State of Florida
Department of Transportation

US 27/SR 25 Pavement Evaluation

FDOT Office
State Materials Office

Research Report Number
FL/DOT/SMO/11-542

Author
Abdenour Nazef, P.E.

Date of Publication
May, 2011

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

The Central Pavement Management Office requested that the State Materials Office perform a pavement evaluation of a one mile long section of US 27/SR 25 in Palm Beach County. The primary objective of the evaluation was to assess whether pavement cracks initiated from the top or bottom of the asphalt. Performance was also evaluated in terms of pavement stiffness, rut depth, and roughness.

Deflection analysis indicates a resilient modulus of 18,000 psi is representative of in-situ subgrade support condition. Variability in pavement thickness was significant and ranged from 4.6 to 10.6 inches. Surface distress was primarily light to moderate severity wheel path fatigue cracking. Stress-strain analysis confirmed the observed mode of failure. Generally, bottom up cracking was found in the moderately thick sections, and top-down cracking in the thickest sections. The thinnest cores showed no sign of cracking. Rutting and roughness was of an acceptable level in the inside lane, but was severe in the outside lane. This increases surface water retention with a propensity for hydroplaning (1). A short-term mitigating solution(s) is recommended to preserve the operational safety of the roadway until the rehabilitation project gets under way.

INTRODUCTION

Background

A one mile section of US 27/SR25 was originally excepted out of a ten-mile resurfacing project (403617-1-52-1) through a Joint Participation Agreement (JPA) between the Florida Department of Transportation (FDOT) and the South Florida Water Management District (SFWD). The JPA postponed the resurfacing for the one mile section of the project to allow for the construction of a bridge. This was to prevent damage resulting from the bridge construction activities to an otherwise new pavement. However, in February of 2010, the bridge construction project was suspended and the JPA was voided, which allowed the FDOT to reprogram the resurfacing of this one mile section which is scheduled for 2012. The rest of the resurfacing project was completed in August, 2007.

Objective

The objective of this study is to investigate the type and failure mechanism in the form of top-down and bottom-up crack initiation for a one mile section of US 27/SR 25 located in Palm Beach County, Florida.

PROJECT DESCRIPTION

US 27/ SR 25 is located in Palm Beach County, Florida, south of Lake Okeechobee (Figure 1). The section is located south of the city of South Bay, south of County Highway 827.

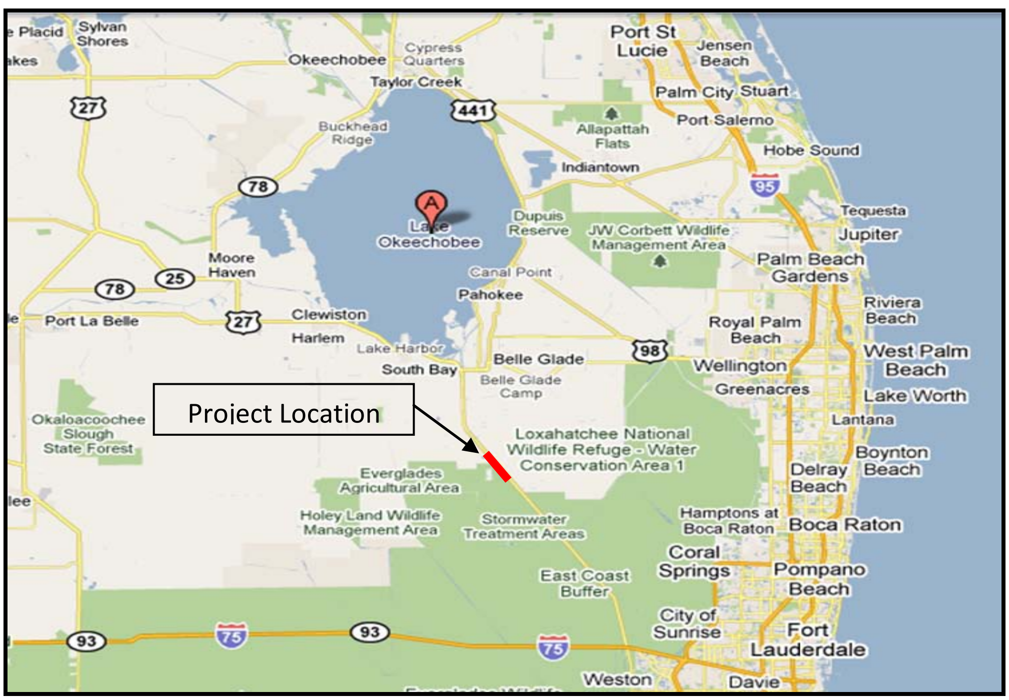


Figure 1 Project Location

The section is a rural four-lane divided roadway (two lanes in each direction) with 12 ft lanes, 4 ft paved inside shoulder, 10 ft paved outside shoulder, and a grassy median. It borders a drainage canal to the east of the facility and has a posted speed limit of 65 mph (Figure 2). The section is in the middle of a sugar cane farming area with an Average Annual Daily Traffic (AADT) between 7,200 and 9,100 vehicles. The truck factor ranged between 30 and 41% for the past ten years, 63% of which was in the two northbound lanes. The northbound passing lane (R1) was reconstructed in the late 1980's at the same time as the two southbound lanes (L1 and L2). The northbound travel lane (R2) was resurfaced several times in the past and is built over the same muck embankment.

Figure 2 US 27/SR 25 Northbound Lanes (MP 11.916)

Resurfacing of this one mile section is programmed for December, 2012. The scope calls for variable milling of both lanes and shoulders, with overbuild and cross-slope correction. The resurfacing includes 0.75 in of FC5 with 1.5 in of type SP in R1; 0.75 in of FC5, 2 in of type SP, and 0.75 in of Asphalt Rubber Membrane Interface (ARMI) in R2 (Figure 3).

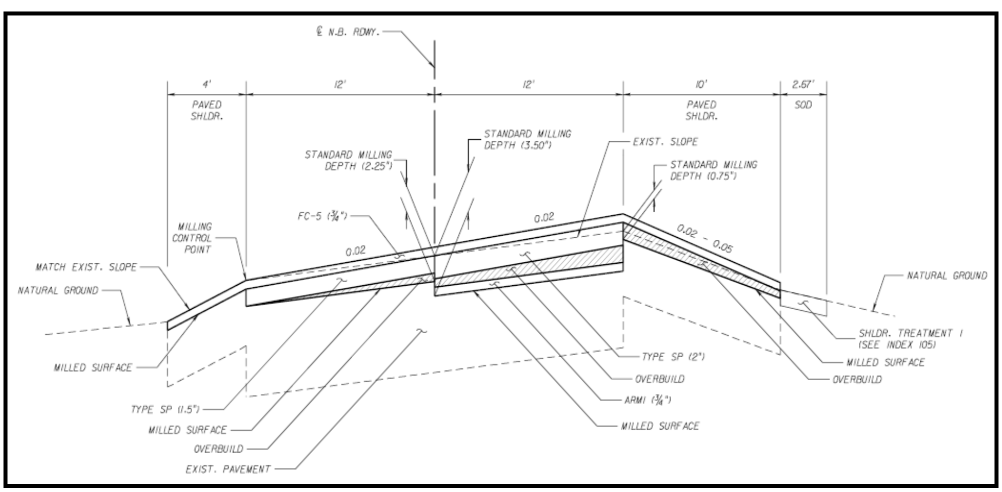


Figure 3 US 27/SR 25 northbound lanes proposed cross-section

PAVEMENT EVALUATION

The State Materials Office (SMO) conducted a pavement evaluation to determine the type of cracking mechanism as well as other pavement performance parameters. Evaluation included deflection testing with a Falling Weight Deflectometer (FWD); roughness, permanent deformation (i.e.; rutting) and pavement imaging using a Multi-Purpose Survey Vehicle (MPSV); and thickness determination using a six-inch coring rig, and a Ground Penetrating Radar (GPR) unit.

Deflection

Deflection measurements were conducted every 0.01 mile interval in the right wheel-path of R2 using a trailer mounted FWD (Figure 4). The test configuration included a 9 kip load on a 12 inch plate and seven deflection sensors placed at 0, 8, 12, 18, 24, 36, and 60 inches from the load plate (1).

Figure 4 Falling weight deflectometer.

Figure 5 illustrates the pavement system deflection response and corresponding stiffness. A modulus (Mr) value of 18,000 psi was determined to represent the subgrade in-situ stiffness as determined according to the Florida Flexible Pavement Design Manual.

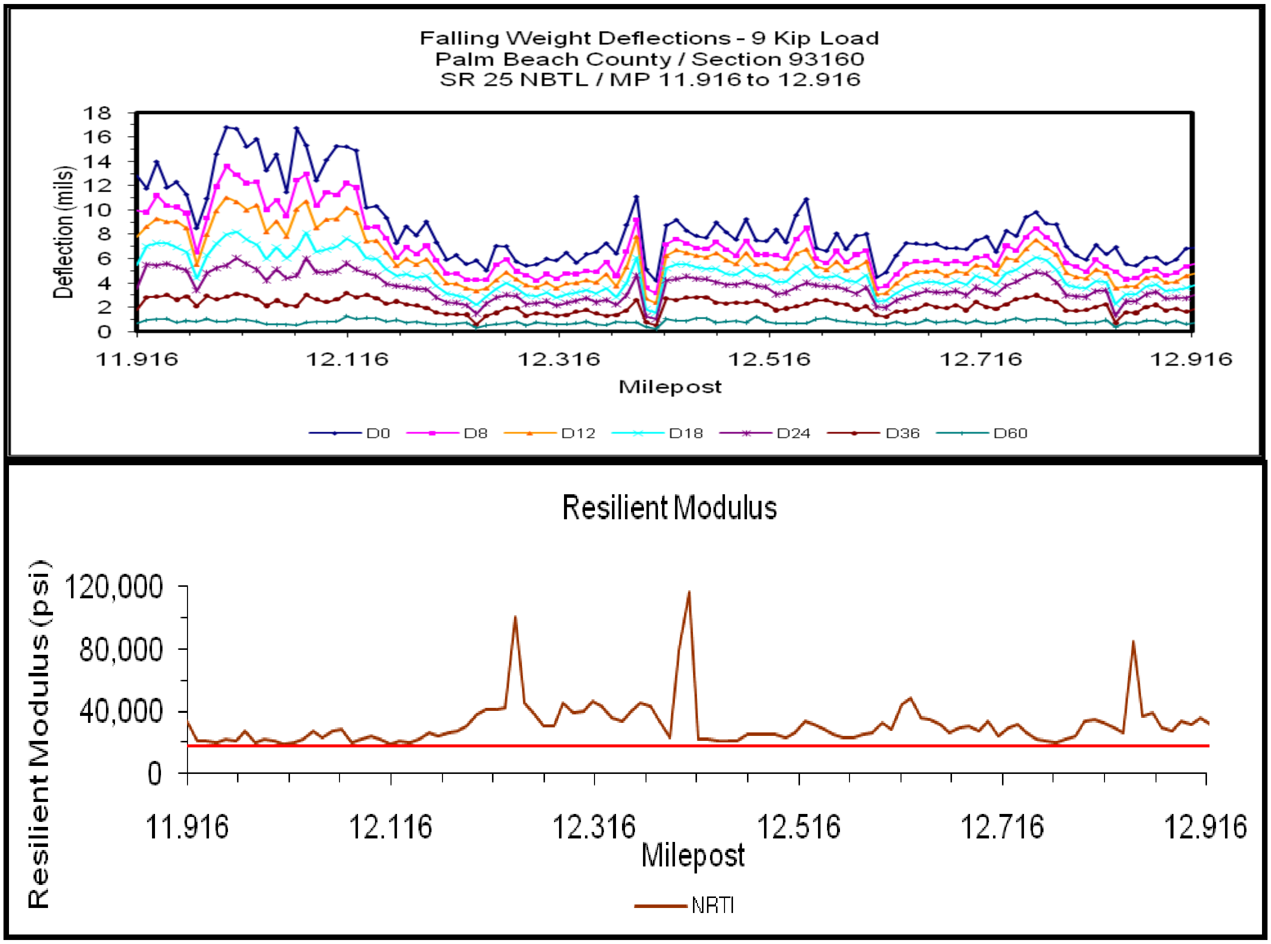


Figure 5 FWD deflections and in-situ subgrade modulus

Permanent Deformation

Permanent deformation expressed as the average rut depth in both wheel-paths was collected automatically using an inertial profiling system on board of the MPSV, with a profile sampling rate of 0.68 in reported at tenth-mile intervals. As Figure 6 shows, rutting was much more significant in R2, which contributed to the higher roughness. Severe rutting results in surface water retention and potentially hazardous driving conditions and hydroplaning (2).

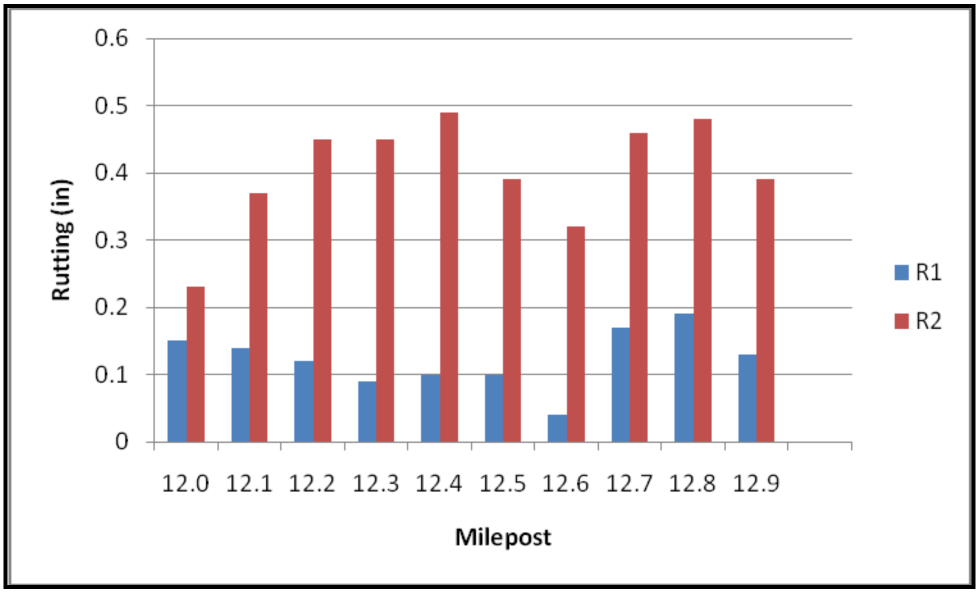


Figure 6 Rutting

Roughness

Roughness (or lack of smoothness) is expressed here in terms of the Mean Roughness Index (MRI), which represents the average International Roughness Index (IRI) for both wheel-paths, reported for every tenth-mile interval. The higher the MRI, the rougher the ride quality. As Figure 7 clearly illustrates, roughness was much more severe in R2. This explains the reason drivers on this roadway prefer to stay in the inside lane which provides a smoother ride quality.

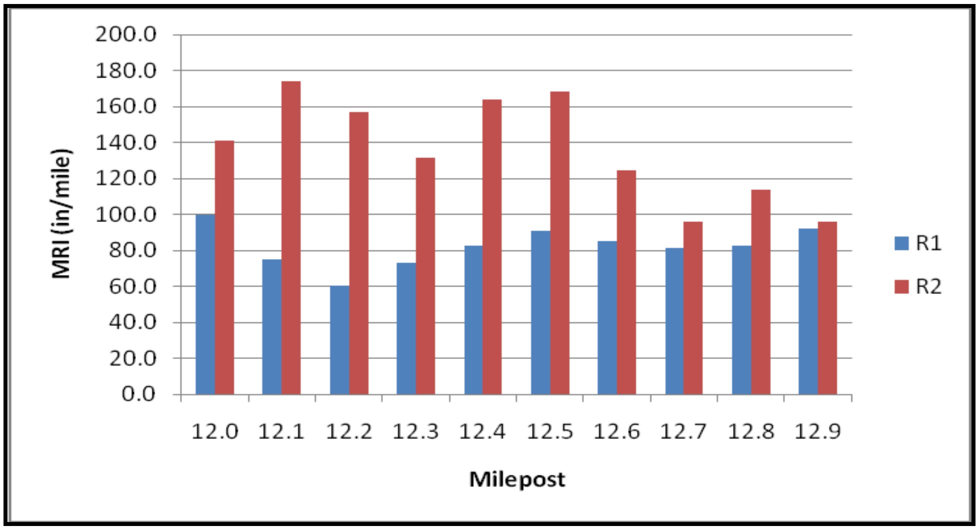


Figure 7 Roughness

HMA Core Thickness

Six-inch diameter cores were taken in the outside wheel-path of R2 to determine HMA thickness and crack initiation. Examination of the cores revealed various cracking conditions including no discernable cracking, bottom up cracking, top-down cracking, and instances where cracking reflected through the entire core length (Table 1). Absence of cracks was noted in the shortest cores ranging between 4.6 and 5.7 inches. Bottom up cracking was mainly observed in mid size cores ranging from 6.4 to 8.1 inches. Top-down cracking was observed exclusively in the longest cores ranging between 9.1 to 10.6 inches.

Table 1 Core Measurements

Core Id	Mile - Post	Avg. Thickness (inch)	Avg. Crack Depth (inch)	Crack Initiation	Surface Cracking	Remarks
O	12.835	4.6	NA	None	None	
I	12.390	5.0	NA	None	None	Box Culvert
J	12.396	5.7	NA	None	None	
N	12.834	5.7	5.7	Full depth	Transverse	Change in base thickness
F	12.139	6.2	6.2	Full depth	Transverse	Change in base thickness
C	12.038	6.4	1.8	Bottom up	None	
B2	12.001	6.5	2.3	Bottom up	None	OWP
B1	12.000	6.8	2.3	Bottom up	None	BWP
D	12.083	7.4	7.4	Full depth	Longitudinal	
F*	12.139	8.0	8.0	Full depth	Transverse	Change in base thickness
E	12.136	8.1	2.3	Bottom up	None	
H	12.376	8.2	NA	None	None	
N*	12.834	9.0	9.0	Full depth	Transverse	Change in base thickness
A	11.950	9.1	7.6	Top down	Longitudinal	
M	12.736	9.7	2.5	Top down	Longitudinal	
L	12.649	10.0	1.8	Top down	Transverse	
K	12.576	10.6	2.0	Top down	Longitudinal	

F*, N*- Same cores as F and N, but different lengths (depending on side measured). This is due to variability in base thickness.

Figure 8 illustrates the sampled cores and modes of cracking observed. In general, cracks in pavements with asphalt thickness greater than 8 inches tended to originate at the surface as a result of excessive stresses due to binder aging and tire-pavement interaction. Pavement areas with HMA between 6 and 8 inches, failure was typically evidenced by bottom-up cracking due to higher tensile strain at the bottom of the HMA. Cores with full depth cracking had transverse surface cracking typically associated with thermal stresses. These cracks were wide, with a fair amount of trapped fines, an indication that failure may have occurred earlier on compared to the rest of the cores. Laboratory analysis of core tensile strength and modulus would have been desirable, but is beyond the scope of this evaluation.


O (4.6 in)


I (5.0 in)


J (5.7 in)

(a)


C (6.4 in)


B2 (6.5 in)

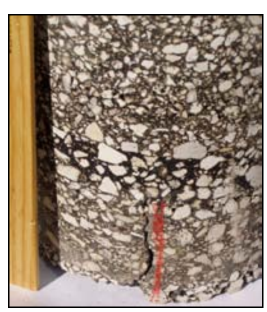

B1 (6.8 in)


E (8.1 in)

(b)


A (9.1 in)


L (9.7 in)


M (10.0 in)


K (10.6 in)

(c)

D (7.4 in)

F (6.2/8.0 in)

N (5.7/9.0 in)

(d)

Figure 8 Cracking in Cores (a) No cracking, (b) Bottom up; (c) Top-down; (d) Full depth

Ground Penetrating Radar (GPR) Pavement Thickness

FDOT's GPR system consists of a Geophysical Survey Systems, Incorporated (GSSI) SIR 20 and two 2.0 GHz air-launched antennas (3). The GPR was used to estimate the thickness of the hot-mix asphalt (HMA) along the section of interest.

Data was collected at 55 mph, using a 1ft sampling interval with the antennas positioned along the inside and outside wheel-paths (Figure 9). HMA thickness was estimated by averaging the six GPR readings closest to each core location and was then compared to actual core thickness (Figure 10). On average, the GPR estimated HMA thickness deviated by 1.0 inch from core thickness. A previous FDOT study on the accuracy of the GPR system showed that on average the system can predict asphalt thickness within approximately 8%. The GPR estimated thickness for US 27 is a relatively good match considering the GPR system was not calibrated against a core value, in addition to compensating error due to data averaging.

Figure 9 FDOT GPR System

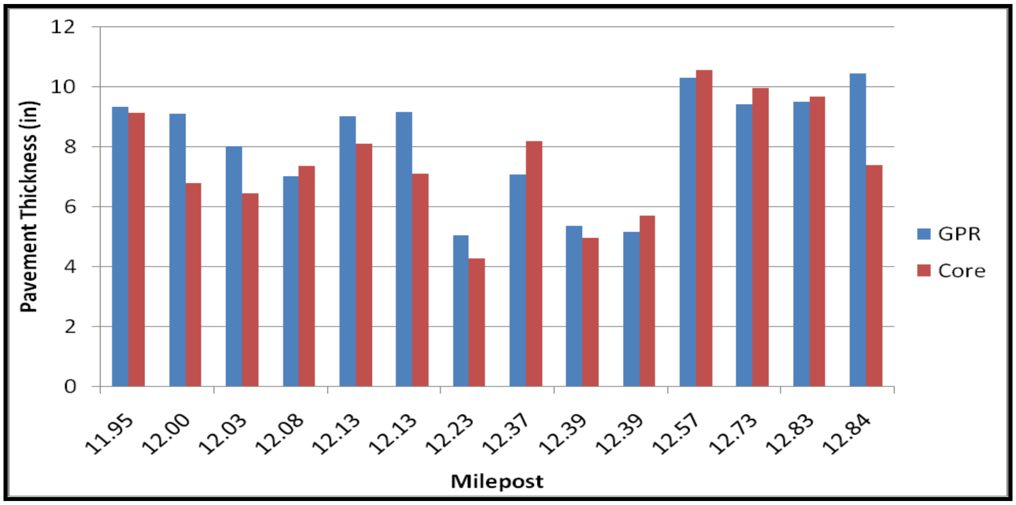
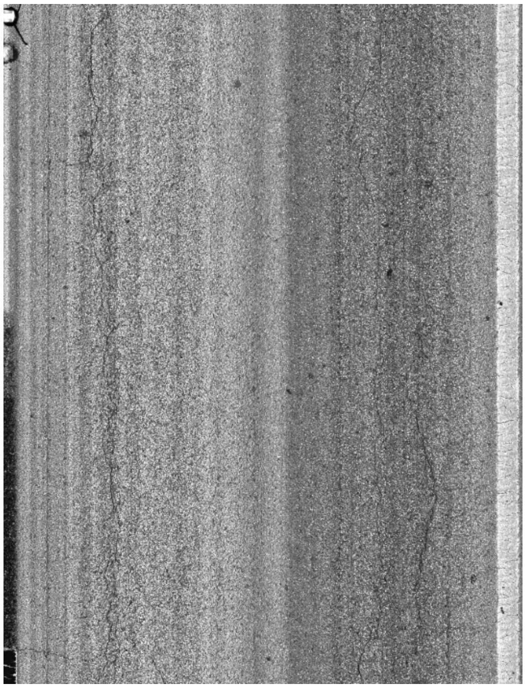
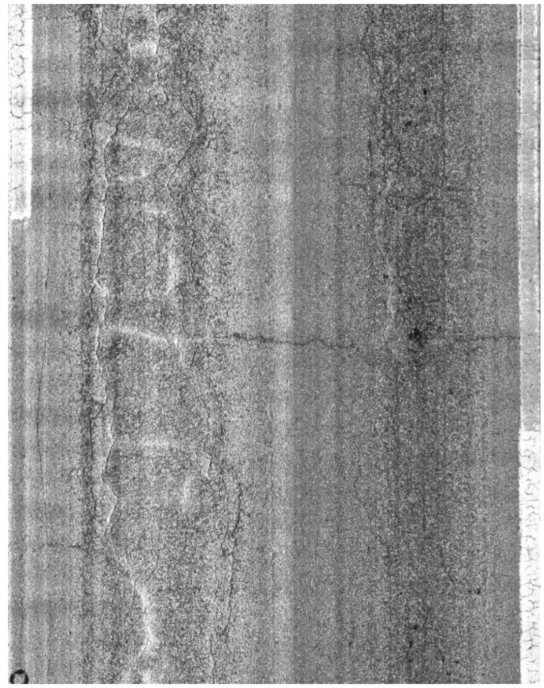


Figure 10 HMA thickness by GPR

Cracking

Surface cracking was evaluated using the Labview Image Crack Analysis Program, an in-house program developed for experimental projects. Pavement images collected with the MPSV in R2 were imported and scanned by the program. In the manual mode, the user analyzes each image by tracing the extent of the distress, selects the distress and severity types using a drop down menu and mouse activated selection tools. The program tallies and summarizes the measurements in an Excel spreadsheet. The cracking was of the fatigue type confined mainly to the wheel-paths, 75% of which was moderate and 15% was light severity (Figure 11). Pumping was also observed mainly in the wheel-paths.





(a) **(b)**

Figure 11 Fatigue cracking in wheel-paths (a) light, (b) moderate

ANALYSIS

Back-calculation

To characterize the stiffness of the pavement system, elastic moduli were estimated by back-calculating the 9 kip FWD deflection data using the Modulus 6.1 computer program based on a three-layer elastic system (Table 2). Layer thicknesses used in the three-layer system analysis consisted of an HMA layer represented by the core thickness, a 24 inch limerock layer for the combined base and subgrade, and a semi-infinite layer for the embankment. A Poisson's ratio of 0.35, 0.40, and 0.45 was assumed for the HMA, base/subgrade, and embankment, respectively.

Table 2. Back-calculated layer moduli

Core Thickness (in)	Mean Modulus Values (ksi)		
	HMA	Base/Subgrade	Embankment
4.6	2050	38	37
5	1780	35	37
5.7	1350	33	38
6.2	1110	32	38
6.4	1040	31	38
6.5	1010	31	38
6.8	920	30	39
7.4	790	28	39
8	680	27	39
8.1	670	27	40
8.2	650	27	39
9	570	26	39
9.1	560	25	39
9.7	490	23	42
10	490	25	38
10.6	450	25	36

Stresses and Strains

A mechanistic analysis of the existing pavement system was performed using the BISAR computerized elastic-layer pavement analysis program. This was done to estimate the critical stresses and strains at the bottom of the HMA to verify the cracking mechanism observed in the core samples. The pavement was modeled as a three-layer linear elastic system consisting of an HMA surface and structural layer represented by the core length, a composite base and subgrade layer of 24 inches, and a semi-infinite layer for the embankment. All layers were assumed to be homogeneous, isotropic and linearly elastic. The static loading configuration consisted of a dual-tire represented by two circular areas loaded at 4,500 lb/tire each and an assumed 100 psi tire pressure. As Figure 10 shows, the tensile strains were higher in the mid-size cores resulting in bottom-up cracking compared to the top-down cracking observed in the thickest cores.

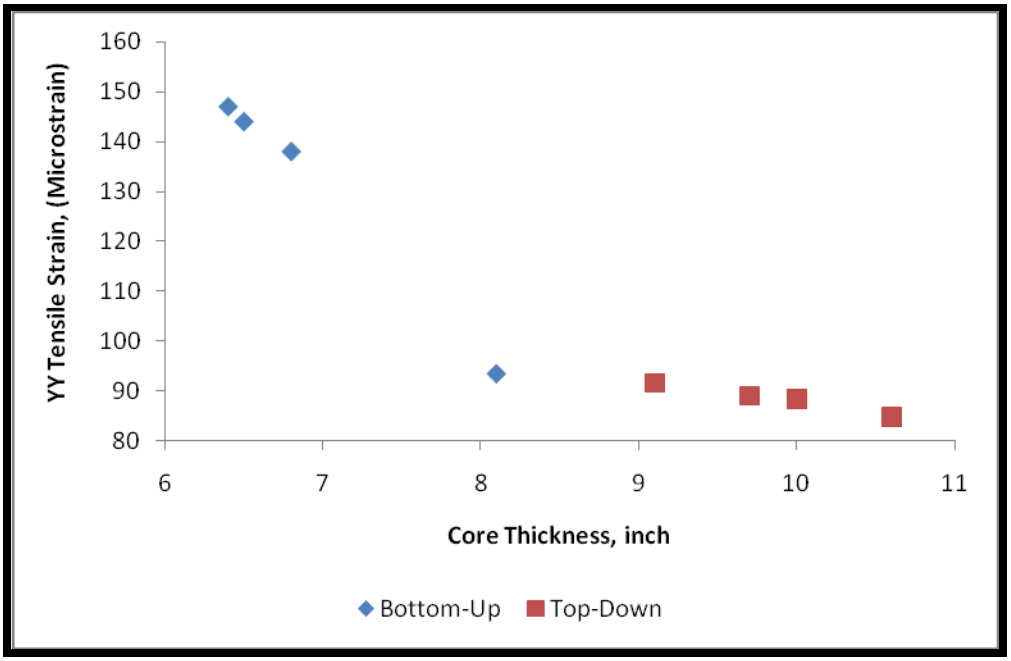


Figure 12 Critical tensile strain at bottom of HMA

CONCLUSION

Bottom-up cracking was prevalent in areas where the HMA layer thickness ranged between 6.4 and 8.1 inches; top-down cracking was observed where the pavement was the thickest (9.1 to10.6 inches), and where surface cracking was longitudinal resulting mainly from stresses due to pavement-tire interaction. Cores taken in areas where the HMA was the thinnest (4.6 to 5.7inches) showed no sign of cracking. However, base/subgrade stiffness was highest in these areas. There was significant rutting in the outside lane which requires immediate attention.

References

1. J. Greene, *Evaluation of Geosynthetics to Improve Performance of Flexible Pavement Systems,* FDOT Research Report, March, 2011.

2. Pavement Interactive, http://pavementinteractive.org/index.php?title=Rutting.

3. C. Holzschuher, H. S. Lee, J. Greene, *Accuracy and Repeatability of Ground Penetrating Radar for Surface Layer Thickness Estimation of Florida Roadways*, FDOT Research Report FL/DOT/SMO/07-505, April, 2007.