SOIL STABILIZATION FIELD TRIAL

INTERIM REPORT II

by

K.P. George

Conducted by the

DEPARTMENT OF CIVIL ENGINEERING
UNIVERSITY OF MISSISSIPPI

in corporation with

THE MISSISSIPPI DEPARTMENT OF TRANSPORTATION

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
And

THE PORTLAND CEMENT ASSOCIATION

The University of Mississippi
University, Mississippi
February 2002

Technical Report Documentation Page

1.Report No. FHWA/MS-DOT-RD-02-133	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Interim Report II Soil Stabilization Field Trial		5. Report Date February 2002 6. Performing Organization Code
7. Author(s) K.P. George		8. Performing Organization Report No. MS-DOT-RD-02-133
9. Performing Organization Name and Address University of Mississippi Department of Civil Engineering University, MS 38677		10. Work Unit No. (TRAIS) 11. Contract or Grant No. State Study 133
12. Sponsoring Agency Name and Address Mississippi Department of Transportation Research Division P.O. Box 1850 Jackson, MS 39215-1850		13. Type Report and Period Covered Interim Report II 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Shrinkage cracks in cement-stabilized bases/subbase can be alleviated by specifying the right cement dosage, or by other additives/procedures that suppress crack susceptibility. A field trial of six 1000 ft sections to investigate several alternative techniques was initiated and constructed in August 2000. The following additives/procedures are included for investigation:

- 5.5% cement additive (control); design based on a reduced strength criteria.
- 5.5% cement precracked while "young".
- 5.5% cement precut (grooved) every 3m (10 ft).
- 3.5% cement with 8% fly ash.
- Ground granulated blast furnace slag (GGBFS) complemented by 2% lime.
- Three percent lime and 12% fly ash, the current favored stabilization technique of MDOT.

First interim report covering the first phase of investigation/monitoring during the 28-day period was submitted in April 21, 2001. Two layers of asphalt concrete – 11 cm (4.5 inches) base, 6 cm (2.25 inches) polymer modified binder – were placed over the stabilized layer beginning September 21, 2000, followed by the second field monitoring on November 13, 2001. Field tests include deflection tests employing Falling Weight Deflectometer (FWD), retrieval of 10-cm (4-in) cores for compression tests, and a manual crack survey. The results are presented in this report along with a discussion as to possible changes (strength- and stiffness-gain, and crack reflection) over a fourteen-month period, since September 15, 2001 when the last monitoring was completed.

The backcalculated results show that the moduli of subgrade and lime-treated subgrade generally increased from 28 days to 440 days. The stabilized layer moduli of all cement sections and lime-fly ash section increased with time, however, the 440-day moduli of the two sections – cement-fly ash and lime-GGBFS – decreased with time. The asphalt concrete (AC) modulus corrected to 22°C (72°F) was reasonably uniform from section to section, except for the cement-fly ash section, where the backcalculated (AC) modulus was relatively low. Unconfined compressive strength (corrected for height to diameter ratio of 2:1) of cores increased from 28 days to 440 days. Despite a hefty percentage increase for LFA mixture, the absolute strength, namely 540 kPa at 440 days, is considered marginal for long-term durability. The test sections with 17 cm (6.75 inches) asphalt concrete remain crack free at the time of survey.

17. Key Words Soil Stabilization, Shrinkage, Crack, Field Trial, Field Tests, FWD Test, Strength	18. Distribution Statement Unclassified

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 22	22. Price

Form DOT F 1700.7 (8-72)

Reproduction of completed page authorized

ACKNOWLEDGMENT

This interim report includes results of a study titled, "Soil Stabilization Field Trial", conducted by the Department of Civil Engineering, The University of Mississippi, in cooperation with the Mississippi Department of Transportation (MDOT) and the U.S. Department of Transportation, Federal Highway Administration.

The author wishes to thank Bill Barstis and Johnny Hart for their excellent cooperation in organizing the field tests. Jackie Harris's (MDOT project office) continued cooperation is acknowledged. Upendra Joshi, former research assistant and Sherra Jones of Civil Engineering Department helped in preparing this report.

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CHAPTER 1

INTRODUCTION

1.1 Background

Stabilizing agents, for example, cement, lime, lime-fly ash and others have been successfully used in pavement base/subbase construction. There is concern, however, over possible shrinkage cracking due to drying and/or thermal contraction, especially in high-strength cement-stabilized soil. Recent studies suggest that crack-related degradation can be abated by adopting materials and/or methods that bring about a “desirable” crack pattern, “desirable” being defined as numerous fine cracks at close spacing, which ensures adequate load transfer across the cracks. It is not so much the number of cracks but the width of these cracks that has a significant influence on the long-term performance of the pavement since wider cracks have the tendency to reflect through the overlying pavement. Limiting/controlling drying shrinkage can effect the development of this “desirable” crack pattern in a stabilized layer. Several alternatives are available to control the drying shrinkage. These include: judiciously selecting the cement dosage, selecting a soil for stabilization having a limited fines content and plasticity, and the use of a fly ash additive in conjunction with Portland cement, all of which promote development of a “desirable” crack pattern in a stabilized layer.

Controlling shrinkage cracking is another method to alleviate the detrimental affects of this cracking to pavement performance. This control can be effected by “precutting” to induce a weak plane in the stabilized layer or “precracking” at an early age (before 48 hours after construction) by several passes of a vibratory roller with 100% coverage.

1.2 Scope/Objective of the Study

Seeking for materials and methods to alleviate cracking in cement-treated soil, six field sections were constructed in August 17 and 18, 2000 incorporating the following material combinations or methods each in a separate but contiguous test section of 305m (1000 feet) long: cement, precracked cement layer, precut cement layer, cement-fly ash, lime-ground granulated blast furnace slag (GGBFS), and lime-fly ash (LFA).

1.3 Scope of this Interim Report

First interim report covering the first phase of investigation/monitoring during the 28-day period was submitted in April 21, 2001 (1). Two layers of asphalt concrete – 11cm (4.5 inches) base, 6cm (2.25 inches) polymer modified binder – were placed over the stabilized layer beginning September 21, 2000, followed by the second field monitoring on November 13, 2001. Field tests include deflection tests employing Falling Weight Deflectometer (FWD), retrieval of 10-cm (4-inch) cores for compression tests, and a manual crack survey. The results are presented in this report along with a discussion as to possible changes (strength- and stiffness-gain, and crack reflection) over a fourteen-month period, since September 15, 2001 when the last monitoring was completed.

Chapter 2

FIELD TEST RESULTS

2.1 Project Description

Six test sections were included in the westbound lane of Highway #302 in Marshall County, Mississippi. Each test section was 305 (1000 ft) long and 8.5m (28 ft) wide, though only the traffic lane 4.25m (14 feet wide) was tested. A typical cross-section of the test pavement is presented in Figure 2.1, where 915m (5000 ft) LAF base was replaced by five other stabilized layers, 305m (1000 ft) each. With MDOT standard LFA base 305m (1000 ft) at the east end included in the test program for comparison purposes, the field trial comprises the following six additives/procedures:

- 190+00 to 195+00: cement 5.5%, cement control – Section 1A
- 195+00 to 200+00: cement 5.5%, precut – Section 1B
- 200+00 to 210+00: cement 5.5%, precracked – Section 2
- 210+00 to 215+00: cement 5.5%, cement control - Section 3A
- 215+00 to 220+00: cement 5.5%, precut – Section 3B
- 220+00 to 230+00: cement 3.5% and fly ash 8% - Section 4
- 230+00 to 240+00: lime 2% and GGBFS 6% - Section 5
- 245+00 to 250+00: lime 3% and fly ash 12%, MDOT Standard – Section 6
- 250+00 to 255+00: lime 3% and fly ash 12% with 10-cm (4-inch) drainage layer – Section 6 (alternate)

In order to eliminate unforeseen variations while transitioning from one section to another, each end of a test section – 31m (100 feet) in 305m (1000 feet) long sections and 15m (50 feet) in 152m (500 feet) sections – is not monitored leaving three 244m (800-feet) test sections and six 122m (400-feet) sections.

2.2 Field Evaluation Tests

2.2.1 Falling Weight Deflectometer Study

Assisted by MDOT Research Division, deflection measurements were conducted on the asphalt layer at every 31m (100 feet) along each test section, gathering deflection data at 9 locations in each test section. The following test set-up was used: three seating drops followed by 40kN (9000 lbs) load drop at eight stations except at the middle. At the mid-point of each section, four load drops, approximately, 27kN, 42kN, 53kN and 76kN (6000 lbs, 9500 lbs, 12,000 lbs and 17,000 lbs). For brevity, FWD deflection data will not be included in this report, however, the backcalculated modulus of each test section is reported and discussed in chapter 3.

2.2.2 Core Samples from Stabilized Layer

Three 10-cm (4-inch) diameter stabilized material cores from 244m (800 feet) sections and two from 122m (400 feet), were extracted. In order to reach the stabilized layer, asphalt layer is cored as well, measuring precisely the thickness of the asphalt and stabilized layers which was employed in the backcalculation routine.

The stabilized layer cores were wiped dry, wrapped and brought to the laboratory. The cores were capped with plaster of paris, and tested for compressive strength in accordance with ASTMD 1633-84. With core samples having different heights, the strengths of each sample was corrected to correspond to height to diameter ratio of 2:1.

In all of the sections (except in the LFA) the cores remained intact whereas the LFA cores, especially those retrieved from section 6 (alternate), were significantly eroded due to drilling water and occasional crushed stone pieces that fell under the drill bit. As a result of excessive grinding, the samples from LFA layers were undersize, diameter about 9cm (3.5 inches) in contrast to 10cm (4 inches), nominal diameter of the core bit.

2.2.3 Crack Mapping

Following the same classification adopted in the first interim report (fine, low, medium, high severities), a crack survey was conducted. The asphalt surface was completely crack-free, as expected.

Chapter 3

RESULTS AND DISCUSSION

3.1 Introduction

The purpose of one-year investigation is to discern whether the stabilized layer has improved in both strength and stiffness as a result of continued pozzolanic reaction producing cementitious compounds. This investigation is particularly relevant as the early studies suggested slight degradation of stabilized layer from 7 to 28 days. The severe hot temperature that existed during and after construction could have caused this temporary setback in the strength gain. The issue addressed here is whether the stabilized layers continue to gain strength/stiffness once it was overlaid with asphalt layer that inhibited further desiccation.

3.2 Modulus of Stabilized Layer

Employing the deflection bowl obtained from FWD tests, moduli of the layers are backfigured. Backcalculation program MODULUS 5.1 is utilized, with the pavement modeled as a four layer system: 17cm (6.75 inches) asphalt concrete, 15cm (6 inches) of stabilized layer, 15cm (6 inches) of lime-treated subgrade and the underlying subgrade. Section #6 alternate of the LFA Section (Station 250+00 to 255+00) included a 10-cm (4-inch) drainage layer as well, where, for analysis purposes, the stabilized layer and the lime-treated subgrade were combined to form a 30-cm (12-inch) layer. Combining those two layers could be justified in view of the close modulus values of LFA and lime-treated material.

The moduli results of 28-day deflection studies are compared with those of the 440-day FWD tests after emplacement of 17cm (6.75-inch) asphalt layer atop the stabilized layer (see Tables 3.1 through 3.7). The modulus of the asphalt layer is corrected to 22ºC (72ºF) temperature, in accordance with BELLS3 method (2) (see Appendix for details). In computing the average for each test section, outliers are detected by Chauvenet's criterion, and few others also excluded, for example, when modulus of the treated subgrade layer larger than that of the stabilized layer. In all of the sections, moduli of the subgrade soil increased owing to added overburden and resulting confinement, and also from possible lime migration from upper treated layer. Whereas the treated subgrade modulus increased in five sections, on average 40%, no increase was observed in the precut sections (#1B and #3B).

A brief discussion of the modulus of the stabilized layers is presented in two parts: first, how much increase is observed from 28-day to 440-day, and second, a comparison of the four experimental sections with the cement control section followed by another comparison of LFA base again with cement control section.

Section #1A and #3A (cement control). The stabilized layer modulus increased by 47% from 28-day to 440-day.

Sections #1B and #3B (precut). Modulus after 440 days is 52% larger compared to that at 28 days. Primarily as a result of the precuts, the modulus at both 28 days and 440 days lags behind that of the control section.

Section #2 (precracked). As expected, the stabilized layers gained its stiffness in that 440-day modulus is 57% larger than the 28-day value. Despite its loss of modulus due to precracking, this section regained its stiffness (owing primarily to crack healing), attaining comparable values obtained in the control section.

Section #4 (cement-fly ash). It is somewhat paradoxical that the modulus of cement-fly ash decreased from 2380 MPa to 1530 Mpa in the 14-month period. Compared to control cement, that is 44% lower. Also observed is that, for unknown reasons, the asphalt concrete modulus in this section is lower than that observed in all other sections. The core strength trend, however, does not follow the modulus trend. That is, 440-day strength exceeded the 28-day strength by 171%.

Section #5 (lime-GGBFS). As seen in section #4, the 440-day modulus is 18% lower than that obtained at 28 days, despite a 88% increase in strength during the same period. Again, compared with that of the cement control, the 440-day modulus of lime-GGBFS is 20% lower.

Why the modulus of the cement-fly ash and lime-GGBFS sections decreased with age (from 28 days to 440 days) is still unresolved. Barring any backcalculation error, one possible explanation could be that those two sections suffered even more cracks, though covered with asphalt layer after 34 days of construction.

Section #6 (lime-fly ash). As expected, lime-fly ash section modulus increased from 270 MPa in 28 days to 380 MPa in 440 days. That the asphalt modulus of the LFA section (Table 3.6) is drastically lower than that of the cement control section (5550 MPa compared to 8550 MPa) could be a concern, however, it will be addressed in future studies. Though a direct comparison between the LFA-modulus and control cement section modulus is inappropriate, a point should be made as to the marginal modulus value of LFA section, namely, 380 MPa after nearly 15 months.

Section #6 (alternate). Here a four-layer analysis is performed, with asphalt layer, drainage layer, LFA and lime-treated subgrade combined, and the subgrade. Although a direct comparison between the 28-day modulus of LFA base and 440-day value of the composite layer cannot be justified, the backfigured moduli of asphalt concrete, the drainage layer, the composite layer and the subgrade seem reasonable.

3.3 Core Strength

As expected, core strength of all of the sections increased from 28-days to 440 days (see Tables 3.8 and 3.9). The percent increase ranges from a low of 78% for precut cement to a high of 171% for cement-fly ash. Other noteworthy observations include:

1. Though the precracked core strength at 28 days was comparable to the two cement control sections (1A, 3A), it surpassed the latters' strength during the intervening period from 28 days to 440 days. This result clearly suggests that, despite the precracked material suffering a temporary strength loss for having induced microcracks, it regained strength (169%) over the 14-month period. Backcalculated moduli also showed a similar increasing trend.
2. Lime-GGBFS appears to be the predominant strength gainer at 28 days as well during the 440-day period. It would be fair to conclude that the admixture percentage – namely, 2 percent lime and 6% GGBFS — is on the high side resulting in a high-strength material. A recommendation may be to consider reducing the additive percentage.
3. That the LFA mixture exhibits a strength of only 560 kPa, despite a substantial increase from 240 kPa in 28 days, raises some concern in that its effectiveness in all of the soil materials cannot be taken for granted.

3.4 Crack Survey

With 17cm (6.75 inches) of asphalt layers constructed in the last few months, and that the road has not been open to truck traffic at the time of survey, it is not all unexpected that there would be no cracks on the surface. The crack survey just confirms this contention.

Chapter 4

SUMMARY AND CONCLUSIONS

Seeking for materials and methods to alleviate shrinkage cracking in cement-treated soil, six test sections were constructed in August 2000. Extensive laboratory tests and field investigations were conducted before and after construction (for a period of 28 days) with the results reported in the first interim report dated April 21, 2001. After emplacement of 17cm (6.75 inches) of asphalt concrete beginning September 21, 2000, the sections, still not opened to traffic, were monitored on November 14, 2001. Field tests include deflection tests employing Falling Weight Deflectometer, retrieval of 4-inch cores and a crack survey.

The backcalculated results show that the moduli of subgrade and lime-treated subgrade generally increased from 28-days to 440 days. The stabilized layer moduli of all cement sections and lime-fly ash section increased with time, however, the 440-day moduli of the two sections – cement-fly ash and lime-GGBFS – decreased with time. The asphalt concrete modulus corrected to 22˚C (72˚F) was reasonably uniform from section to section, except for the cement-fly ash section, where the backcalculated modulus was relatively low. Unconfined compressive strength (corrected for height to diameter ratio of 2:1) of cores increased from 28 days to 440 days. Despite a hefty percentage increase for LFA mixture, the absolute strength, namely 540 kPa at 440 days, is considered marginal for long-term durability. The test sections with 17cm (6.75 inches) asphalt concrete remain crack free at the time of survey.

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Table 3.1 Comparison of backcalculated moduli from 28-day and 440-day FWD deflection tests. Cement control section

Section	Station	440 - day Modulus, MPa				28 - day Modulus, MPa			
		E1	E2	E3	E4	E1	E2	E3	E4
1-A	190+50	6760	4780	890	160	—	2540	210	80
	191+50	8540	2320	660	140	—	1380	260	90
	192+50	6590	2110	750	250[b]	—	190[d]	730[d]	120[b]
	193+50	7090	2300	490	110	—	1450	1310[b]	90
	194+50	9970	850	390	100	—	810[c]	380[c]	80[c]
3-A	210+50	10520	2940	440	180	—	1160	200	80
	211+50	7500	1680	570	180	—	980	230	90
	212+50	7900	2460	1030[b]	210	—	3270	100	70
	213+50	15310[b]	4730	650	150	—	2570	740	80
	214+50	12110	2960	550	160	—	1430	520	100
	Average	8550	2710	600	150		1850	320	90

[a] 1 MPa = 0.145 ksi

[b] Outlier tested according to Chauvenet's criterion

[c] Not considered in the average calculation because of unsatisfactory deflection bowl

[d] Modulus of treated subgrade larger than the cement – treated soil

E1 Modulus of asphalt concrete

E2 Modulus of cement-treated soil (control section)

E3 Modulus of lime-treated subgrade

E4 Modulus of subgrade

Table 3.2 Comparison of backcalculated moduli from 28-day and 440-day FWD deflection tests. Precut cement section

Section	Station	440 - day Modulus, MPa				28 - day Modulus, MPa			
		E1	E2	E3	E4	E1	E2	E3	E4
1-B	195+50	13250	1150	470	90	—	940	770	90
	196+50	6990	3010	710	140	—	1340	890	130
	197+50	7950	2070	380	120	—	2670	520	110
	198+50	12990	2240	480	120	—	1660	170	160
	199+50	10640	2210	420	100	—	600[c]	210[c]	160[c]
3-B	215+50	7700	1810	840	140	—	1500	440	110
	217+50	8720	2810	360	170	—	3430[b]	610	140
	218+50	9830	3440	760	170	—	1060	320	110
	219+50	9420	9580[b]	210[b]	200	—	1520	190	140
	Average	9560	2240	530	140		1470	540	120

[a] 1 MPa = 0.145 ksi

[b] Outlier tested according to Chauvenet's criterion

[c] Not considered in the average calculation because of unsatisfactory deflection bowl

E1 Modulus of asphalt concrete

E2 Modulus of precut cement-treated soil

E3 Modulus of lime-treated subgrade

E4 Modulus of subgrade

Table 3.3 Comparison of backcalculated moduli from 28-day and 440-day FWD deflection tests. Precracked cement section

Section	Station	440 - day Modulus, MPa				28 - day Modulus, MPa			
		E1	E2	E3	E4	E1	E2	E3	E4
2	201+00	8580	2660	870	140	—	710[d]	1430[d]	140
	203+00	12940	2990	450	150	—	2160	460	170
	204+00	13070	2540	620	150	—	290[d]	1870[d]	80
	205+00	8930	3010	860	110	—	720[d]	940[d]	80
	206+00	6930	1250	560	130	—	480[d]	1800[d]	90
	208+00	8730	1240	490	140	—	990	590	90
	209+00	8050	1060	480	120	—	1950	320	70
	Average	9280	2170	640	140		1380	410	100

[a] 1 MPa = 0.145 ksi

[b] Outlier tested according to Chauvenet's criterion

[d] Modulus of treated subgrade larger than the precracked cement - treated soil

E1 Modulus of asphalt concrete

E2 Modulus of precracked cement-treated soil

E3 Modulus of lime-treated subgrade

E4 Modulus of subgrade

Table 3.4 Comparison of backcalculated moduli from 28-day and 440-day FWD deflection tests. Cement-fly ash section

Section	Station	440 - day Modulus, MPa				28 - day Modulus, MPa			
		E1	E2	E3	E4	E1	E2	E3	E4
4	222+00	6310	1450	630	140	—	434[d]	2180[d]	80
	223+00	8190	1450	280	140	—	330[d]	2110[d]	80
	224+00	7560	1510	1360[b]	150	—	2760	170	70
	225+00	5230	1540	540	150	—	920[c]	280[c]	90[c]
	226+00	5260	1690	290	170	—	480[c]	140[c]	100[c]
	227+00	4950	1460	570	150	—	810[c]	250[c]	100[c]
	228+00	6960	360[d]	1140[d]	180	—	830[c]	250[c]	100[c]
	229+00	6560	1580	660	160	—	2340	510[b]	130[b]
	Average	6380	1530	510	155		2380	215	70

[a] 1 MPa = 0.145 ksi

[b] Outlier tested according to Chauvenet's criterion

[c] Not considered in the average calculation because of unsatisfactory deflection bowl

[d] Modulus of treated subgrade larger than the cement - fly ash soil

E1 Modulus of asphalt concrete

E2 Modulus of cement-fly ash section

E3 Modulus of lime-treated subgrade

E4 Modulus of subgrade

Table 3.5 Comparison of backcalculated moduli from 28-day and 440-day FWD deflection tests. Lime-GGBFS section

Section	Station	440 - day Modulus, MPa				28 - day Modulus, MPa			
		E1	E2	E3	E4	E1	E2	E3	E4
5	231+00	6860	2270	1340	130	—	6900	200	100
	232+00	5170	2800	1300	130	—	4530[c]	40[c]	110[c]
	233+00	8360	2780	1430	160	—	9960[b]	840[b]	90
	234+00	6890	2840	1330	130	—	1070	550	80
	235+00	8630	1640	800	160	—	1900	210	70
	236+00	7570	1800	470	170	—	1960	470	110
	237+00	10110	1040	310	130	—	1010[c]	130[c]	90[c]
	238+00	12140	2080	760	180	—	1350	270	120
	239+00	8980	4100[b]	470	150	—	3760[c]	100[c]	130[c]
	Average	8300	2160	910	150		2640	340	100

[a] 1 MPa = 0.145 ksi

[b] Outlier tested according to Chauvenet's criterion

[c] Not considered in the average calculation because of unsatisfactory deflection bowl

E1 Modulus of asphalt concrete

E2 Modulus of lime-GGBFS soil

E3 Modulus of lime-treated subgrade

E4 Modulus of subgrade

Table 3.6 Comparison of backcalculated moduli from 28-day and 440-day FWD deflection tests. Lime-fly ash section without drainage layer

Section	Station	440 - day Modulus, MPa				28 - day Modulus, MPa			
		E1	E2	E3	E4	E1	E2	E3	E4
6	246+00	5790	350	180	130	—	220	400	140
	247+00	5700	420	210	140	—	370	270	120
	248+00	4360[b]	350	230	80[b]	—	220	740	70
	249+00	5340	400	340[b]	160	—	260	5240[b]	100
	249+50	5380	720[b]	220	160	—	—	—	—
	Average	5550	380	210	150		270	470	110

[a] 1 MPa = 0.145 ksi

[b] Outlier tested according to Chauvenet's criterion

[c] Not considered in the average calculation because of unsatisfactory deflection bowl

E1 Modulus of asphalt concrete

E2 Modulus of lime-fly ash soil

E3 Modulus of lime-treated subgrade

E4 Modulus of subgrade

Table 3.7 Comparison of backcalculated moduli from 28-day and 440-day FWD deflection tests. Lime-fly ash section with drainage layer. LFA and lime-treated subgrade combined

Section	Station	440-day Modulus, MPa				28-day Modulus, MPa			
		E1	Drainage layer[e]	Composite[f]	E4	E1	E2	E3	E4
6 (alternate)	25100	6790	160	540	120	—	—	—	—
	25200	6430	130	410	90	—	—	—	—
	25300	8420	160	270	70	—	—	—	—
	25400	8030	170	590	150	—	—	—	—
	Average	7420	160	450	110				

[a] 1 MPa = 0.145 ksi

E1 Modulus of asphalt concrete

[e] Modulus of drainage layer

[f] Composite modulus of lime-fly ash and lime-treated subgrade

E4 Modulus of subgrade

Table 3.8 Properties of core samples along with unconfined compressive strength corrected to 2:1 height to diameter ratio

Station	Section	Moisture Content(%)	Dry Density (lb/ft^3)	Compressive Strength (kPa)	Height (inch)	H/D ratio	Correction factor	Corrected Strength (kPa)
1A	190+50	11.35	114.78	2300	6.18	1.55	1.16	1980
	194+50	15.00	116.40	1510	6.43	1.61	1.14	1330
1B	195+50	12.89	114.00	2880	5.44	1.36	1.23	2350
	199+50	14.36	116.00	1840	6.43	1.61	1.14	1620
2	201+00	12.43	117.00	2490	4.72	1.18	1.29	1930
	203+00	13.53	116.67	3900	6.40	1.60	1.14	3420
	209+00	17.70	115.25	1930	6.90	1.73	1.10	1760
3A	210+50	15.14	115.30	1980	5.60	1.40	1.21	1630
	214+50	14.51	116.25	2270	4.41	1.10	1.32	1720
3B	215+50	14.34	117.11	1370	6.23	1.56	1.16	1190
	219+50	17.38	113.66	2960	5.81	1.45	1.19	2480
4	221+00	16.10	118.65	5050	7.60	1.90	1.04	4880
	223+00	11.77	118.00	1920	4.70	1.18	1.29	1490
	229+00	9.92	120.40	1180	6.40	1.60	1.14	1030
5	231+00	15.46	117.10	4460	7.92	1.98	1.01	4430
	233+00	12.59	118.20	4220	6.40	1.60	1.14	3700
	239+00	10.03	116.63	3720	5.41	1.35	1.23	3030
6	247+00	14.76	114.55	1240	3.82	0.96	1.37	910
6(alternate)	251+02	11.51	115.19	540	4.01	1.09[a]	1.31	410
	254+00	12.17	113.49	430	3.80	1.13[b]	1.23	350

[a] Core diameter 3.67 inches
[b] Core diameter 3.34 inches

Table 3.9 Unconfined compressive strength of core samples (height to diameter ratio 2:1). Twenty eight-day strength compared with that of 440-day

Station	Section	Unconfined Compressive Strength, kPa[a]			
		28 - day	Average	440 - day	Average
1A	190+50	1280[b]	710	1980	1670
	192+50	720		-	
	194+50	750		1330	
3A	210+50	660		1630	
	212+50	690		-	
	214+50	-		1720	
	214+56	720		-	
1B	195+50	-	1070	2350	1910
	197+50	1390		-	
	199+50	1240		1620	
3B	215+50	-		1190	
	215+56	630		-	
	217+55	670		-	
	219+50	-		2480	
	219+55	1430		-	
2	201+00	1310	880	1930	2370
	203+00	890		3420	
	205+00	580		-	
	207+00	500		-	
	209+00	1120		1760	
4	221+00	-	910	4880	2470
	221+05	1270		-	
	223+00	-		1490	
	223+05	760		-	
	225+05	990		-	
	227+05	870		-	
	229+00	-		1030	
	229+05	680		-	
5	231+00	-	1980	4430	3720
	231+05	3740		-	
	233+00	-		3700	
	233+05	1550		-	
	235+05	1880		-	
	237+05	730		-	
	239+00	-		3030	
	239+05	-		-	
6	245+05	240	300	-	560
	247+00	-		910	
	247+05	-		-	
	248+95	-		-	
6 (alternate)	250+50	230		-	
	251+02	-		410	
	251+50	-		-	
	252+50	-		-	
	253+50	-		-	
	254+00	-		350	
	254+50	440		-	

[a] kPa = 0.145 psi
[b] Outlier tested according to Chauvenet's criteria

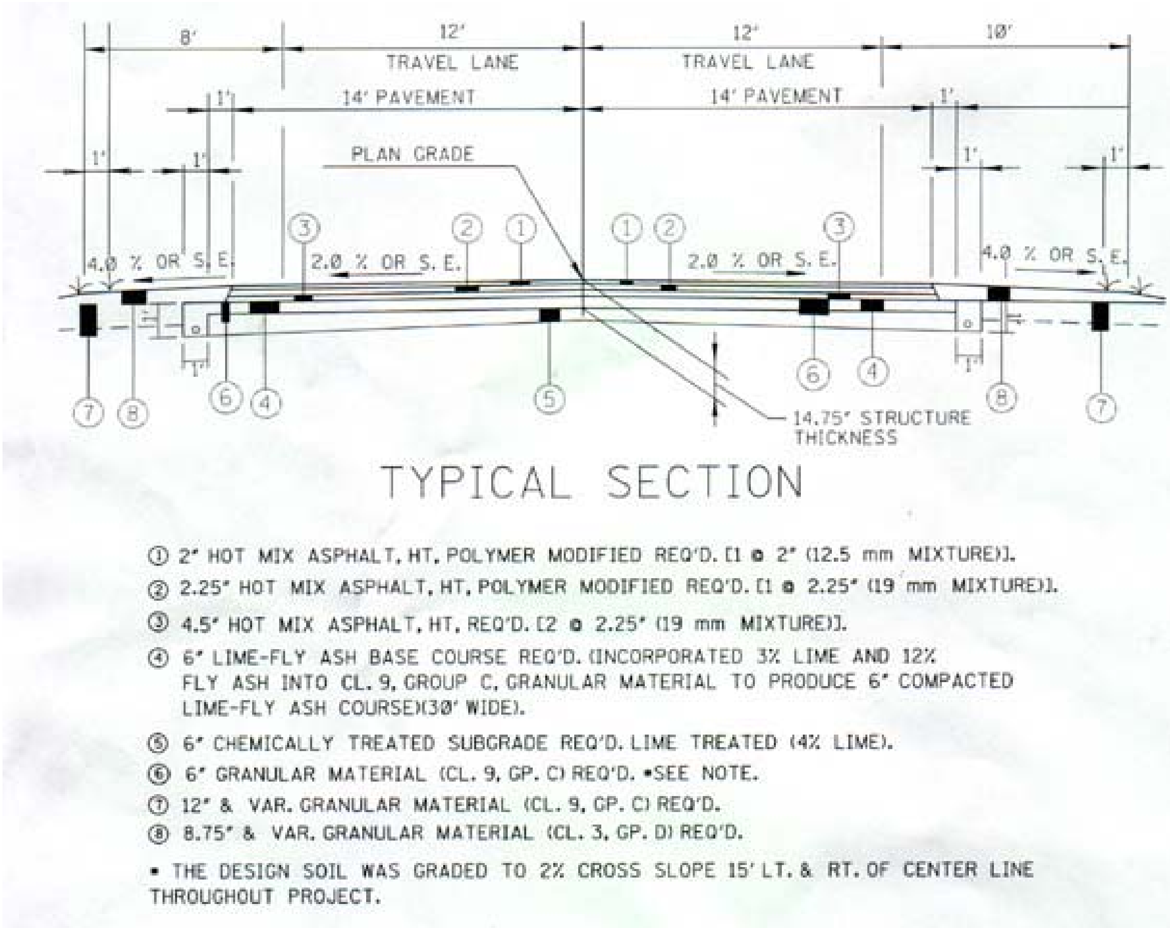

Figure 2.1 –Typical Test Section X-Section, Mississippi Highway #302, Marshall County

APPENDIX

In order to apply temperature correction to moduli value, a two-step procedure needs to be followed:

1. Predict the temperature at the mid-depth from surface temperature time of test and average air temperature (ºC) the day before testing. BELLS3 method (2), developed in connection with LTPP testing is employed for this purpose. The following equation is solved to obtain pavement temperature at mid-depth:

$$T_d = 0.95 + 0.892 * IR + \{\log(d) - 1.25\}\{-0.448 * IR + 0.621 * (1\text{-day}) + 1.83 * \sin(hr_{18} - 15.5)\} + 0.042 * IR * \sin(hr_{18} - 13.5)$$

where:

T_d = Pavement temperature at depth d, ºC
IR = Infrared surface temperature, ºC
Log = Base 10 logarithm
d = Depth at which mat temperature is to be predicted, mm
1-day = Average air temperature (ºC) the day before testing
sin = sine function on an 18-hr clock system, with 2π radians equal to one 18-hr cycle
hr_{18} = Time of day on a 24-hr clock system, but calculated using an 18-hr AC temperature rise- and-fall time cycle

2. For temperature adjustment of backcalculated asphalt moduli, the following equation is employed:

$$ATAF = 10\ (slope * (T_r - T_d))$$

where:

ATAF = Asphalt temperature adjustment factor
slope = Slope of the log modulus versus temperature equation (-0.0195 for the wheelpath and -0.021 for mid-lane are recommended)
T_r = Reference mid-depth hot-mix asphalt (HMA) temperature, ˚C
T_d = Mid-depth HMA temperature at time of measurement, ˚C

Note: Most of the slopes range between -0.010 and -0.027 (a reasonably broad range). The most common occurring slopes are -0.0195 for tests taken in the wheelpaths and -0.021 for tests taken mid-lane.