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16. Abstract The purpose of this research was to evaluate the effectiveness of shrinkage crack mitigation techniques for soil cement. The contents of this report include an evaluation of the construction and 8-year performance of 10 test sections. This was accomplished through a four-part program that consisted of constructing test sections, laboratory evaluation of materials, structural evaluation of test sections, and crack mapping of the soil cement base course and asphaltic concrete pavement.

Ten test sections were constructed on LA 89, State Project Number 397-04-0004. Each test section was 1,000 ft. long. The shrinkage crack mitigation methods that were addressed included cement contents of 9 and 5 percent, base thicknesses of 8.5 and 12 in., fibers contents of 0.1 and 0.05 percent, interlayers, curing membranes, and curing periods.

As expected, the cement treated design (CTD) base courses generally produced less transverse cracks than the cement stabilized design (CSD) base courses. Fibers generally did not reduce transverse cracks in either the CSD or CTD sections. As with the fiber sections, the treatments of interlayers and extended cure periods did not significantly mitigate transverse cracks.

Treatment cost evaluations for each test section relative to the control section indicated that the extended cure period (TS 10) and CSD section with random moisture variation had similar costs to the control section. The CTD section costs approximately 7 percent more than the control section while the interlayer sections, TS 7 and TS 8, cost approximately 75 percent more to construct than the control section. The fiber sections cost ranged from 170 to 410 percent more than the control section. Of the sections evaluated in this study, the CTD section (TS 4) proved to be the most cost-effective method option for mitigating cracking distresses.

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In-Place Cement Stabilized Base Reconstruction Techniques
Final Report: "Construction and Eight Year Evaluation"

by

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ABSTRACT

The purpose of this research was to evaluate the effectiveness of shrinkage crack mitigation techniques for soil cement. The contents of this report include an evaluation of the construction and 8-year performance of 10 test sections. This was accomplished through a four-part program that consisted of constructing test sections, laboratory evaluation of materials, structural evaluation of test sections, and crack mapping of the soil cement base course and asphaltic concrete pavement.

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As expected, the cement treated design (CTD) base courses generally produced less transverse cracks than the cement stabilized design (CSD) base courses. Fibers generally did not reduce transverse cracks in either the CSD or CTD sections. As with the fiber sections, the treatments of interlayers and extended cure periods did not significantly mitigate transverse cracks.

Treatment cost evaluations for each test section relative to the control section indicated that the extended cure period (TS 10) and CSD section with random moisture variation had similar costs to the control section. The CTD section costs approximately 7 percent more than the control section while the interlayer sections, TS 7 and TS 8, cost approximately 75 percent more to construct than the control section. The fiber sections cost ranged from 170 to 410 percent more than the control section. Of the sections evaluated in this study, the CTD section (TS 4) proved to be the most cost-effective method option for mitigating cracking distresses.

ACKNOWLEDGMENTS

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IMPLEMENTATION STATEMENT

The results of this study indicated that cement treated base course is an economically feasible method of mitigating shrinkage cracks. Several research projects were conducted using cement treated base courses, and this project assisted DOTD in its decision to allow cement treated design as an alternate to cement stabilized design.

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INTRODUCTION

Soil cement has been used internationally since 1935 to enhance the load distribution and durability of base courses and subbases. DOTD has been using Portland cement to stabilize or treat soils either for base courses or subbases in excess of 50 years *[1], [2]*. Many of the older pavements have undergone either rehabilitation or reconstruction. Because of this, soil cement base courses on those pavements have been restabilized with cement as many as four times.

Soil cement has proven itself to be an excellent base course through the years in Louisiana; however, it is not without drawbacks. The major soil cement issue addressed in this study was shrinkage cracking. It is natural for cementitious materials to shrink as a result of the hydration and the curing process. Factors that can influence shrinkage in soil cement blends are cement content, moisture content, density, compaction, curing, and fine grain soils *[1], [2]*. Common methods to abate this are using lower cement contents (4 to 8 percent), controlling the moisture content to within (+/- 2 percent of optimum), compacting the material in excess of 95 percent maximum density, applying a moisture barrier (curing membrane) over the soil cement, and selecting soils with a plasticity index (PI) of less than 25 *[1],[2],[3],[4],[5],[6],[7],[8],[9]*. In Louisiana, soils selected for base course cement stabilization or treatment must have a PI less than 15.

Reflective cracking in the asphaltic concrete (AC) pavement is often witnessed when soil cement base courses are used. Surface cracks increase roughness and decreases structural capacity by allowing water to infiltrate into the pavement, base course, and subgrade, thereby weakening the entire pavement system over time. Mitigating reflective cracks entails abating shrinkage cracks as previously mentioned, utilizing crack relief layers (interlayers), and fiber reinforcing the base course to name a few.

An interim report was published in August 2002 *[1]*. Topics covered in that report were constructing test sections, a laboratory program, a two-year performance analysis, and a technical assistance study *[1],[7]*. A summary of the interim report follows:

Interim Report Summary *[1]*

In an effort to explore and catalogue shrinkage crack mitigation effectiveness, strength, costs, and their respective constructability, 10 test sections, 1000 ft. in length, were constructed on LA 89 in Vermillion Parish in 1999. Shrinkage crack mitigation methods employed were:

(1) percentage of cement content, (2) base course thicknesses, (3) polypropylene fibers, (4) pavement interlayers, (5) curing membranes, and (6) curing periods.

Observations during construction revealed that there was little difference between constructing CSD sections and CTD sections. There were two interlayers, asphalt surface treatment and curing membrane with sand, built on this project. The asphalt surface treatment was easy to construct, but problems developed in the curing membrane with sand because the sand had to be spread manually with a shovel due to problems with equipment. Polypropylene fiber installation progressed slowly because there was no automated way to place and spread the fibers.

Strength measurements were taken before and after being overlaid with asphaltic concrete with the Dynaflect and falling weight deflectormeter (FWD). The results of testing indicated that, with the exception of one test section, all constructed sections met or exceeded strength requirements.

Costs for the test sections constructed were tabulated. A critique of the costs indicated that CSD and CTD are similar, while the interlayer sections added about $3 a square yard to the construction costs. Adding fibers to the soil cement sections increased the cost from about $7 to $16 dollars per square yard.

Pavement distresses of any type were not present on the roadway during the two-year evaluation period. Therefore, a critique of the effectiveness of different shrinkage crack mitigation techniques was not conducted at the time of the interim report publication.

OBJECTIVE

The purpose of this research was to evaluate the performance and cost of soil cement shrinkage crack mitigation techniques. This was accomplished through a four-part program that consisted of constructing test sections, laboratory evaluation of materials, structural evaluation of test sections, and crack mapping of the asphaltic concrete pavement over an 8-year period.

SCOPE

Ten test sections were constructed on LA 89, State Project Number 397-04-0004. This project had an average daily traffic (ADT) of 4000. Each test section was 1,000 ft. long. The shrinkage crack mitigation methods that were addressed included cement content, base thicknesses, fibers, interlayer, curing membrane, and curing periods.

After the test sections were constructed, their structural properties were assessed with the Dynaflect and FWD. Crack mapping was conducted by LTRC field technicians, the pavement management section with ARAN, and LTRC's pavement distress imaging system for a period of 8 years.

METHODOLOGY

Experiment Design

This project was designed using the control section versus treatment method with no replicates *[10]*. Since no replicates are available, robust statistical methods such as Analysis of Variance were not utilized. Instead, a simple comparison of measurement values was performed. In this experiment, the control section was CSD, 8.5 in. thick. The treatment levels were CTD at 12 in. thick, interlayers, polypropylene fibers (fibers), and curing duration. During the construction of the test sections, equipment problems occurred causing the CSD section to be constructed with varying degrees of moisture content. Because of that, an additional CSD section was properly constructed and the CSD section with moisture variations was added to the experiment as a treatment. Table 1 presents the sections used in this experiment.

Table 1
Treatment levels

Treatment	Treatment levels	Test section number/ Location (Beg. & End Sta.)
Control section (CSD)	9% cement content – 8.5 in. thick	TS / 9 (85+00 to 95+00)
CTD	5% cement content – 12 in. thick	TS 4 / (Sta. 35+00 to 45+00)
Interlayers		
	Crack relief layer	TS 7 / (Sta. 65+00 to 75+00)
	E.A. curing membrane with sand	TS 8 / (Sta. 75+00 to 85+00)
Fibers		
	CSD with 0.1% fiber concentration	TS 2 / (Sta. 15+00 to 25+00)
	CSD with 0.05% fiber concentration	TS 3 / (Sta. 25+00 to 35+00)
	CTD with 0.1% fiber concentration	TS 5 / (Sta. 45+00 to 55+00)
	CTD with 0.05% fiber concentration	TS 6 / (Sta. 55+00 to 65+00)
Extended cure period	14 days < Cure period < 30 days	TS 10 / (Sta. 95+00 to 105+00)
CSD	9% cement content – 8.5 in. thick with random moisture content variations	TS 1 / (Sta. 5+00 to 15+00)
CSD - Cement stabilized design *,CTD - Cement treated design *, E.A. - Emulsified asphalt		

The purpose of the project was to assess the effectiveness of the treatments specifically on soil cement shrinkage crack mitigation and monitor their overall performance for a period of approximately 8 years. Past research has shown that shrinkage cracks from soil cement typically manifest as either transverse or block cracks in the asphaltic concrete pavement surface and were measured during the monitoring period of this project *[1],[2],[3]*. In addition to measuring shrinkage and block cracks, longitudinal and alligator cracks, rutting, and roughness (IRI) were monitored during the 8-year period as well.

Hypothesis

The research team postulated the following:

1. With the exception of the CSD moisture variation treatment, each treatment selected would decrease the amount of transverse, longitudinal, and alligator cracks in the AC relative to the control section *[2],[3],[4],[11]*.
2. The addition of fibers to either CSD or CTD would increase its strength (resilient modulus) and could be demonstrated using the FWD *[12],[13]*.
3. The CSD and CTD sections would meet or exceed typical resilient modulus values for those sections in accordance with nationally accepted published data *[13]*.

Treatments

The treatments and the reasons for their selection used in this experiment were defined in the interim report and are presented in Table 1 *[1]*. Because of that, only a brief description of each will be presented here.

Control Section. This section was soil blended with 9 percent cement and was 8.5 in. thick (CSD). The percentage of cement selected is based upon the amount required to achieve a 300 psi unconfined compressive strength (USC) at 7 days *[1], [2]*.

CTD. This section was soil blended with 5 percent cement content and was 12 in. thick. The percentage of cement selected was based upon achieving a 150 psi USC at 7 days *[1],[2]*.

Fibers. There were four sections with fibers in this experiment. Fiber concentrations of 0.1 percent and 0.05 percent were added to both CSD and CTD sections *[1],[6],[8],[9]*.

Interlayers. There were two types of interlayers used on this project: asphalt surface treatment (AST) and emulisfied asphalt curing membrane (EACM) with sand added to it. The AST was constructed in accordance with standard DOTD specifications and was about 0.5 in. thick. The EACM was a modified version of the curing membrane typically used by DOTD. The modifications included increasing the emulisifed asphalt dosage rate and spreading a 0.5-in. layer of sand over it just after it was applied *[1],[3],[11]*.

Curing Period. The specifications required that 9 out of the 10 test sections be overlaid with AC within 7 days and that one section be overlaid between 14 and 30 days *[1],[2],[3]*.

Base Course/Treatment Costs

The construction costs for the base course and treatments were obtained from the construction bids and tabulated in Table 2 *[1]*. These values were used to compare the costs of the treatments.

Table 2
Construction costs

Test sections - Description	Cost($) per square yard				
	Cement stabilizing (1)	Fibers (2)	Crack relief layer	Curing mem. w/sand	Total
1. CSD	4.05	—	—	—	4.05
2. CSD with 0.1% fibers	5.85	10.19	—	—	16.04
3. CSD with 0.05% fibers	5.85	5.10	—	—	10.95
4. CTD	4.35	---	—	—	4.35
5. CTD with 0.1% fibers	6.24	14.40	—	—	20.64
6. CTD with 0.05% fibers	6.24	7.20	—	—	13.44
7. CSD with crack relief layer	4.05	—	3.00	—	7.05
8. CSD with E.A. curing layer with sand	4.05	—	—	3.05	7.10
9. Control section (CSD)	4.05	—	—	—	4.05
10. CSD with extended cure period	4.05	—	—	—	4.05
CSD - 9% cement content and 8.5 inches thick, CTD - 5% cement content and 12 inches thick (1)Includes cost of cement, (2) actual cost of fibers exclusive of mixing with soil cement base course					

Pavement Distresses and Roughness

Distresses in AC pavements are generally placed in five categories, cracking, patching/potholes, surface deformation, surface defects, and miscellaneous distresses as shown in Table 3 *[14]*.

Table 3
Pavement distresses

Distress categories	Types per category
Cracking	Fatigue (alligator), block, edge, longitudinal, reflection at joints, and transverse
Patching/potholes	Patch/Patch deterioration, potholes
Surface deformation	Rutting, shoving
Surface defects	Bleeding, polished aggregate, raveling
Miscellaneous defects	Lane to shoulder drop off, water bleeding and pumping

The pavement management system (PMS) collects and warehouses the pavement data on the massive servers. On AC pavements, transverse cracks, longitudinal cracks, alligator cracks, patching, rutting, and IRI data were obtained and stored. An additional category, random cracks, which is the sum of the transverse and longitudinal cracks, is also stored *[1]*.

On this project, the only distresses observed and catalogued during the 8-year review period were transverse cracks, longitudinal cracks, alligator cracks, rutting, and roughness (IRI). This information was placed in figures for each test section and utilized in hypothesis testing.

IRI. At the time of test section construction, profile index not IRI, was used to determine pavement smoothness, so IRI data was not collected at the time of construction. Data points were available for years 1.8, 3.8, and 5.9 from the PMS database and year 7.8 from LTRC. Since no data was available just after construction, it was presupposed that the initial IRI reading was similar to year 1.8 IRI values as shown in Figure 1. IRI readings, unlike cracking data, do not begin at zero; because of this, there is an intercept value as shown in Figure 1. The slope of the line (m) demonstrates the rate of deterioration exclusive of the intercept value. The intercept values, which infer the initial IRI readings, can’t be used as a means of comparison, since the initial IRI readings are unknown. Furthermore, it is probable that the IRI at the time of construction varied between test sections so that a comparison of their magnitudes as a means of determining performance would be invalid. Following this logic, deterioration lines (y = mx + b) were constructed for each test section, and their slopes were compared to the control section. For example, if the slope of the line for the control section and the 5 percent cement content section were 0.003 and 2.200, respectively, the section with the least slope (control section) performed the best.

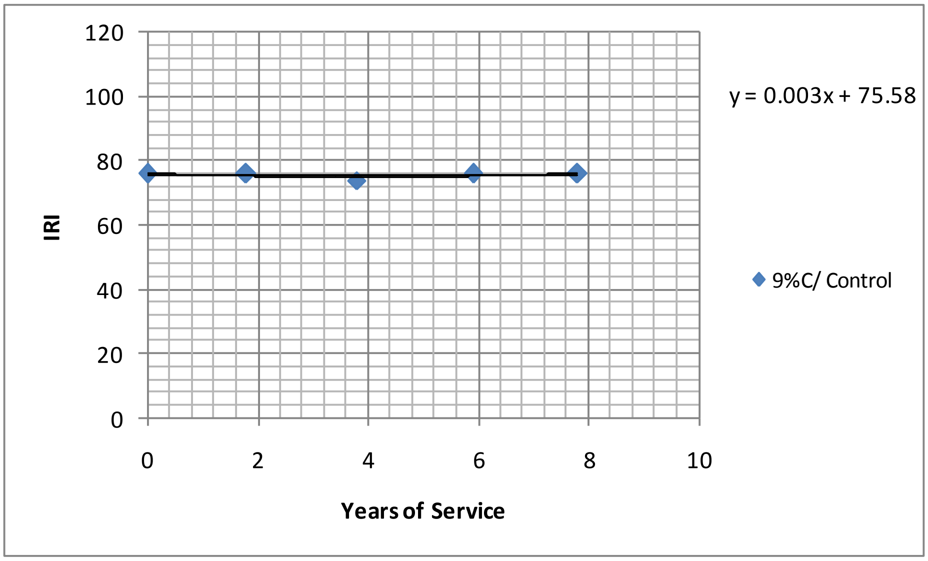

Figure 1
IRI values

Pavement Survey Dates

LTRC technicians conducted manual crack mapping surveys on October 19, 1999, and December 11, 2000. Automated distress surveys were conducted by Louisiana Department of Transportation and Development's PMS on March 2001, January 2003, and April 2005. LTRC conducted an automated distress survey on March 2007. Distress data such as transverse, longitudinal, and alligator cracking were collected at each survey date and ride quality information was not collected during the LTRC manual crack mapping surveys. Table 4 presents the survey dates.

Table 4
Pavement survey dates

Test date	Pavement condition	Test agency	Age of pavement
October 1999	No cracks	LTRC (1)	0.5
December 2000	No cracks	LTRC (1)	1.6
March 2001	No cracks	DOTD / ARAN	1.8
January 2003	Cracks	DOTD / ARAN	3.8
April 2005	Cracks	DOTD / ARAN	5.9
March 2007	Cracks	LTRC	7.8
(1) Manual survey			

Base Course Resilient Modulus Obtained from Falling Weight Deflectometer Tests

The FWD is a device that closely approximates the effect of a moving wheel load, both in magnitude and duration. The 9,000-lb. load is applied through a circular plate that causes the pavement to deflect. Once the load is applied, it is measured by a precision heavy duty load cell that is above the loading plate. By means of a high speed transducer, the deflection data are acquired by a computer. Through a back calculation process, the elastic modulus is determined for each layer. The resilient modulus (M_r) is a measure of a material's stiffness and can provide an indication of the condition and uniformity of a material. In flexible pavement design, resilient modulus is one of five variables used to determine the design structural number (SN) *[12]*. This number was compared to typical values found in CSD (200 ksi) and CTD (100 ksi) *[13]*.

Ten FWD readings were taken on each test segment and then averaged to provide a representative resilient modulus for that test section. The raw data from the FWD were processed by Dynatest's ELMOD 4 software to obtain the resilient modulus for the base courses.

DISCUSSION OF RESULTS

Test Section Performance Evaluation

Transverse Cracking

Figure 2 presents the quantity of transverse cracks in each test section at 3.8, 5.9, and 7.8 years of service. No cracking was present at the time of initial construction or 1.8 years of service.

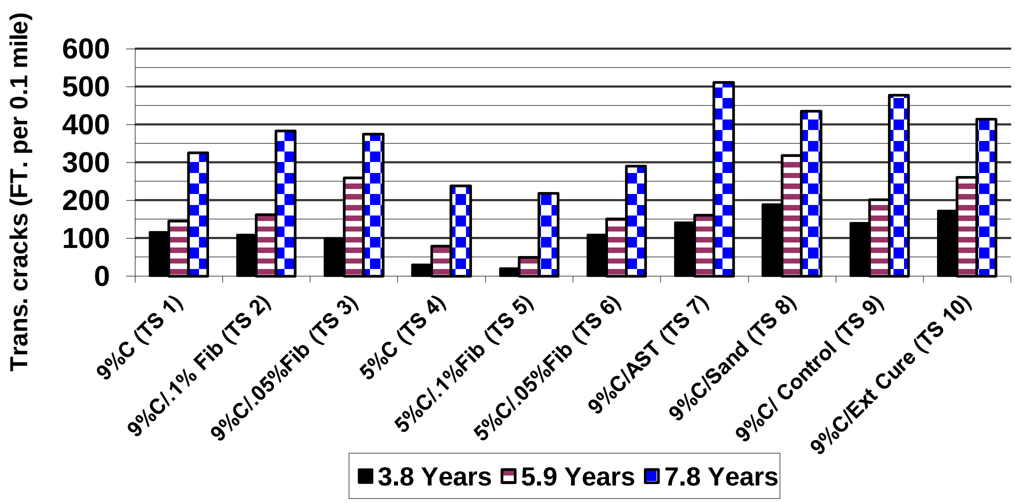

Figure 2
Transverse cracks

The CTD sections (5% cement content) had the least amount of transverse cracks. The addition of fibers to the soil cement sections had little influence on abating transverse cracks on either CTD or CSD sections. In fact, in most cases, transverse crack quantities were slightly higher on CSD and CTD sections with fibers. As with the fiber sections, the treatments of interlayers and extended cure periods did not significantly mitigate transverse cracks. Table 5 presents a summary of the findings.

Table 5
Crack distress summary

Treatment	Treatment levels	Test section number/ Location (Beg. & End Sta.)	Did the treatment level reduce cracking?		
			Transverse	Long.	Alligator
Control section (CSD)	9% cement content – 8.5 in. thick	TS 9 / (85+00 to 95+00)	–	–	–
CTD	5% cement content – 12 in. thick	TS 4 / (Sta. 35+00 to 45+00)	Y	Y	Y
Interlayers					
	Crack relief layer	TS 7 / (Sta. 65+00 to 75+00)	N	Y	N
	E.A. curing membrane with sand	TS 8 / (Sta. 75+00 to 85+00)	Y	N	N
Fibers					
	CSD with 0.1% fiber concentration	TS 2 / (Sta. 15+00 to 25+00)	Y	Y	N
	CSD with 0.05% fiber concentration	TS 3 / (Sta. 25+00 to 35+00)	Y	Y	N
	CTD with 0.1% fiber concentration	TS 5 / (Sta. 45+00 to 55+00)	Y	Y	Y
	CTD with 0.05% fiber concentration	TS 6 / (Sta. 55+00 to 65+00)	Y	Y	N
Extended cure period	14 days < Cure period < 30 days	TS 10 / (Sta. 95+00 to 105+00)	Y	Y	Y
CSD	9% cement content – 8.5 in. thick with random moisture content variations	TS 1 / (Sta. 5+00 to 15+00)	Y	Y	N
"Y" means that the section had less cracks than the control and "N" means that the section had more cracks than the control.					

Longitudinal Cracking

Figure 3 presents the longitudinal cracks for each test section that were measured at 7.8 years of service. Data from years 3.8 and 5.9 were not used because of measurement errors discovered during the review process. The maximum observed longitudinal cracking was in the 9 percent interlayer section with sand (TS 8). The 9 percent section (control section) (TS 8) had significant cracking as well. The remaining test sections had less than 42 ft. per 0.1 mile longitudinal cracks with some sections having no longitudinal cracks at all. Table 5 presents the results of the analysis.

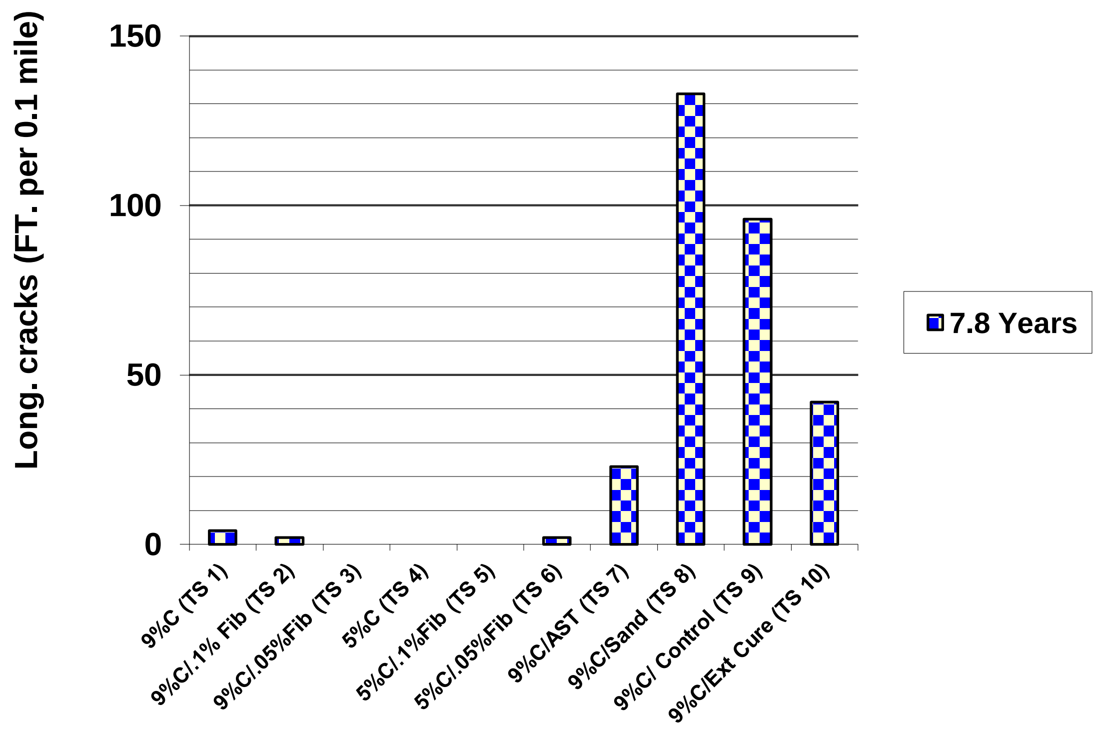

Figure 3
Longitudinal cracks

Alligator Cracks

Figure 4 presents the alligator cracks for each test section that were measured at 7.8 years of service. Data from years 3.8 and 5.9 were not used because of measurement errors discovered during the review process.

Test sections 5 and 10 had no alligator cracks and test sections 1, 4, 6, and 9 had minimal amounts of alligator cracks. For this distress category, the CSD fiber sections (test sections 1 and 2) and interlayer sections (test sections 2, 3, 7, and 8) had significant amounts of alligator cracks relative to the control section. Table 5 presents the results of the analysis.

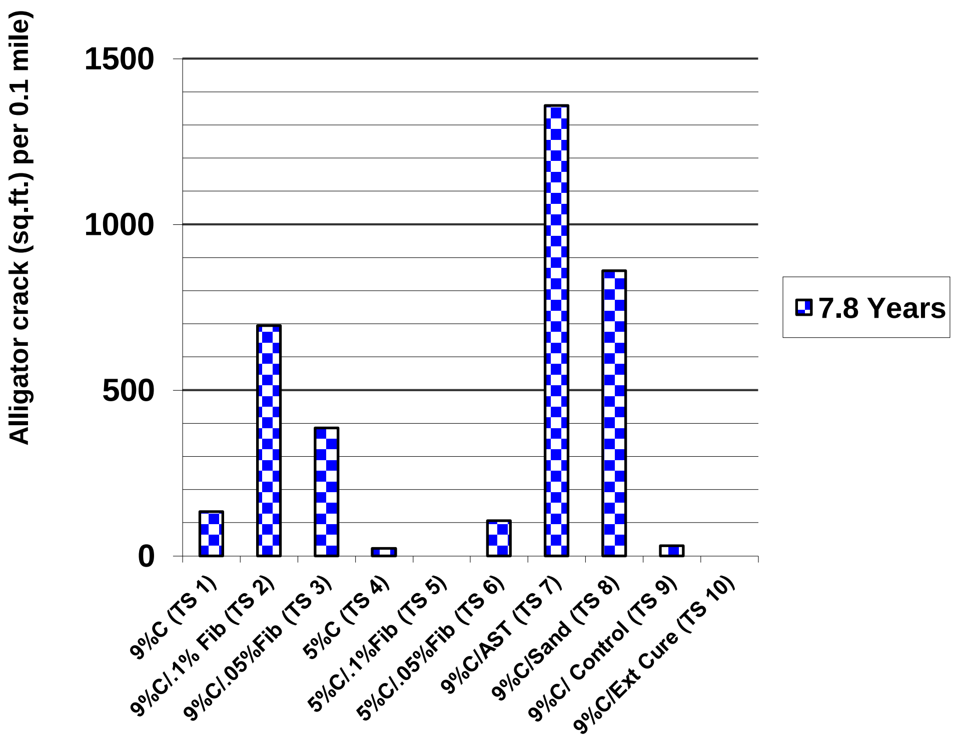

Figure 4
Alligator cracks

IRI

Figure 5 presents the IRI for each test section at 1.8, 3.8, 5.9, and 7.8 years of service. IRI readings were not taken at the time of construction.

Test sections 1, 2, 3, 4, and 8 had higher rates of IRI deterioration than test sections 5, 6, 7, 9 and 10. In fact, the changes in the IRI for test sections 5, 6, 7, 9, and 10 are negligible and can be contributable to high speed measurement device variance. Table 6 presents the deterioration results.

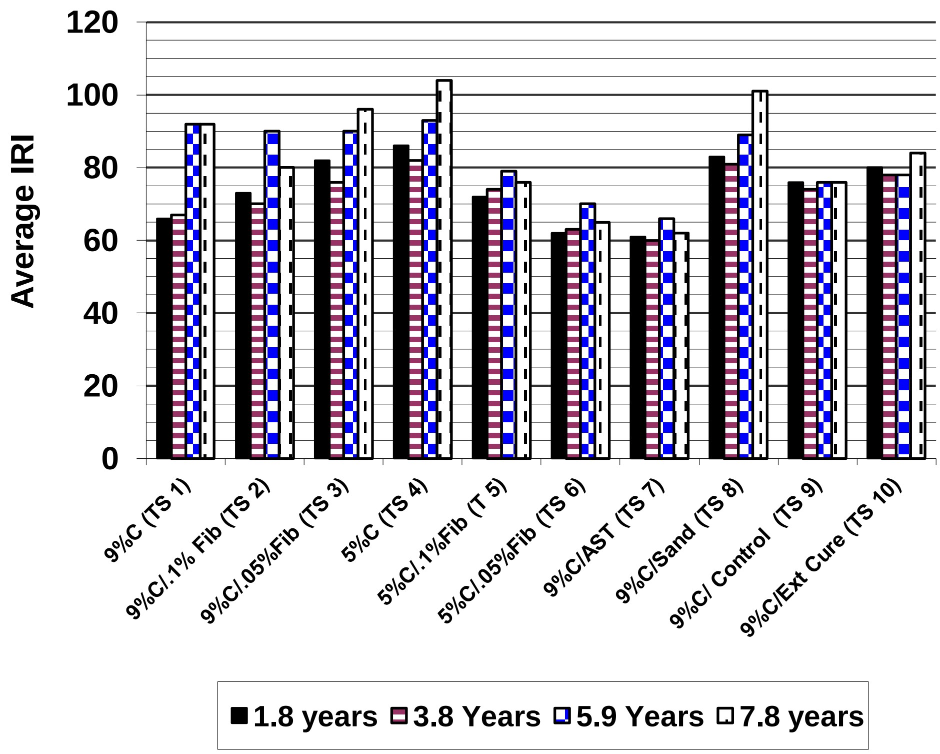
120
100
80
60
40
20
0
Average IRI
9%C (TS 1)
9%C/.1% Fib (TS 2)
9%C/.05%Fib (TS 3)
5%C (TS 4)
5%C/.1%Fib (T 5)
5%C/.05%Fib (TS 6)
9%C/AST (TS 7)
9%C/Sand (TS 8)
9%C/ Control (TS 9)
9%C/Ext Cure (TS 10)
1.8 years
3.8 Years
5.9 Years
7.8 years

Figure 5
IRI

Table 6
IRI deterioration rate comparison

Treatment	Treatment levels	Test section number/ Location (Beg. & End Sta.)	IRI rate of deterioration (IRI/yr.)	Less than Control Section
Control section (CSD)	9% cement content – 8.5 in. thick	TS / 9 (85+00 to 95+00)	0.003	_
CTD	5% cement content – 12 in. thick	TS 4 / (Sta. 35+00 to 45+00)	2.200	NO
Interlayers				
	Crack relief layer	TS 7 / (Sta. 65+00 to 75+00)	0.771	NO
	E.A. curing membrane with sand	TS 8 / (Sta. 75+00 to 85+00)	2.144	NO
Fibers				
	CSD with 0.1% fiber concentration	TS 2 / (Sta. 15+00 to 25+00)	2.622	NO
	CSD with 0.05% fiber concentration	TS 3 / (Sta. 25+00 to 35+00)	1.850	NO
	CTD with 0.1% fiber concentration	TS 5 / (Sta. 45+00 to 55+00)	1.074	NO
	CTD with 0.05% fiber concentration	TS 6 / (Sta. 55+00 to 65+00)	1.230	NO
Extended cure period	14 days < Cure period < 30 days	TS 10 / (Sta. 95+00 to 105+00)	0.149	NO
CSD	9% cement content – 8.5 in. thick with random moisture content variations	TS 1 / (Sta. 5+00 to 15+00)	4.002	NO

Rutting

Figure 6 presents the rutting in each test section. It was assumed that no rutting was present at the time of construction. The PMS system reports rutting values as 0.1 in., even if the actual value was less than 0.1 in. For that reason, no rutting values less than 0.1 appear in Figure 6. At 7.8 years of service, all rut values were below 0.25 in., which can be attributed to AC normal densification. Each section was considered to have performed both equally and favorable within this distress category.

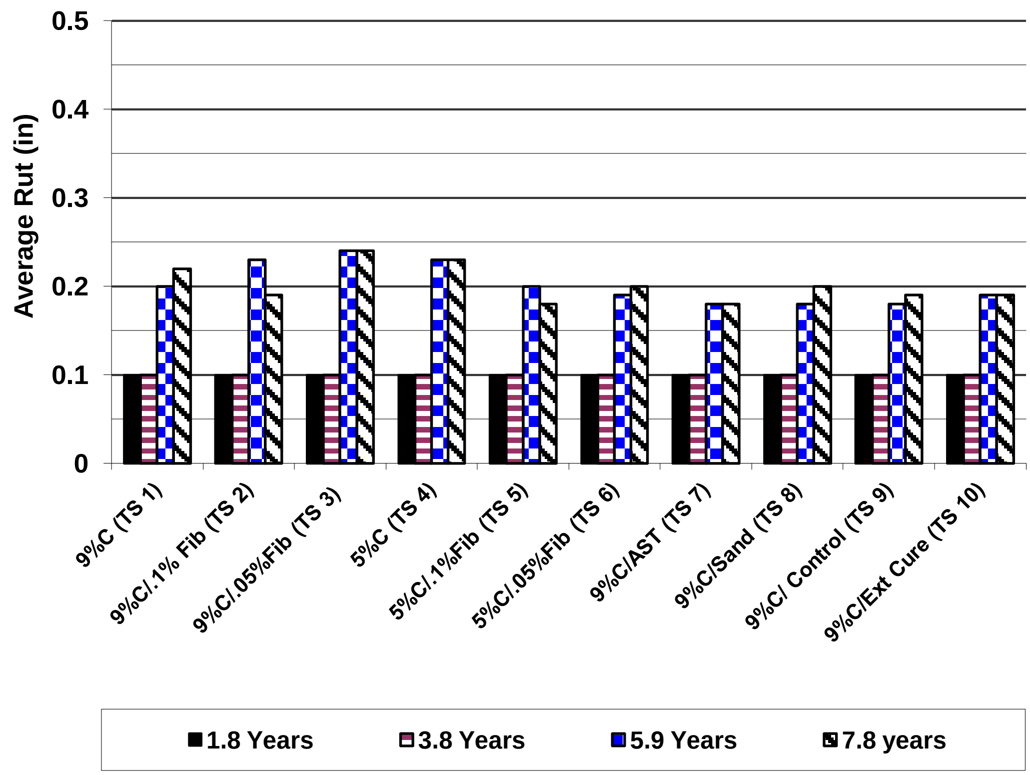

Figure 6
Rutting

Treatment Construction Costs

Table 7 presents a comparison of the construction costs for each treatment. The extended cure period (TS 10) and CSD section with random moisture variation had similar costs to the control section. The CTD section costs approximately 7 percent more than the control section while the interlayer sections, TS 7 and TS 8, cost approximately 75 percent more to construct than the control section. The fiber sections cost ranged from 170 to 410 percent more than the control section.

Table 7

Construction cost comparison

Treatment	Treatment levels	Test section number/ Location (Beg. & End Sta.)	Cost Increase (%) relative to the control section	More than Control Section
Control section (CSD)	9% cement content – 8.5 in. thick	TS / 9 (85+00 to 95+00)	N/A	—
CTD	5% cement content – 12 in. thick	TS 4 / (Sta. 35+00 to 45+00)	7	YES
Interlayers				
	Crack relief layer	TS 7 / (Sta. 65+00 to 75+00)	74	YES
	E.A. curing membrane with sand	TS 8 / (Sta. 75+00 to 85+00)	75	
Fibers				
	CSD with 0.1% fiber concentration	TS 2 / (Sta. 15+00 to 25+00)	296	YES
	CSD with 0.05% fiber concentration	TS 3 / (Sta. 25+00 to 35+00)	170	YES
	CTD with 0.1% fiber concentration	TS 5 / (Sta. 45+00 to 55+00)	410	YES
	CTD with 0.05% fiber concentration	TS 6 / (Sta. 55+00 to 65+00)	232	YES
Extended cure period	14 days < Cure period < 30 days	TS 10 / (Sta. 95+00 to 105+00)	0	NO
CSD	9% cement content – 8.5 in. thick with random moisture content variations	TS 1 / (Sta. 5+00 to 15+00)	0	NO

Base Course M_r Obtained from FWD Tests

The M_r of the base course was determined on three separate occasions as shown in Table 8 with the FWD. On those occasions, each CTD test section exceeded the 100 ksi design value and each CSD test section exceeded the 200 ksi design value *[13]*. It is interesting to note that fibers were shown to increase the M_r in laboratory tests, but the in-place M_r obtained from field testing with the FWD generally indicated otherwise *[6]*. Perhaps this is due to the fact that the FWD didn't induce enough stress into the pavement structure to engage the fibers. Further research is needed to test this hypothesis.

Table 8
Base course M_r values

Test section	Description	M_r (1) 10-99	M_r 7-02	M_r 11-05
1	CSD	250	456	1018
2	CSD with 0.1% fibers	222	417	933
3	CSD with 0.05% fibers	182	258	321
4	CTD	265	558	870
5	CTD with 0.1% fibers	230	182	288
6	CTD with 0.05% fibers	270	204	342
7	Crack Relief Layer	241	461	874
8	E.A. Curing Layer w/sand	276	515	906
9	Control Section	257	349	341
10	Extended Cure Period	236	381	514
(1) Measurement taken approximately 6 months after construction **Note: Mr values are in units of ksi.**				

CONCLUSIONS

As expected, the CTD base courses generally produced less transverse cracks than the CSD base courses. Fibers generally did not reduce transverse cracks in either the CSD or CTD sections. As with the fiber sections, the treatments of interlayers and extended cure periods, did not significantly mitigate transverse cracks. The maximum observed longitudinal cracking was in the CSD interlayer section with sand (TS 8). The CSD (control section) (TS 8) had significant longitudinal cracking as well. The remaining test sections had less than 42 ft. per 0.1 mile longitudinal cracks with some sections having no longitudinal cracks at all. Test sections 5 and 10 had no alligator cracks, and test sections 1, 4, 6, and 9 had minimal amounts of alligator cracks. For the alligator crack distress category, the CSD fiber sections (test sections 1 and 2) and interlayer sections (test sections 2, 3, 7, and 8) had significant amounts of alligator cracks relative to the control section.

IRI data indicated that the control section (CSD) had no deterioration over the 8-year review period, while (CSD) test section 1 had the highest deterioration rate. Because the control section had no change in IRI, all test sections had higher IRI deterioration rates than the control section, which made it difficult to truly gauge the IRI performance of the test sections relative to that of the control section. However, the IRI measurements indicated that test sections 1, 2, 3, 4, and 8 had higher rates of IRI deterioration than test sections 5, 6, 7, 9 and 10. In fact, the changes in the IRI for test sections 5, 6, 7, 9, and 10 are negligible and can be contributable to high speed measurement device variance.

At 8 years of service, all rut values were below 0.25 in., which can be attributed to AC densification. Each section was considered to have performed both equally and favorably within this distress category.

Treatment cost evaluations for each test section relative to the control section indicated that the extended cure period (TS 10) and CSD section with random moisture variation had similar costs to the control section. The CTD section costs approximately 7 percent more than the control section, while the interlayer sections, TS 7 and TS 8, cost approximately 75 percent more to construct than the control section. The fiber sections cost ranged from 170 to 410 percent more than the control section. Of the sections evaluated in this study, the CTD section (TS 4) proved to be the most cost-effective method option for mitigating cracking distresses.

The treatment M_r analysis indicated that the test sections met or exceeded design standards and were consistent with other projects in Louisiana *[4]*. The addition of fibers to the soil cement base course did not contribute to increasing its modulus values; in fact, modulus values were generally lower in the fiber sections as measured with the FWD.

RECOMMENDATIONS

The results of this analysis has shown that cement treated bases perform structurally as well as cement stabilized bases and produce less distress cracks. DOTD should continue to utilize cement treated bases as a viable alternate to cement stabilized bases unless conditions warrant otherwise.

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

AC	Asphaltic concrete
ADT	Average Daily Traffic
AST	Asphalt surface treatment
CSD	Cement stabilized design
CTD	Cement treated design
DOTD	Department of Transportation and Development
EA	Emulsified asphalt
EACM	Equivalent uniform annualized cost
Fibers	Fibrillated polypropylene fibers
FWD	Falling Weight Deflectometer
IRI	International Roughness Index
LC	Layer coefficient
LTRC	Louisiana Transportation Research Center
M_r	Resilient modulus
PI	Plasticity Index
PMS	Pavement management system
SN	Structural Number
UC	Unconfined compression
USC	Unconfined compressive strength

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