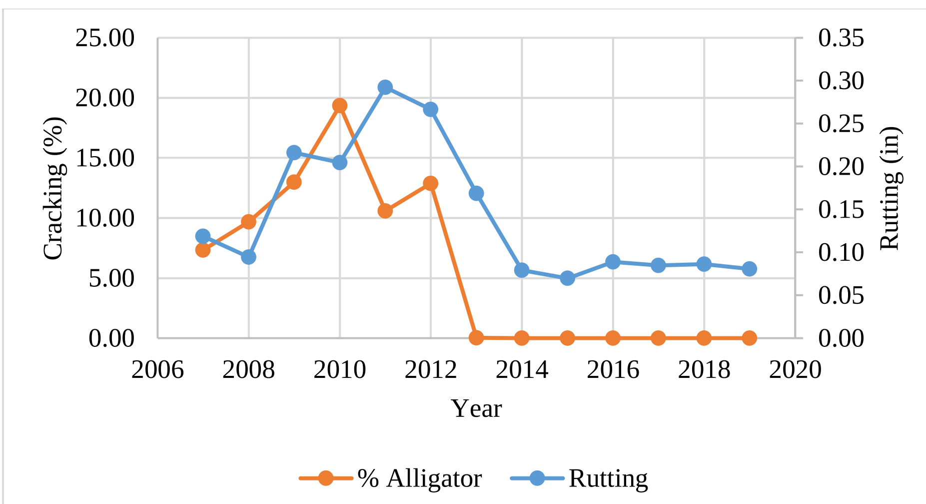

Figure 20. Rutting and Cracking Data for Rte. 24. Full depth reclamation was completed in 2012 (after the 2012 condition survey).

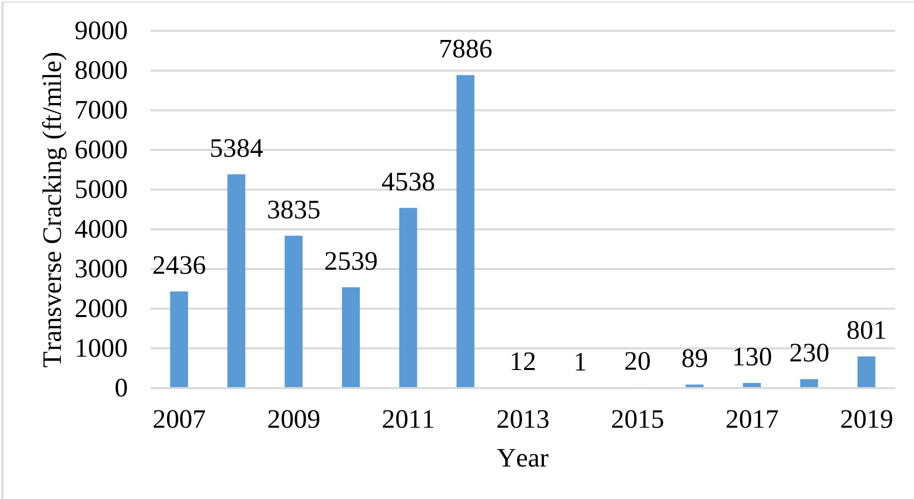

Figure 21. Transverse Cracking Data for Rte. 24. Full depth reclamation was completed in 2012 (after the 2012 condition survey).

Rte. 30 in King William County in the Fredericksburg District used FDR with cement stabilization in 2014. The project involved FDR to a depth of 12 in with a 4-in AC surface. Figures 22, 23, and 24 show the excellent performance thus far for this section.

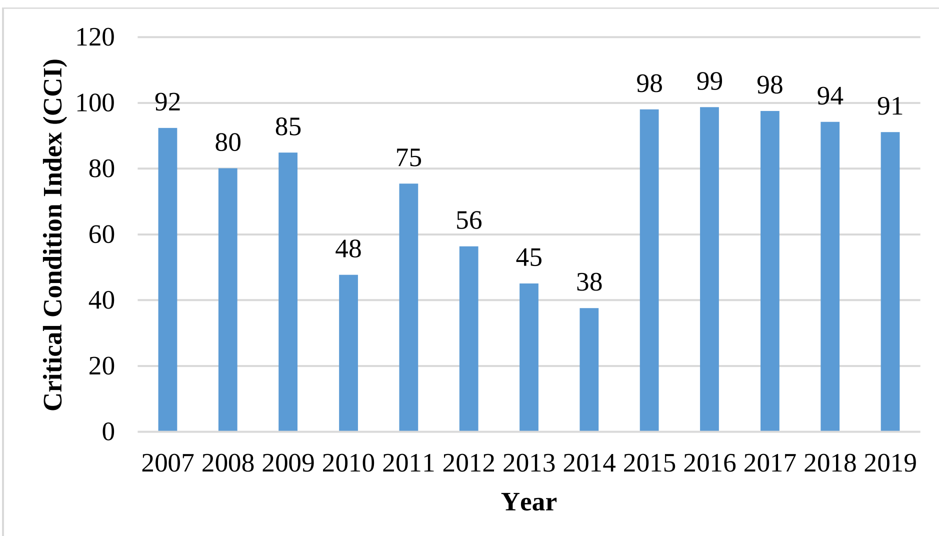

Figure 22. CCI Data for Rte. 30. Full depth reclamation was completed in 2014 (after the 2014 condition survey).

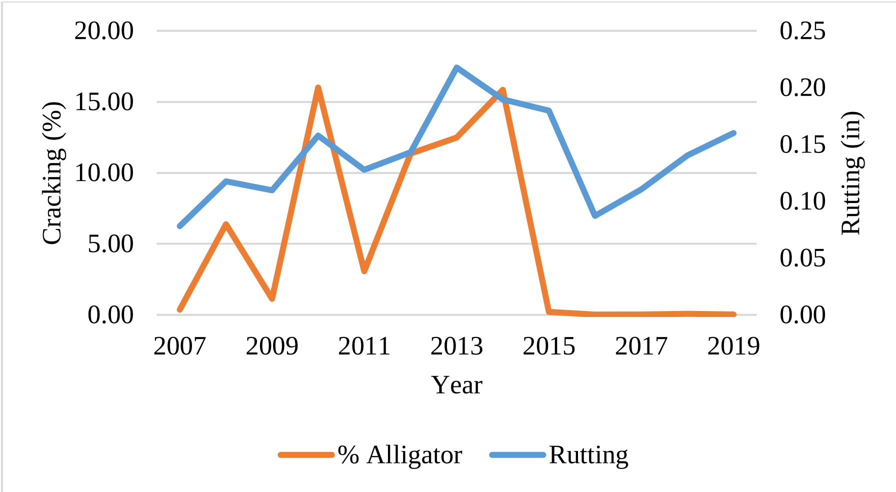

Figure 23. Rutting and Cracking Data for Rte. 30. Full depth reclamation was completed in 2014 (after the 2014 condition survey).

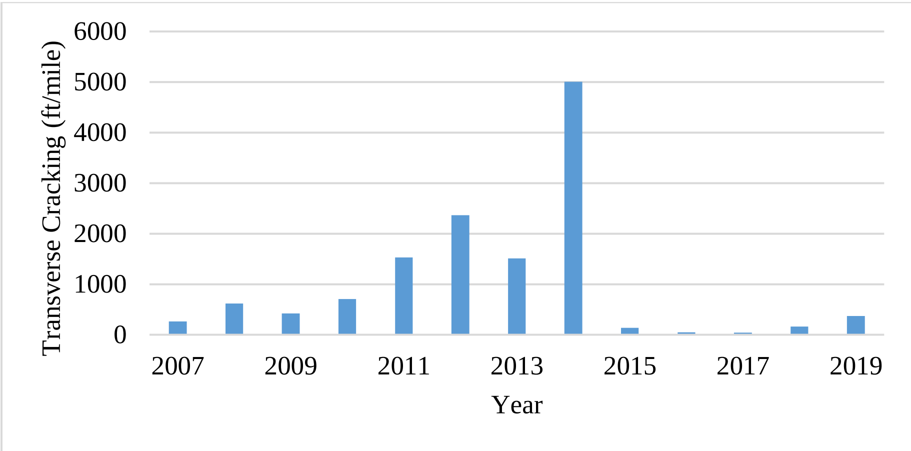

Figure 24. Transverse Cracking Data for Rte. 30. Full depth reclamation was completed in 2014 (after the 2014 condition survey).

Figures 25, 26, and 27 show the performance data for Rte. 3, Richmond County, in the Fredericksburg District. The FDR was conducted using cement as the stabilizing agent in 2012. The AADT for this section in 2007 was 6,000 with 6% trucks. This section showed considerable cracking after a few years, resulting in a reduced CCI. The transverse cracking was noted to be higher compared to the Rte. 40, Rte. 24, and Rte. 30 FDR sections. A preconstruction field investigation showed that this section had drainage issues. Figure 28 (preconstruction) and Figure 29 (post-construction) show fines collected on the edge of the road and the elevation of surrounding land and low stiffness soil underneath, which may be a reason for the lower than expected performance. Table 5 shows the summary of PMS distress data for FDR projects evaluated in this study.

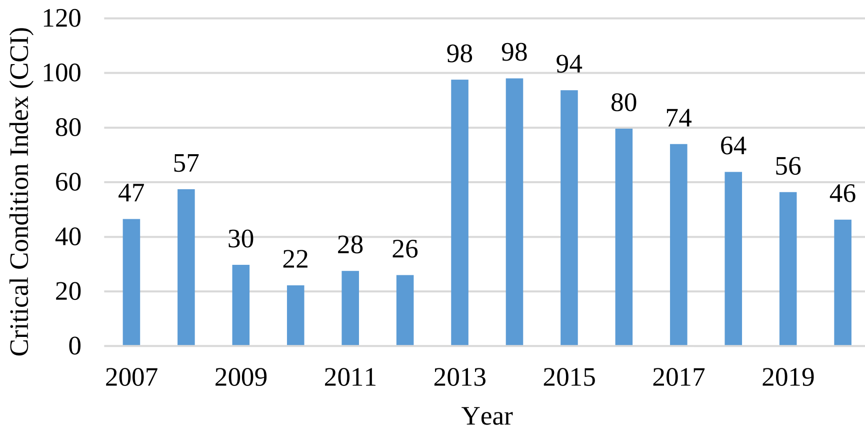

Figure 25. CCI Data for Rte. 3. Full depth reclamation was completed in 2012 (after the 2012 condition survey).

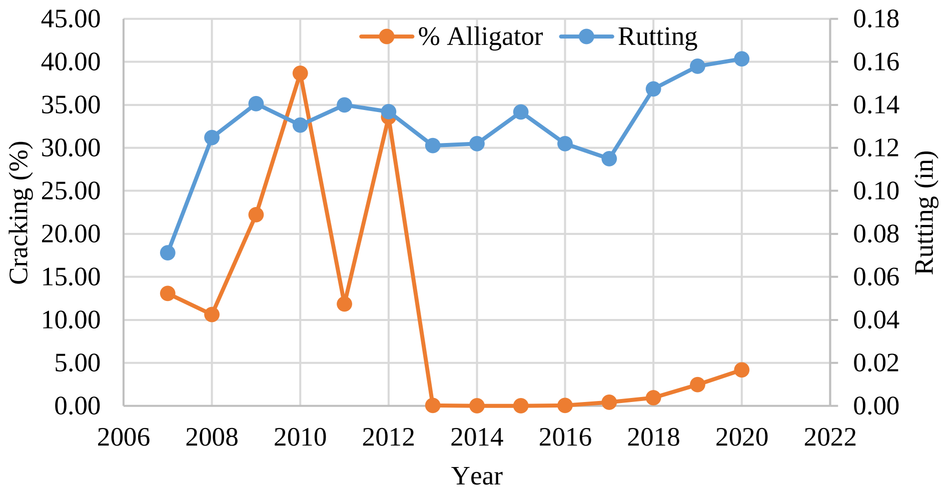

Figure 26. Rutting and Cracking Data for Rte. 3. Full depth reclamation was completed in 2012 (after the 2012 condition survey).

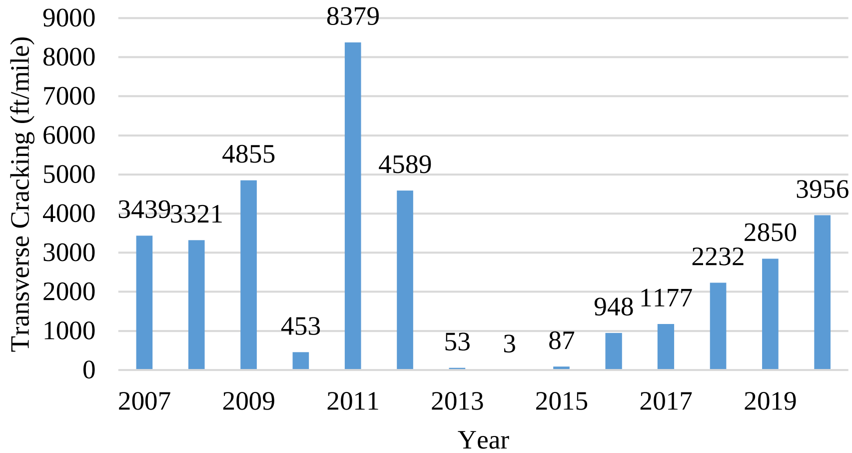

Figure 27. Transverse Cracking Data for Rte. 3. Full depth reclamation was completed in 2012 (after the 2012 condition survey).

Figure 28. Preconstruction Condition of Rte. 3, 2010.

Figure 29. Google Map Image of Same Rte. 3 Location, 2018. Copyright 2021, Google.

Summary of Findings

- During construction of the Rte. 602 project, several potential issues were observed, including (1) high and uneven cement application in certain locations, and (2) segregation and raveling in the SM-9.0 mixture that were indicative of cold weather paving.
- Nearly all the strength testing results from the Rte. 602 project were less than the maximum allowable strength of 450 psi; more than 40% of the tests (26 of 64) failed to meet the minimum strength of 250 psi.
- A visual survey of the Rte. 602 project conducted 1 year after construction revealed minor transverse cracks in the modified double chip seal section and the 1-in AC overlay section. No transverse cracks were noted in the blotted seal section.
- During construction of the Estates at Leeland project, values were higher than the OMC for 8 of 21 test results. Three specimens for strength testing were fabricated during construction, and two were found to have compressive strengths higher than the maximum allowable. However, the values were close to the maximum allowable and tests were run at 9 days after fabrication rather than the typical 7 days.
- A visual survey of the Estates at Leeland project was conducted at 1 year after construction. Despite the higher strength values measured during construction, there were no cracks in the pavement and the overall condition was considered to be excellent.
- Based on a visual survey of the Rte. 651 project (Hogback Mountain Road in Loudoun County, having cement as the stabilizing agent and a chip seal surface), the FDR was performing well 3 years after construction.

Table 5. Summary of PMS Data for FDR Projects Evaluated

District	County	Route Number	FDR Year	FDR Thickness, Stabilizing Agent, Dosage Rate	AC Surface Thickness, in	Two-Way AADT, % Trucks, 2017	Before Construction CCI	After Construction CCI (Year After Construction)	Rutting (in) (Year After Construction)	Alligator Cracking (%) (Year After Construction	Transverse Cracking (ft/mi) (Year After Construction
Salem	Franklin	40[a]	2008	8 in, emulsified asphalt, 3.5%	2 in	4,400, 4%	-	-	-	-	-
		40[b]	2008	8 in, foamed asphalt + cement, 2.7% + 1%	2 in	4,400, 4%	56	78 (after 11 years)	0.20 (after 11 years)	0.59% (after 11 years)	540 (after 11 years)
Salem	Bedford	24	2012	FDR with cement	3.5 in	2,000, 3%	16	93 (after 6 years)	0.08 (after 6 years)	0% (after 6 years)	801 (after 6 years)
Fredericksburg	King William	30	2014	8 in, FDR with Cement	4 in	4,600, 22%	38	91 (after 5 years)	0.16 (after 5 years)	0.02% (after 5 years)	369 (after 5 years)
Fredericksburg	Richmond	3	2012	8 in, FDR with cement	4 in	6,000, 6%	26	46 (after 7 years)	0.16 (after 7 years)	4.19% (after 7 years)	3956 (after 7 years)

PMS = pavement management system; FDR = full depth reclamation; AC = asphalt cement; AADT = annual average daily traffic; CCI = critical condition index; - = not available.

[a]The western half of both lanes was constructed using emulsified asphalt as the stabilizing agent.

[b]The eastern half of both lanes was constructed using foamed asphalt plus portland cement as the stabilizing agent and active filler.

- A visual survey of two FDR projects in Hanover County (Stonewall Parkway and Lee Park Road, having cement as the stabilizing agent and a 2.5-in AC surface) was conducted at 8 years after construction. There was minor transverse cracking, but both projects were in good condition.

- A review of data from VDOT's PMS for the FDR project constructed in 2008 on Rte. 40 EB in Franklin County (having both foamed asphalt and emulsified asphalt as a stabilizing agent in separate sections and a 2-in AC surface) showed that the CCI decreased from 100 to 78 in 11 years. Also, the total cracking was less than 0.6% and the rut depths were less than 0.2 in. The rate of change of transverse cracking was shown to have increased at 8 years after construction.

- For the FDR project constructed in 2012 on Rte. 24 in Bedford County (having cement as the stabilizing agent and a 3.5-in AC surface), a review of VDOT's PMS found that the CCI remained above 90 after 8 years in service. Also, there was no cracking, and the rut depth was less than 0.1 in. The rate of change of transverse cracking was shown to have increased at 6 years after construction.

- For the FDR project constructed in 2014 on Rte. 30 in King William County (having cement as the stabilizing agent and a 4-in AC surface), a review of VDOT's PMS showed that the CCI remained above 90 after 5 years of service. No cracking was observed, and the rut depth was less than 0.16 in. The rate of change of transverse cracking was shown to have increased at 5 years after construction and remained below 400 ft/mi.

- A review of VDOT's PMS for the FDR project constructed in 2012 on Rte. 3 in Richmond County (having cement as the stabilizing agent and a 4-in AC surface) showed a sharp decrease in CCI (from 98 to 46) after 8 years in service. A considerable increase in fatigue cracking was observed after 6 years in service. An increase in transverse cracking was observed after 4 years. A preconstruction field investigation showed that this section had drainage issues and low stiffness soils, which may be a reason for the lower than expected performance.

- For the projects reviewed in this study, the major cracking distress found was transverse cracking. The rate of change of transverse cracking increases 5 to 8 years after construction.

CONCLUSIONS

- *The initial performance of the FDR project on Rte. 602 (having three different thin surfacing treatments) and the FDR project at Estates at Leeland (having a 2-in AC surface) is promising at early ages.*

- *The information gathered to date is not sufficient to make conclusions about the long-term performance of FDR with thin surfacings.*

- *In general, for the projects reviewed, the visual survey and PMS data showed that FDR with 2 to 4 in of AC surface performed well at ages of 7 to 13 years after construction.*

- *Transverse cracking could be a common issue with cement-stabilized FDR with thin surfacing.*

RECOMMENDATIONS

1. *The Virginia Transportation Research Council (VTRC) and the pavement design and materials staff of VDOT's Hampton Roads and Fredericksburg districts should continue to assess the performance of the FDR sites surveyed in this study.* The continued assessment will allow for quantification of any potential benefits of thinner surfacing and transverse cracking performance.

2. *VTRC, VDOT's Maintenance and Materials divisions, and VDOT district pavement design and materials staff should identify sites on the secondary network system for additional field trials using FDR with thin surface treatments.* This could help better document performance and potential cost savings.

3. *VTRC should investigate potential ways to reduce transverse cracking, such as using an asphalt-based stabilizing agent or verifying the compressive strength requirement for cement-stabilized FDR at design.*

4. *VTRC and VDOT's Maintenance and Materials divisions should develop a framework to consider using VDOT PMS performance data to predict the future conditions of pavement sections on the secondary network.* Being able to identify those sections that could benefit from FDR treatments in the future would allow VDOT to allocate funding proactively for these sections based on early findings from this study.

IMPLEMENTATION AND BENEFITS

Implementation

With regard to Recommendation 1, VTRC will start a technical assistance project in 2022 to monitor the field performance of the FDR sections in this study.

With regard to Recommendation 2, VTRC will work with the Richmond District and the Hampton Roads District to construct several field projects that incorporate FDR with thin surface treatments in the 2022 and 2023 construction season.

With regard to Recommendations 3 and 4, VTRC will develop a research needs statement for this task and will present it to VTRC's Pavement Research Advisory Committee by fall 2022.

Benefits

Table 6 shows VDOT's secondary network, which clearly shows that sufficient lane mileage (AADT <3,500) should be available for FDR with thin surface application and can benefit from potential increased pavement service life. With additional field sites, and continued monitoring of current FDR sites (Recommendations 1 and 2), a more detailed life-cycle cost analysis can be conducted to show the benefit of recycling on the secondary network.

Table 6. VDOT's Secondary Network in Different Districts

Network		District								
		1/BR	**2/SA**	**3/LY**	**4/RI**	**5/HR**	**6/FR**	**7/CU**	**8/ST**	**9/NV**
Secondary	AADT ≥ 3,500	62	290	124	963	217	500	266	263	2,721
	AADT < 3,500	9,637	11,673	10,396	12,005	6,462	8,356	6,521	8,117	7,426

AADT = annual average daily traffic.

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