SOIL CEMENT LOW VOLUME
ROADS IN ARKANSAS

by

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16. Abstract

This report covers an investigation of low volume soil cement roads in Arkansas which, according to District Engineers, have experienced high maintenance costs due to distress. Distress of soil cement roads was minor in many cases. Observed conditions at many of the test sites indicated only longitudinal and transverse cracks which are characteristic of most soil cement stabilized material.

In a comparison of a distressed section and a section without distress, unconfined compressive strength of the cement treated base was found to be the best indicator of highway performance. Density of the cement treated base was not a good indicator because high densities were found in the sections with both good and poor performance.

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FINAL REPORT

HIGHWAY RESEARCH PROJECT 48

conducted for

The Arkansas State Highway Department

in cooperation with

The U.S. Department of Transportation

ABSTRACT

This report covers an investigation of low volume soil cement roads in Arkansas which, according to District Engineers, have experienced high maintenance costs due to distress. Distress of soil cement roads was minor in many cases. Observed conditions at many of the test sites indicated only longitudinal and transverse cracks which are characteristic of most soil cement stabilized material.

In a comparison of a distressed section and a section without distress, unconfined compressive strength of the cement treated base was found to be the best indicator of highway performance. Density of the cement treated base was not a good indicator because high densities were found in the sections with both good and poor performance.

GAINS, FINDINGS, CONCLUSIONS

Distress of Arkansas low volume soil cement roads was minor in many cases. Observed conditions at many of the test sites indicated only longitudinal and transverse cracks which are characteristic of most soil cement stabilized material.

Unconfined compressive strength of the cement treated base is the best indicator of highway performance. Density of the cement treated base is not a good indicator because density was high on all three highways in the final testing program.

IMPLEMENTATION

Implementation of this research will depend on the findings of an AHTD review of the design and construction procedures for low volume soil cement roads.

ACKNOWLEDGEMENTS

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INTRODUCTION

Some soil cement low volume roads in Arkansas have performed well, others have not. According to a 1976 survey of District Engineers, soil cement failures are most common in south and east Arkansas.

The effect of early distress is increased maintenance costs and the creation of poor riding surfaces. Maintenance costs of low volume roads are important because Arkansas has 11,558 miles of secondary roads compared to 3,531 miles of primary roads.

BACKGROUND

Most of the technology for soil cement roads was developed before the 1970s and was reported by the Highway Research Board and Portland Cement Association. The following information on cement types, reaction with soil, and design criteria is drawn mainly from the reports of those two organizations and laboratory tests conducted by the author.

Cement Types

Portland cement is manufactured in three types:

ASTM Type I	General Purpose - This type is used in most roadbed stabilization. A sand mortar cube is required to develop 5500 psi in 28 days.
ASTM Type II	Lower Heat Sulfate Resistant - This type can be used in massive applications such as dams, piers, and abutments.
ASTM Type III	High Early Strength - This type should be used where high early strength is required, for example, where traffic must be placed on the stabilized soil within a week or two. A sand mortar cube is required to develop 7500 psi in 28 days.

ASTM Type IV, a type which minimizes heat, and Type V, a maximum sulfate resistance type, also are produced but seldom are used in roadbed stabilization.

Reaction with Soil

Cement is most effective in stabilizing granular soils. Mixed with water, cement forms a paste which hardens to tobermorite gel thereby cementing the soil particles together. The very strong gel cements the particles with which it is in contact regardless of their size. Because clay has many more particles than sand, more cement is required in clay than in sand. In addition, sand is stronger than clay.

The generalized reaction of cement with water is:

$$C_3S + 2H = C_2SH + \text{FREE LIME}$$

and

$$C_2S + 2H = CSH + \text{FREE LIME}$$

where

C is CaO

S is SiO_2

H is H_2O

The calcium silicate gel crystalizes slowly to form the tobermorite gel.

Because free lime is released, some of the same cation exchange and flocculation that occur in lime stabilization also take place during the reaction, but the formation of the gel is of overriding importance.

Strength is the most important property that cement contributes to soil. Unconfined compressive strength is the easiest and most common measure of strength. Unconfined compressive strength of cement stabilized soils ranges from 200 to 2000 psi. The usual range of seven day design strength for soil cement is 300 to 700 psi.

Cement content and the soil type affect the seven day unconfined compressive strength of cement treated soils (Figure 1). Strength increases with increasing cement content. Coarse grained soils may have strength greater than 1000 psi at a cement content of 10%. In fine grained soils the increase is much less dramatic. Unconfined compressive strength for fine grained soils at 10% cement is typically less than 500 psi.

The strength of soil-cement mixtures increases with time but the rate of gain decreases after a month (Figure 2).

After a year or more, the rate of increase in strength is very slow. An increase in strength with time occurs in both coarse grained and fine grained soils.

An increase in density of a soil cement mixture will increase the unconfined compressive strength of that mixture (Figure 3). An increase in density, as measured by dry unit weight, of 10% may result in a 30 to 100% increase in strength. The rate of strength gain from an increase in density is slightly higher in coarse grained soils than in fine grained soils.

Curing temperature also affects the strength of soil cement mixtures (Figure 4). As the curing temperature increases, unconfined compressive strength increases. The rate of increase due to curing temperature is approximately linear between 20^{o} and $50^{o}C$ ($70^{o}F$ and

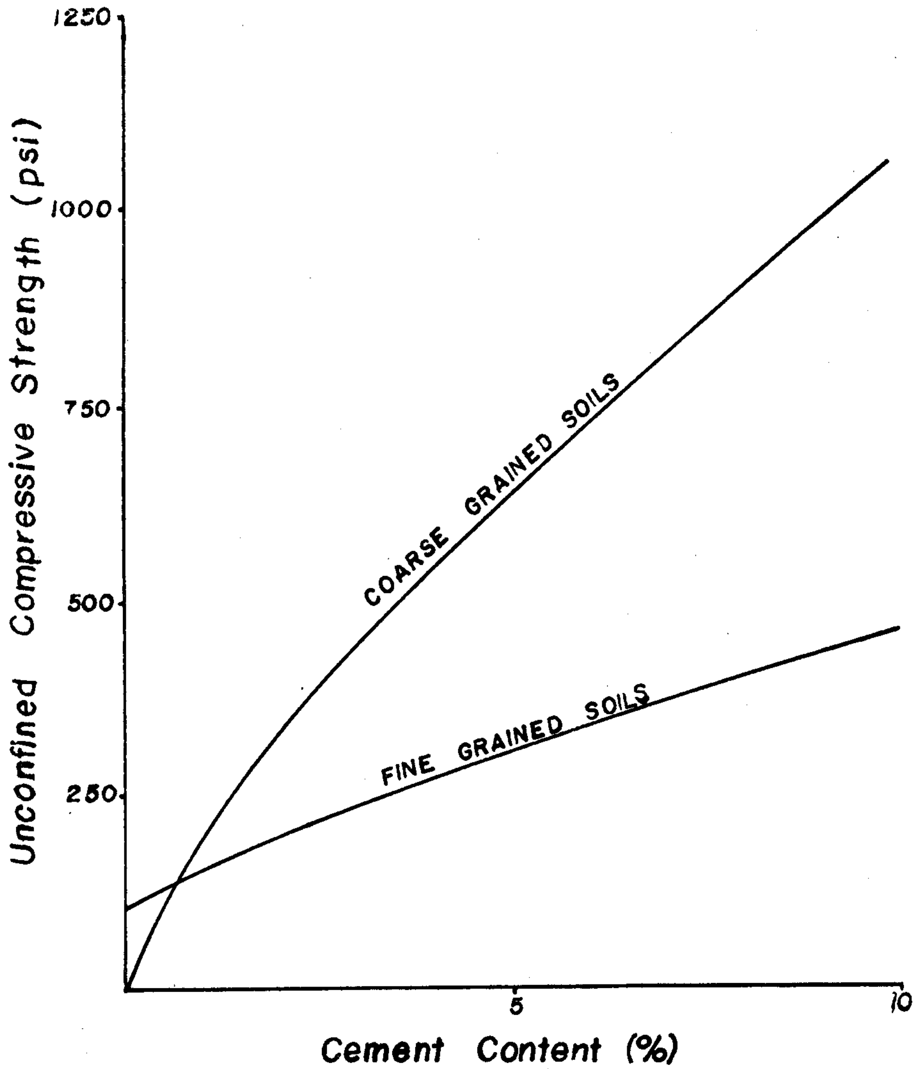


Figure 1. Effect of Cement Content on Strength

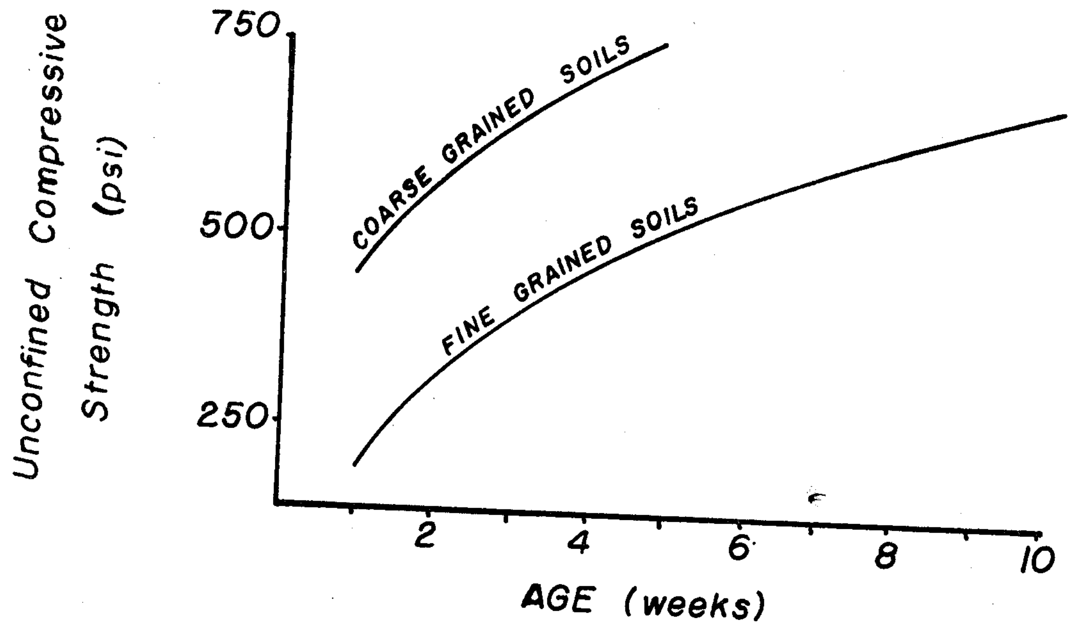


Figure 2. Effect of Curing Time on Strength

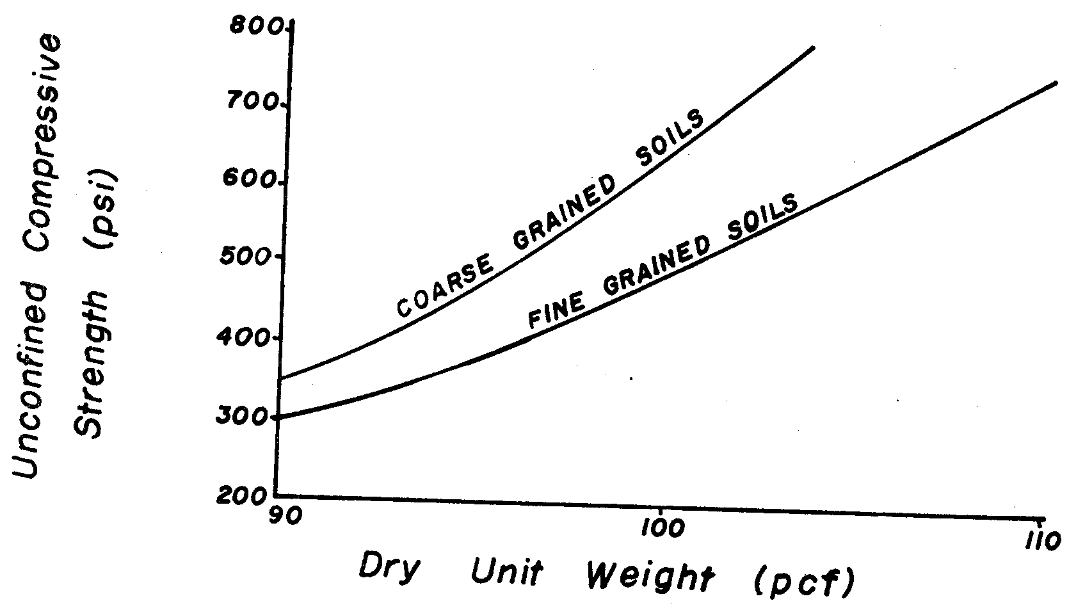


Figure 3. Effect of Density on Strength

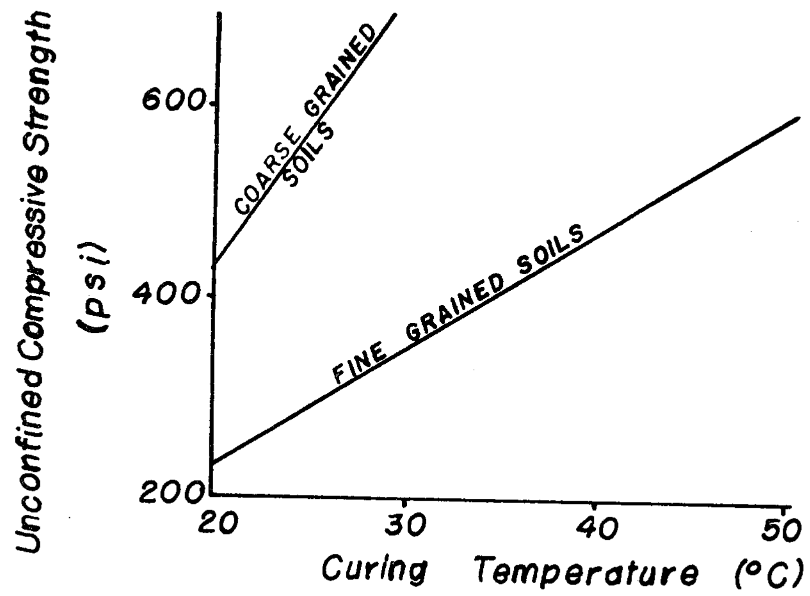


Figure 4. Effect of Curing Temperature on Strength

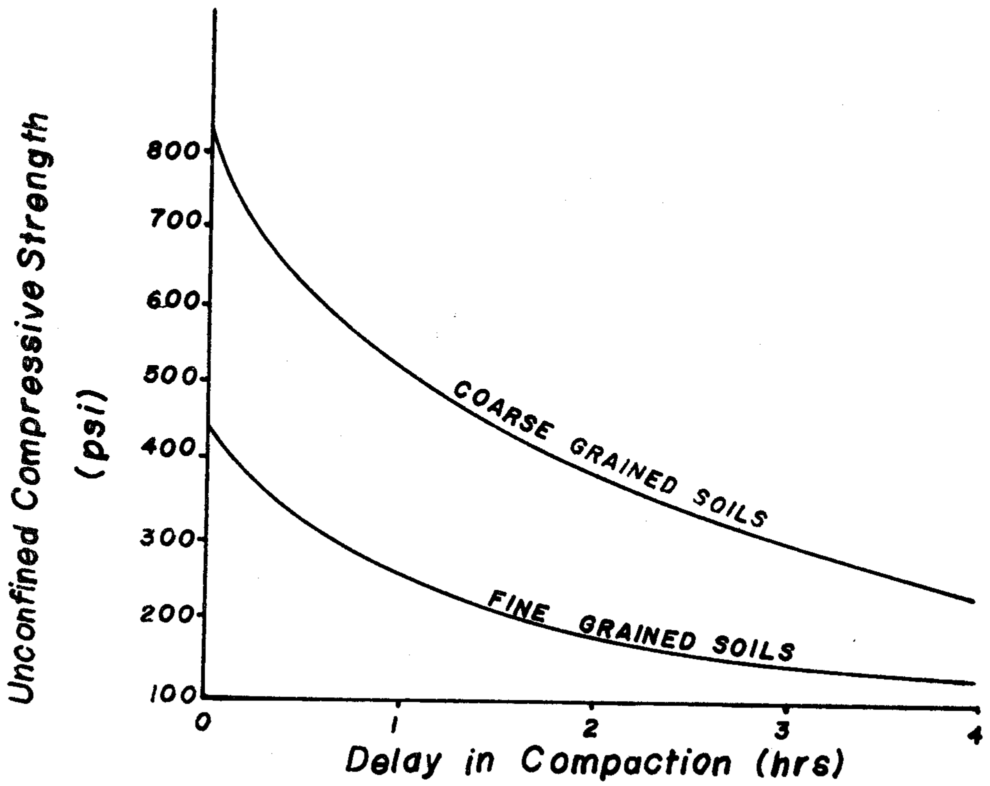


Figure 5. Effect of Delay in Compaction After Mixing on Strength

120°F). For this reason, soil cement bases for highways should be constructed in the summer while curing temperatures are high. The rate of strength gain from increased curing temperatures is more rapid in coarse grained soils than in fine grained soils.

A delay from the time of mixing to compaction significantly reduces the strength of soil cement (Figure 5). After cement is mixed with water, a reaction begins and continues with the passage of time. If soil, cement, and water are mixed but remain in a loose state, the mixture will gradually become cemented but the material will be weak.

Design Criteria

The design criteria for a roadway indicate the amount of cement to be used and the unconfined compressive strength required. As little cement should be used as possible to obtain the unconfined compressive strength desired. Cement above the amount required for strength is costly and may create a minor increase in shrinkage (Norling, 1973). An increase in longitudinal and transverse shrinkage cracks is not sure, however, and block cracking is reduced by increased strength (Zube et al., 1969, p. 60).

Unconfined compressive strength in the 300-1000 psi range usually is required in a 6 inch thick compacted roadbed base. The strength required depends on the amount and type of traffic and the strength and thickness of subbase and surface courses. Many roadways are designed on the basis of the recommendations of the AASHO test road. A good treatment of this method can be found in the text, Highway Engineering, 3rd edition, by Oglesby, 1975, pp. 481-486.

The strength requirement based on the design factors should be increased because field strengths are not as high as lab strengths. In an excellent report on cement treated bases in California, Zube et al. (1969) concluded, "It would appear advisable, therefore, to design new cement treated bases for a strength about 25 to 30 percent higher than considered necessary in the completed CTB."

An additional strength requirement commonly is included to compensate for a small percentage loss of weight, usually 10 to 14%, due to brushing in the freeze-thaw test. The freeze-thaw test, a durability test, is now out of favor because of the method of freezing the samples and the time required to conduct the test (Dempsey and Thompson, 1973). As a result, Dempsey and Thompson (1976) suggest a vacuum saturated unconfined compression test to replace the freeze-thaw test. Cumberage et al. (1976) conducted tensile strength tests on stabilized soil as a replacement for the standard freeze-thaw test. They concluded that a 68 psi tensile strength is necessary for freeze-thaw protection in Pennsylvania. Radd et al. (1977), in a study of fatigue behavior, concluded that tensile strength is a good indicator of fatigue resistance. Through questioning, they disclosed that the true tensile strength is 10% less than the split tensile strength which in turn is related to compressive strength.

The Portland Cement Association still recommends that durability testing, i.e., freeze-thaw and wet-dry tests, remain at the core of the design . . . "The three control factors for soil-cement construction -- density, moisture content and cement content -- are determined by standard ASTM laboratory tests that lead to a high degree of durability in the material rather than a specified compressive strength.

The tests were developed in such a way that the effect of any detrimental material in the soil - clay, organic materials, soft particles, etc. -- would cause a higher cement content for hardening due to the degree of chemical reaction of the cement with the soil (compressive strength is also a measure of this) and very importantly, how well the bonds of cementation hold together against repeated expansions and contractions caused by moisture absorption and loss, and volume changes due to temperature changes and freezing (compressive strength gives no indication of these effects). As a result, for many soils there is a poor correlation between the cement content required for a given compressive strength and the cement content required for durability" (PCA, Sept. 1978). Details of the PCA design procedure can be found in the following PCA publications:

Thickness Design for Soil Cement Pavements, 1970

Soil Cement Laboratory Handbook, 1971

PCA Soil Primer, 1973

Soil Cement Construction Handbook, 1969

Previous Study Findings

In an evaluation of "Service Performance of Cement-Treated Bases as Used in Composite Pavements," Zube et al. (1969) summarized the main causes of failure as:

1) insufficient cement content,
2) poor mixing,
3) over trimming of the compacted base,
4) insufficient base thickness,
5) inadequate compaction, and

6) poor quality or thin asphalt concrete.

A more recent study by Melacon and Shah (1973) shows mixing to be a major problem: "In-place mixing of cement with soil appears to be somewhat less than desirable. Results of 311 observations show a variation of ± 5% from the theoretical cement content."

Improvements in base performance can be made, however. Zube et al. (1969) found improvements from:

1) extending the base one foot into the shoulder,
2) plant mixing the base,
3) building the road in a temperate climate,
4) increasing the thickness of the asphalt concrete,
5) using a minimum base thickness of .5 feet,
6) making the thickness of any single layer a maximum of .5 feet,
7) using ASTM Type II cement, and
8) providing a minimum in-place base strength of 500 psi.

A 1963-1966 Arkansas study, HRC-9, was conducted to determine the performance of eight sections of newly constructed soil cement stabilized roadways (Hensley, October 1966). Although the study was terminated early, no extensive base failures were found. However, edge raveling was common and significant transverse and longitudinal cracking was reported through photographs. Also shown through photographs was the effective repair of cracks by resealing.

THE TESTING PROGRAM

Seventeen sections of soil cement stabilized state highways listed as distressed by District Engineers (Figure 6) were included in a preliminary testing program. The final testing program, formulated with the aid of a research subcommittee, included two of the distressed sections from the preliminary program and a different section for comparison which has no distress (Figure 7).

Interviews

As a part of the investigation, interviews with Highway Department officials, including design, testing, construction and maintenance officials, were conducted to obtain opinions about possible causes of the failures. The interviews included an inspection of the highways listed as distressed by the District Engineers.

The interviews were of little help in determining the cause of distress in the highways. In addition, little was learned from the inspection trips becuase the highways, with the exception of one or two, had recently been resurfaced in a special resurfacing program. It was apparent from the inspection trip, however, that no single problem such as poor drainage or unusual subsoil explained the distress.

Roadway Background

Investigation of the background of distressed highways included the following items:

a) type wheel loads,

b) use of road,

c) general terrain,

Figure 6

PRELIMINARY TEST SECTIONS

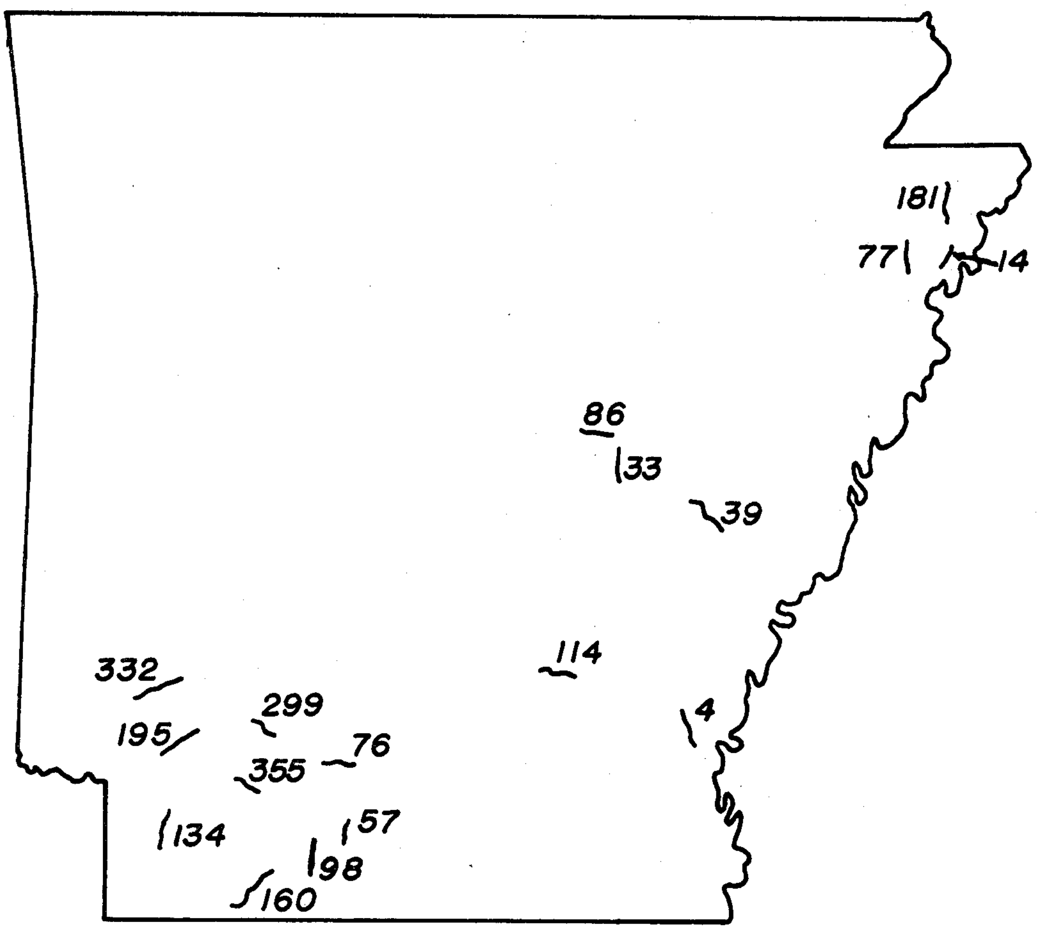
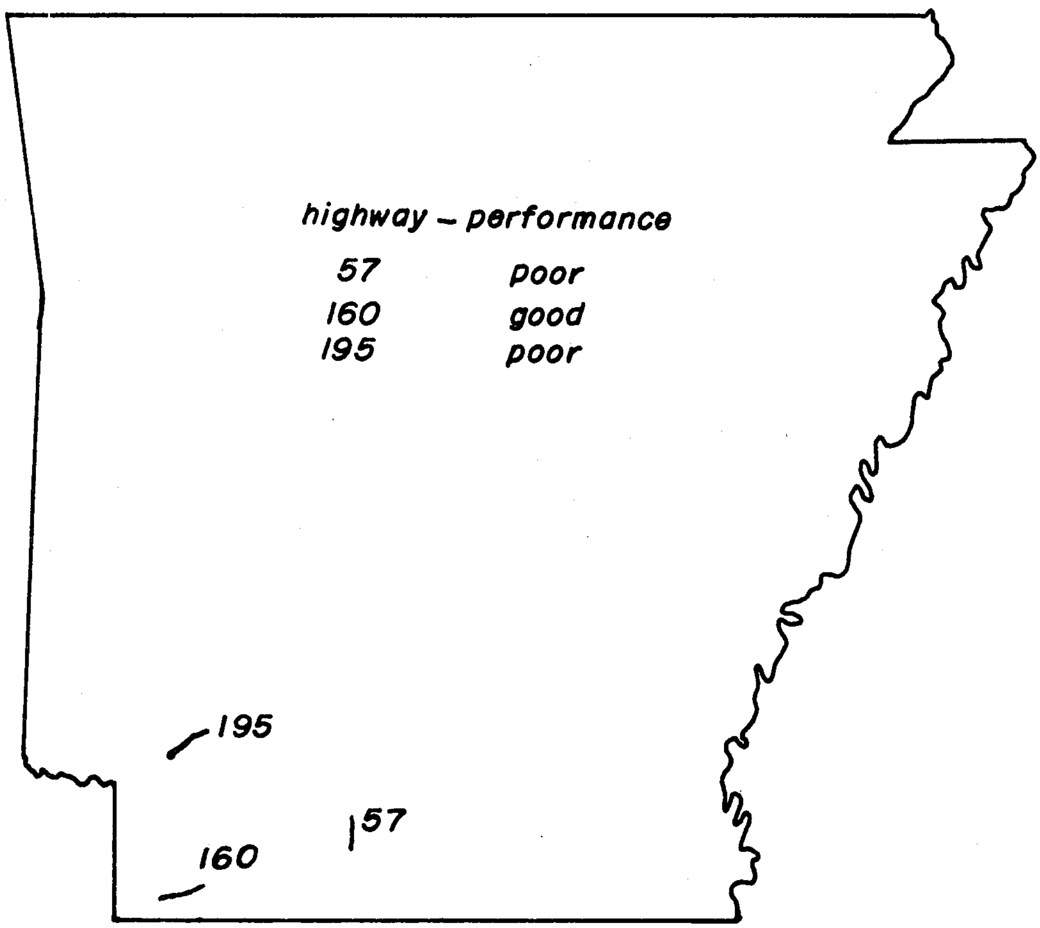


Figure 7

FINAL TEST SECTIONS



d) ADT (average daily traffic) at time of design,

e) Agriculture Department soil classification,

f) type of distress or overlay,

g) overload violations,

h) select material used,

i) typical section

j) construction practices used

k) present traffic counts

The wheel loads generally were light with an occasional very heavy load. For example, Highway 114 was subjected to local rural automobile traffic and an occasional timber or gravel truck. Exceptions to the light loading were noted for State Highways 39, 134, and 181 which were subjected to very heavy wheel loads.

All of the roads in the study were in rural or agricultural use except State Highway 4. Highway 4 was in agricultural use until 1974 when construction began on a paper mill and later a bean grainery.

Traffic volume did not explain the distress. Table 1 is a comparison of the traffic volume at the time of design with the volume at the beginning of the study (1976). Time of design is taken as the date completed less one year. Average daily traffic, ADT, was highest on Highway 160, but did not exceed 1100 vehicles per day.

Traffic volumes alone give little explanation of distress. A few heavy loads, not necessarily overloads, especially during wet or thawing conditions, will distress the pavement structure more than all the light traffic during the design life. In the case of the soil-cement roads in the study, however, there is no reason to believe that an unusual volume of heavy loads occurred during wet or thawing

TABLE 1

Traffic Volume for Preliminary Test Sections

State Highway	Design Year	Traffic Volume (ADT) In Design Year	Traffic Volume (ADT) In 1976
39	1970	220	410
114	1966	395	850
4	1962	125	340
195	1970	170	340
332	1970	130	390
134	1971	100	190
299	1971	110	200
355	1974	110	130
86	1971	320	340
33	1965	325	600
33	1958	100	440
76	1966	50	280
57	1971	500	750
160	1961-65	750	1100
98	1970	350	300
181	1967	140	600
77	1972	140	280
14	1967	300	250

conditions.

Most area subgrade soils, as classified by the Agriculture Department, are loam. Poor subgrade soils were expected because the highways are located in south and east Arkansas where many subgrade soils are poor.

Most of the highways showed no distress at the time of inspection because they were resurfaced in a major resurfacing project just before the beginning of the investigation.

A search of the records of overload violations did little to explain the distress. Overload violations were concentrated on a few highways, usually the main routes. Very few overload violations were recorded for the low volume roads included in the study, with the exception of Highway 196, which heavy trucks may use to avoid weighing scales.

Without exception all the roads were constructed by cement stabilizing the top 6 inches of a select material fill. Total base thickness ranged from 6 to 12 inches. A typical cross-section with a schedule of base thicknesses as determined by Highway Department records is given in Figure 8.

Typed copies of the data sheets for background are in Appendix A. The information on the sheets is summarized in Table 2.

Preliminary Testing Program

Preliminary testing included the taking of cores of the cement treated base and disturbed samples of subgrade material. Two sites per roadway were selected for cores. Originally, cores were to be taken at distressed and nondistressed sections of the highways, but

TYPICAL CROSS SECTION

State Highway	Total Base Thickness (in)
33	6
39	8
57	8-11
86	8
98	9
114	7
134	8
160	8-10
195	8
299	7
332	7
355	7

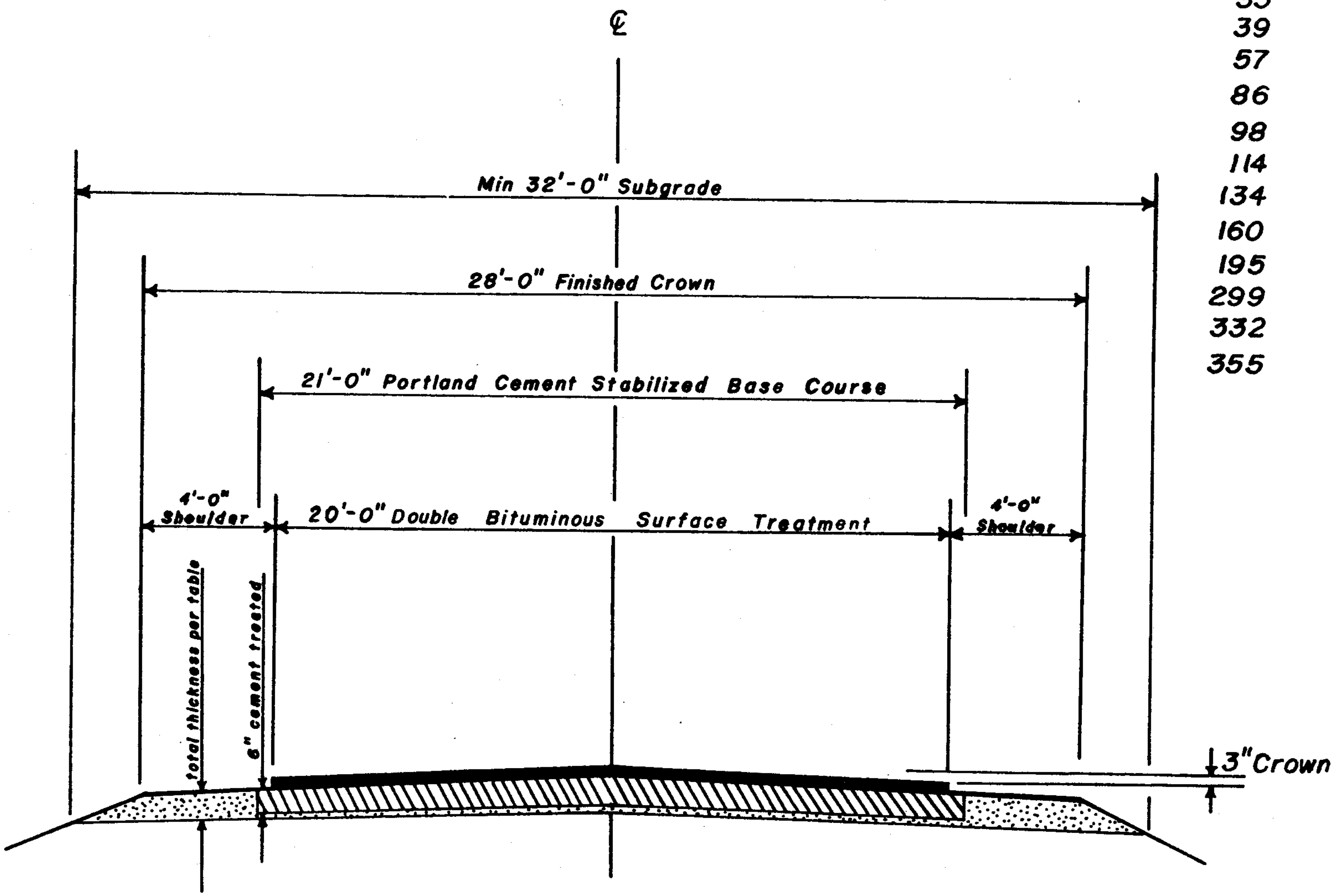


Figure 8

Table 2

Summary of Roadway Backgrounds

Hwy.	Road Use	Design Cement	AASHTO Class	General Drainage	Wheel Loading	Constr. Proced.	Observed Conditions	Repair Method	Comments
39	Rural	10.5%	A-3(0)	Poor	Grain trucks	MIP*/SM-6	Longituninal cracks	Seal	Blow-up failure
114	Farm	6%		Good	Timber/ gravel	Gravel added	Base failure	Overlay cut base 12-36"	$\frac{1}{2}$" premix over poured cracks
4	Farm			Poor	Grain/ gravel	SM-2 12"	Longitunidal crack base	Cut base-7-8% premix sealed	Constr. Pot-latch Plant
195	Rural Farm	8%	A-2-4(0)	Poor	Gen. light w/ overloads		Base		Bypass for weigh scales
332	Rural Farm	7.5%	A-2-4(0)	Moderate-good	Gen. light w/ overloads	SM-4	Longitudinal & transverse cracks		Clay subgrade
299	Rural Farm	6.5%	A-2-4(0)	Good	Light		Slight cracking		Some timber hauling
355	Rural	5%	A-4(0)	Good	Light w/ timber	MIP	No Failure		Observe low cement
14	Rural	6%		Poor	Farm	MIP	Slight Cracking	SBST	Sandy loam little distress

* MIP - mixed in place

TABLE 2 (cont.)

Hwy.	Road Use	Design Cement	AASHTO Class	General Drainage	Wheel Loading	Constr. Procedure	Observed Conditions	Repair Method	Comments
86	Rural Farm	10%	A-2-4(0)	Poor	Rice farming	MIP*/ SM-2	Ravel	?	Good contractor, smooth ride
33 Sect. 5	Rural	8%		Good	Grain/ timber	SM	Base Failures	SB-2/hot mix	
33 Sect. 6	Rural			Poor	Grain/ timber	SM	Base shrinkage	SB-2/hot mix	Roots in SM
76	Rec.			Good			New seal	Premix seal	
57	Rural	8.5%	A-2-4(0)			SM-2		Pour cracks	ACHMSC surface course
160	Rural	9%				SM		Premix and seal	
98	Rural	6%				SM-2 DBST		Premix and seal	
181	Farm	9%	A-2-4(0)	Poor	Grain	MIP/ SM	Base Failures	Asphalt/ sand	New surface
77	Rural Farm	9.5% 10.5%	A-3(0) A-2-4(0)	Poor	Farm	MIP/ SM	L&T cracks & ravel	2-300' patch	Poor subgrade
134		9.0%	A-2-4(0)	Poor	Farm	SM	Chunks	Rebuild	Corpos of Engineers hauled rip-rap

* MIP - mixed in place

because of the recent overlays the cores were taken at random in the sections. Cores were tested for density, strength, and moisture content. Disturbed subgrade samples were tested for moisture content, in-place density, R-value, liquid and plastic limits, and Proctor density.

Results from the preliminary testing program are given in Tables 3, 4, and 5. Table 3 includes the design data, e.g., percent cement and classification of the stabilized select material. The results from core strength and density tests are given in Table 4. Subgrade data are listed in Table 5.

Cement content ranged from 5 to 10.5% (Table 3). The select material which was stabilized was classified as A-2 or A-3 by the AASHTO system except that of Highway 355, which was classified A-4. Design density ranged from 109 to 133 pcf and optimum moisture content was low, 8 to 15%, as is expected in coarse grained soils.

Thickness of the cement treated bases was near the design thickness of 6 inches (Table 4). Only for Highway 332 were both cores less than 6 inches long. Compressive strength was low, however, in at least one of two cores from 13 of the 16 highways. Seventeen highways were included in the study but one, Highway 355, had no distress and was included for observation only. An analysis of the probable causes of low strength (Table 6) indicated the most common causes to be cement lenses, clay nodules, and organic matter (Figures 9, 10). In general, higher field density and lower field moisture content indicated higher compressive strength. For example, the 1300 psi of Highway 299 corresponds to a density of 114 pcf and moisture content of 9.4%, whereas the 210 psi of Highway 355 corresponds to 107 pcf and 13.5%.

TABLE 3

Summary of Roadway Design Data

Highway	Design Cement Content (%)	Base (SM) Material AASHTO Class	Design Density (pcf)	Design Optimum Moisture (%)
39	10.5	A-3(0)	110 110	13.0 13.0
114	6		133 133	8.2 8.2
4	9-10		County Job	
195	8	A-2-4(0)	118 118	10.4 10.4
332	7.5	A-2-4(0)	116 116	13.8 13.8
299	6.5	A-2-4(0)	123 123	8.8 8.8
355	5	A-4(0)	122 122	11.5 11.5
86	10	A-2-4(0)	110 110	12.8 12.8
33	8		N.A.	N.A.
76			N.A.	N.A.
57	8.5	A-2-4(0)	111 111	12.3 12.3
160	9-10		111 111	11.6 11.6
98	7		120 120	10.3 10.3
181	9	A-2-4(0)	110 110	13.1 13.1

TABLE 3 (cont.)

Highway	Design Cement Content (%)	Base (SM) Material AASHTO Class	Design Density (pcf)	Design Optimum Moisture (%)
77	9.5	A-3(0)	109	14.9
	10.5	A-2-4(0)	109	14.9
14	6		N.A.	N.A.
134	9	A-2-4(0)	116	12.2
			116	12.2

TABLE 4

Summary of Field Observations and Tests

Hwy.	Observed Surface Conditions	Field Base Thickness (in.)	Field Compressive Strength (psi)	Field Dry Density (pcf)	Field Moisture Content (%)	Comments
39	T & L	6	Low*			CTB contained loose SM pockets
	L in centers	5-3/4	1250	108	15.7	
114	None	6	Low*			Cement lenses in CTB & gravel
	CF	6	Low*			
4	T & L	7-1/4	1080	114	15.3	R-value = 7
	CF	6-5/8	700	118	12.2	
195	CF	6-1/2	Low*			Cement lenses in CTB
	CF	6	Low*			
332	None	4	Low*			Cement lenses in CTB
	None	5	600	100	15.1	
299	T & L	7	Low*			Low cement content apparent
	None	7-1/4	1300	114	9.4	
355	L	7	210	107	13.5	CTB contained clay/well-mixed
	None	4-3/4	620	113	11.7	
86	T	6-1/2	Low*			Cement lenses in CTB
	T	6-1/2	Low*			
33	CF	7	660	111	11.6	R-value = 9
	T & L	7	Low*			
76	None	5-1/2	210	107	17.3	Organic material in CTB; lenses & roots in CTB
	CF	6	Low*			
57	L & T	6	Low*			Cement lenses & organic in CTB; sample taken under 3 oak trees
	L & T	5-3/4	600	109	15.5	
160	CF	7	Low*			Clay or organic in CTB
	None	7-1/2	1400	109	17.0	

TABLE 4 (cont.)

Hwy.	Observed Surface Conditions	Base Thickness (in.)	Compressive Strength (psi)	Dry Density (pcf)	Moisture Content (%)	Comments
98	T	8	1160	114	11.1	
	None	6	940	115	13.0	
181	CF	6-1/2	710	106	14.6	
	None	6-3/4	1080	110	13.5	
77	CF	7	Low*			Clay nodules in SM
	None	6-1/2	Low*			
14	None	6-3/4	540	110	12.4	
	CF	6-1/4	750	106	17.4	
134	CF	3	Low*			CTB app. 50% 1/2"-3/4" gravel; CTB contained 2-1/2 rock & clay
	CF	6	Low*			

* No sample recovered, unconfined strength estimated at less than 200 psi.

L - Longitudinal.

T - Transverse.

CF - Block.

CTB - Cement treated base.

TABLE 5

Summary of Field Subgrade Data

Hwy.	Visual Classification (Unified)	Subgrade Density (pcf)	Moisture Content	Proctor Density (pcf)	Proctor Moisture (%)	R-Value	Liquid Limit	Plastic Index
39	CL	96	28.0	114.1	13.7	39	21	4
	SC/CL	117	15.8					
114				121.2	10.8	20	26	10
	CL	122	12.5					
4	OH/CH	114	19.4	101.8	20.0	7	32	13
	OH/CH							
195	CH	96	27.5	110.2	17.1	7	31	15
	SC	138	8.4					
332	SC	97	26.0					
	SC	110	18.3					
299	SC			116.0	12.9	74	NP	NP
	SC							
355	SM					46		
	SM	111	11.7					
86	CH/org	97	22.4	115.3	13.2		23	5
	CH/org	105	19.1					

TABLE 5 (cont.)

Hwy.	Visual Classification (Unified)	Subgrade Density (pcf)	Moisture Content	Proctor Density (pcf)	Proctor Moisture (%)	R-Value	Liquid Limit	Plastic Index
33	SC/CL SC/CL	100 107	21.4 19.3	108.4	16.4	9	29	10
76	SC/org SC/CL/org	109	15.3	116	12.9	14	28	9
57	CH/org CH	89 97	29.2 28.3	111.8	14.7	21	24	8
160	SC/SM SC/SM	120 123	12.0 13.8	123.0	10.0	72	NP	NP
98	SC SC/org	106 111	19.5 19.3			46		
181	OL/OH OL/OH	107 97	20.4 26.3	116	12.9	16	27	9
77	CH/org CH/org	88 76	35.1 42.2	85.5	30.7	< 5	60	33
14		Too dense						
134		96	27.6	93.0	25.3	< 5	57	31

Table 6

Possible Causes of Base Related Failures

Dist.	Hwy.	Design Cement Content	Observed Surface Conditions	Avg. CTB Thickness	CTB Comp. Strength	CTB Dry Density	% Proctor Density	Observed Conditions in CTB						
								Cement Lenses	Low Cement	Organic	Clay Nodules	Well-Mixed Silt/Clay	Pockets Loose-SM	Gravel in SM
1	39*	10.5%	Long. & Trans.	6 "	<200 psi	108 pcf	98%						X	
2	114	6	Block	6 "	<200	N/A	N/A	X						X
3	134*	9	Block	4½"	<200	N/A	N/A							X
3	195	8	Block	6¼"	<200	N/A	N/A	X						
3	332	7.5	None	4½"	<200	100	86%	X						
3	299	6.5	Long.& Trans.	7-1/8"	<200	114	93%		X					
3	355	5	Long.	6 "	210	107	88%					X		
6	86	10	Trans.	6½"	<200	N/A	N/A	X						
7	76	N/A	Block	5-3/4"	<200	107	N/A	X		X				
7	57	8.5	Long. & Trans.	6 "	<200	N/A	N/A	X		X				
7	160	9-10	Block	7¼"	<200	N/A	N/A			X		X		
10	77	9.5-10.5	Block	6-3/4"	<200	N/A	N/A				X			

* Subjected to very heavy wheel loads

N/A - Data not available

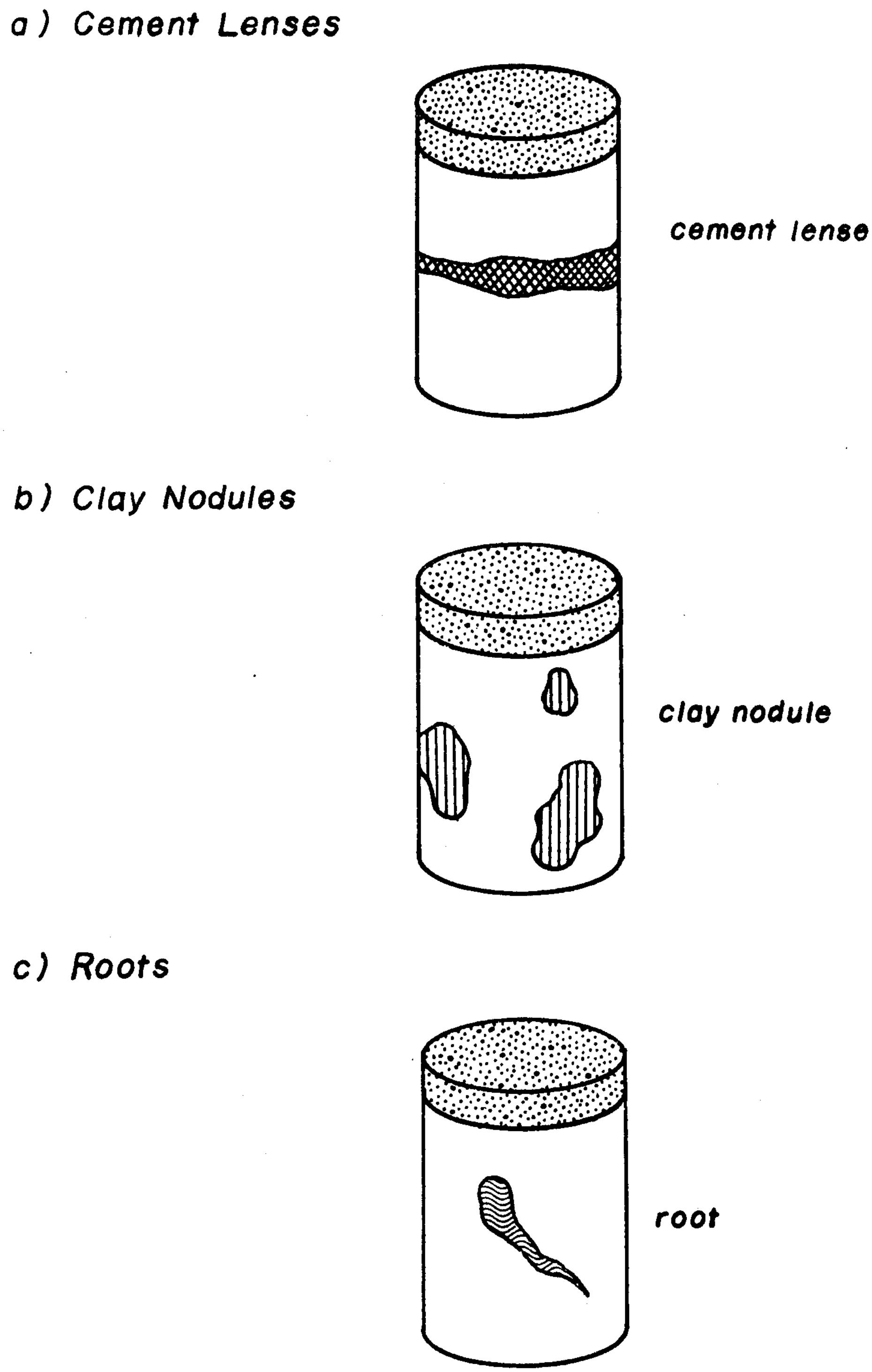
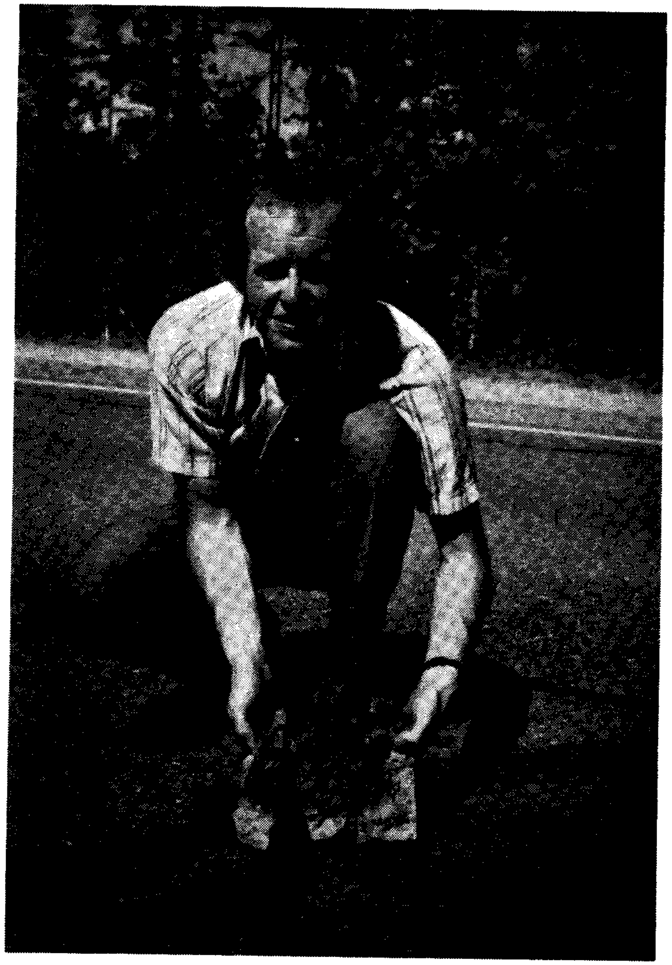


Figure 9. Three Causes of Low Base Strength



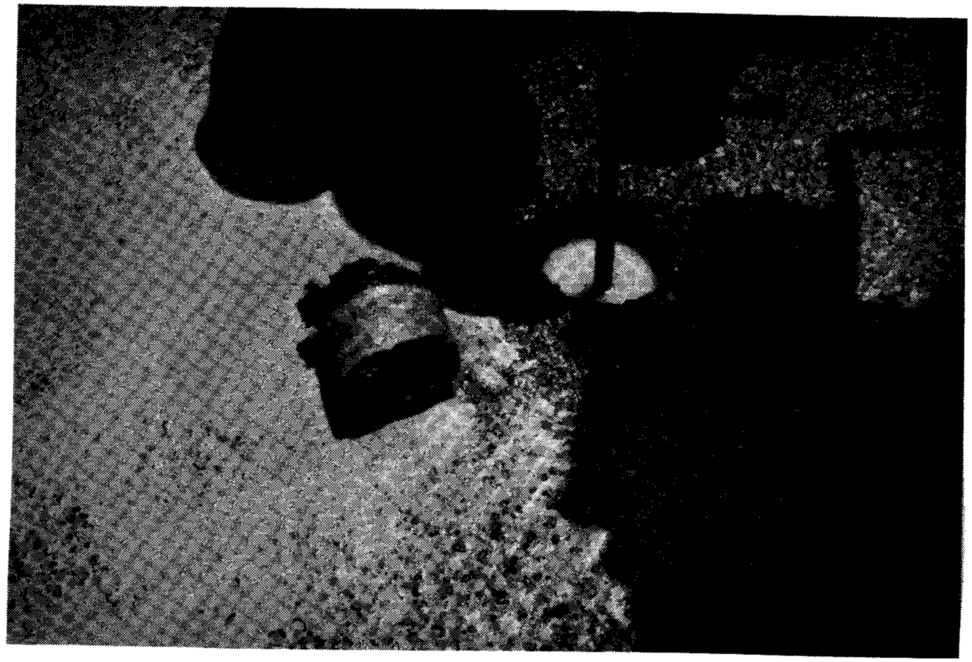


Figure 10. Two Common Mixing Problems

Clay Nodules (left)

Cement Seams (above)

Subgrade soils were relatively poor (Table 5). Organic material was noted in seven of the soils and the R-value was below 50 in all except two. Subgrade soils were mostly granular, however, on all except Highways 77 and 134, where the Proctor density was low, 85.5 and 93.0 pcf, and the plastic index was high, 33 and 31, respectively.

<u>Final Testing Program</u>

Three highways were selected for detailed testing in the final testing program. Two of them, Highways 57 and 195, were used in the preliminary testing program. The third, Highway 160 from the Red River for 5.3 miles east (Figure 7), had little distress and was included for comparison. Highway 160, Highway Department Job No. 3581, was listed only as 12 inches of SM material with the top 6 inches cement stabilized. Highway 160 was constructed prior to 1971.

The sampling program was to be conducted according to the following specifications.

Intense: Approximately midway into the section, take 10 samples in sets of two at 100 meter (yd) intervals (one lane only per highway). At each interval, one sample will be taken in the center of the lane and one in the right wheel path. Each sample will consist of a core of the base material and a Shelby tube of subgrade material.

Regular: One sample, a base core and subgrade Shelby tube, should be taken at one quarter mile intervals in the center of the lane for the rest of the job.

In addition to the undisturbed samples, disturbed subgrade samples were to be taken in the intensive sampling area for Proctor and R-value tests.

Subgrade density varied widely along the three test sections (Table 7). Density averaged 95 pcf in Highway 195. Water content associated with the density values averaged 29%. Atterberg limits in the subgrade of Highway 195 were high, the liquid limits averaging 75 and the plastic limits averaging 27. Atterberg limits this high are indicative of swelling soil. Density values were high on Highway 57, averaging 105 pcf. Associated moisture content averaged 20% and, with the exception of one site, liquid limits averaged 35 and plastic limits averaged 19. Highway 160 was so dense that Shelby tube samples could not be taken for analysis. However, the predominant soil type for the Highway 160 subgrade is a fine sand whereas the Highway 57 and 195 subgrades are clay.

Thickness of the cement treated base and asphalt surface was normal for all three highways except Highway 57, which had an asphalt surface thickness of 4 inches. Cement treated bases of all three highways ranged from 5.5 and 8.0 inches, averaging 6.5 inches. Asphalt thickness averaged .5 inches on Highways 160 and 195.

TABLE 7

Subgrade Properties of Final Test Sections

Highway	γ	w	LL	PL
195	90-99	25-33%	55-92	24-31
57	95-116	14-26%	25-50	13-25
160	Very dense	No samples retrieved		

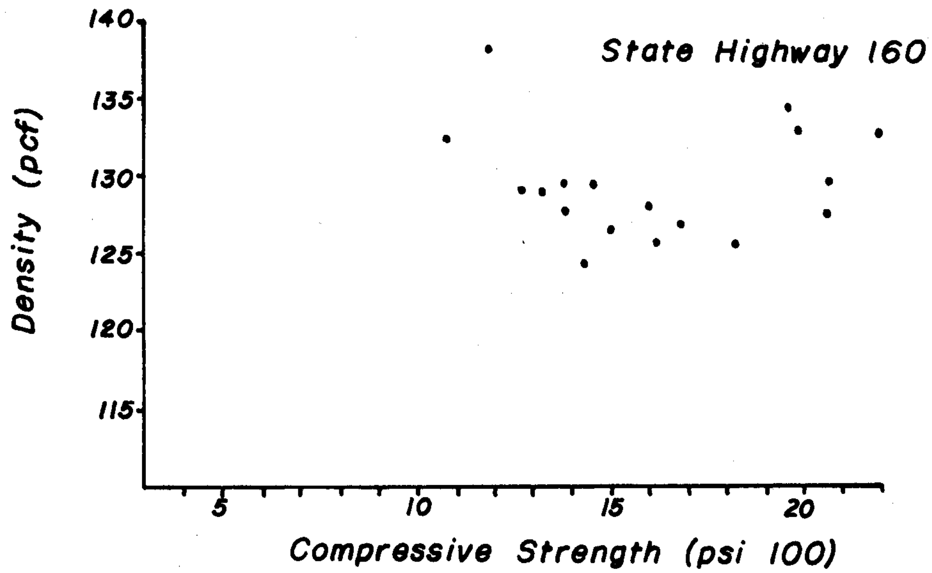
Surface cracking was noted in all three highways. Highways 57 and 160 had longitudinal and transverse surface cracks. Block cracking was the predominant surface crack in Highway 195. Many of the longitudinal and transverse cracks which were observed are characteristic of most soil cement stabilized material. These cracks are not the result of structural failure.

Density of the cement treated base was high for all three highways. Highways 160 and 57 had density values between 125 and 135 pcf with associated moisture content of 10 to 17%. Density was even higher in Highway 195, 133 to 141 pcf. Moisture content in the base of Highway 195 was similar to that of Highways 57 and 160.

Compressive strength of the cement treated base was the most significant difference between Highway 160 and Highways 57 and 195. The average compressive strength for Highway 160 and 1700 psi whereas the Highway 57 and 195 values were 820 and 420 psi, respectively. Average strength for Highways 57 and 195 included estimates of 200 psi compressive strength for samples broken during coring based on studies in California (Zube, et. al. 1969) and minimum strength of cores taken in the preliminary study.

Attempts to correlate such data as base density, base compressive strength, subgrade moisture content, and subgrade density were unsuccessful. However, plots of the base density vs. base unconfined compressive strength (Figure 11) and base thickness vs. unconfined compressive strength (Figure 12), show the base strength of Highway 160 to be much higher than that of Highway 57.

Appendix B is a summary of the test results of the final testing program.



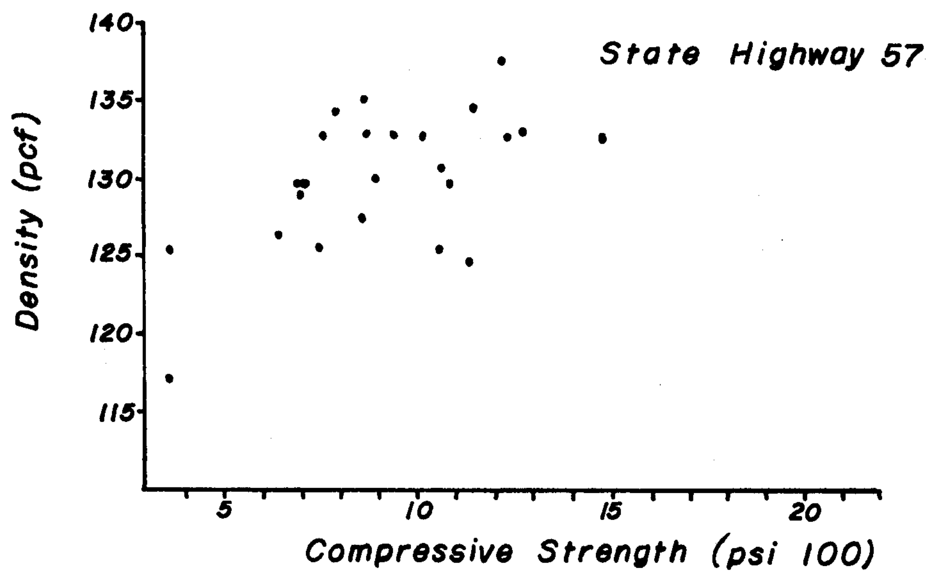


Figure 11. Relation Between Strength and Density in Two Final Test Sections

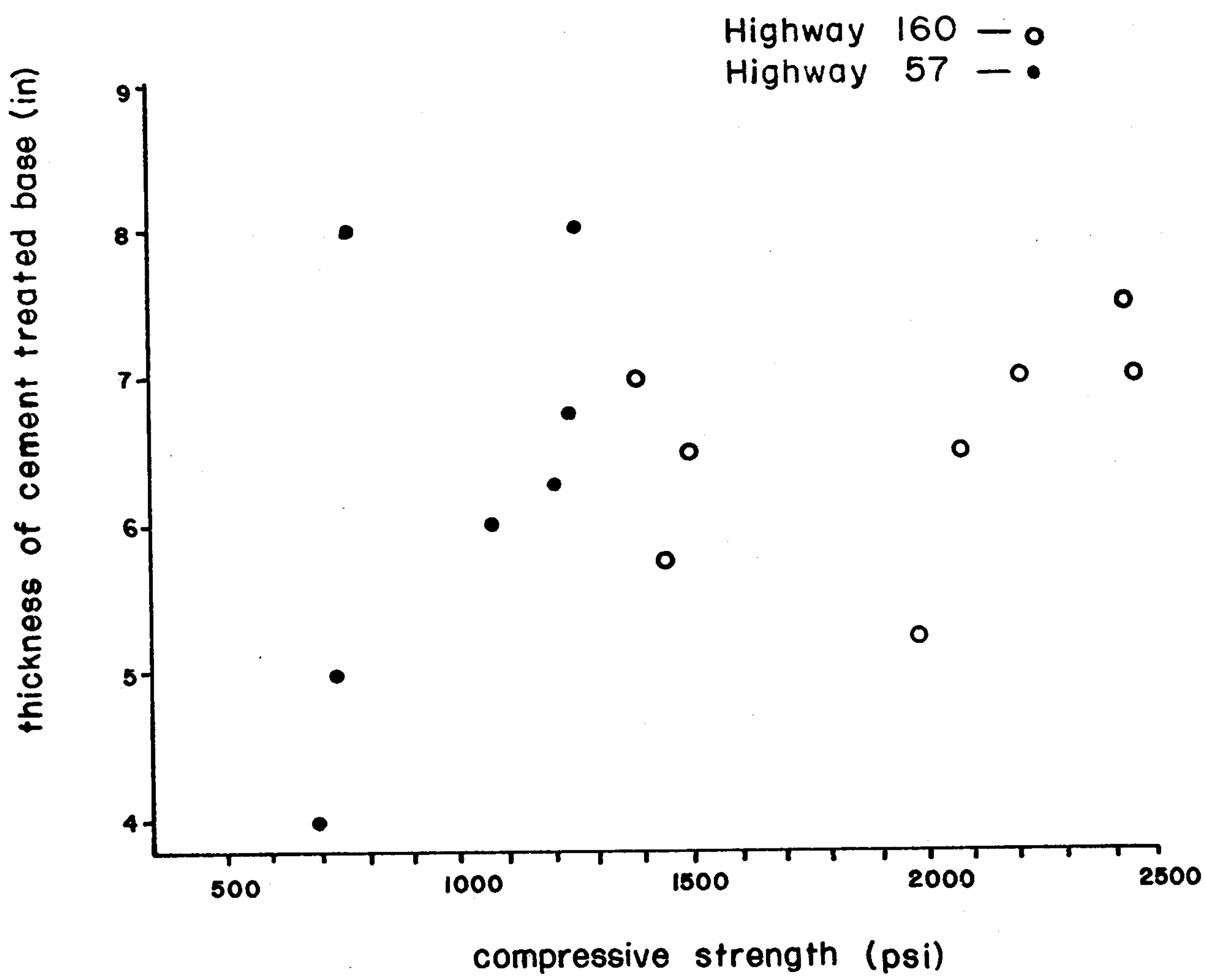


Figure 12. Relation of Base Thickness and Strength in Two Final Test Sections

THE ARKANSAS DESIGN

The typical Arkansas design (Figure 8) for soil cement low volume roads is to cement stabilize in place the top 6 inches of an 8 inch thick layer of select material, then cover the stabilized layer with a double bituminous surface treatment. Thickness of the surface treatment varies but averages one half inch.

Strength of the cement treated layer is to be 450 psi at seven days in the laboratory. Cement content is the minimum amount which will produce the seven day 450 psi strength. Table 8 is a summary of design data for the highways included in the preliminary investigations. In addition to strength testing, the design testing includes grain size analysis, liquid limits, plastic limits, compaction, and in some cases wet-dry and freeze-thaw testing.

Table 8. Summary of Design Data for Highways in Preliminary Study

SH	Job#	Recommended Cement % by Volume	% by Volume (7 day psi)	Liquid Limit/ Plastic Index	AASHTO Soil Group	Laboratory Compaction Density(pcf)/optimum water(%)
114	2668A	6.0	4.1(358-376)	NP		
			6.7(794-589)			132.8/8.2
195	3735	8.0	7.1(447-441-445)	NP		
			9.4(694-692-648)		A-2-4(0)	118.4/10.4
332	3734	7.5	5.9(431-409-410)	NP	A-2-4(0)	
			8.1(555-533-557)			116.2/13.8
134	3703	9.0	9.1(484-475-453)	NP	A-2-4(0)	115.6/12.2
299	3706	6.5	6.2(467-502-476)	NP	A-2-4(0)	
			8.5(733-832-824)			122.7/8.8
355	3779	5.0	5.0(446-458-446)	23/7	A-4(0)	
86	6836	10.0	8.9(401-404-442)	NP	A-2-4(0)	
			10.6(556-561-571)			109.5/12.8
57	7680A	8.5	7.8(427-450-426)	NP	A-2-4(0)	
			9.8(687-676-665)			
57	7680B	8.0	6.1(450)	NP	A-2-4(0)	
			8.4(735)			
98	7674A	6.0	5.3(544-536-454)	17/2	A-2-4(0)	

SH	Job#	Recommended Cement % by Volume	% by Volume (7 day psi)	Liquid Limit/ Plastic Index	AASHTO Soil Group	Laboratory Compaction Density(pcf)/optimum water(%)
98	7674A	6.0	7.9(799-807-859)			130.3/8.6
77	10725A	10.5	10.5(505-473-519)	NP	A-2-4(0)	108.9/14.9
77	10725B	9.5	8(369-352-325)	NP	A-3(0)	
			10.1(555-610-417)			
39	11790	10.5	9.7(356-387-409)	NP		110.3/13.0
			11.6(590-679-788)		A-3(0)	
98	7674B	7.0	7.2(679-646-675)	NP	A-2-4(0)	
160	7586	9.0	7.8(334-318)			
			9.8(525-541)			111.4/11.6
160	7594	10.0	10.2(844-732)			
			12.2(1066-1033)			
181	10716	9.0	7.7(350-362)	NP	A-2-4(0)	
			9.7(486-525)			
181	10716	9.0	8.6(425-444-439)	NP	A-2-4(0)	124.5/10.7
			11.0(695-660-640)			
30	11790	10.5	9.7(356-387-409)	NP	A-3(0)	
			11.6(590-679-788)			

MAINTENANCE

Maintenance practices of Arkansas and surrounding states were reviewed. Information on maintenance was gathered in a letter survey of adjacent states, by review of standard maintenance procedures in Arkansas, and through suggestions of the research subcommittee.

Letter Survey

Letters requesting information on maintenance procedures were sent to seven neighboring states - - Texas, Louisiana, Oklahoma, Missouri, Tennessee, Mississippi, and Kansas.

Besides Arkansas, only Louisiana had maintenance procedures for soil cement highways. Table 9 is a summary of the distress and the maintenance procedures used in Arkansas and Louisiana. The methods described keep surface water away from the roadway base.

The other five states had no specific maintenance procedures for cement stabilized roadways (Table 9). Typical of the comments received is that of Missouri: "As our experience has been limited we have not developed maintenance procedures to date." The maintenance procedures mentioned for Texas applied to lime stabilized highways only.

Arkansas Maintenance

In addition to the local or minor maintenance procedures listed in Table 9, Arkansas uses several seal procedures for major repairs.

One method of repair is "tar and sanding" (Figure 13). Cracks are swept clean, then filled with asphaltic material and covered with sand. This method has the following disadvantages: (1) it requires much

Table 9. Summary of Maintenance Procedures in Arkansas and Surrounding States

State	Distress	Maintenance Procedure
Arkansas	Pitting, raveling, oxidation, small cracks	Clean surface, apply bituminous material, apply aggregate, roll ASAP using truck tires at least twice, remove excess.
	cracks (> 1/8")	Clean w/ compressed air, fill large cracks (> ½") w/asphalt emulsion slurry or mixture of liquid asphalt and sand or sawdust when cured seal w/ liquid asphalt. Fill small cracks (< ½") w/liquid asphalt or emulsion, remove excess material.
	Shoving, corrugation, heaving, displacement, severely cracked and broken areas, base failure	Remove old surface material, shape and square hole, remove old base material as necessary and replace w/good, properly compact, apply tack coat, place premix first around sides then toward center in lifts ≤ 3", compact each layer before proceeding, smooth and compact final layer w/steel wheel roller, remove excess material.
	Potholes, edge breaks	Remove loose/broken material, shape up area (vert. sides), tack the area (removing water, etc.), place premix (in layers), tamp each layer, remove excess (≈ 2").
	Severe depressions (> 1" in 10")	Remove loose material, apply tack, spread premix, tamp or roll w/truck wheels (from edges to center), remove excess.
Louisiana	Pitting, raveling, oxidation, light hairline cracking	If over 15% of surface is affected, clean surface, shoot asphalt, spread aggregate, compact.

Table 9 (cont.)

State	Distress	Maintenance Procedure
Louisiana (cont.)	Premix patch, spot surface replacement	Apply small surface treatment patch.
	Resurfacing after base repair	Apply surface treatment patch using same number of applications as on original surface.
	Potholes, severe depressions and distortions	Hand place premix, use enough to level with road after rolling.
	Shoving on shoulder; wet, soggy base showing through cracks	Cut out surface failure and bad base material. Place good base material, compact every 2"-4", level with or a little above the road surface. If water is suspected cause of failure, build a small french drain to facilitate drainage, replace surface.
	Reflection cracks	Blow out crack with air, fill it with cationic emulsion or hot asphalt. Make sure crack is filled. 3/16" minimum size of crack to be repaired in this method.
	General distortion (minor depressions), large areas of severe depressions and distortions (more than 2 depressions per 25' or 1 greater than 50' long)	Clean surface, place light asphalt tack on distressed areas, place premix (in lifts of 2" or less), spread premix, compact, seal.
	Isolated areas of broken pavement	Remove surface material, check base-recompact if necessary, place premix (in lifts of 2" or less, rolling or tamping each layer), level with surface of road, compact.

Table 9 (cont.)

State	Distress	Maintenance Procedure
Louisiana (cont.)	Pitting, raveling, oxidation, light alligator cracking	Slurry seal (not for depressions or cracks greater than 3/16"). Clean surface, spread slurry, drag with burlap, roll with rubber tired roller.

	Comments
Texas	Procedures supplied apply to lime stabilized highways only.
Oklahoma	"There are very few roads constructed by this method in Oklahoma and we have no specific procedures for maintaining them."
Missouri	"As our experience has been limited we have not developed maintenance procedures to date."
Tennessee	"There are no roadways maintained by state forces of this type construction."
Kansas	"To the best of my knowledge, we have not done any of this type of construction in the last 20 years."

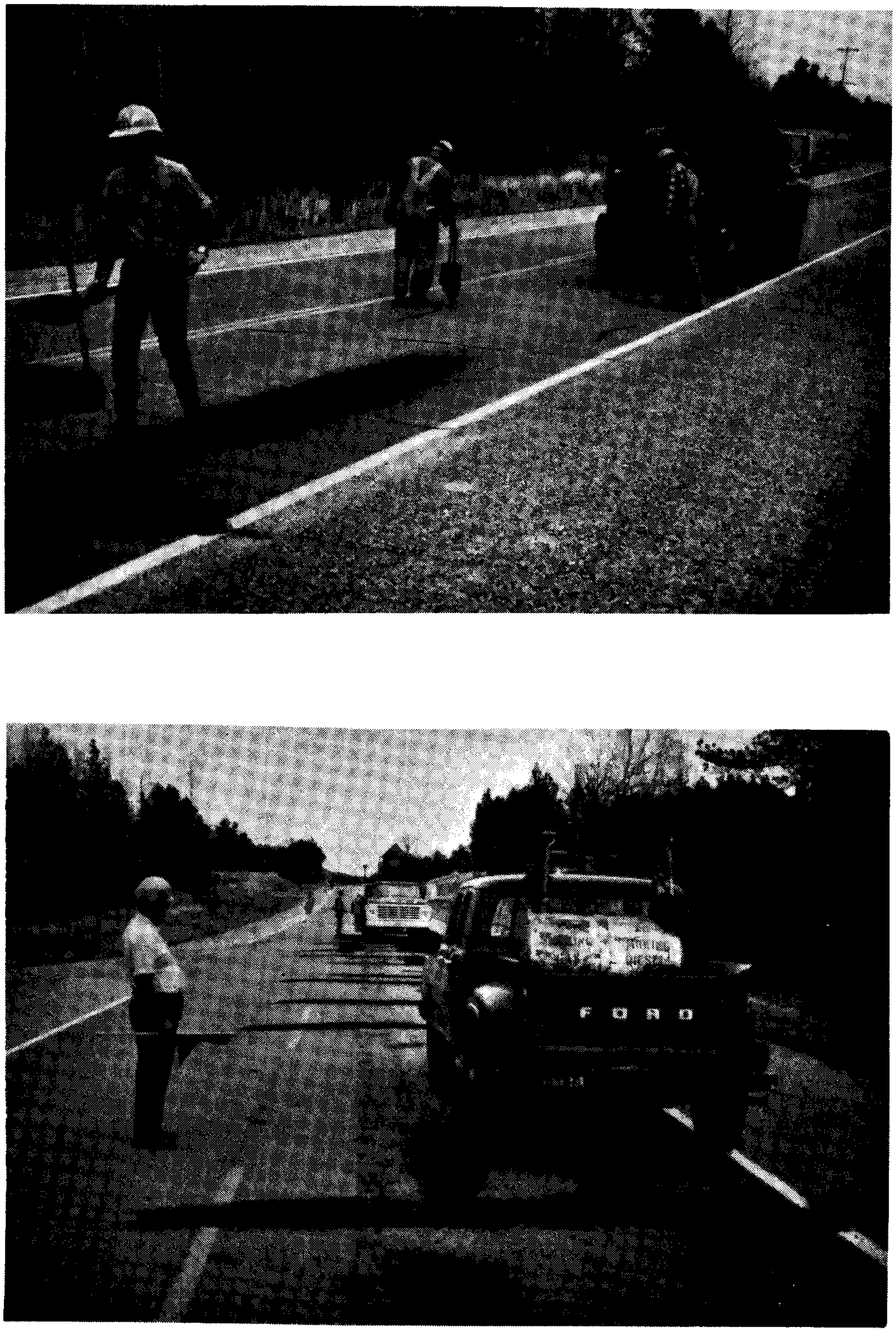


Figure 13. Tar and Sanding Repair

Application of Materials (top)

Process Train (botton)

equipment and labor, 2) the road surface is unsightly after repair because the repair calls attention to the cracks, and 3) quality of the riding surface usually is reduced because the transverse repairs produce a distinct bump when they are elevated above the riding surface.

Applying a one inch layer or so of asphaltic wearing course, is perhaps the best but most expensive repair. Asphalt cement increases the load carrying capacity of the highway and provides a new and smooth riding surface.

A "slurry seal" can also be used but this method is not popular in Arkansas. A slurry seal is a mixture of emulsified asphalt with fine graded aggregate spread approximately three eights (3/8) inch thick.

Asphalt penetrating primer, asphalt in a kerosene carrier, is also a good crack sealer. Asphalt penetrating primer is applied as a prime coat for the single seal. It penetrates and seals the cracks to prevent water intrusion.

Finally, an asphalt wash or "fog seal" can be used on the roadway. The fog seal is an asphalt emulsion which is sprayed over the entire roadway surface.

The method recommended by the Portland Cement Association (Hellums, 1978) is to apply "a single seal consisting of .3 to .4 gallon of liquid asphalt per square yard covered with the proper amount of aggregate, a slurry seal or an asphalt wash blotted with sand. This normal maintenance procedure is usually repeated every 5 to 8 years on soil-cement secondary roads".

CONCLUSIONS

Distress of Arkansas low volume soil cement roads was minor in many cases. For example, Highway 355 had no distress. Observed conditions at many of the test sites indicated only longitudinal and transverse cracks which are characteristic of most soil cement stabilized material. These cracks are not the result of structural failure and have not been a significant problem except in some localized instances.

No single cause of distress for low volume soil cement roads in Arkansas was identified. Several possible causes were found including poor mixing, an excessive number of clay nodules, organic material, traffic overloads, low cement content and inadequate subgrade. Causes other than these could be responsible for the distress. For example, an excessive time delay between application and mixing of the cement and compaction could be responsible for low strengths. Since the study originated after construction, little information was available on construction procedures.

Unconfined compressive strength of the cement treated base is the best indicator of highway performance. Density of the cement treated base is not a good indicator because high densities were found in highways having high maintenance costs.

RECOMMENDATIONS

It is recommended that the Arkansas Highway and Transportation Department review their design and construction procedures for low volume soil cement roads.

In the review, the following items should be addressed;

Strength:	Determine the required compressive strength and thickness of the base.
Mixing:	Evaluate the effectiveness of in-place and plant mixing.
Drainage:	Determine the minimum depth of ditch required.
Overloads:	Consider restrictions on heavy truck loads during periods of wet and freezing weather.
Specifications:	Consider revising material specifications to define "unsuitable material" to include large or numerous clay nodules, roots, organic material, etc.

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APPENDIX A

Appendix A contains typed copies of the original background data forms. Data from these forms were taken from: 1) the field inspection trips, 2) interview information, and 3) soil surveys made by the U.S. Department of Agriculture.

INTERVIEW: Bill Mulhollen
J.E. Belknap (Gene)

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 39 District 1 Job No. 11790

From US 49 To Monroe at US 79 Distance 4.89 mi

1. Type of wheel loads: Grain trucks (up to 80,000 lb.)

2. Use of the road: Rural

3. General terrain and drainage: Flat-poor drainage, water in ditch

4. ADT at time of Design 19 70 = 220

5. Agriculture soil classification: Silty loam

6. Type of distress/degree of failure: A few long cracks - N-S Section in center caused most trouble (blow ups or similar). Had to be cut out.

7. Overload violations:

8. Soil cement in place or select material: Mixed in place (est. 1973) w/s.m.

9. Percent cement: 10.5

10. Typical section (6" ?): 6" in 8" of compacted SM-6 (3" crown)

11. Construction practices: Normal

12. Present traffic counts (1976): 410

13. Method of repair used: North section has recent seal (past season) cold mix base put back

14. Comments: Soil condition normal - might be too much cement because it acted like a blow up.

INTERVIEW: Sam Smith

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 114 District 2 Job No. 2-668

From SH 54 (Palmyra) To Star City Distance 5.442 mi

1. Type of wheel loads: Timber haul and gravel

2. Use of the road: Logging and farm market

3. General terrain and drainage: Rolling terrain and good drainage, pines and woods

4. ADT at time of Design 1966 = 375

5. Agriculture soil classification: Silty loam and clay

6. Type of distress/degree of failure: Base failures first 3 years after construction. Bad soil underneath stabilized material. Had some deep settlement resulting in roller coaster effect. Overlayed 3/4 miles ± base failures not too severe.

7. Overload violations: Has 64000 # load limit raised to 72560 about 3 years ago and this resulted in more failures.

8. Soil cement in place or select material: Added low metal gravel 7" ± test reports are on file

9. Percent cement: 5% but check records

10. Typical section (6" ?): 6" cores on file

11. Construction practices: Normal - good contractor and good crew

12. Present traffic counts (1976): 850

13. Method of repair used: Cut out base failures 12" to 36" depth. Replaced with cement stabilized low metal gravel about 7-8% cement. With 1" to 2" premix asphalt top. Have poured cracks at various (con't on next page)

14. Comments: People at store in Palmyra said road was rough in spots before resurfacing. Bad places near bridge.

(con't.)

times. Have overlayed in spots due to roller coaster resulting from settlement.

Added low metal gravel to existing gravel roadway in many areas and failures indicated poor material had been in place prior to construction.

Had to use extensive amount of underdrains due to springs and ground water. Job records should show amount and location.

Started project in spring (grading) and completed that construction season. This would indicate good weather.

Had trouble stabilizing shoulders which were same gravel that was stabilized with cement. Had problem stabilizing slopes--no erosion control in project. Most of this trouble resulted after rains.

INTERVIEW: Sam Smith

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 4 District 2 Job No. 2-104

From SH 1 To Arkansas City Distance 11.908 mi.

1. Type of wheel loads:

2. Use of the road: Agricultural use until last two years when construction started on paper mill After construction, a bean grainery was constructed at about the location of the paper mill.

3. General terrain and drainage:

   Flat terrain - drainage good for flat land. Mississippi River flood plain poorly drained

4. ADT at time of Design 1962 = 125

5. Agriculture soil classification: Clay

6. Type of distress/degree of failure: From Hwy. 1 to grainery had 40% surface failure (top 1 ½" sealed off - some settlement) Some base failures with bad soil underneath. Longitudinal cracking outside wheel track mostly.

7. Overload violations:
   Farmers hauling beans to grainery
   material hauled to build paper mill.

8. Soil cement in place or select material:

   Selected material (SM-2) 12" deep

9. Percent cement:
   9 or 10% check job records.

10. Typical section (6" ?):

    6" stabilized

11. Construction practices:

    Normal-good crew

12. Present traffic counts (1976): 340

13. Method of repair used: Surface patches repaired with premix asphalt base failure dug out replaced with low grade gravel with 7-8% cement capped with premix 1"+. Poured cracks.

14. Comments:

    Potlatch plant under construction (near center) and Bunce Corp.

(cont., on next page)

(cont.)

26 foot subgrade, 12" sel. material, processed 6" ±
24 foot wide, one double seal 18" wide, outside of sealed area only cover was curing asphalt for stabilization.

Project extended over 2 seasons. Stabilized entire roadway during first season and single sealed south end and no seal on north end. Next season completed seal. Contractor repaired some longitudinal cracking and some surface failures (sealing of top 1" or so).

Steep slopes on grading with 26' subgrade, 1:1 slopes on S.M. with top 6" stabilized and bottom 6" unstabilized. Typical section gave problems during construction.

Project showed extensive erosion when added to state system (date?) and was seeded by state forces.

INTERVIEW: C.H. Mitchell

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 195 District 3 Job No. 3735

From Fulton To SH 73 Distance 9.37 mi.

1. Type of wheel loads: Light with some overloads

2. Use of the road: Rural; farm-market

3. General terrain and drainage: Poorly drained

4. ADT at time of Design 1970 = 170

5. Agriculture soil classification: Clayey loam

6. Type of distress/degree of failure: Isolated complete failures

7. Overload violations: 2/21/77 overload 3,630 lb. Ticket #4914 / 2/24/77 overload 3000 lb. Ticket #4916

8. Soil cement in place or select material:

9. Percent cement:

10. Typical section (6" ?): 6" in 8" compacted depth SM-2, 3" crown

11. Construction practices:

12. Present traffic counts (1976): 340

13. Method of repair used:

14. Comments: Bypass weight scales - loads of as much as 100,000 lb. have been caught.

INTERVIEW: C.H. Mitchell

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 332 District 3 Job No. 3734

From Tollette To SH 4 Distance 7.981 mi.

1. Type of wheel loads: Light w/occasional heavy truck

2. Use of the road: Rural - farm market

3. General terrain and drainage: good-moderate

4. ADT at time of Design 19 70 = 130

5. Agriculture soil classification: Loam

6. Type of distress/degree of failure: Longitudinal & transverse cracks

7. Overload violations:

8. Soil cement in place or select material: SM-4

9. Percent cement: 8½%

10. Typical section (6" ?): 6" in 7" comp. depth 3" crown

11. Construction practices:

12. Present traffic counts (1976): 390

13. Method of repair used:

14. Comments: Soil cement placed on clay soil

INTERVIEW: C.H. Mitchell

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 134 District 3 Job No. 3703

From SH 196 To South Distance 2.82 mi.

1. Type of wheel loads: Heavy to very heavy

2. Use of the road: Rural - farm market

3. General terrain and drainage: Flat - poorly drained

4. ADT at time of Design 19 71 = 100

5. Agriculture soil classification: Clay

6. Type of distress/degree of failure: Complete failure - chunks came out

7. Overload violations: 10/9/76 - Ticket #2835, gross wt.=87700 lb., legal overload.
2/14/77-Ticket #4865, overload=13,220 lb. 2/23/77-Ticket #4874, overload=4,500 lb.
2/14/77-Ticket #4866, overload=27,900 lb. 12/13/76-Ticket #3325, overload=2,720

8. Soil cement in place or select material:
SM-2

9. Percent cement:

10. Typical section (6" ?): 6" in 8" comp. depth, 3" crown

11. Construction practices:

12. Present traffic counts (1976): 190

13. Method of repair used:

14. Comments: Corps of Engineers trucked in riprap to Red River.
Stabilized full width (no gravel shoulders), heavy clay subsoil.
Heavy trucks may avoid weight scales

INTERVIEW: C.H. Mitchell

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 299 District 3 Job No. 3706

From SH 19 To Morris Distance 6.786

1. Type of wheel loads: Light w/some timber hauling

2. Use of the road: Rural-farm market

3. General terrain and drainage: good (rolling country)

4. ADT at time of Design 1971 = 110

5. Agriculture soil classification: Sandy loam

6. Type of distress/degree of failure: slight failure (in places)

7. Overload violations:

8. Soil cement in place or select material:

9. Percent cement:

10. Typical section (6" ?): 8" SM-2, compact w/6" soil cement (3" crown)

11. Construction practices:

12. Present traffic counts (1976): 200

13. Method of repair used:

14. Comments: several failures due to haulage by a contractor-better subsoil conditions

INTERVIEW: C.H. Mitchell

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 355 District 3 Job No. 3779

From Hempstead County Line To Falcon Distance 3.996

1. Type of wheel loads: Light w/timber load occasionally
2. Use of the road: Rural; farm-market
3. General terrain and drainage: Well drained
4. ADT at time of Design 1974 = 110
5. Agriculture soil classification: Sandy loam
6. Type of distress/degree of failure: None
7. Overload violations:
8. Soil cement in place or select material:
9. Percent cement: 5%
10. Typical section (6" ?): 6" in 7" comp. depth, 3" crown
11. Construction practices:
12. Present traffic counts (1976): 130
13. Method of repair used:
14. Comments: Mentioned in order to keep an eye on it because of low % cement. High density obtained (128 pcf raw soil).

INTERVIEW: George Ingle

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 86 | District 6 | Job No. 6836

From Highway 33 Sect. 2 | To West 4.5 mi. | Distance 4.674 mi.

1. Type of wheel loads: Rice farming

2. Use of the road: Rural

3. General terrain and drainage: Rice farming - poor drainage

4. ADT at time of Design 1971 = 320

5. Agriculture soil classification: Silty loam

6. Type of distress/degree of failure: No base failures - a little ravel but in good shape

7. Overload violations:

8. Soil cement in place or select material: SM mixed in place SM-2

9. Percent cement:

10. Typical section (6" ?): 8" compacted depth, 3" crown

11. Construction practices: Local fill subgrade, let winter because of rice water; put SM on from Duvalls Bluff and stab. WITH PULVER MIXER

12. Present traffic counts (1976): 340

13. Method of repair used: Fog seal

14. Comments: Good contractor, water in ditches (17 Feb. 77); fresh oil on road - smooth ride

INTERVIEW: George Ingle

SOIL CEMENT LOW VOLUME ROADS
HRP-48

(Sample near lake on Rt. w/old cabins on Rt. (7 mi. ≅ north of I 40)

SH 33   District 6   Job No. 6-540

From Sect. 6 (See Sect. 5- another sheet)   To   Distance

1. Type of wheel loads: Local-rural traffic; heavy log and grain trucks

2. Use of the road:

3. General terrain and drainage: Flat flood plain

4. ADT at time of Design 1965 = 325

5. Agriculture soil classification: Silty loam

6. Type of distress/degree of failure: Spot failures in the base and surface failures due to small dust pockets between the base and seal coat/longituninal cracks (horizontal too) - shrinkage cracks.

7. Overload violations:

8. Soil cement in place or select material: used select material

9. Percent cement:

10. Typical section (6" ?):

11. Construction practices: Pugmill Mix

12. Present traffic counts (1976): 600

13. Method of repair used: Dig out and replace base with SB-2 stone cover with hot mix (2") - patches 10 x 20" avg.

14. Comments: Begins north of I-40 near White River flood levee (5 mi ≅ N of I40 runs to levee again (1½ to 2 mi S of 38). Inspector complained about roots in select material in one of the worst seen.

INTERVIEW: George Ingle
(see Vernon Ellis (area foreman) to pick spot to sample)

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 33 District 6 Job No. 6664

From Sect. 5 To Distance

1. Type of wheel loads: Same as sec. 6

2. Use of the road:

3. General terrain and drainage: More relief than 6-most is well drained

4. ADT at time of Design 1958 = 100

5. Agriculture soil classification: Silty loam

6. Type of distress/degree of failure: First pitting due to dust pockets. Separation of surface from base; then more extensive base failures (due to haul of SM for Hwy 86) some 200-300 ft. lg.

7. Overload violations:

8. Soil cement in place or select material: Select material pit at DuValls Bluff-good sand

RAYMOND JONES

9. Percent cement: near 8%

10. Typical section (6" ?):

11. Construction practices: Rebuilt roadbed; put SM down - used pulver mixer put cure coat (had trouble with striping) so put inverted seal to make surface stick.

12. Present traffic counts (1976): 440

13. Method of repair used: Base replaced either SB-2 or probably hot mix, base/patches in progress (17 Feb 77) tack on pavement and cold mix

14. Comments:
From junction of 302 approx. 12-1400 ft. south is most extensive failure (flat place-rice each side).

INTERVIEW: Coy Campbell

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 76 District 7 Job No. 7-564

From SH 59 To SH 24 Distance 6.48 mi.

1. Type of wheel loads:

2. Use of the road: Recreation-tree farm

3. General terrain and drainage: Pine woods, rolling - well drained

4. ADT at time of Design 1966 = 50

5. Agriculture soil classification: Sandy loam

6. Type of distress/degree of failure: New seal

7. Overload violations:

8. Soil cement in place or select material:

9. Percent cement:

10. Typical section (6" ?):

11. Construction practices: Nothing unusual (DBST seal). Little or no undercut.

12. Present traffic counts (1976): 280

13. Method of repair used: Premix (2" - 6-7") and seal patch then seal, small sect. - dig out then place patch (premix) and roll; then seal (may wait 1½ years); may use hot mix if available.

14. Comments:

INTERVIEW: Coy Campbell

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 57 District 7 Job No. 7680

From Marysville To Mount Holly Distance 7.256 mi.

1. Type of wheel loads: Light w/occasionally heavy traffic

2. Use of the road: Rural

3. General terrain and drainage: Well drained

4. ADT at time of Design 1971 = 500

5. Agriculture soil classification: Sandy loam

6. Type of distress/degree of failure:

7. Overload violations:

8. Soil cement in place or select material: SM-2

9. Percent cement:

10. Typical section (6" ?): 6" in 8" to 11" total

11. Construction practices: ACHMSC placed under contract as a wearing course-asphalt cement hot mix surface course

12. Present traffic counts (1976): 750

13. Method of repair used: To date only repair has been to pour cracks

14. Comments:

INTERVIEW: Coy Campbell

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 160 District 7 Job No. 7-537
7586
7594
7607

From Taylor To Macedonia Distance 2.28 mi.
5.783
1.078
3.297

1. Type of wheel loads:

2. Use of the road: Rural

3. General terrain and drainage: Well drained

4. ADT at time of Design 1961-65 = 750

5. Agriculture soil classification: Sandy/loam and clay

6. Type of distress/degree of failure:

7. Overload violations:
   #3843 overload 2/2/77 6,320 lb.
   #3844 overload 2/2/77 15,970 lb.

8. Soil cement in place or select material:
   DBST = double bituminous surface treatment

9. Percent cement:

10. Typical section (6" ?): 6" in 8" comp. depth, 3" crown

11. Construction practices: Nothing unusual (minor undercut)

12. Present traffic counts (1976): 1100

13. Method of repair used: Same as other (dig out replace with asphalt and reseal)

14. Comments:

INTERVIEW: Coy Campbell

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 98 District 7 Job No. 7674

From SH 344 To Village Distance 6.763 mi.

1. Type of wheel loads:

2. Use of the road: Rural

3. General terrain and drainage: Well drained

4. ADT at time of Design 19 70 = 350

5. Agriculture soil classification: Loam

6. Type of distress/degree of failure:

7. Overload violations:

8. Soil cement in place or select material: SM-2

9. Percent cement:

10. Typical section (6" ?): 6" in 9" comp. depth

11. Construction practices: Nothing unusual (surfaced with DBST)

12. Present traffic counts (1976): 300

13. Method of repair used: Dig out failures and replace with asphalt reseal about every 4 or 5 years

14. Comments:

Norman Pumphrey
INTERVIEW: Bob Faulkner

(Sample ½ mile north of bridge between 18 & 158)

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 181 District 10 Job No. 10716

From SH 18 To South Distance 10 miles (north is worse)

1. Type of wheel loads: Lots of heavy loads - beans & grain trucks

2. Use of the road: Farming

3. General terrain and drainage: Flat - ditches with water; road elevated 3-4 ft.

4. ADT at time of Design 19 67 = 140

5. Agriculture soil classification: Silty clay (subgrade is gumbo)

6. Type of distress/degree of failure: Base failure, develops from cracks

7. Overload violations:

8. Soil cement in place or select material: SM

9. Percent cement:

10. Typical section (6" ?):

11. Construction practices: Pulver mixer

12. Present traffic counts (1976): 600

13. Method of repair used: Asphalt sand mix (1½ - 2") then reseal

14. Comments: New surface (new seal last year - 2nd seal its had; road is 8-10 years old)

Bill Montgomery
Charles Hesselbein
Darrell Holder

INTERVIEW: Norman Pumphrey
Bob Faulkner

SOIL CEMENT LOW VOLUME ROADS
HRP-48

SH 77 District 10 Job No. 10725

From SH 118 To SH 14 Distance

1. Type of wheel loads: General farm and rural traffic

2. Use of the road: Farming-rural

3. General terrain and drainage: Flat-water in ditch

4. ADT at time of Design 19 72 = 140

5. Agriculture soil classification: Silty clay

6. Type of distress/degree of failure: Many patches - longitudinal cracks and transverse cracks and shoulder ravel

7. Overload violations:

8. Soil cement in place or select material: SM each side of Tyronza River bridge has gravel (GB 3) cement stabilized ¼ mile north/1 mile south

9. Percent cement:

10. Typical section (6" ?): 9" comp., GB-3, ALT #1

11. Construction practices: Pulver mixer

12. Present traffic counts (1976): 280

13. Method of repair used: Spot patches + 2-300 ft. patches

14. Comments: ough ride; worst road yet-suspect subgrade problems (gumbo)

INTERVIEW: Norman Pumphrey
Bob Faulkner

SOIL CEMENT LOW VOLUME ROADS
HRP-48

Sample mid-length

SH 14 District 10 Job No. 10-566

From Wilson To South Distance

1. Type of wheel loads: Local-to store

2. Use of the road: Wilson Foods

3. General terrain and drainage: Flat-poorly drained (in sight of Mississippi River levee)

4. ADT at time of Design 1967 = 300

5. Agriculture soil classification: Loam

6. Type of distress/degree of failure: Little distress

7. Overload violations:

8. Soil cement in place or select material: In place - brought in some river sand

9. Percent cement: 6% ?

10. Typical section (6" ?):

11. Construction practices: Cut the ditch, shaped up and processed pulver mixer

12. Present traffic counts (1976): 250

13. Method of repair used: Seal (single seal)

14. Comments: not much trouble in sandy loam soil

HRP 48 - FINAL TESTING PROGRAM

HWY 57 (Poor Performance) DISTRICT 7 CONSTRUCTION DATE 1971

BORING	COMP. STRENGTH (psi)	WET DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	DESCRIPTION	OBSERVED CONDITIONS	SUBGRADE DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	LL	PL
1	*			Numerous clay nodules	L&H cracks	108.7	16.11	41.5	19
2	*			Nodules, roots	L&T cracks				
3	751	133.1	12.36	Nodules, some straw	L&T				
4	*			Clay nodules	L&T	103.81	21.81	46.8	23
5	*			Clay nodules, roots	T cracks				
6	1232	133.24	14.43	Numerous large clay nodules	L&T				
7	1070	126.14	15.01		L&T	96.86	23.48	49.8	25
8	1256	133.06	14.42	Numerous large clay nodules	L&T				
9	1210	138.24	15.64	Numerous large clay nodules	L&T				
9-5	2463	131.33							
10	*				L&T	115.9	13.32	24.6	15

*Sample broken when coring.

APPENDIX B

Appendix B contains the summarized data from the final testing program.

HRP 48 - FINAL TESTING PROGRAM

HWY 57 (Poor Performance) DISTRICT 7 CONSTRUCTION DATE 1971

BORING	COMP. STRENGTH (psi)	WET DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	DESCRIPTION	OBSERVED CONDITIONS	SUBGRADE DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	LL	PL
11-1	1137	134.68	14.38	Small clay nodules, cement lenses	L&T				
11-2	890	130.06	16.47	Small clay nodules, cement lenses	L&T	114.35	21.96	29.5	13
11-3	1014	133.17	16.2	Numerous clay nodules	L&T	107.7	14.14	44.7	18
11-4	694	129.6	14.73	Few large clay nodules	L&T				
11-5	928	133.1	15.57	Numerous clay nodules	L&T				
11-6				Clay nodules, bad mixture	L&T				
11a-1	1137	125.18	17.83	Numerous large clay nodules	L&T				
11a-2	637	126.8	14.57		L&T	107.5	16.75	28.7	15
11a-3	857	135.45	17.23	Clay nodules, cement lenses	L&T	115.7	19.76	33.8	17
11b-1	1062	131.33	13.99	Numerous clay nodules	L&T				

HRP 48 - FINAL TESTING PROGRAM

HWY 57 (Poor Performance) DISTRICT 7 CONSTRUCTION DATE 1971

BORING	COMP. STRENGTH (psi)	WET DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	DESCRIPTION	OBSERVED CONDITIONS	SUBGRADE DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	LL	PL
11b-2	1092	129.6	10.78	Numerous large clay nodules	L&T	111.4	16.03	29.3	15
11b-3	854	127.87	11.88	Numerous clay nodules, cement lenses	L&T				
11c-1	1480	133.06	13.58	Numerous clay nodules	L&T				
11c-2	788	134.78	12.11	A few clay nodules	L&T				
12	858	133.48	11.87		L&T	94.28	25.62	86.7	24
13	353	126.14	11.16	Red sand with a few clay nodules	L&T				
14	698	129.38	10.35	Red sand, clay nodules and cement lenses, select material not stabilized	L&T				
15	731	126.14	14.36	Red sand and numerous clay nodules	L&T not as bad				
16	347	117.5	12.06	Red sand and a few clay nodules	L&T more than #15				
17	200			Red sand, cement lenses, and clay nodules	L&T				

HRP 48 - FINAL TESTING PROGRAM

HWY 195 (Poor Performance) DISTRICT 3 CONSTRUCTION DATE 1970

BORING	COMP. STRENGTH (psi)	WET DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	DESCRIPTION	OBSERVED CONDITIONS	SUBGRADE DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	LL	PL
1	*	*	*	Cement lenses	Block, L&T failures under surface				
2	*			Cement lenses	Block				
3	*			Asphalt lenses, voids	Block				
4	*			Cement lenses	Block				
5	1216	139.3	14.97	Clay nodules, cement lenses	Block	98.89	27.09	80.13	25
6	*			A lot of clay nodules	Near block failure	90.78	32.46	92.15	27
7	1223	134.9	13.49	Numerous clay nodules	Near				
8	*			Cement lenses, voids, roots	Block failures				
9	2116	140.90	11.92	Numerous clay nodules	Near block failures				

*Sample broken when coring.

HRP 48 - FINAL TESTING PROGRAM

HWY 195 (Poor Performance) DISTRICT 3 CONSTRUCTION DATE 1970

BORING	COMP. STRENGTH (psi)	WET DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	DESCRIPTION	OBSERVED CONDITIONS	SUBGRADE DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	LL	PL
10	*			Clay crumbles in CTB	Near block failures				
11	*			Numerous small clay nodules	T-cracks				
12	*			Cement lenses	L&T cracks	94.28	25.62	86.7	24
13	*			Lenses	Longitudinal heave				
14	*			Cement lenses, voids	Heave near center				
15	*			Clay crumbles, sandy clay pockets	Block failure on edge				
16	1030	134.78	16.63	Nodules	Long cracks, block failure				
17	*			Cement lenses	Heave in center of lane				
17b-1	*					89.18	32.95	73.40	31
17-1	*					96.9	24.44	63.5	27
17-3	1681	138.00	13.68			96.40	27.16	54.2	27

*Sample broken when coring.

HRP 48 - FINAL TESTING PROGRAM

HWY 195 (Poor Performance) DISTRICT 3 CONSTRUCTION DATE 1970

BORING	COMP. STRENGTH (psi)	WET DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	DESCRIPTION	OBSERVED CONDITIONS	SUBGRADE DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	LL	PL
18	*			Lenses	Complete block failure				
19	*			Lenses	Long, cracks				
20	*			Clay nodules	Long, cracks, heave				
21	*			Cement lenses	Long, heave				
22	*			Cement, voids	Long, cracks				
23	*			Lenses	L&T cracks				
24	*			Lenses	Block failure				
25	*				Block failure				
26	*				L&T cracks, block failure				

*Sample broken when coring.

HRP 48 - FINAL TESTING PROGRAM

HWY 195 (Poor Performance) DISTRICT 3 CONSTRUCTION DATE 1970

BORING	COMP. STRENGTH (psi)	WET DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	DESCRIPTION	OBSERVED CONDITIONS	SUBGRADE DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	LL	PL
27	*			Roots, pockets of loose selected material					
28	1260	133.36	13.64	Clay nodules, cement lenses	L&T cracks				
29	*			Lenses					
30	*				Block failure				
31	*			Lenses	T-cracks				
32	*			Roots	L&T cracks				
33	*			Lenses	L&T cracks				
34	1233	133.10	14.63	Clay nodules, cement lenses	L&T cracks				
35	*			Lenses	L&T cracks				

*Sample broken when coring.

HRP 48 - FINAL TESTING

HWY 160 (Performance - Good) DISTRICT 7 CONSTRUCTION DATE Prior to 1972

BORING	COMP. STRENGTH (psi)	WET DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	DESCRIPTION	OBSERVED CONDITIONS
1	2463	129.60		Numerous clay nodules, cement cured before compaction	T&L cracks
2	2081	128.53	11.20		L&T cracks
3	2205	133.06	10.49		L&T cracks
4	1970	134.78	11.04	Cement lenses	T-cracks
5	1993	133.06	13.41	A few small nodules	L&T cracks
6	>2443	130.90		Clay nodules, cement lenses	Hairline L&T cracks, no subgrade
7	1603	127.90	11.31	Small clay nodules	L&T cracks, L-cracks in center of lane
8	1388	127.90	12.18		T-cracks, no subgrade
9					L&T cracks
9-2	1814	126.14	13.93		L&T cracks
9a-2	1433	124.40	12.30		L&T cracks
9b-1	1268	128.93	12.70	Few small nodules	L&T cracks
9b-2	1388	129.60	13.14	A few nodules	L&T cracks
9b-3	1069	132.80	13.03	A few nodules	L&T cracks

HRP 48 - FINAL TESTING

HWY 160 (Performance - Good) DISTRICT 7 CONSTRUCTION DATE Prior to 1972

BORING	COMP. STRENGTH (psi)	WET DENSITY (lb/ft^3)	MOISTURE CONTENT (%)	DESCRIPTION	OBSERVED CONDITIONS
9-3	1607	126.30	14.46		L&T cracks
9-4	1184	138.40	17.8	A few large clay nodules, cement lenses	L&T cracks
9-5	2065	127.87	13.75		L&T cracks
9-6	1679	127.12	12.51	Few clay nodules	L&T cracks
10				Clay nodules, pieces of rock	L&T cracks, near block failure
11	1502	126.81	14.63		L&T cracks
12				Cement lenses, a few clay nodules	L&T cracks
13	1322	128.93	12.18	Lenses and numerous clay nodules	L&T cracks
14	1450	129.60	13.03	A few clay nodules	L&T cracks (severe

HIGHWAY 57 (POOR PERFORMANCE)

LOCATION	BORING	SURFACE CONDITIONS	THICKNESS CTB (in.)	THICKNESS ASPHALT (in.)	SOIL TYPE*	COMMENTS
200' N 86	1	L&H	6.5	3.75	BSC	Numerous nodules
---	2	L&T	6.5	3.5	-	-
.5 mi. N-86	3	L&T	8	3.5	BSC	-
.75 mi. N-86	4	L&T	8.5	4	-	-
1.0 N 86	5	T	6.5	4	-	Clay in sm
1.25 N 86	6	L-T	6.75	4	YSC	Numerous large nodules
1.5 mi. N 86	7	L-T	6	4	-	-
1.75 N 86	8	L-T	8	4	YSC	Numerous nodules
2 N 86	9	L-T	6.25	4	YSC	Numerous large nodules/good mix
2.25 N 86	10	L-T	6.25	4	-	-
2.5 N 86	11	L-T	6.5	4	-	-
	11-1	L-T	-	-	YSC	Numerous nodules, few large cement lenses
	11-2	L-T	-	-	YSC	Numerous small nodules, few small cement lenses
	11-3	L-T	-	-	-	-
	11-4	L-T	-	-	YSC	Few large nodules
	11-5	L-T	-	-	YSC	Numerous nodules
	11-6	L-T	-	-	YSC	Nodules, bad mixture
	11a-1	L-T	-	-	YSC	Numerous large nodules
	11a-3	L-T	-	-	YSC	Nodules, cement lenses
	11b-1½	L-T	-	-	YSC	Numerous large/small nodules
	11b-2	L-T	-	-	YSC	Numerous large nodules
	11b-3	L-T	-	-	YSC	Numerous nodules, cement lenses
	11c-1	L-T	-	-	YSC	Numerous nodules
	11c-2	L-T	-	-	YSC	Few nodules
2.75 N 86	12	L-T	-	-	-	-
3 N 86	13	L-T	-	-	RSC	Few nodules

*F-fine SC-sandy clay WBS-white brown sand
C-coarse FS-fine sand BSC-brown sandy clay
YSC-yellow sandy clay
RSC-red sandy clay

HIGHWAY 57 (POOR PERFORMANCE)

LOCATION	BORING	SURFACE CONDITIONS	THICKNESS CTB (in.)	THICKNESS ASPHALT (in.)	SOIL TYPE*	COMMENTS
3.25 N 86	14	L-T	4	4	RSC	Numerous nodules/cement lenses/ 3" select material in bottom of hole not stabilized
3.5 N 86	15	L-T	5	-	C-RSC	Numerous nodules
3.75 N 86	16	L-T	too thick for bit		C-RSC	Few nodules/good mix
4 N 86	17	L-T	-	-	RSC	Nodules throughout/bad mix/crack in CTB that didn't come to surface

*F-fine SC-sandy clay WBS-white brown sand
C-coarse FS-fine sand BSC-brown sandy clay
YSC-yellow sandy clay
RSC-red sandy clay

HIGHWAY 195 (POOR PERFORMANCE)

LOCATION	BORING	SURFACE CONDITIONS	THICKNESS CTB (in.)	THICKNESS ASPHALT (in.)	SOIL TYPE*	COMMENTS
.25 m. E Fulton	1	L-T/ block	no sample 4"	3/8	-	Highway recently resurfaced/failures under surface apparent
.5	2	block	6	3/8	FS	Cement lenses, had mix
.75	3	bloxk	7	3/8	-	-
1	4	block	-	.5	-	Lenses in CTB/sample cracked in hole
1.5	5	block	5.5	.5	YSC	Numerous nodules/few cement lenses
1.75	6	near block failure	7	.5	BSC	Numerous nodules/mixture of gumbo
2	7	near block failure	7	.5	BSC	Numerous nodules (large and small)
2.25	8	block failure	6.5	.5	-	-
2.5	9	near block failure on bridge approach	6	.5	F-BSC	Numerous nodules
2.75	10	near block	6	.5	Clay	Some crumbles
3	11	T	6	.5	FS	Numerous small nodules/good mix
3.25	12	L-T	6	.5	-	CTB broken
3.5	13	L heave	6	.5	-	Lenses/crumbled CTB

*F-fine SC-sandy clay WBS-white brown sand
C-coarse FS-fine sand BSC-brown sandy clay
YSC-yellow sandy clay

HIGHWAY 195 (POOR PERFORMANCE)

LOCATION	BORING	SURFACE CONDITIONS	THICKNESS CTB (in.)	THICKNESS ASPHALT (in.)	SOIL TYPE*	COMMENTS
3.75	14	heave near center	6	.5	-	Lenses in CTB/pushed shelby tube
4	15	block failure on edge	6	.5	No sample	Loose SC pockets crumbled to ½" size in CTB
4.25	16	L cracks	6	.5	-	200' block failure in opposite lane (3 patches in next 500') SM appears to have fine-grain material (by grey color) greyish brown C-SC w/numerous green nodules block failure 200' ahead/ CTB came out in pieces (inadequate cement content or poor mix)
4.5	17	heave in center of L-lane	6.5	.5	-	-
4.5	17-1 to 17-6					
	17a-2					Lenses/complete failure, R value taken here
	17a-3					Lenses
	17b-3					Lenses
5	18	complete block fail	7	.5	Lenses	Lenses in CTB

*F-fine SC-sandy clay WBS-white brown sand
C-coarse FS-fine sand BSC-brown sandy clay
YSC-yellow sandy clay

HIGHWAY 195 (POOR PERFORMANCE)

LOCATION	BORING	SURFACE CONDITIONS	THICKNESS CTB (in.)	THICKNESS ASPHALT (in.)	SOIL TYPE*	COMMENTS
5.25	19	L	6.5	.5		Horizontal lenses @ 3" depth
5.5	20	L	-	-	Grey-ish yellow F-SC	Heave in opposite lane (numerous nodules (L&S)
5.75	21	L-heave	6	.5	SC	Bad mix/lenses throughout
6	22	L	6	.5	-	
6.25	23	L-T	6	.5	-	CTB cracked but lenses found
6.5	24	block	7	.5	-	Lenses
		fail	6	.5	-	Cracked CTB/no lenses
7	26	L-T near block fail	6.25	.5	-	
7.25	27	none	5.5	.5	-	Root in CTB/pockets of loose SM
7.5	28	L-T	6	.5	YBSC	Few nodules/cement lenses
7.75	29	none	7	.5	-	Lenses in CTB/crumbled subgrade (bent tube/sand)
8	30	block fail	6	.5	-	CTB broken up
8.25	31	T	6	.5	-	Lenses in CTB
8.5	32	L-T	6	.5	BS soil	Good mix
8.75	33	L-T	6	.5	-	Lenses in CTB
9	34	L-T	6	.5	C-YBSC	Few nodules/lenses/not thoroughly mixed
9.25	35	L-T	6	.5	-	Lenses

*F-fine SC-sandy clay YBSC-yellow brown sandy clay
C-coarse FS-fine sand BS-brown sandy

HIGHWAY 160 (GOOD PERFORMANCE)

LOCATION	BORING	SURFACE CONDITIONS	THICKNESS CTB (in.)	THICKNESS ASPHALT (in.)	SOIL TYPE*	COMMENTS
4.5 W-GC	1	L-T	7	.5	SC	Numerous nodules/cement cured before compaction
4.75 W-GC	2	L-T	6.5	.5	FS	Good cement mix
5 W-GC	3	L-T	7	.5	FS	Good cement mix/2 pieces CTB
5.25 W-GC	4	T	-	-	FS	Bad cement mix/cement lenses throughout CTB cracked vertical
5.5	5	L-T	5.25	.5	FS (pinkish-white)	Few small nodules/good mix
5.75	6	L-T (hairline)	7.5	.5	C-YSC	Nodules/cement lenses
6	7	L-T	-	-	FS (white)	Small nodules/good mix/L cracks in center of base
6.25	8	T	7	.5	FS (brown)	Good mix
6.5	9	L-T	-	-	-	-
	9-1	L-T	-	-	-	Broke in hole
	9-2	L-T	-	-	FS	Good mix
	9-3	L-T	-	-	Sand (white)	Good mix
	9-4	L-T	-	-	BSC	Few large nodules/numerous cement lenses
	9-6	L-T	-	-	Yellow clay sand	1 or 2 nodules/good texture
	9a-1	L-T	-	-	-	Broke in hole
	9a-2	L-T	-	-	FS	Good mix/black base (looks like pumice)
	9a-3	L-T	-	-	-	Broke in hole
	9b-1	L-T	-	-	FS	Few small nodules (clay & silt)/good mix
	9b-2	L-T	-	-	BSC-C	Few nodules

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C-coarse FS-fine sand BSC-brown sandy clay
YSC-yellow sandy clay

HIGHWAY 160 (GOOD PERFORMANCE)

LOCATION	BORING	SURFACE CONDITIONS	THICKNESS CTB (in.)	THICKNESS ASPHALT (in.)	SOIL TYPE*	COMMENTS
	9b-3	L-T	-	-	FS	Few nodules throughout/good mix
6.75	10	L-T	6.25	.5	-	Near block failure
7	11	L-T	6.5	.5	FS	Good mix
7.25	12	L-T	6	.5	WBS	Nodules/cement not thoroughly mixed/ lenses/horizontal crack
7.5	13	L-T	-	-	FS	Good mix
7.75	14	L-T	5.75	.5	FWBS	Good mix/very few nodules/severe cracks

F-fine SC-sandy clay WBS-white brown sand
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YSC-yellow sandy clay