Technical Memorandum

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State Route 138—Test Site Evaluation

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and

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ITS/PRC Technical Memorandum

To: Mr. Bruce Rymer, P.E.
Caltrans

From: David Bush, P.E.
Dynatest Consulting, Inc.

Date: 6/5/2001

Re: State Route 138 – Test Site Evaluation

Bruce:

The following is a draft report of the tests conducted on HWY 138 on April 26th and 27th 2001 and the results. This information was used to evaluate the structural uniformity of the potential test site.

If you have any questions please contact me at (805) 648-2230 or at my e-mail address: dbush@dynatest.com.

Dave

Cc: Dr. John Harvey, P.E. and Clark Scheffy

1.0 INTRODUCTION

On April 26 and 27, 2001 destructive and non-destructive tests were conducted on California State Route 138 between milepost MP16.5 and MP20.0 located between Gorman and Lancaster, CA. The starting station for the project was Station 10140.7 (m) and the ending station was Station 17141.7 (m). The entire section length is approximately 7.0 kilometers. For purposes of discussion, the pavement was divided into 15 sections based primarily on the deflection analysis results, as shown in Table 1.

Table 1 HWY 138 Sections (from FWD Analyses)

Section	Length (m)	From Station (m)	To Station (m)
1	250	10141	10391
2	775	10392	11166
3	525	11166	11691
4	400	11691	12091
5	225	12091	12316
6	800	12316	13116
7	525	13116	13641
8	500	13641	14111
9	350	14111	14491
10	370	14491	14861
11	400	14861	15261
12	395	15261	15656
13	685	15656	16341
14	300	16341	16641
15	500	16641	17141

The purpose of these tests was to evaluate the structural uniformity of the pavement. This project was organized through the Strategic Plan Research Services Implementation Studies Program. This was a joint effort between Caltrans (Headquarters and District 7), the University of California at Berkeley Pavement Research Center (UCB), and Dynatest Consulting, Inc. (DCI) located in Ventura, California.

In order to ensure safety for the crew collecting the test data, traffic control was supplied by Caltrans out of the District 7 Lebec Maintenance Station. The researchers would also like to thank Mr. Chuck Webster who was extremely helpful in the organization of the traffic control and has contributed significantly to the CAL/APT program over the past 4 years.

2.0 STATEMENT OF OBJECTIVES

Caltrans' interest in the test section described in Section 1 is primarily for research. It is the goal of Caltrans to use this site for two purposes, 1) as a site to compare and track maintenance treatment performance, and 2) to record traffic noise associated with each maintenance treatment.

The objective of the UCB/DCI team was to evaluate the structural uniformity and consistency of the proposed test section through the use of certain destructive and non-destructive test procedures. After all of the tests had been completed and the results determined, recommendations would be given to Caltrans on the use of this site as a test section.

3.0 DATA COLLECTED

The evaluation of the section on State Route 138 included four (4) separate elements: 1) a visual condition survey, 2) coring of the pavement, 3) Dynamic Cone Penetrometer (DCP) testing and 4) Falling Weight Deflectometer (FWD) testing.

3.1 Visual Condition Survey

A visual condition survey was conducted on the entire project. The purpose of the survey was to determine what type(s) of distress were visible on the pavement surface. The pavement was divided into 50-meter sections and both lanes in each section were evaluated at the same time. The survey process consisted of moving along the shoulder and observing from the back of a truck at about 10 km/h, and walking short sections. A picture of typical pavement distress is presented in Figure 1. The distresses observed are summarized in Table 2.

Figure 1. Typical distress visible on State Route 138.

Table 2 Condition Survey of State Route 138 Test Site

Section	Actual Station (m)	Other Reference	Eastbound						Westbound					
			Surface Type	Ru	Fa	Tr	Lo	Ra	Surface Type	Ru	Fa	Tr	Lo	Ra
1	10290	Core 23	CS	1,2	3	1	1	1	CS	1,2	3	1	1	1
1	10340		CS	1,2	3	1	1	1	CS	1,2	3	1	1	1
1	10390		CS		1	1			CS		3	1		
2	10440	C 24-28	CS		1	1		1	CS		1	1		1
2	10490	Core 1, Photo 4	CS	1	3	1			CS	1		1		
2	10540		CS		1,2,3	1			CS		1,2	1		
2	10590	Photo 6	CS		3	1	1		CS		3	1	1	
2	10640	Photo 10	CS		2,3	1			CS		2,3	1		
2	10690		CS		1,3	1			CS		1			
2	10740	Core 2, Photo 11	CS		3	1		1	CS			1		
2	10790	MP16.50	CS		3				CS	1,2	3			
2	10840		CS		1	1			CS		3			
2	10890	P16	CS		2,3	1			CS	1	3	1		
2	10940		CS	1	2,3	1			CS	1	3			1
2	10990	P 18	CS	1	3				CS	1	3	1		

Section	Actual Station (m)	Other Reference	Eastbound						Westbound					
			Surface Type	Ru	Fa	Tr	Lo	Ra	Surface Type	Ru	Fa	Tr	Lo	Ra
2	11040		CS	1	3			1	CS	2	3	1		
2	11090		CS		2,3	1			CS	2	3	1		
2	11140	Core 3 Photo 22	CS		2	1			CS	1	1,3	1		
3	11190	C 29-32	CS		1,2				CS		3	1		1
3	11240		CS		1				CS		1			
3	11290	Photo 23	CS		1,2,3	1			CS	2	1,2,3	1		
3	11340		CS		1	1			CS	1,2	3	1		
3	11390	Core 4 Photo 1	CS		1,2,3	1			CS		1,2	1		
3	11440		CS		2,3	1			CS	2	1,3	1		
3	11490		CS		1,2	1			CS		2,3	1		
3	11540		CS		1,2	1			CS	2	3	1		
3	11590		CS	1,2		1			CS	2		1		
3	11640	4	CS		1	1			CS	2	2,3			
3	11690	Core 5	CS			1			CS	2	3	1		
4	11740	Core 33	CS	2	1,2	1			CS	2	1,2,3	1		
4	11790	Core 34	CS		1,2,3	1			CS	1,2				
4	11840		CS		1,2	1			CS	1	3	1		
4	11890		CS		1,2	1			CS	1,2	1,2,3	1		
4	11940		CS			1			CS	1	3	1		
4	11990	Core 6	CS		3				CS		3			
4	12040	5	CS		1,2	1			CS	1	3	1		
4	12090		CS	1	3	1			CS	1	3	1		
5	12140	Photo 6	CS	1	3	1			CS	1	3	1		
5	12190	Photo 7	CS	1	3	1			CS	1	3	1		
5	12240		CS	1	3	1			CS	1	3	1		
5	12290	Core 7	CS	1	3	1			CS	1	3	1		
5	12340	Core 36	CS	1	2,3	1			CS	1				
6	12390		CS			1			CS		2	1		
6	12440	MP17.50	CS		2	1			CS		2	1		
6	12490		CS			1			CS	2	3	1		
6	12540	Photo 9	CS		1,2	1			CS	2	3	1		
6	12590	Core 8 Photo 10	CS		2	1			CS	2	2	1		
6	12640	Core 38	CS		2	1			CS	2	3	1		
6	12690	Core 40	CS		2,3	1	1		CS			1		
6	12740		CS		2	1			CS			1		
6	12790	7	CS		1,2		1		CS			1		
6	12840		CS		1	1			CS		1,2	1		
6	12890	Core 9	CS	1	2,3	1			CS		3	1		
6	12940	10k	CS	2	2,3				CS		2,3			
6	12990		CS	1	1,3	1			CS		2	1		
6	13040		CS			1			CS		3	1		
6	13090		CS	1	3	1			CS		1	1		
7	13140	Core 42	CS		3	1			CS		2,3	1		
7	13190	MP1800 8 Core 10 Photo 14	CS		2	1			CS			1		
7	13240		CS		3	1			CS		3	1		

Section	Actual Station (m)	Other Reference	Eastbound						Westbound					
			Surface Type	Ru	Fa	Tr	Lo	Ra	Surface Type	Ru	Fa	Tr	Lo	Ra
7	13290	210th West	CS	1	2		1		CS		2	1	1	
7	13340	Core 44	CS			1			CS		3	1		
7	13390		CS	2	3	1			CS	2				
7	13440		CS			1			CS	2	2,3	1		
7	13490	Core 11	SS			1			CS	2	2,3			
7	13540		SS		3	1			CS		3	1		
7	13590	9	SS		3	1			CS		3	1		
7	13640		CS		1,2,3	1			CS		1,2,3	1		
8	13690	Core 46	CS		1,2	1			CS		2,3	1		
8	13740		CS		2,3	1			CS		2,3	1		
8	13790	Core 12	CS		2	1			CS		3	1		
8	13840	Core 48	CS		2,3	1			CS		2,3	1		
8	13890		CS		2,3	1			CS		2,3	1		
8	13940		CS		2,3	1			CS		2,3	1		
8	13990	MP 1850 Core 13	CS	1	2,3	1			CS	1	2,3	1		
8	14040		½ w/ SS			1			½ w/ SS	1	3			
8	14090		SS		2				SS	1	2,3			
9	14140		SS		2				SS		1,2			
9	14190	Core 50	SS						CS		2			
9	14240		SS		2	1			CS		2	1		
9	14290		½ CS – ½ SS		2	1			CS		2	1		
9	14340	Core 52	SS		2				CS	1	2,3			
9	14390	Core 14	SS		2	1			CS	2	2,3	1		
9	14440		CS		2	1			CS		2	1		
9	14490	Photo 20	½ SS		1,2				CS		2,3	1		
10	14540		½ SS		1,2	1			CS		1,2	1		
10	14590	Core 54	CS			1			CS	1	2,3	1		
10	14640		CS		2,3	1			CS		2,3	1		
10	14690	Core 15	CS			1			CS		2,3			
10	14740		CS		2	1			CS		2	1		
10	14790		CS			1			CS		2,3	1		
10	14840	12 MP19	CS		2,3	1			CS		2,3	1		
11	14890		CS			1			CS		2	1		
11	14940	Core 56	CS		2,3	1			CS		2,3	1		
11	14990		CS			1			CS		3	1		
11	15040	Core 16	CS			1			CS		2	1		
11	15090		CS		3	1			CS		3	1		
11	15140		CS		2,3	1			CS		2,3	1		
11	15190	13	CS		2	1			CS	1	3	1		
11	15240		CS		2	1	1		CS		2	1		
12	15290		CS			1	1		CS		2	1		
12	15340	Core 17	CS			1			CS	1	2,3	1		
12	15390		CS			1			CS	1,2	2,3	1		
12	15440	Core 58	CS		2	1			CS	1	3	1		
12	15490	Core 60	CS	2	3	1			SS	1,2	2,3			
12	15540		CS		2,3	1			SS	2	2,3	1		
12	15590		CS		2	1			SS		2	1		

Section	Actual Station (m)	Other Reference	Eastbound						Westbound					
			Surface Type	Ru	Fa	Tr	Lo	Ra	Surface Type	Ru	Fa	Tr	Lo	Ra
12	15640	4 Core 18	CS		2,3	1			SS					
12	15690	MP 1950	CS		2,3	1			SS		2	1		
13	15740		CS	1	3	1			SS		2	1		
13	15790	Core 62	CS		1	1			SS			1		
13	15840	Core 64	CS		2,3	1			SS		1	1		
13	15890		CS		2,3	1			SS					
13	15940	Roll 3 P3	CS		2,3	1			SS			1		
13	15990	Core 19	CS		2	1			SS		1	1		
13	16052	15	CS		2	1			CS		1	1		
13	16115		CS		2	1			CS			1		
13	16177		CS	1	3	1			CS		1,2	1		
13	16239	Core 20	CS	1	2,3	1			SS		1,2	1		
13	16302		CS		2	1			SS			1		
14	16364		CS	1	2,3				SS		1	1		
14	16426	164	CS		3	1			½ SS		2	1		
14	16488	Core 66	CS			1			CS	1	2,3	1		
14	16551	Core 21 90th St	CS			1			CS			1		
14	16613		CS			1			CS		1,2	1		
15	16675	Core 68	CS			1			CS	1	2,3	1		
15	16738		CS			1			CS		1,2	1		
15	16800	168	CS			1			CS			1		
15	16862	Core 22	CS			1			CS			1		

Notes

1) Each distress identified indicates the presence of that distress in that section.
2) Extent within each section is not noted, except as a comment.
3) Both directions were surveyed at the same time.
4) Noted in the "Other Ref" column are mile posts, photos, Eastbound and Westbound cores, cross streets and the numbers of Caltrans environmental section paddles
5) Surface Type: CS = chip seal; SS = slurry seal. All seals are on asphalt concrete.
6) Transverse crack spacing approximately 20 m throughout the entire project.
7) Ru – Unbound Layers Rutting: 0 = not present
   1 = moderate < 12 mm
   2 = severe > 12 mm

   Note: severe rutting is usually patched or extensively crack sealed.
8) Fa – Fatigue cracking: 0 = not present
   1 = Type A (hairline, not connected)
   2 = Type B (connected)
   3 = Type C (edges spalled)
9) Tr – Transverse Cracking: 0 = not present
   1 = present

   Typical spacing is 15 to 20 m.
10) Lo – Longitudinal Cracking: 0 = not present
   1 = present.
11) Ra – Raveling 0 – not present
   1 = present.

3.2 Pavement Coring

Coring of the pavement was conducted in order to determine 1) materials in the pavement structure, 2) thickness of each material, and 3) a thickness profile of the entire section.

A private contractor was hired to complete the coring. For the eastbound lane, the coring frequency was 1 core every 300 m. In the westbound lane, the frequency was increased to 1 core every 150 m for the first 14 cores. Then at core 36 (approximate Station 12890) the frequency was decreased to the original 1 core every 300 m due to time constraints.

The cores are numbered in the westbound lane after core 36 in an even numbered sequence (i.e., 38, 40, 42, etc.) The coring is summarized in Table 3. A picture of a typical core and the thickness profile are presented in Figures 2 and 3, respectively.

Table 3 Pavement Coring on State Route 138 Test Site

Core ID #	Direction	Actual Station (m)	Thickness of AC Above Fabric (mm)	Thickness of AC Below Fabric (mm)	Cement Treated Base Thickness (mm)
1	EB	10491	96.6	93.6	88.5
2	EB	10787	101.8	74.3	75.7
3	EB	11086	78.5	82.7	31.8
4	EB	11384	113.8	184.3	N/A
5	EB	11678	104.2	129.3	64.7
6	EB	11979	86.0	87.0	97.5
7	EB	12278	74.0	68.3	76.2
8	EB	12576	61.0	61.3	115.5
9	EB	12895	68.5	63.3	74.6
10	EB	13201	58.4	61.7	36.1
11	EB	13501	52.1	65.8	90.7
12	EB	13811	59.9	58.9	89.9
13	EB	14111	77.4	43.7	80.1
14	EB	14425	63.1	61.7	106.6
15	EB	14729	55.6	146.7	N/A
16	EB	15035	60.0	102.0	71.7
17	EB	15342	71.2	39.2	108.0
18	EB	15647	57.5	87.3	69.2
19	EB	15952	75.0	76.0	82.7

Core ID #	Direction	Actual Station (m)	Thickness of AC Above Fabric (mm)	Thickness of AC Below Fabric (mm)	Cement Treated Base Thickness (mm)
20	EB	16258	66.9	49.9	103.6
21	EB	16563	62.6	107.7	N/A
22	EB	16862	64.9	101.6	68.8
23	WB	10343	71.5	102.2	43.6
24	WB	10494	123.7	61.8	128.5
25	WB	10642	106.7	45.9	106.4
26	WB	10791	109.7	39.0	109.2
27	WB	10941	121.9	31.0	98.2
28	WB	11091	107.0	55.4	92.1
29	WB	11241	105.6	131.6	70.7
30	WB	11391	90.4	237.9	21.8
31	WB	11541	100.5	57.4	94.4
32	WB	11690	82.9	187.5	69.1
33	WB	11841	94.8	83.2	79.4
34	WB	11991	94.1	81.8	65.7
36	WB	12291	57.0	67.1	76.7
38	WB	12647	54.1	160.0	80.4
40	WB	12863	60.8	76.8	85.1
42	WB	13129	55.8	53.7	65.3
44	WB	13402	140.9	108.8	25.2
46	WB	13688	113.9	68.3	102.5
48	WB	13957	127.0	81.9	55.0
50	WB	14225	98.9	49.4	70.1
52	WB	14475	107.1	66.2	120.0
54	WB	14679	129.7	67.4	58.9
56	WB	14980	63.6	80.5	124.0
58	WB	15279	62.2	66.9	N/A
60	WB	15579	91.9	78.0	34.3
62	WB	15879	76.0	72.4	92.7
64	WB	16179	80.6	97.9	107.5
66	WB	16479	62.2	94.4	71.2
68	WB	16779	66.1	75.5	69.2

Notes: 1) Actual Station defines exact station of core location
2) N/A – no CTB found

Figure 2. Typical pavement core for State Route 138.

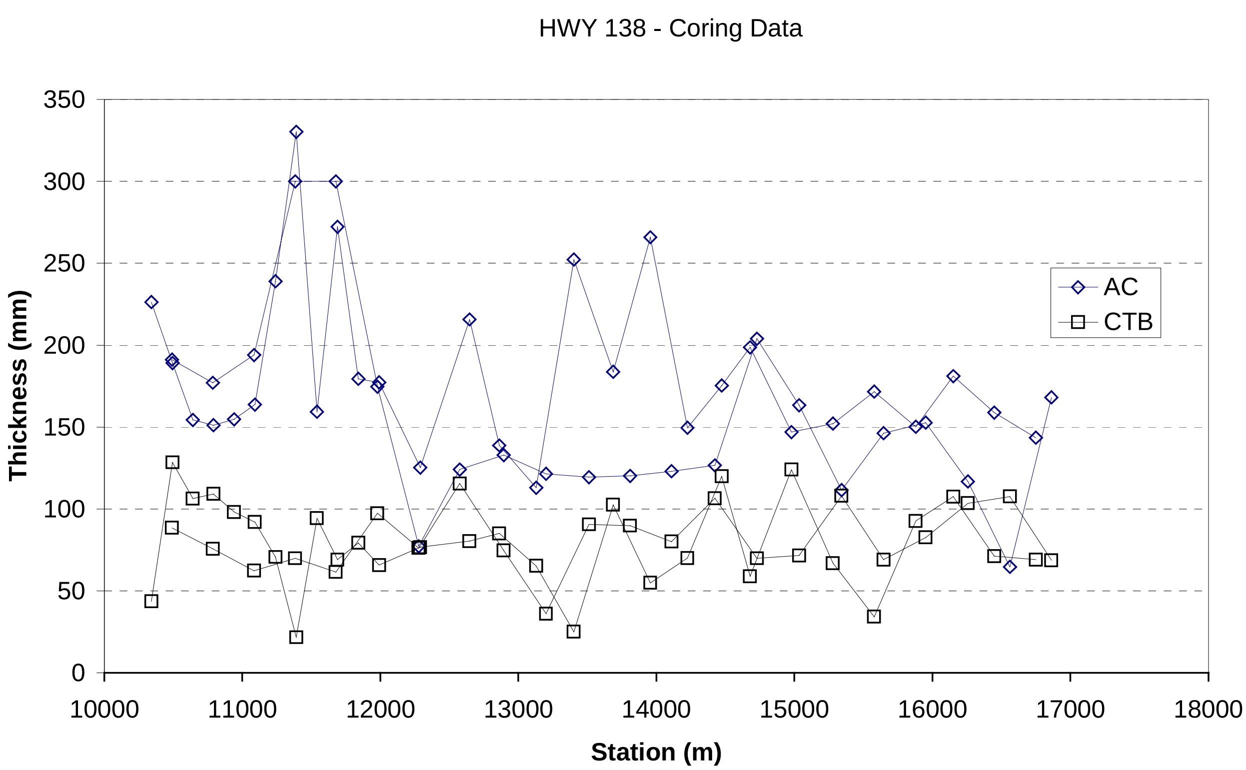

Figure 3. Coring profile for State Route 138.

3.3 Dynamic Cone Penetrometer (DCP) Testing

After the pavement cores were removed from the core holes, a crew performed DCP testing (Figure 4). The DCP technology has been used extensively in South Africa over the past 30 years to characterize in-situ pavement materials. The DCP is a valuable tool because it can provide the engineer an indication of shear strength and stiffness (elastic modulus) of the in-situ soil.

Figure 4. Crew performing DCP measurements on State Route 138.

The DCP equipment and test procedure is relatively simple. It consists of a metal cone attached to a rod and an 8-kilogram hammer. The hammer is dropped from a specific height in order to drive the cone into the in-situ pavement material, typically through a core hole. A measuring tape is secured to the rod in order for the technician to record the depth of penetration with the increasing blow count. The recorded blow counts and associated depth of penetration are plotted and the slope of this curve is, DN (mm/blow). The Council for Scientific and Industrial Research (CSIR) has developed an equation that correlates DN with the effective elastic modulus of the material tested. This equation is as follows:

$$\text{Log}(E_{eff}) = 3.04758 - 1.06166 \times \text{Log}(DN) \qquad \text{Eqn. 1 Ref. 1}$$

3.4 Falling Weight Deflectometer (FWD/HWD) Testing

The Dynatest Model 8082 Heavy Weight Deflectometer (HWD) test system was used to generate the requisite NDT load-deflection data analyzed for this report (Figure 5). The HWD is similar to the FWD although the loading range of the HWD is significantly greater than the FWD.

The HWD generates a transient, impulse-type load of 25-30 msec duration, at any desired (peak) load level between 27 and 245 kN (6,000 and 55,000 lbf.), thereby approximating the effect of a 50-80 km/h (30-50 mph) moving wheel load. For this project, test loads ranged from 27 to 90 kN (6,000 to 20,000 lbf.) and deflections were normalized at 27, 40 and 67 kN (6, 9 and 15 kips). The sensor spacing was set at: 0, 200, 300, 600, 900, 1200 and 1500 mm from the center of the load plate. A test was performed every 50 meters in each lane. The productivity of the HWD was 46 tests/hour in the eastbound lane and 47 tests/hour in the westbound lane. It is possible to achieve 30 tests/hr with the HWD under almost any routine testing scenario.

Figure 5. Heavy Weight Deflectometer.

The FWD/HWD-generated load-deflection data was analyzed using the so-called "Mechanistic-Empirical" methodology, through a specially developed software package designed to do the task in the best and most efficient manner available. The system is "Mechanistic" in the sense that actual, in-situ material properties and wheel load responses are derived through a reverse, layered analysis technique. It is still "Empirical," however, in the sense that the relationships between the load related response of these mechanistic or analytical properties and future pavement performance are based upon past experience (observed performance) and associated research. The software package employed was the Dynatest ELMOD4, a Windows®-based version of the older ELMOD3 analysis program. New features have been added to the ELMOD4 program. However, the backcalculation routines are relatively similar.

For this analysis, some assumptions were made due to the pavement structure. These are 1) the asphalt concrete (AC) layer was combined with the cement treated base (CTB) layer due to the similar stiffness of the materials, and 2) a surfacing thickness (AC +CTB) of 300 mm was assumed because of the wide variation in thickness shown in the coring data. Therefore, all relatively similar sections are primarily based on subgrade response. The plots presented in Figures 6 and 7 show the variation in the deflection response and in the backcalculated moduli.

4.0 DISCUSSION OF RESULTS

4.1 Visual Condition Survey Results

The pavement is generally in poor condition throughout the entire project length. However, in terms of pavement rutting, the eastbound lane is in better condition than the westbound lane.

Longitudinal, transverse and fatigue cracking are visible in both lanes over the entire project length. The transverse cracking occurs at approximately 20-meter intervals. A small amount of raveling is also present. The entire pavement surface has been chip sealed and both Eastbound and Westbound Section 9 and Westbound Sections 12 and 13 have been slurry sealed.

Each 50-meter section had relatively similar distress in both directions. However, severe distress is evident at numerous isolated locations randomly distributed across the westbound lane. This may be due to an increase in the number of trucks, truck weight, or poor construction quality in the westbound lane.

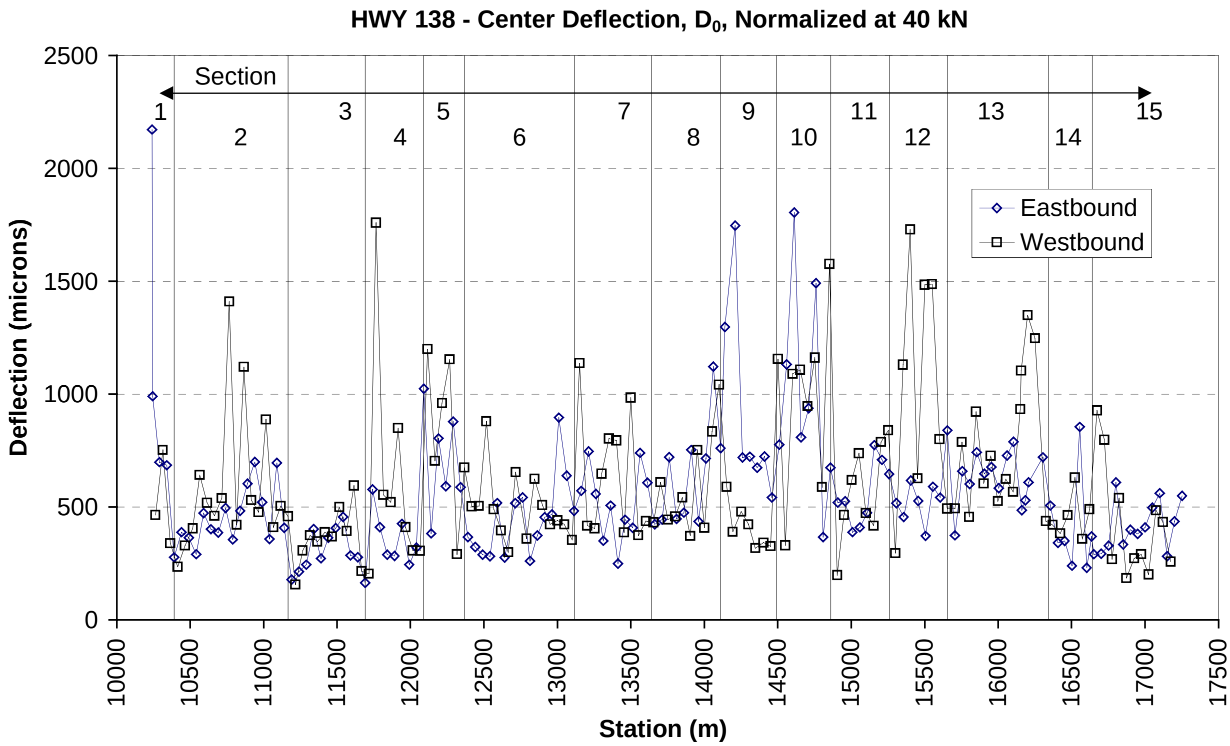

Figure 6. Center deflection, D_0, at 40 kN for Eastbound and Westbound lanes.

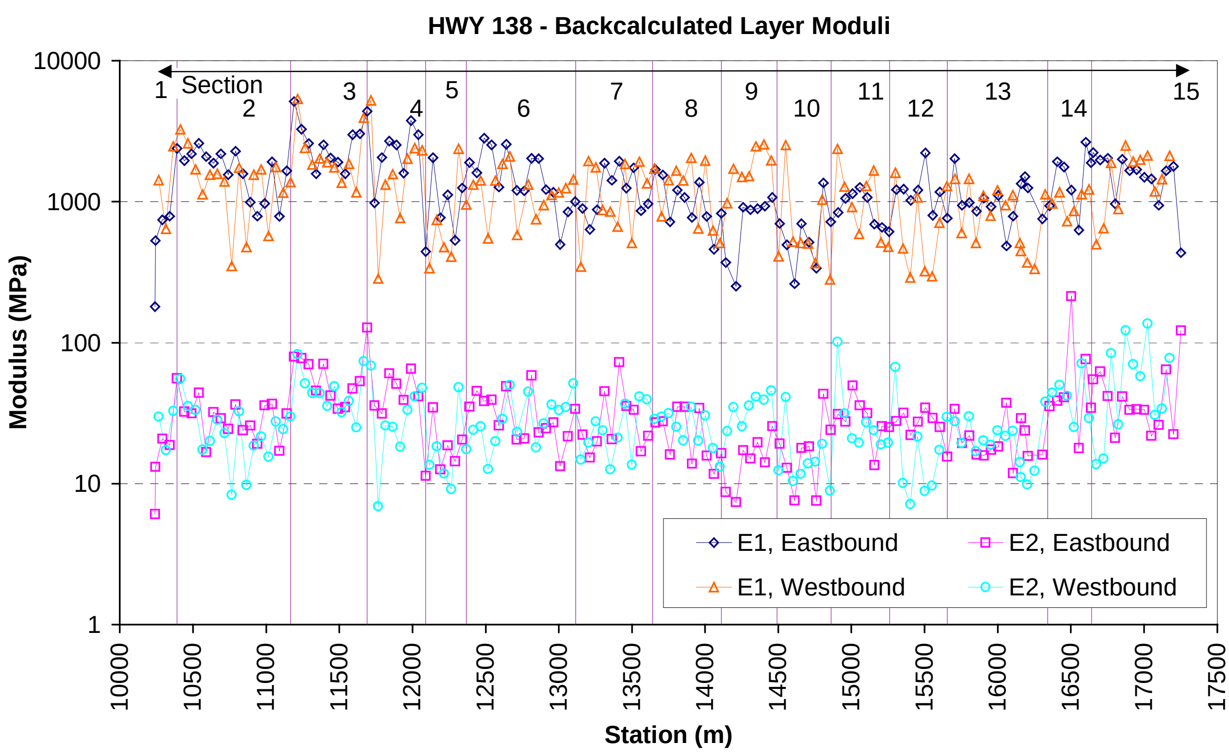

Figure 7. Backcalculated layer moduli for East- and Westbound lanes.

4.2 Coring Results

The coring data was highly variable, as can be seen in Figure 3. The total pavement structural section varies between 150 and 325 mm. Of that total, the AC layer thickness ranges between 115 and 225 mm and the CTB layer thickness ranges between 35 and 125 mm. It is also evident from examination of the cores that there are several AC layers, i.e. "lifts." During the coring operation, core separation was noted, which indicates a poor bond between the AC layers. However, there was little or no evidence of stripping of the AC. The number of layers varies between 3 and 6 and there is no consistency with regards to the change in thickness of each layer over the length of the project. Also, there is evidence of a fabric interlayer within the pavement. The interlayer exists between 100 to 250 mm above the subgrade. Again, there is no consistency in the AC thickness either above or below the fabric, as shown in Figures 8 and 9.

4.3 Dynamic Cone Penetrometer (DCP) Test Results

The DCP testing indicated the presence of two different in-situ materials below the AC layers. From Figure 10, it can be estimated that the first layer, Layer 1, under the AC ranges between 0 to 0.5 m, whereas the second layer, Layer 2 ranges from 0.5 to 0.9 m.

The mean DN for Layer 1 is 9.6 mm/blow and for Layer 2 it is 35.8 mm/blow. This is shown graphically in Figures 11 and 12.

The DCP results are highly variable throughout the entire project. Using the CSIR equation presented in Section 3.3, which correlates DN to effective modulus or stiffness of the material, the estimated stiffness of Layer 1 calculated from the mean DN is 101 MPa (14.6 ksi) and for Layer 2 is 25 MPa (3.6 ksi).

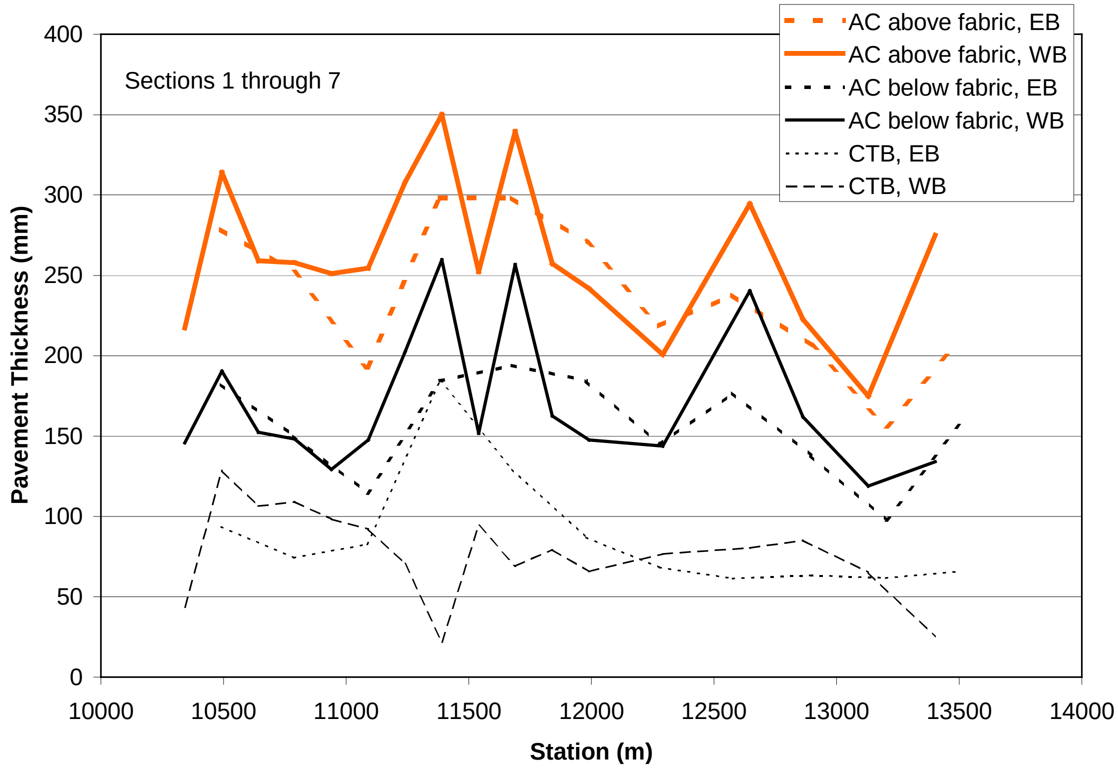

Figure 8. Layer thickness variability, Sections 1–7, State Route 138.

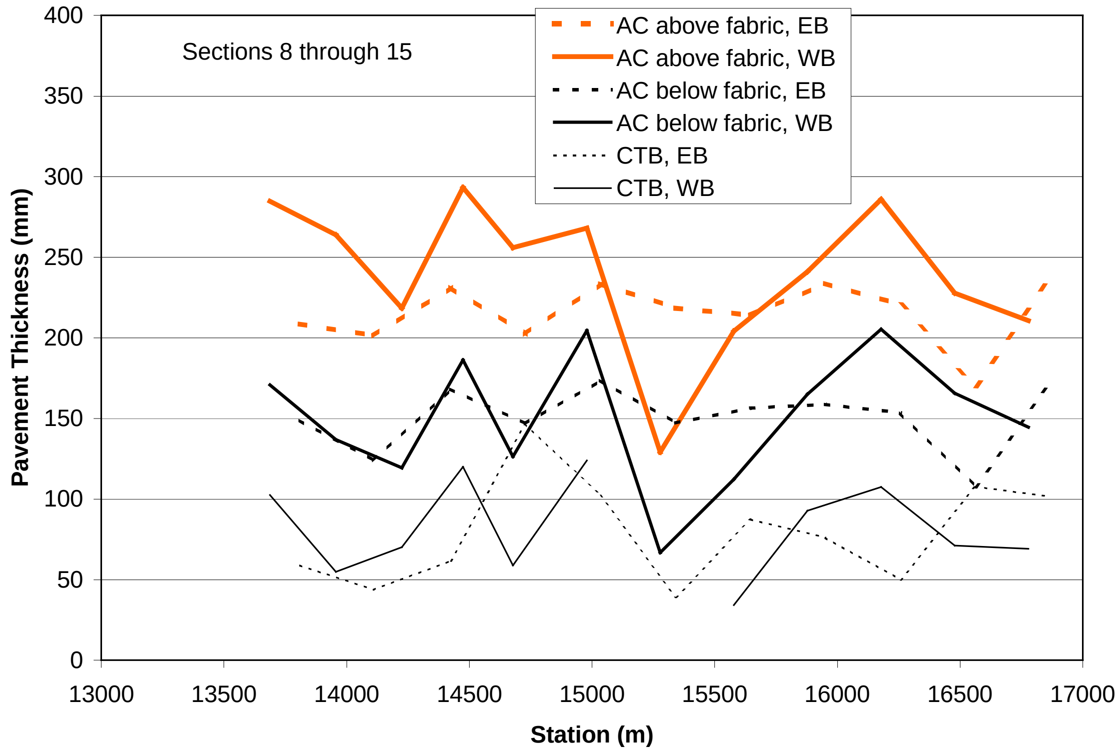

Figure 9. Layer thickness variability, Sections 8–15, State Route 138.

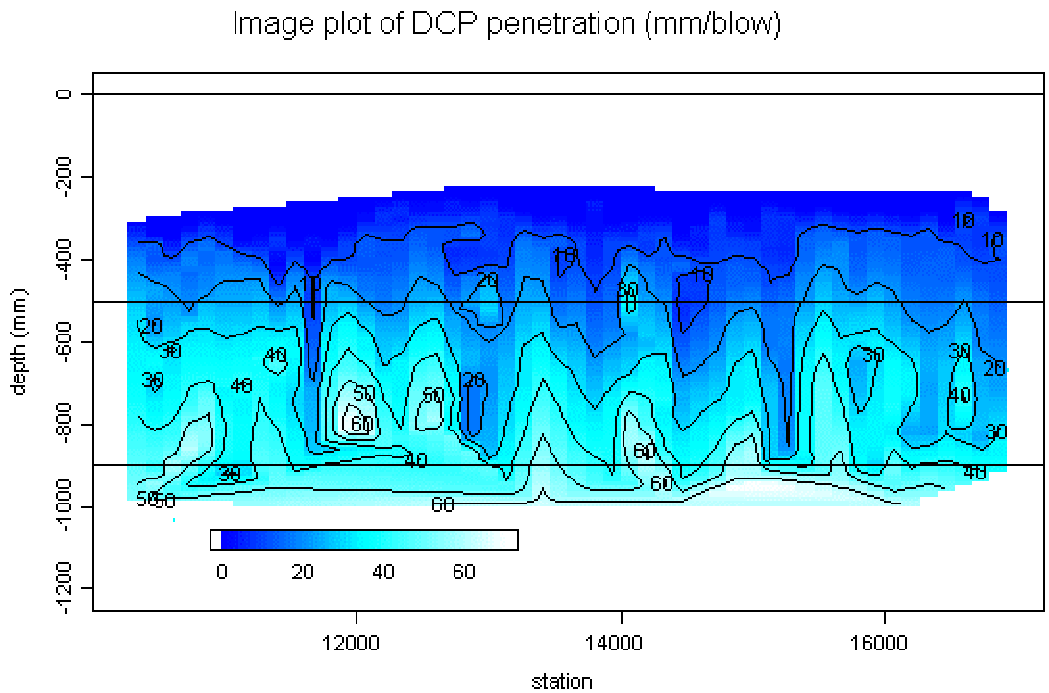

Figure 10. Recorded DCP penetration (mm/blow) on HWY 138.

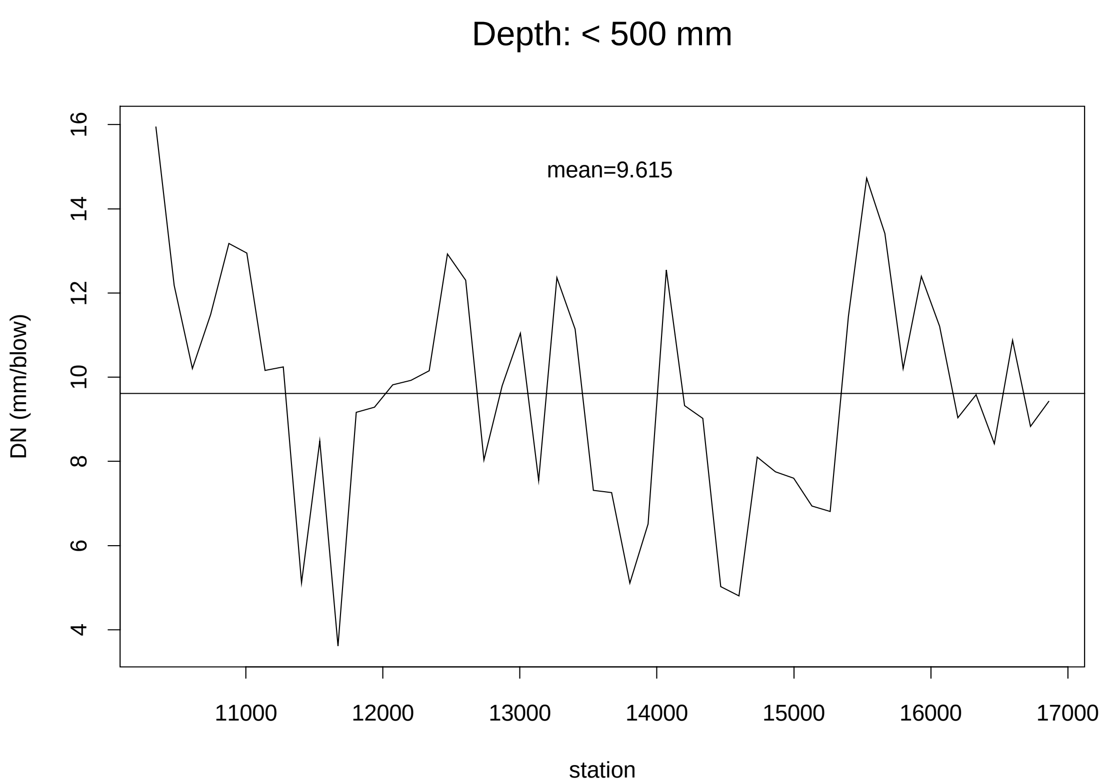

Figure 11. Layer 1 plot of DN versus Station for State Route 138.

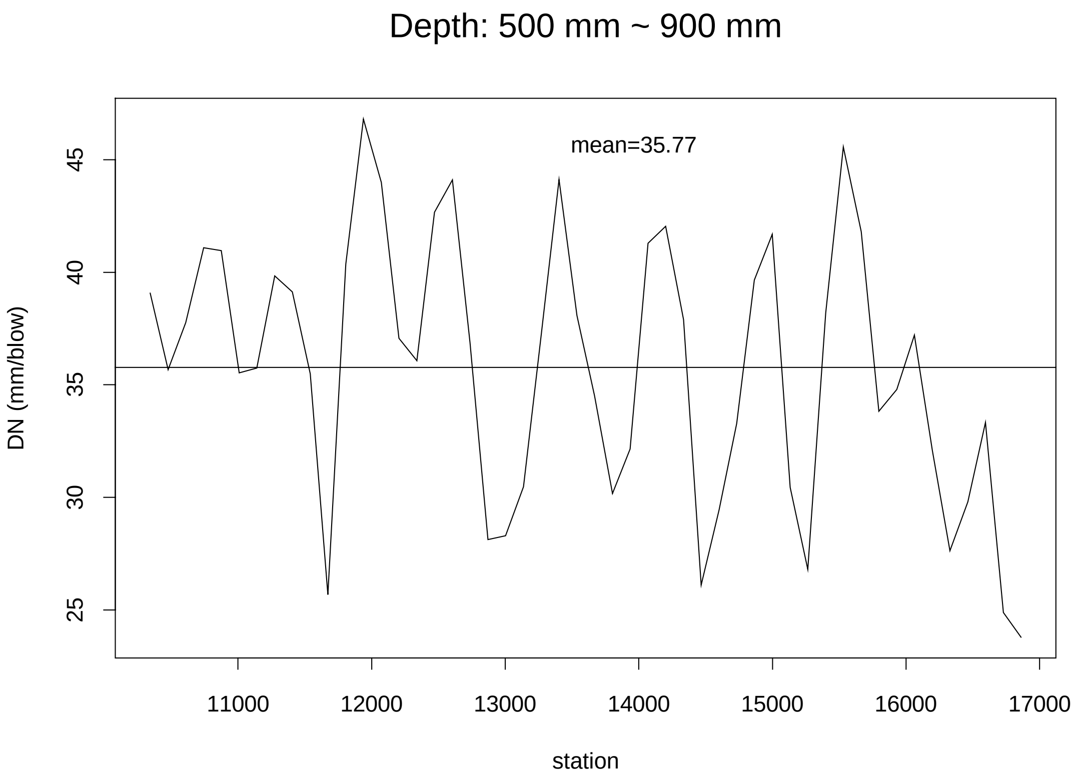

Figure 12. Layer 2 plot of DN versus Station for State Route 138.

4.4 Heavy Weight Deflectometer (HWD) Results

The recorded center deflection, D_0, values, shown in Figure 5, are highly variable for both eastbound and westbound lanes. This may be due to variations in the surfacing thickness, pavement materials and structural condition.

The surfacing stiffness, (i.e., AC+CTB), is generally not consistent across lanes nor along either lane, throughout the entire project. However, the subgrade stiffness is relatively consistent across lanes, but not along the lanes. Because of this consistency, it was decided to use the subgrade stiffness as the criterion for dividing the project into relatively similar sections varying from 250 to 850 meters in length. Table 4 summarizes the surfacing stiffness and subgrade stiffness for each section and the limits of each section.

Table 4 Stiffness Summary for Each Section on State Route 138

Section	Length	From Station	To Station		Surfacing Modulus (MPa)		Subgrade Modulus (MPa)	
					Eastbound	Westbound	Eastbound	Westbound
1	250	10141	10391	*average*	560	1507	15	27
				standard deviation	278	914	7	8
				84th percentile	282	592	8	18
2	775	10392	11166	*average*	1735	1490	31	25
				standard deviation	583	730	10	11
				84th percentile	1152	760	21	14
3	525	11166	11691	*average*	2817	2353	62	48
				standard deviation	1126	1290	27	18
				84th percentile	1691	1064	35	29
4	400	11691	12091	*average*	1328	511	30	12
				standard deviation	537	8	9	2
				84th percentile	791	503	21	10
5	225	12091	12367	*average*	1143	880	20	20
				standard deviation	580	765	9	14
				84th percentile	563	115	11	5
6	800	12367	13116	*average*	1587	1226	32	31
				standard deviation	686	435	12	12
				84th percentile	901	791	19	19
7	525	13116	13641	*average*	1243	1204	30	25
				standard deviation	470	626	18	11
				84th percentile	773	577	13	14
8	500	13641	14111	*average*	1045	1275	23	25
				standard deviation	400	584	9	7
				84th percentile	645	691	14	18
9	350	14111	14491	*average*	757	1808	15	35
				standard deviation	314	560	6	8
				84th percentile	443	1248	9	27
10	370	14491	14861	*average*	635	767	19	16
				standard deviation	338	740	11	10
				84th percentile	297	27	7	6
11	400	14861	15261	*average*	916	1135	30	33
				standard deviation	248	654	10	28
				84th percentile	668	481	20	5
12	395	15261	15656	*average*	1203	755	27	21
				standard deviation	449	508	6	20
				84th percentile	754	247	21	1
13	685	15656	16341	*average*	1077	852	21	21
				standard deviation	388	393	8	8
				84th percentile	689	459	14	13
14	300	16341	16641	*average*	1568	1010	65	44
				standard deviation	686	193	68	16
				84th percentile	882	817	-2	27
15	500	16641	17141	*average*	1561	1561	44	61
				standard deviation	511	670	27	42
				84th percentile	1049	891	17	19

The average surfacing stiffness ranges from 500 to 1500 MPa (72.5 to 217.5 ksi), which is relatively low, even though the pavement surface temperature during the deflection testing was high, (i.e., > 32°C (90°F). The average subgrade stiffness ranges from 15 to 65 MPa (2.2 to 9.5 ksi). The subgrade stiffness is generally in good agreement with the stiffness calculated using the DCP approach.

Further inspection of this table clearly shows that not all of the 15 sections have similar stiffness values for either surfacing or subgrade. Therefore, it was decided to rank the sections from the strongest to the weakest structure based on highest average stiffness of both materials. The rankings are summarized in Table 5.

Table 5 Ranked Subsets Strongest to weakest structure from 15 sections on State Route 138

Sections		Esurface		Esubgrade	
		average	standard deviation	average	standard deviation
3,6,14,15	Eastbound	1883	623	51	16
	Westbound	1538	589	46	12
	Combined	1710	606	48	14
2,4,7,8,11	Eastbound	1253	314	29	3
	Westbound	1123	367	24	8
	Combined	1188	341	26	5
5,9,12,13	Eastbound	1045	199	21	5
	Westbound	1074	492	24	7
	Combined	1059	346	23	6
10	Eastbound	635	N/A	19	N/A
	Westbound	767	N/A	16	N/A

5.0 CONCLUSIONS

5.1 Comparison of Maintenance Treatments

The comparison of relative maintenance performance on the tested section of State Route 138 between MP 16.5 and 20.0 may be feasible if the number of different maintenance treatments is limited to no more than five. The sections that should be used are Sections 3, 6, 14, and 15 as defined in Table 1. These same treatments can be repeated on sections 2, 4, 7, 8 and 11 as defined in Table 2, and repeated again on sections 5, 9, 12 and 13. Replication of the same treatment once in each set of approximately comparable existing pavement sections will add a great deal of statistical validity to any comparison of their performance. Four treatments should be repeated across each of the three sets of sections. One additional treatment can be added to the second set, which has five available sections.

5.2 Mechanistic-Empirical Analysis

The Mechanistic-Empirical analysis approach can provide a significant amount of useful data within a relatively short time frame.

5.3 Subsurface Investigation

Subsurface investigation using limited destructive and non-destructive techniques is a viable and useful analysis procedure.