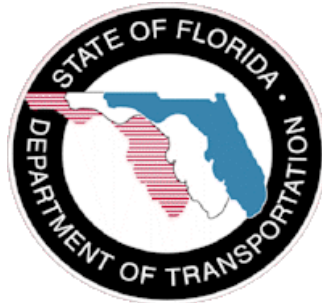


State of Florida
Department of Transportation



**Evaluation of Soil Stabilized Columns Used
for Flexible Pavement Embankment
Support and Settlement Control**

State Materials Office

FL/DOT/SMO/13-561

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BACKGROUND

SR-100 is a two-lane rural roadway in Putnam County with a history of settlement one mile east of Flora Home, between milepost 7.000 and 8.000, due to a 5 feet thick compressible peat layer located 6 feet below the pavement surface. Repeated patching of the asphalt surface over the years resulted in placement of more than 12 inches of asphalt, whereas the asphalt thickness of the surrounding area is approximately 5 inches. In 2011, a test section including Soil Stabilized Columns (SSC) and a high-strength geocomposite Stress Absorbing Membrane (SAM) also known as PavePrep was constructed in the Eastbound (EB) and Westbound (WB) lanes between mileposts 7.109 and 7.815 (i.e. between stations 375+38 and 412+62). A control section without SSC and SAM in the EB and WB lanes was also constructed between mileposts 7.815 and 8.099 (i.e. between stations 412+62 and 427+62). The layout of the project sections, schematic of grout columns arrangement and pavement structures are shown in Figures 1 through 3.

Annual evaluations of the test and control sections were conducted between 2011 and 2013 to assess the effect of grout column embankment support on pavement settlement and performance characteristics based on the Falling Weight Deflectometer (FWD), the Multi-Purpose Survey Vehicle (MPSV), and surface elevation measurements. Results indicated that the application of SSC and PavePrep SAM appears to improve the structural condition of pavement system. However, differential settlement between the grout columns and the surrounding has resulted in surface protrusions that impact the ride quality. Rut depths measured to date were negligible, but were relatively deeper for the sections treated with SSC and PavePrep SAM. The difference in rut depth also appears to be associated with the SSC protrusions.

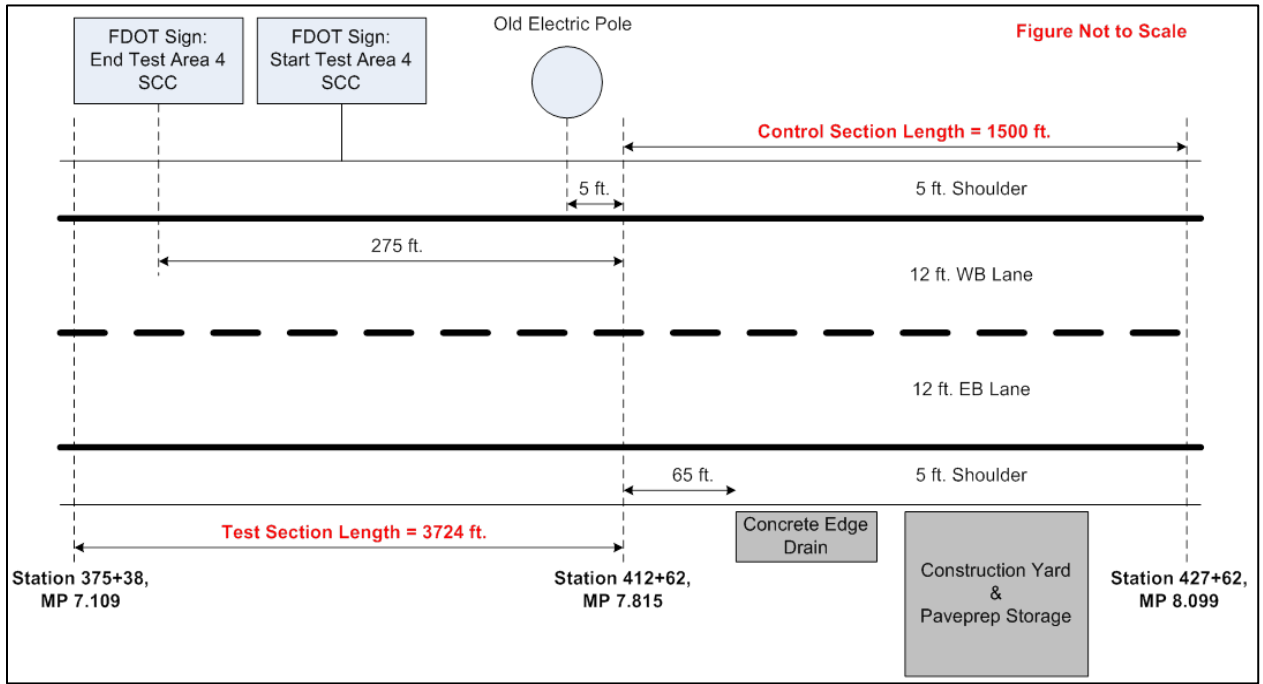


Figure 1 Section layout for SR-100 in Putnam County

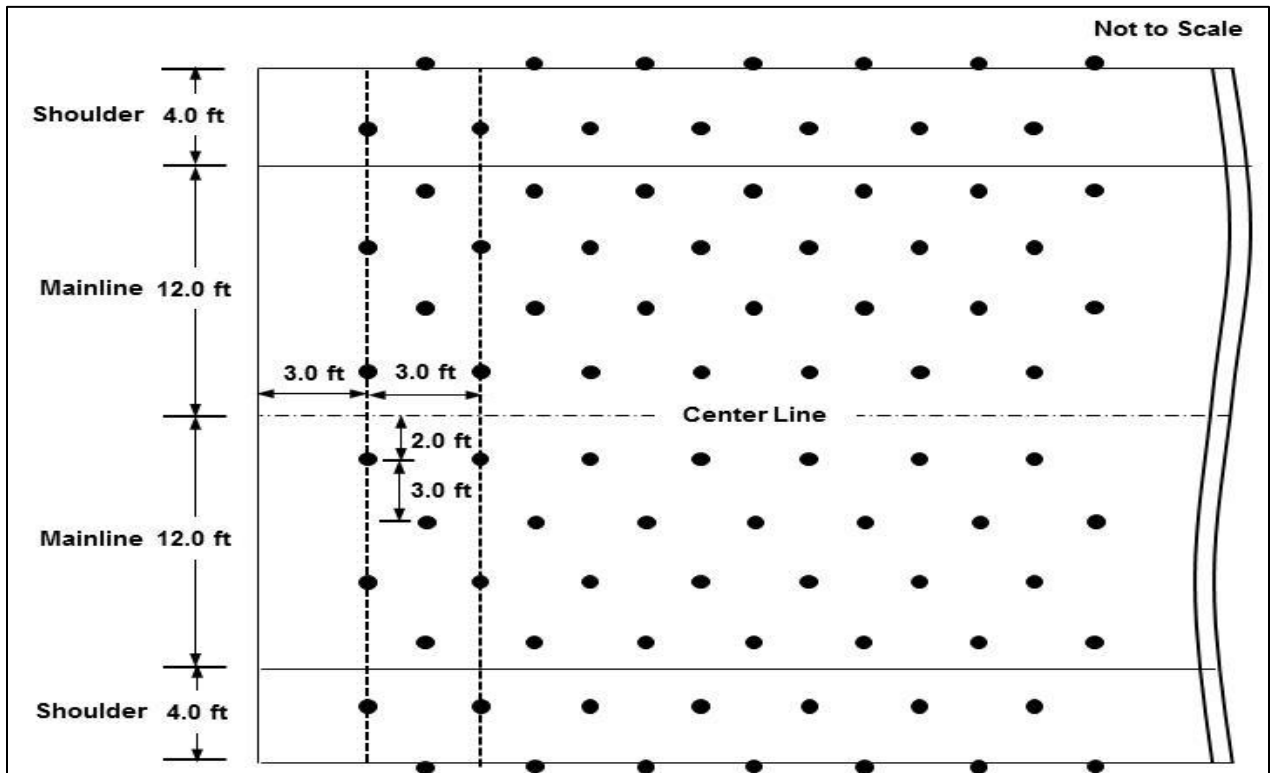


Figure 2 Schematic of grout columns arrangement

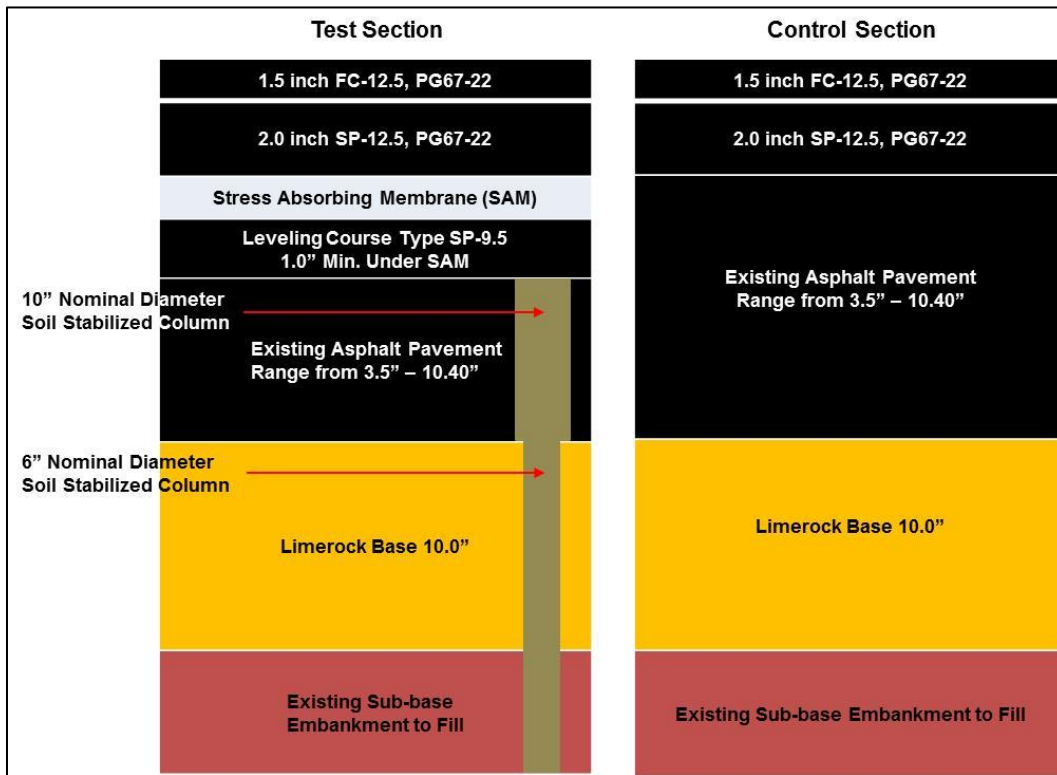


Figure 3 Pavement structures used

FIELD INVESTIGATIONS

Visual Inspection

A visual field inspection was conducted to identify any observed condition(s) related to SSC effects on future pavement performance. Signs of pavement settlement around the SSC protrusions were noted in both the eastbound and westbound test sections. These protrusions were more evident in the shoulders than in the mainlines. Figure 4 shows the surface protrusions/deformations were observed in the westbound test section and paved shoulder. The severity and extent of deterioration of paved area and natural soil along the guardrails is illustrated in Figure 5.

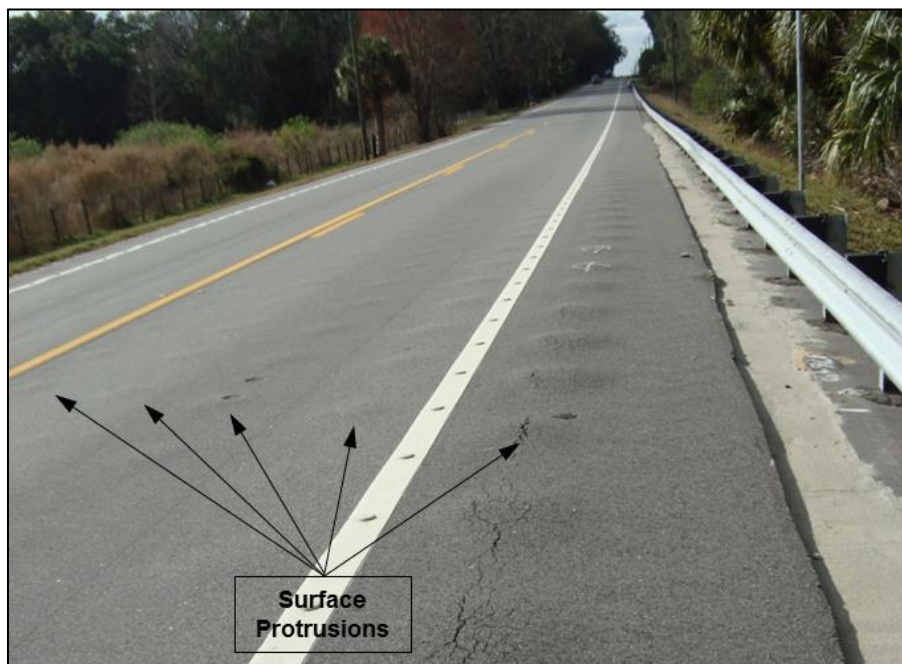


Figure 4 Protrusions in westbound test section and shoulder

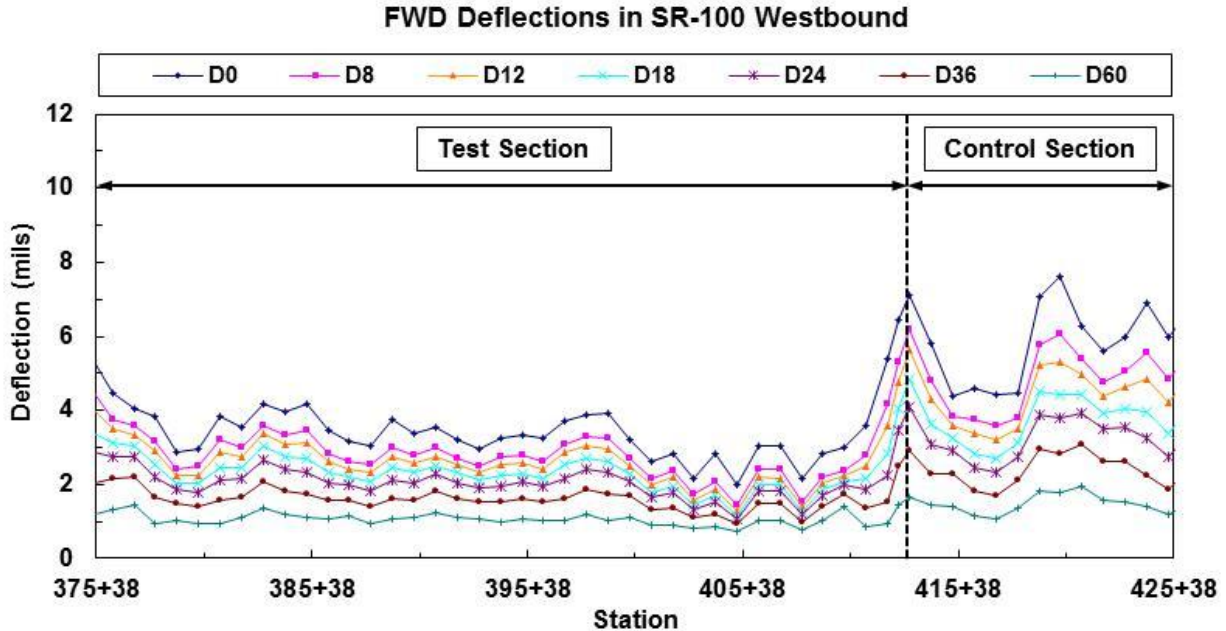
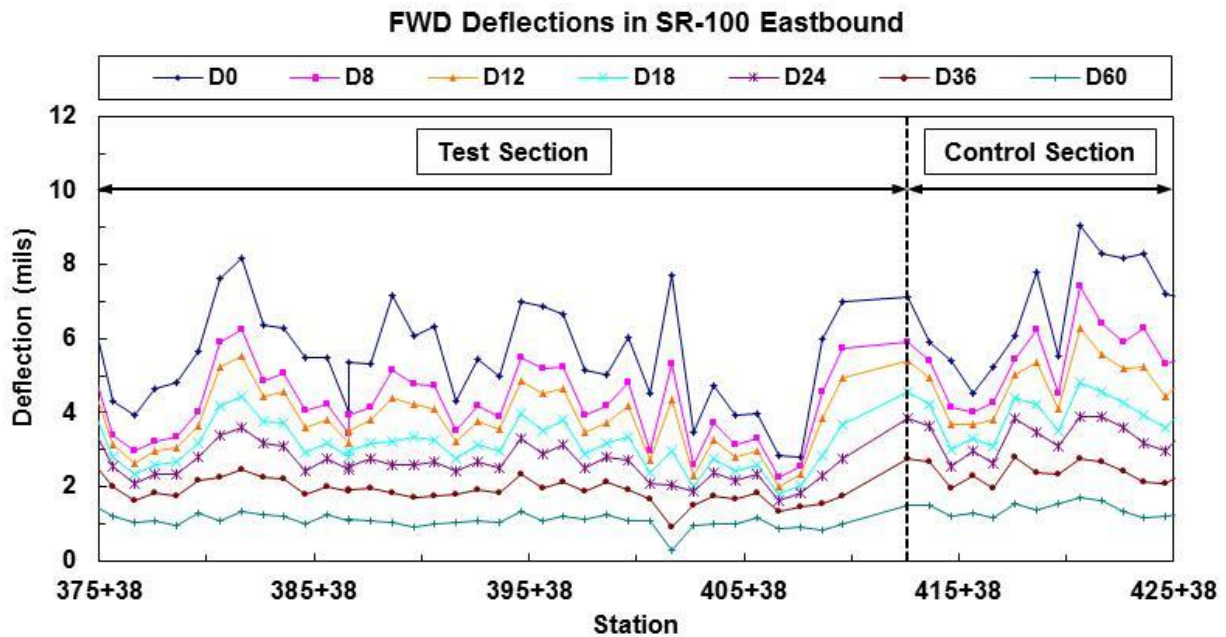


Figure 5 Unstable shoulder conditions

Falling Weight Deflectometer (FWD) Tests

To evaluate pavement support response, a Falling Weight Deflectometer (FWD) was used to apply an impact load onto the pavement surface, which is similar in magnitude and duration to a single moving truck wheel load. Seven geophone sensors placed at preset distances from the center of the loading plate along the pavement surface measure the pavement deflection. Figures

6 and 7 show the deflections measured in the eastbound and westbound lanes of SR-100 project section on January, 2013, respectively.



The relative stiffness of a pavement system may be inferred through the determination of several different deflection parameters. Deflections measured near the load plate are primarily influenced by the response of the pavement layers and near the surface, while deflections measured further from the load

plate are indicative of subgrade and embankment response. Therefore, portions of the FWD deflection basin may be used to estimate the relative stiffness of individual layers. Table 1 summarizes these deflection parameters, while Table 2 summarizes the design embankment modulus and pavement surface temperature obtained from the latest (i.e.; 2013) and previous FWD surveys.

Table 1 Summary of Deflection Parameters Measured at SR-100 in Putnam County

Test Date	Direction	Section							
		Test				Control			
		Overall Pavement Response (D0)	Asphalt Response (D0-D12)	Base Response (D12-D24)	Subgrade/Embank. Response (D36)	Overall Pavement Response (D0)	Asphalt Response (D0-D12)	Base Response (D12-D24)	Subgrade/Embank. Response (D36)
09/2011	EB	6.4	2.3	1.5	1.8	7.0	3.2	1.6	1.6
	WB	6.6	2.7	1.2	1.9	7.1	3.0	1.7	1.8
	Overall	6.5	2.5	1.3	1.9	7.1	3.1	1.6	1.7
12/2011	EB	4.0	0.9	0.8	1.7	5.3	1.1	1.0	2.4
	WB	3.3	0.7	0.6	1.6	5.4	1.0	1.0	2.6
	Overall	3.7	0.8	0.7	1.7	5.3	1.0	1.0	2.5
03/2012	EB	4.6	1.2	1.0	1.8	7.0	2.2	1.5	2.3
	WB	4.1	1.1	0.7	1.7	7.2	2.1	1.6	2.5
	Overall	4.3	1.2	0.8	1.7	7.1	2.1	1.5	2.4
01/2013	EB	5.5	1.7	1.1	1.9	7.0	2.1	1.5	2.4
02/2013	WB	3.4	0.8	0.5	1.6	6.0	1.5	1.2	2.4
	Overall	4.4	1.3	0.8	1.7	6.5	1.8	1.3	2.4

Note: Higher numbers indicate weaker material/structure.

Table 2 Summary of Embankment Resilient Modulus and Pavement Temperature

Test Date	Embankment Resilient Modulus (ksi)						Average Pavement Temperature at Time of Testing (°F)					
	Section						Section					
	Test			Control			Test			Control		
	EB	WB	Overall	EB	WB	Overall	EB	WB	Overall	EB	WB	Overall
09/2011	25.0	24.0	24.5	29.0	24.0	26.5	96.6	116.7	106.7	103.8	122.1	113.0
12/2011	28.0	28.0	28.0	18.0	18.0	18.0	66.6	67.8	67.2	66.3	70.2	68.3
03/2012	27.0	27.0	27.0	17.0	17.0	17.0	74.4	92.4	83.4	102.2	103.7	103.0
01 & 02 /2013	24.0	29.0	26.5	20.0	19.0	19.5	97.0	85.7	91.3	86.6	74.7	80.6

The results in Table 1 and Table 2 indicate that deflection response of the upper layers (i.e. asphalt and base layers) tend to fluctuate with temperature. The results also show that the SSC and PavePrep SAM treated test section provided relatively higher stiffness to the overall pavement system indicated by lower deflections and higher embankment moduli compared to the non-treated control section.

Ride Quality, and Rutting

Ride quality, represented by the Ride Number (RN) and the International Roughness Index (IRI), and surface deformation represented by rut depth (Rutting) were evaluated with an inertial profiling system (IPS). Ride Number (RN) has historically been used to estimate the subjective ride quality rated by the roadway user on a 0 to 5 rating scale, where a RN of 5 indicates a pavement with a perfectly smooth ride, and a 0 indicates a virtually impassable road. The IRI has also been used to estimate a pavement roughness or smoothness. IRI is expressed in inches/mile and represents the dynamic response of a vehicle traveling on a pavement surface which is estimated by the summation of cumulative vertical movement of the wheel divided by the distance traveled in miles.

The IPS uses three laser height sensors and two accelerometers mounted in the front of bumper to generate longitudinal profile traces in the left wheelpath (LWP), right wheelpath (RWP) and between wheelpath (BWP). The RN, IRI, and Rut Depth are reported as averages for the LWP and RWP. Table 3 summarizes the RN and IRI obtained for the test and control sections over the evaluation period. As shown in Table 3, the ride quality improved significantly after construction and has remained relatively stable over the performance monitoring period.

The results in Table 3 also show no significant difference in ride quality between the test section and control section. It should be noted that the RN and IRI results were derived from profiles obtained in the wheel paths. However, because surface deformations were identified just outside and offset from the wheel paths additional passes were conducted with the IPS host vehicle driven directly over the deformations.

Table 4 summarizes RN, IRI, and Rut Depth for each section in both travel directions, in the wheelpaths, and offset from the wheelpaths. The ride quality in the wheelpaths was

generally smooth and comparable for test and control sections. However, lower ride quality was obtained over the deformations offset from the wheelpaths (EB_Offset and WB_Offset) represented by lower RN and higher IRI, with the lowest numbers in the RWP. The surface deformations offset from the wheelpaths resulted in increased pavement roughness. This is further verified by the Power Spectrum Density (PSD) plots in Figure 8 showing a higher frequency of 1.7 feet and 3.5 feet wavelength features, which appear to correspond to the spacing of surface protrusions and grout columns. The difference in profile elevations in the EB and WB eastbound shown in Figure 9 further illustrate the effect of these surface protrusions on ride quality. In general, the measured rut depths were not significant (i.e. less than 0.1 inch for both test and control sections) but relatively higher in the test section compared to the control section.

Table 3 Summary of RN and IRI

Test Date	Direction	RN		IRI (inch/mile)	
		Test	Control	Test	Control
07/2010 (Pre-Const.)	EB	3.7	3.3	106	95
09/2011	EB	4.1	4.1	66	68
	WB	4.2	4.1	61	63
12/2011	EB	4.1	4.1	62	66
	WB	4.2	4.1	61	64
02/2012	EB	4.1	4.1	62	65
	WB	4.2	4.1	60	62
08/2012	EB	4.1	4.1	63	67
	WB	4.1	4.1	62	62
01/2013	EB	4.0	4.1	62	65
	WB	4.1	4.1	61	62

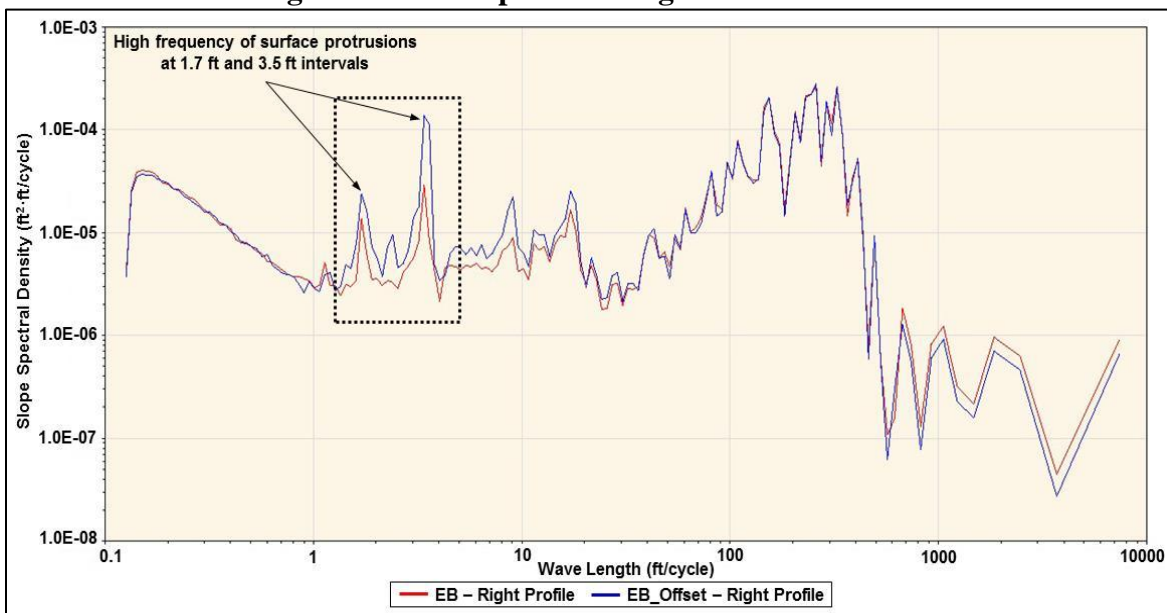
Note: Lower RN and higher IRI correspond to rougher ride.

Table 4 Summary of Ride Quality and Rutting

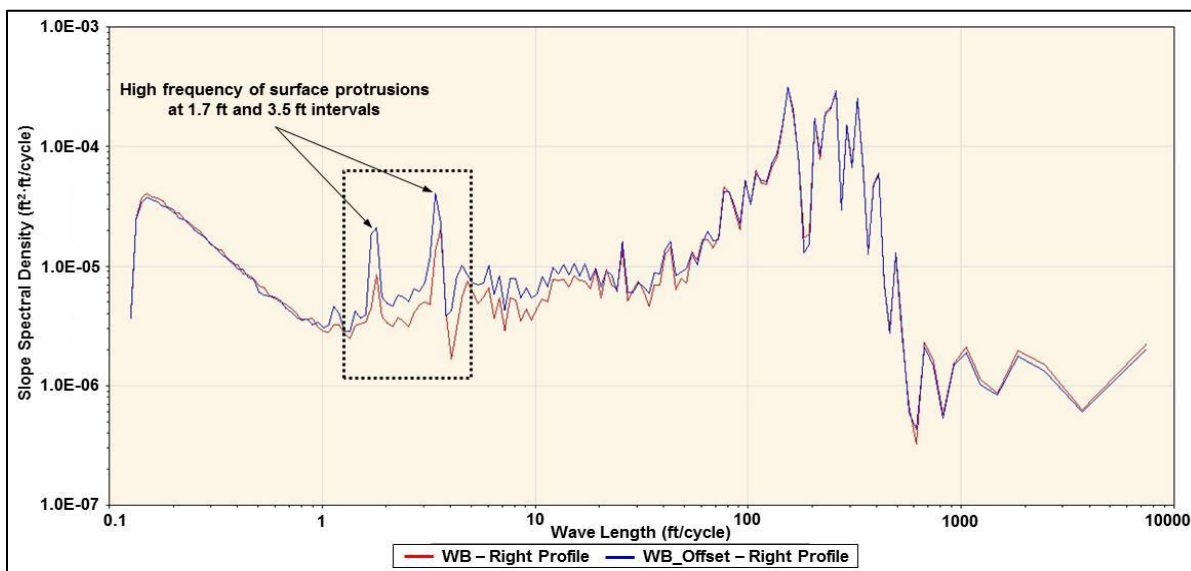
Test Date	Direction	RN				IRI (inch/mile)				Rut Depth (inch)	
		Test		Control		Test		Control		Test	Control
		LWP	RWP	LWP	RWP	LWP	RWP	LWP	RWP		
08/2012	EB	4.1	4.0	4.2	4.0	54	72	58	75	0.09	0.04
	EB_Offset	4.1	3.9	4.2	3.9	56	83	60	83	0.08	0.05
	WB	4.2	4.0	4.2	4.0	53	70	55	70	0.08	0.04
	WB_Offset	3.9	3.7	4.1	4.0	57	76	58	76	0.08	0.04
01/2013	EB	4.2	4.0	4.2	4.1	53	70	58	71	0.09	0.03
	EB_Offset	3.7	3.4	4.2	4.0	60	93	59	78	0.07	0.05
	WB	4.2	4.0	4.2	4.1	53	70	56	68	0.07	0.04

WB_Offset	3.9	3.7	4.1	4.0	57	76	58	76	0.08	0.04
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Note: Lower RN and higher IRI correspond to rougher ride.

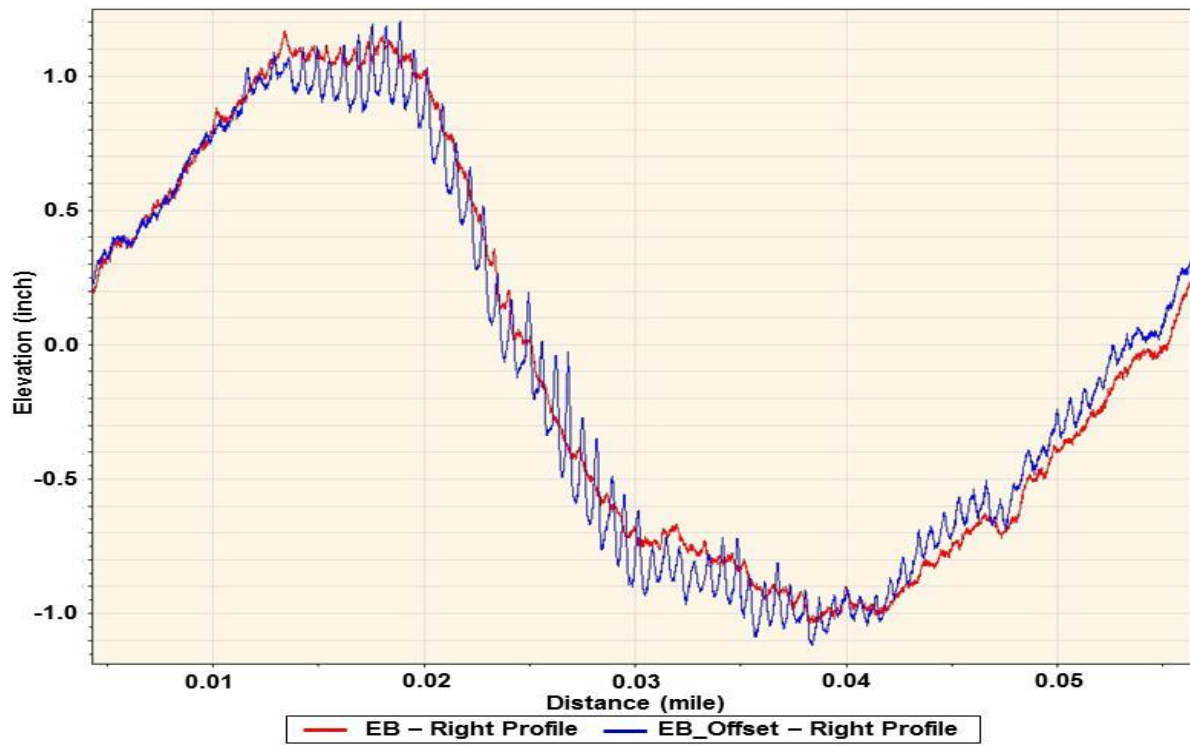


(a) Eastbound right profile

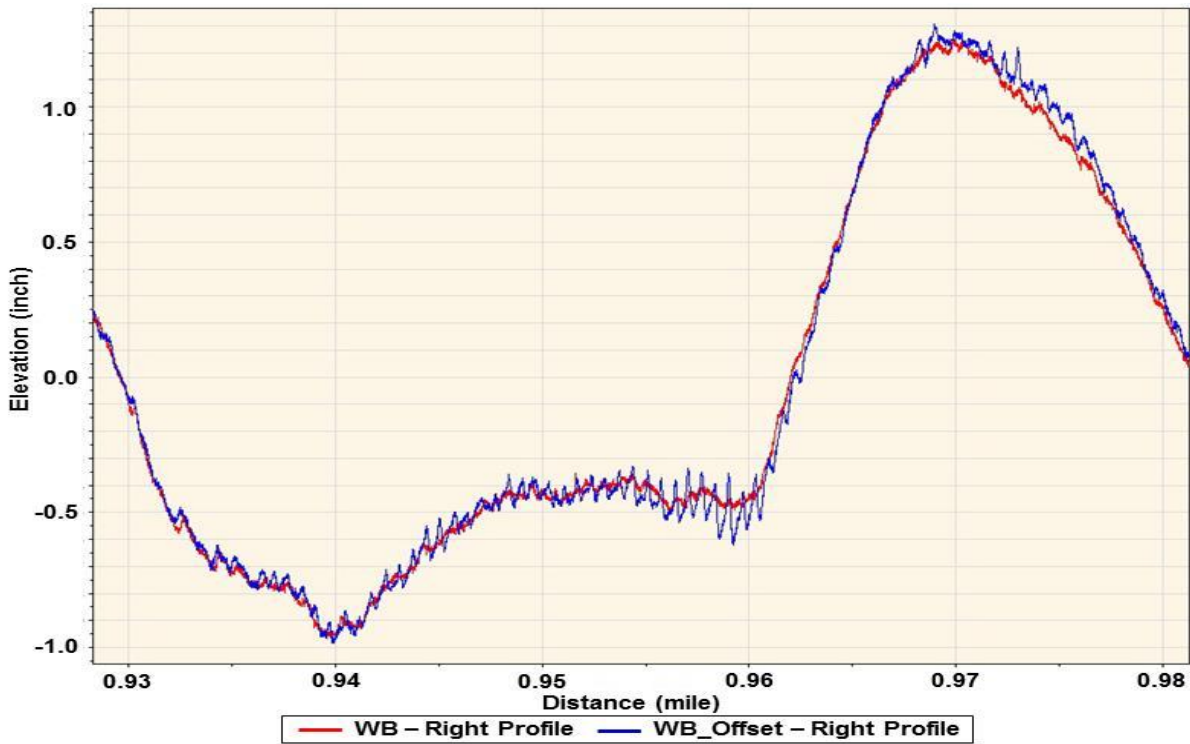


(b) Westbound right profile

Figure 8 Surface protrusions depicted by higher frequency of short wavelength features



(a) Eastbound right profile



(b) Westbound right wheelpath profile

Figure 9 Test section sample profile elevation in right wheelpath and offset from right wheelpath

Elevation Data

Elevation measurements using stadia rod and level were performed to determine whether the roadway continued to settle after the installation of SSC and PavePrep SAM. Figures 10 and 11 show the elevation measurements in the center of each lane for the eastbound direction and westbound direction, respectively.

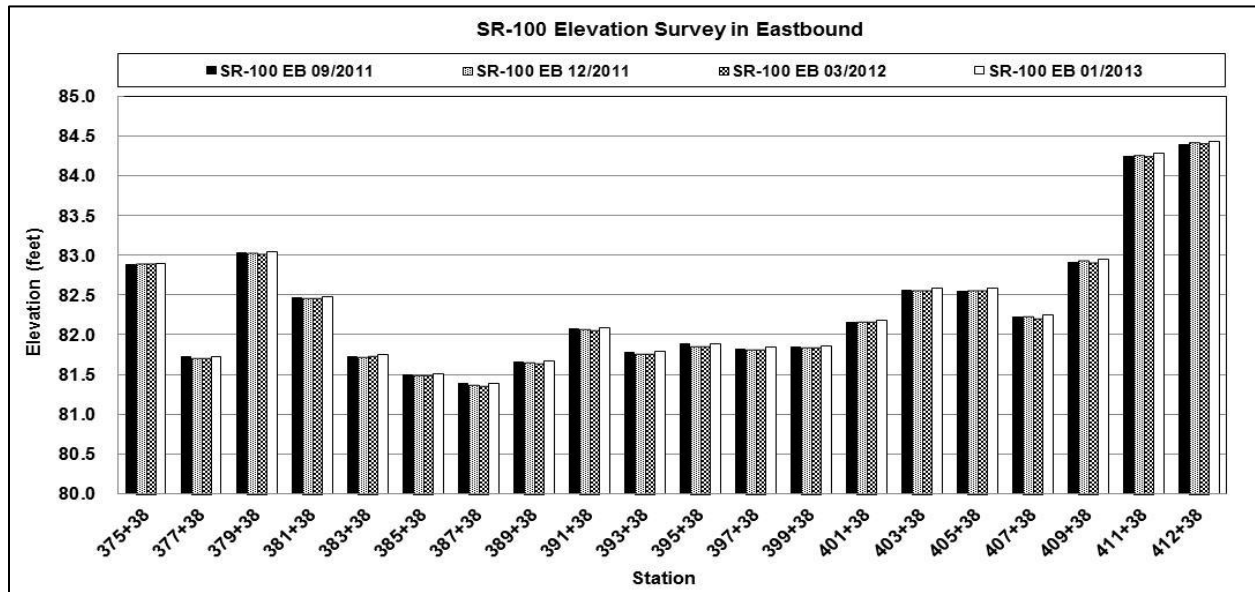


Figure 10 Elevation measurements of SR-100 eastbound

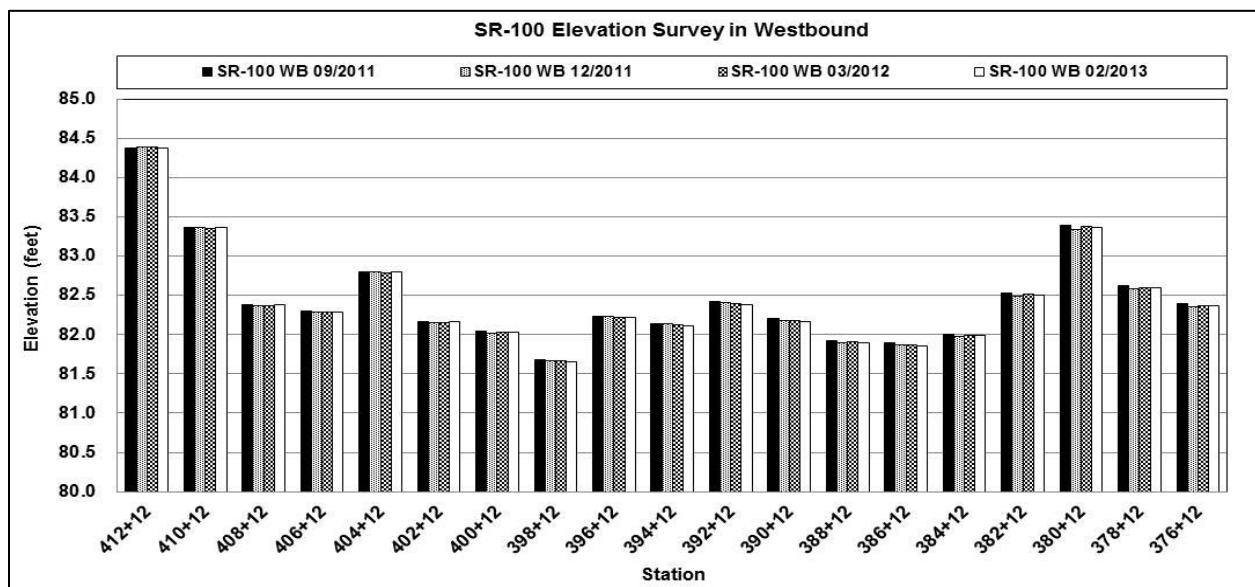


Figure 11 Elevation measurements of SR-100 westbound

SUMMARY AND CONCLUSIONS

A section of SR-100 in Putnam County was monitored for performance to assess the efficacy of using SSC and PavePrep SAM treatment to provide subgrade support and controlling pavement settlement. A summary of the findings and conclusions is presented below:

- The SSC and PavePrep SAM increased the overall stiffness of the pavement as indicated by lower deflections and higher embankment moduli when compared to the control section.
- Although the SSC and PavePrep SAM improved the pavement stiffness, differential settlement between the grout columns and the surrounding soil resulted in surface protrusions and deformations.
- Both the test and control sections exhibited similar pavement smoothness within the wheel paths. However, the SSC test section had a rougher ride when the evaluated profile was offset slightly from the wheel paths directly over the surface protrusions and particularly the RWP. Severe shoulder surface protrusions were likely exacerbated by the unstable shoulder and slope of the natural embankment.
- Rut depths measured to date were negligible, but relatively higher for the SSC test section compared to the control section.