CHEMKRETE MODIFIED ASPHALTIC CONCRETE FIELD TRIAL CONSTRUCTION AND THREE YEAR EVALUATION

EXPERIMENTAL PROJECT PROGRAM NO. 3
ASPHALT ADDITIVES

By

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ABSTRACT

This report documents the construction of a Chemkrete modified asphaltic concrete field trial and presents three year performance data. Normal plant and roadway operations were maintained throughout the production of the Chemkrete modified mix. Initial binder testing, however, indicated the possibility of non-uniform blending of the Chemkrete additive. An additional problem surfaced during production control and acceptance testing: stabilities below specification limits. While upon curing the mix attained stabilities greater than the control mix, the low initial stabilities may require changes to control and acceptance procedures.

Performance evaluations were conducted on an annual basis and included Pavement Condition Ratings, structural evaluation and the examination of binder properties (as extracted and recovered from roadway samples). No discernable performance differences were observed on the basis of these parameters. Both the conventional AC-30 binder and the Chemkrete modified binder demonstrated excessive aging characteristics. The aged binders, both conventional and modified, have contributed to loss of surface fines and wider than normal reflected shrinkage cracking from the soil cement base. The benefits of Chemkrete could not be ascertained during this evaluation period.

IMPLEMENTATION STATEMENT

As the conclusions of this report state there are no discernable differences in performance between the Chemkrete modified and control sections. It is further suggested that inconsistencies in the data obtained leave doubt as to the value of this project to evaluate the potential benefits of the Chemkrete additive. With this in mind the use of Chemkrete could not be recommended at this time.

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INTRODUCTION

Background

From the late 1970's to the present, Louisiana has directed much of its bituminous research effort in the area of asphalt additives. These efforts were initiated in response to a steadily decreasing quality aggregate supply in several districts. The associated problems were reflected by deteriorating mix properties and the higher costs of transporting quality materials. A number of additives were examined in either the laboratory and /or field including sulphur, Styrelf 13 (a polymerized asphalt), SBR latex, and Trinidad Lake Asphalt. (1-3) Each of these products proclaimed mix enhancements such as increased strength and durability as reflected by fatigue resistance, improved temperature susceptibility, resistance to deformation and resistance to water susceptibility. These additives were examined in dense graded asphaltic concrete in order to obtain better mix properties. Also, several of these additives were utilized to upgrade sand/asphalt mixes to take advantage of marginal sand materials prevalent in those districts where gravel was in short supply or non-existent.

In 1979, the Department was approached by representatives of Chem-Crete Corporation (later changed to Chemkrete when acquired by Lubrizol Corporation). They had developed an asphalt additive (soluble manganese) which, when blended with asphalt cements, would improve asphaltic concrete properties such as strength, temperature susceptibility and water susceptibility. The increased structural capacity of Chemkrete mixes due to the improved strength characteristics would allow for the use of non-quality aggregates such as sand. According to their literature, successful projects utilizing desert sand had been constructed in the Middle East.(4) On this basis it was decided to examine Chemkrete in the laboratory.

Laboratory Research Effort

In November 1979, a research study (5) was initiated to examine, in the laboratory, the physical characteristics of Chemkrete binder and sand/Chemkrete mixes. The binder was characterized by penetration (77°F), viscosity (140, 275, 350°F), and ductility (77°F). Optimization of binder content for three distinct gradations (coarse to fine) was accomplished using the Marshall method. Also, mix properties such as retained strength, resistance to water, fundamental properties and strength-temperature susceptibility were examined.

The results of this study demonstrated that, upon curing, sand/Chemkrete mixes could attain Marshall stabilities equal to or superior to Louisiana's dense-graded Type 1 asphaltic concrete (1200-pound stability) and that these mixes were able to withstand strains at which failure occurred in conventional mixes at significantly higher failure stresses than the conventional mixes. Additionally, the Chemkrete mixes proved less water susceptible than control mixes.

Additional Considerations

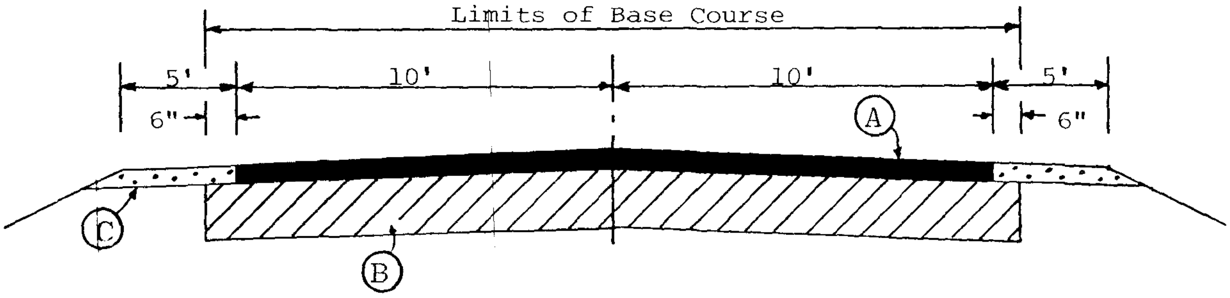
On the basis of the research study findings, a field trial was recommended utilizing a sand/Chemkrete mix as a base or binder course mix. Additionally, it was believed that the additive could be used in dense graded asphaltic concrete to either decrease section design thickness or provide a mix with increased strength characteristics. About this time, however, Chemkrete was experiencing problems in their field demonstration projects as modified sections displayed extensive cracking and ravelling. (6,7,8,9) Generally these problems were traced to quality control and construction practices. Also, during this time period the manganese concentration was reduced along with the use of softer grades of asphalt. Upon acquisition of the U.S. patents by Lubrizol in 1982, Chemkrete Technologies Inc. was formed as a wholly owned subsidiary. The product was additionally modified and the blended ratio of asphalt cement to Chemkrete was increased. The newer field trials did not experience the extensive cracking and ravelling of the earlier projects.(6) With this in mind, Louisiana decided to attempt a field trial.

In August 1983, a plan change was issued to an on-going contract to include the use of the Chemkrete additive for approximately 2.5 miles of a 10.2 mile reconstruction project. This report documents the construction of the Chemkrete field trial and presents three year performance data.

FIELD EXPERIMENTAL PROJECT

Location and Section Design

An agreement was made whereby the construction of the test section was made part of an on-going contract with Prairie Construction Company, Inc. This 10.2-mile project on La. 10 in St. Landry Parish from Palmetto to Melville, Louisiana, consisted of 2.5 inches of asphaltic concrete overlay over existing surfacing for 3.5 miles and 3.0 inches of asphaltic concrete over 9.5 inches of in-place cement stabilized base course for 6.7 miles. The change order provided for the addition of Chemkrete modifier in 2.5 inches of asphaltic concrete for 2.5 miles of the cement stabilized section. The Chemkrete modified mix was placed in a single lift, while the normal design called for two 1.5 inch lifts of binder and wearing course. Figure 1 presents a design typical section for the Chemkrete treated materials.



A	2½" Chemcrete Modified Wearing Course
B	8½" In-Place Cement Stabilized Base Course
C	3" Av. Aggregate Surface Course

Figure 1. Design Typical Section

The reduction in design thickness for the Chemkrete section was attempted on the basis of two considerations: 1) to evaluate the manufacturer's claim of reduced section design due to the increase in strength associated with modified mix; and, 2) to take advantage such reduction for economically equivalent designs. A plan view of the Chemkrete and control sections is provided in Figure 2.

The plant was located in the town of Opelousas, Louisiana; this was approximately 22 miles from the La. 10 construction site.

Plant Operations

The original plans for this project called for the Chemkrete additive to be blended with a Texaco AC-20 in a storage tank at Port Neches, Texas. These plans, however, was not realized and the Chemkrete personnel provided a portable in-line volumetric proportioning device. This blending device meters both asphalt and modifier at the proper ratios using an air actuated control into an in-line blender prior to pumping into the plant asphalt working tank. Unfortunately, due to the locations and capacities of the pump at the plant, the control device was rendered useless. In order not to inconvenience the contractor by halting construction and after assurance from the manufacturer's representative that adequate blending could still be achieved, work continued using an alternative procedure. Using the known flow rate of the AC-20 from the tank truck, the Chemkrete was pumped at an appropriate rate through the in-line blender.

The first day's production produced an additional problem. Approximately 10,000 gallons of AC-30 which was used for the conventional hot mix in the control section remained in the working tank. As the contractor had only one asphalt cement tank it was decided to blend Chemkrete with this material and evaluate it apart from the AC-20 section. About 700 gallons of Chemkrete was pumped into the working tank and circulated for 24 hours as

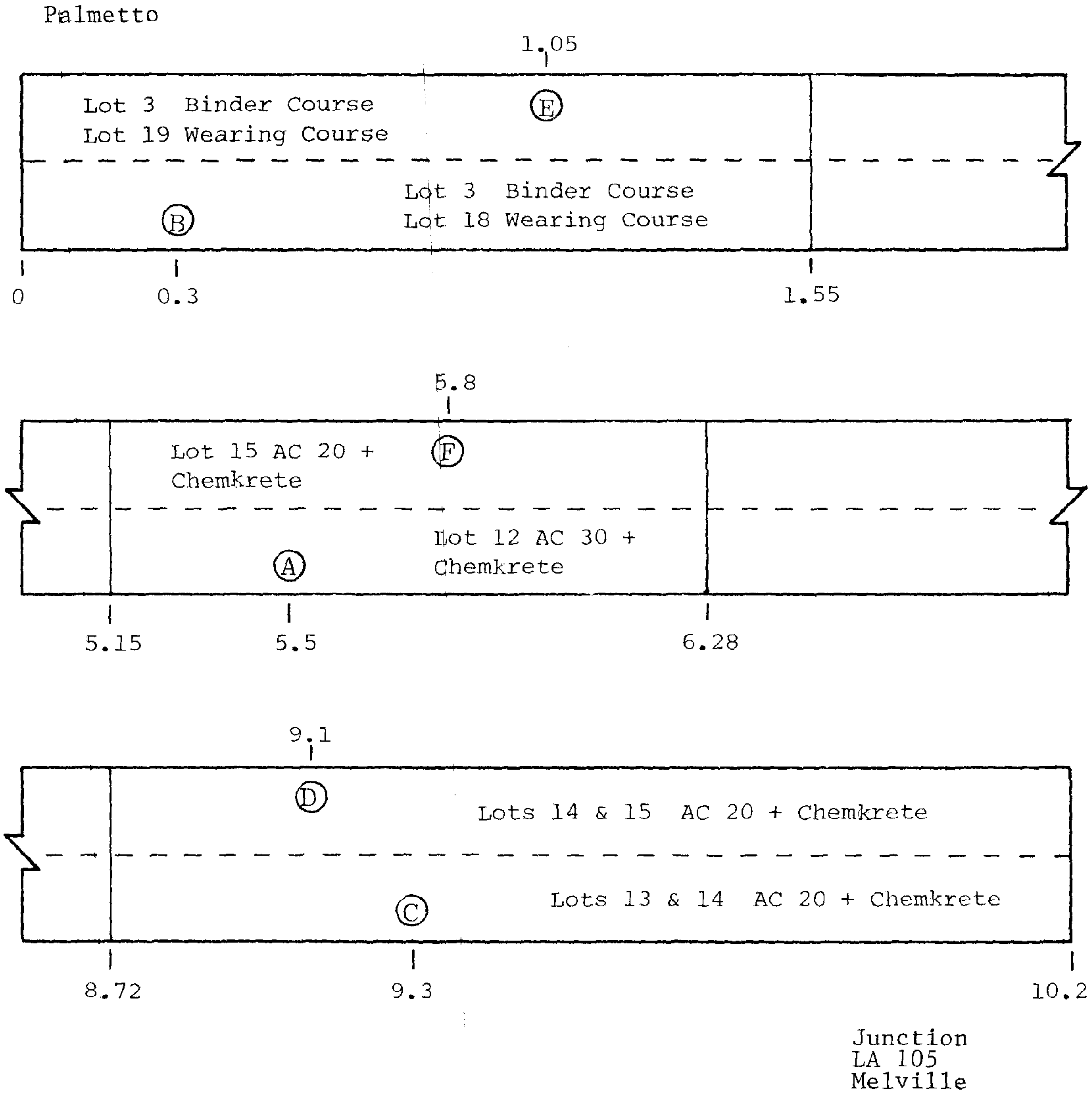


Figure 2. Location of Chemkrete and Control Sections

recommended by Chemkrete personnel. The location of this material is annotated in Figure 2 and consisted of the majority of the first day's production.

No modifications or changes in production were necessary for the 400 ton per hour capacity dryer drum plant.

Materials and Mix Design

The source of coarse aggregate was a silicious river gravel from Red Stick No. 1 (Bayville) while the source for the coarse and fine sands were Trinity (Longville) and Mamou Pit, respectively. Texaco supplied both the AC-30 and AC-20 asphalt cements from their plant at Port Neches, Texas. Perma-Tac antistrip agent from Dasch Oil and Chemical Company was utilized at a rate of 0.5% by weight of the asphalt cement according to specifications.

Job Mix Formulas for the binder and wearing course mix used on this project are shown in Table 1. The Chemkrete mixes utilized the same JMF as the control mix wearing course.

Construction

Plant production of the Chemkrete modified asphalt concrete began on September 2, 1983 and continued on September 8-9, 1983 under fair-to-cloudy skies with daytime temperatures in the mid nineties and nighttime temperatures in the high seventies. There were no modifications to normal plant or roadway procedures during the three days of production of the Chemkrete mix. Table 2 presents production data for the Chemkrete mix. Data for the conventional mix used as a control is also provided. It should be noted that the control wearing course was not placed until March 1984.

TABLE 1

PROJECT JOB MIX FORMULAS

JMF Sequence No.	1	4
Mix Use	Binder	Wearing
Recommended Formula Percent Passing		
U. S. Sieve Size		
1 - 1/4"	100	100
1"	99	100
3/4"	94	97
1/2"	86	91
No. 4	57	57
No. 10	44	45
No. 40	28	28
No. 80	14	14
No. 200	7	7
% AC	5.0	5.5
% Crushed	80	80
Mix Temp.	300	300
Marshall Properties		
Specific Gravity	2.33	2.33
Theoretical Grav.	2.44	2.43
% T Theoretical	95.5	95.9
% Voids	4.5	4.1
% V.F.A.	72.0	75.2
Marshall Stability	1400	1400
Flow	6	8

TABLE 2

PLANT PRODUCTION

LOT NO.	DATE LAID	MIX TYPE	BINDER TYPE	DAILY TONNAGE
3	8/8/83	Binder	AC-30	1078
12	9/2/83	Wearing (Mod)	AC-30+Chemkrete	998
13	9/2/83	Wearing (Mod)	AC-20+Chemkrete	593
14	9/8/83	Wearing (Mod)	AC-20+Chemkrete	1523
15	9/9/83	Wearing (Mod)	AC-20+Chemkrete	925
18	3/9/84	Wearing	AC-30	1034
19	3/13/84	Wearing	AC-30	947

Temperature control at the plant was generally maintained within the limits of the job mix formula (275 - 325°F). There were several truckloads during the first day of production (Lot 15) where low temperatures were observed at the plant as indicated in Table 3. This mix was, however, laid within allowable specification temperature limits (± 25°F of job mix formula tolerance limits).

TABLE 3

PLANT PRODUCTION TEMPERATURES
(°F)

	Lot 12	Lot 13	Lot 14	Lot 15
	310	300	310	265
	310	285	285	275
	295	285	295	270
	295	285	290	265
	280	285	310	280
			310	280
			280	275
			285	275
			305	280
			280	295
n	5	5	10	10
x	298	288	295	276
s	13	7	13	9

Quality Control

Marshall properties and aggregate gradation were used for control testing during plant production according to specifications. Based on the prior knowledge that the Chemkrete modified mix develops its strength over an extended curing period, additional Marshall specimen constructed at the plant were taken to the research laboratory for such tests. Table 4 contains the Marshall property data and Table 5 presents aggregate gradations and binder content attained from extracted loose mix samples. The lots representing the control sections are also included.

An anticipated concern was realized during the Marshall property testing; that the prior laboratory research had indicated an *initial drop in binder viscosity upon addition of the* Chemkrete additive. Also adding to this problem was the use of a softer asphalt. The direct consequence was observed in the reduction of Marshall stability at the plant. The mean stability for the conventional wearing course mix was 1383 lbs. (std dev = 118) while the Chemkrete modified mix had a mean of 1150 (std dev = 169) at the plant. Even though the cured specimen produced the expected higher stabilities, the lower than specification stabilities (1200 lb. minimum) found at the plant will pose problems from the aspect of both mix control and acceptance. As payment is dictated by acceptance tests for mix stability, specification requirements may need to be adjusted for Chemkrete modified mixes should they be utilized beyond the experimental mode. *Certainly, additional data would have to be attained to* promulgate such a change.

TABLE 4

MARSHALL TEST DATA FOR PLANT SPECIMEN

Chemkrete Modified Mix

Lot No.	Specimen Number	Stability (lbs)	Flow (0.01 in)	Specific Gravity	Air (%)	VFA (%)
12	1	1179	9	2.34	3.7	77
	2*	1260	9	2.34	3.7	77
	3	1366	9	2.34	3.7	77
	4**	1650	9	2.35	3.3	79
13	1	1210	10	2.35	3.3	79
	2*	1660	9	2.36	2.9	81
	3	1436	11	2.35	3.3	79
	4**	1400	10	2.34	3.7	77
14	1	1228	9	2.34	3.7	77
	2***	2010	8	2.34	3.7	77
	3	1018	10	2.31	4.9	72
	4****	3020	9	2.31	4.9	72
	5	901	9	2.32	4.5	74
	6***	2280	8	2.32	4.5	74
	7	1138	10	2.35	3.3	79
	8****	2210	10	2.34	3.7	77
15	1	991	11	2.35	3.3	79
	2***	1610	10	2.35	3.3	79
	3	1037	9	2.35	3.3	79
	4****	2230	9	2.35	3.3	79
	5***	1700	9	2.37	2.5	84
	6****	2200	9	2.37	2.5	85
Control Mix						
3	1	1184	-	2.32	4.9	70
	2	1238	-	2.33	4.5	72
	3	1265	-	2.31	5.3	68
	4	1125	-	2.33	4.5	72
18	1	1251	-	2.33	4.1	75
	2	1209	-	2.34	3.7	77
	3	1362	-	2.34	3.7	77
	4	1448	-	2.34	3.7	77
19	1	1585	-	2.34	3.7	77
	2	1368	-	2.33	4.1	75
	3	1448	-	2.36	2.9	81
	4	1389	-	2.34	3.7	77

* 4 days cure at ambient temperature
** 1 week cure at 140°F
*** 2 week cure at 140°F
**** 4 week cure at 140°F

TABLE 5

EXTRACTED GRADATION AND BINDER CONTENT

Lot No. Date Laid Mix Type	3 8/8/83 B.C.	12 9/2/83 Mod W.C.	13 9/2/83 Mod W.C.	14 9/8/83 Mod W.C.
Gradation % Passing				
1 - 1/4"	100	100	100	100
1"	100	100	100	100
3/4"	98	98	97	98
1/2"	88	85	91	89
No. 4	54	55	55	60
No. 10	42	43	42	46
No. 40	24	26	26	27
No. 80	11	12	13	12
No. 200	6	6	7	6
Binder (% by Weight)	4.9	5.4	5.5	5.1

Lot No. Date Laid Mix Type	15 9/9/83 Mod W.C.	18 3/9/84 W.C.	19 3/13/84 W.C.
Gradation % Passing			
1 - 1/4"	100	100	100
1"	100	100	100
3/4"	100	98	97
1/2"	90	90	88
No. 4	57	60	54
No. 10	46	49	40
No. 40	31	28	24
No. 80	14	12	10
No. 200	8	8	6
Binder (% by Weight)	5.9	5.2	5.4

The Marshall briquettes brought back to and tested at the research section indicate that, when cured, the Chemkrete mix does develop the additional strength associated with the additive. Generally, the data follows the trend established in the earlier laboratory study with strengths leveling off in approximately two weeks. Figure 3 presents this relationship.

Fortunately, the lower than anticipated plant stabilities did not pose a problem at the roadway. In fact when queried, roadway personnel, both department inspectors and contractor, replied that the Chemkrete modified mix was easier to lay and compact than the conventional mix. These results seem to be substantiated by the roadway core data as presented in Table 6, wherein the Chemkrete modified mix had higher specific gravities than the conventional mix.

In addition to normal quality tests, two 1 quart samples of the asphalt cement/Chemkrete binder were returned to the Department's materials laboratory to determine manganese content (manganese content being the Chemkrete identifier). These samples, tested according to procedures established by the manufacturer, registered manganese contents of 0.012 and 0.022 based on two determinations. The manufacturer's representative indicated that the level of manganese should be approximately 0.1.

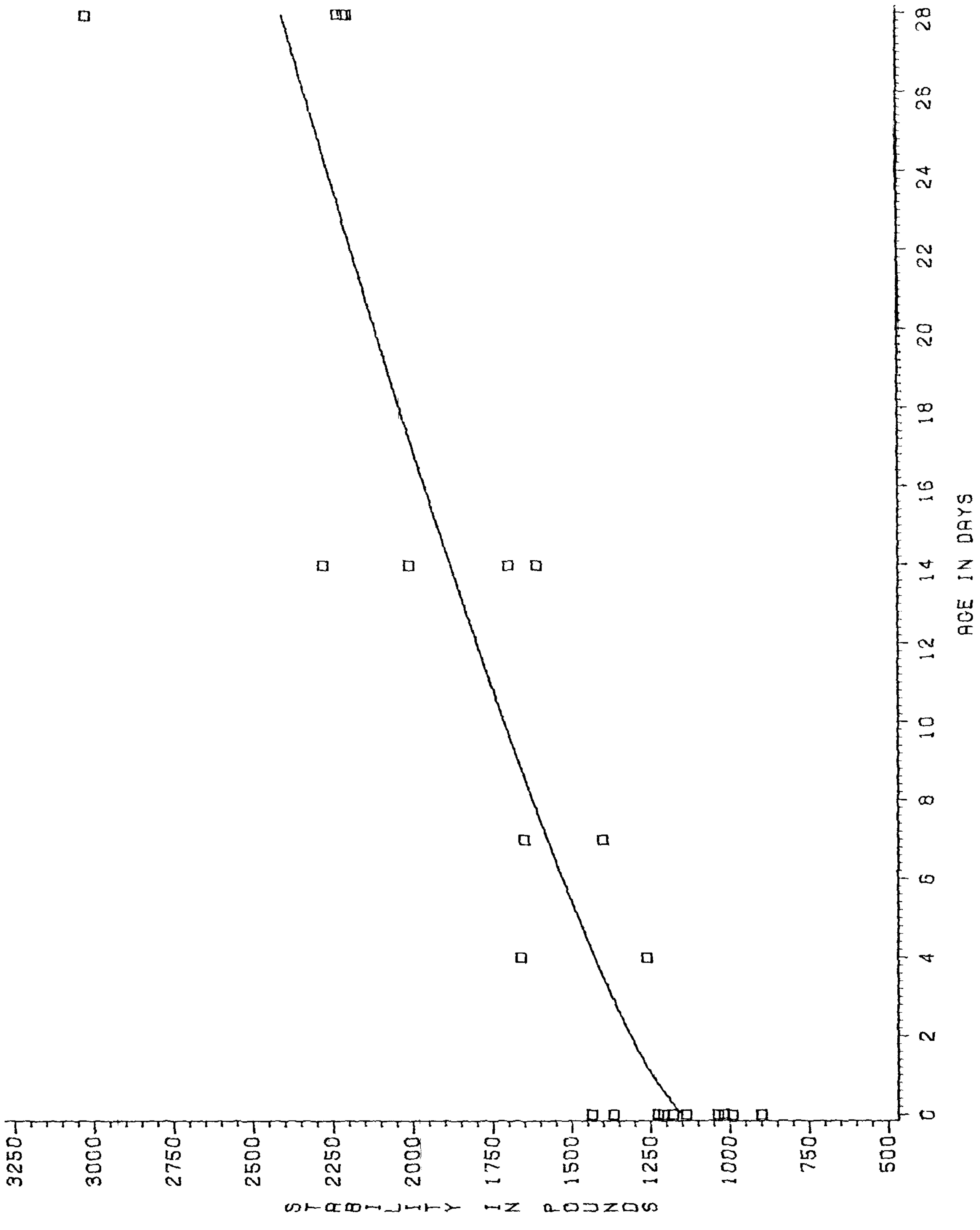


Figure 3. Strength-Cure Time Relationship

TABLE 6

ROADWAY CORE SPECIFIC GRAVITIES

Lot No.	3	12	13	14
Date Laid	8/8/83	9/2/83	9/2/83	9/8/83
Mix Type	B.C.	Mod W.C.	Mod W.C.	Mod W.C.
Specific Gravity	2.25 2.23 2.25 2.23 2.23	2.30 2.27 2.29 2.28 2.28	2.27 2.28 2.30 2.29 2.27	2.25 2.23 2.23 2.29 2.29
Mean	2.238	2.284	2.282	2.258
Std. Dev.	0.011	0.011	0.013	0.030
% of Plant Specific Gravity	96.5	97.6	97.1	96.9

Lot No.	15	18	19
Date Laid	9/9/83	3/9/84	3/13/84
Mix Type	Mod W.C.	W.C.	W.C.
Specific Gravity	2.27 2.22 2.28 2.28 2.28	2.22 2.19 2.23 2.24 2.28	2.21 2.25 2.23 2.23 2.24
Mean	2.266	2.232	2.232
Std. Dev.	0.026	0.033	0.015
% of Plant Specific Gravity	96.4	95.4	95.4

THREE YEAR PERFORMANCE EVALUATION

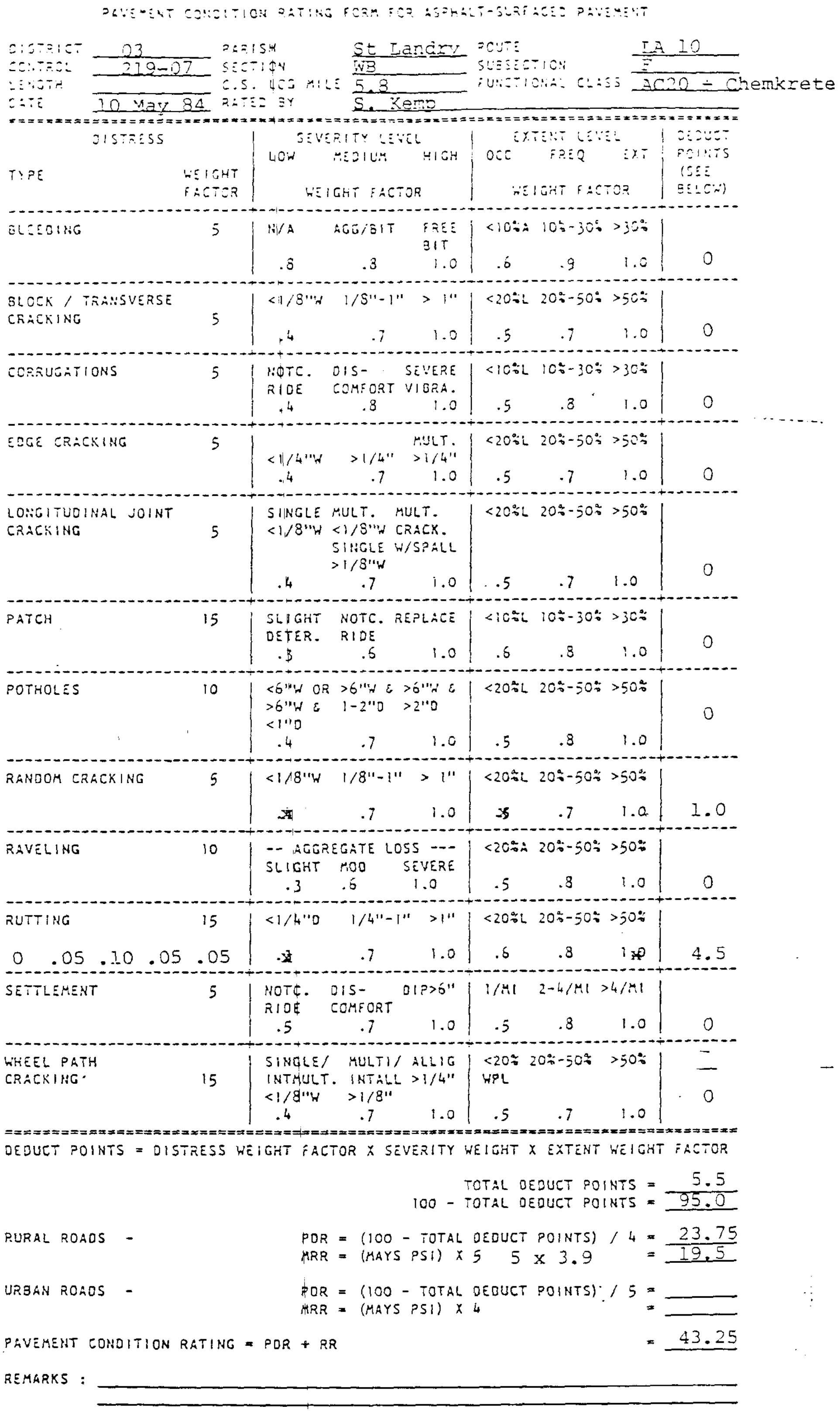
Chemkrete modified and conventional asphaltic concrete sections were examined to evaluate performance characteristics from both a structural and serviceability aspect. Serviceability was monitored with a pavement condition rating (PCR) which incorporates Mays Ridemeter measurements for smoothness and different types of pavement distress such as bleeding, block, transverse and longitudinal cracking, corrugations, patching, rutting and ravelling. Each distress type is evaluated and assigned weighted deduct points abased on severity and intensity of the distress. A sample rating form is presented in Figure 4. The sum total of deduct points forms a pavement distress rating, PDR, by subtracting from 100 percent, weighing and then combining with a weighted Mays reading in PSI in the following manner to provide the pavement condition rating.

$$PCR = [(100 - \text{Deduct Total Points})/4] = (\text{Mays PSI}) \times 5$$

(A perfect pavement score would be 50)

The Dynamic Deflection Determination system (Dynaflect) was used to evaluate the relative strengths of both the modified and conventional pavements. In addition, roadway cores were examined for further densification due to traffic and the quality of the asphalt cement. Performance evaluations were conducted at six sites on the project with each site encompassing approximately 200 feet. These sites were located as follows and in Figure 2 (page 7):

Site I.D.	Mix Type	Location		
A	Modified W.C. (AC-30)	RL	Logmile	5.5
B	Wearing Course	RL	Logmile	0.3
C	Modified W.C. (AC-20)	RL	Logmile	9.3
D	Modified W.C. (AC-20)	LL	Logmile	9.1
E	Wearing Course	LL	Logmile	1.05
F	Modified W.C. (AC-20)	LL	Logmile	5.8



PAVEMENT CONDITION RATING FORM FOR ASPHALT-SURFACED PAVEMENT

DISTRICT 03 PARISH St Landry ROUTE LA 10
CONTROL 219-07 SECTION WB SUBSECTION F
LENGTH C.S. LOG MILE 5.8 FUNCTIONAL CLASS AC20 + Chemkrete
DATE 10 May 84 RATED BY S. Kemp

DISTRESS TYPE	WEIGHT FACTOR	SEVERITY LEVEL LOW	MEDIUM	HIGH	EXTENT LEVEL OCC	FREQ	EXT	DEDUCT POINTS (SEE BELOW)
		WEIGHT FACTOR			WEIGHT FACTOR			
BLEEDING	5	N/A .6	AGG/BIT .3	FREE BIT 1.0	<10%A .6	10%-30% .9	>30% 1.0	0
BLOCK / TRANSVERSE CRACKING	5	<1/8"W .4	1/8"-1" .7	> 1" 1.0	<20%L .5	20%-50% .7	>50% 1.0	0
CORRUGATIONS	5	NOTC. RIDE .4	DIS-COMFORT .8	SEVERE VIBRA. 1.0	<10%L .5	10%-30% .8	>30% 1.0	0
EDGE CRACKING	5	<1/4"W .4	>1/4" .7	MULT. >1/4" 1.0	<20%L .5	20%-50% .7	>50% 1.0	0
LONGITUDINAL JOINT CRACKING	5	SINGLE <1/8"W .4	MULT. <1/8"W .7	MULT. CRACK. SINGLE W/SPALL >1/8"W 1.0	<20%L .5	20%-50% .7	>50% 1.0	0
PATCH	15	SLIGHT DETER. .3	NOTC. RIDE .6	REPLACE 1.0	<10%L .6	10%-30% .8	>30% 1.0	0
POTHOLES	10	<6"W OR >6"W & <1"D .4	>6"W & 1-2"D .7	>6"W & >2"D 1.0	<20%L .5	20%-50% .8	>50% 1.0	0
RANDOM CRACKING	5	<1/8"W .4	1/8"-1" .7	> 1" 1.0	<20%L .5	20%-50% .7	>50% 1.0	1.0
RAVELING	10	-- AGGREGATE LOSS --- SLIGHT .3	MOD .6	SEVERE 1.0	<20%A .5	20%-50% .8	>50% 1.0	0
RUTTING 0 .05 .10 .05 .05	15	<1/4"D .4	1/4"-1" .7	>1" 1.0	<20%L .6	20%-50% .8	>50% 1.0	4.5
SETTLEMENT	5	NOTC. RIDE .5	DIS-COMFORT .7	DIP>6" 1.0	1/MI .5	2-4/MI .8	>4/MI 1.0	0
WHEEL PATH CRACKING	15	SINGLE/ INTMULT. <1/8"W .4	MULTI/ INTALL >1/8" .7	ALLIG >1/4" 1.0	<20% WPL .5	20%-50% .7	>50% 1.0	0

DEDUCT POINTS = DISTRESS WEIGHT FACTOR X SEVERITY WEIGHT X EXTENT WEIGHT FACTOR

TOTAL DEDUCT POINTS = 5.5
100 - TOTAL DEDUCT POINTS = 95.0

RURAL ROADS - PDR = (100 - TOTAL DEDUCT POINTS) / 4 = 23.75
RRR = (MAYS PSI) X 5 5 x 3.9 = 19.5

URBAN ROADS - PDR = (100 - TOTAL DEDUCT POINTS) / 5 = ______
RRR = (MAYS PSI) X 4 = ______

PAVEMENT CONDITION RATING = PDR + RR = 43.25

REMARKS : ______

Figure 4. Pavement Condition Survey Form

As the control section was constructed six months after the experimental Chemkrete sections, those sites representing the conventional mix, B and E, were evaluated separately with a six month lay time.

Pavement Condition Rating

The pavement distress, Mays Ridemeter and overall pavement condition ratings are provided in Table 7. It is noted that the Mays readings for the second year Chemkrete evaluation and consequently the pavement condition ratings are missing. This was due to the loss of the Mays equipment for major overhaul.
It would appear that the control sections were performing better than the Chemkrete sections from the third year data. However, a look at the PDR shows very little deference in distress between the sections. While the Mays rating for section E is similar to previous ratings, section B at 4.8 appears to be rather high. In fact, with 5.0 being a perfect rating and 4.8 reading seems erroneous in light of the previous Mays ratings and the distress rating.

For all sections, the distress deduct points were related to either cracking or rutting. Rutting was measured at five locations in the outside wheelpath within each 200 foot designated evaluation site. All sections with the exception of "C" displayed up to 0.1 inch rutting measurements after the first year. Section C reached that level at year three. No rut depths exceeded 0.2-inch by the third year. Measurements of 0.1-0.2 inch are common in Louisiana mixes and are assumed to be caused by additional densification by traffic.

Generally, block and transverse cracking due to reflected soil cement shrinkage cracks were observed during the second year evaluation at all sites. The severity and extent were equivalent for the conventional and Chemkrete sections. Wheel path cracking

TABLE 7
PAVEMENT CONDITION RATING

	Pavement Distress Rating			Mays Ridemeter (PSI)			Pavement Condition Rating		
Eval. Year	1	2	3	1	2	3	1	2	3
Section									
A	23.0	22.5	21.5	3.9	-	3.6	42.5	-	39.5
C	23.5	21.7	21.9	4.0	-	3.6	43.5	-	39.9
D	22.2	21.7	21.6	3.7	-	3.6	40.7	-	39.6
F	22.6	21.5	21.5	4.1	-	3.6	43.1	-	39.5
B	23.4	23.0	22.9	4.3	4.1	4.8	44.9	43.5	46.9
E	23.4	21.5	21.6	4.1	3.8	4.0	43.9	40.5	41.6

was apparent in all sections except B by the first year evaluation. The severity of this distress mode was greatest for sections A and F. As of the third evaluation, section B did not have any wheel path cracking, while the other conventional section, E, had cracking similar to the Chemkrete sections.

Although it was not noted on the distress rating forms, a loss of surface fines was observed throughout the project on both the experimental and conventional sections. Loss of surface fines is not common for Louisiana pavements for this term of service.

Structural Evaluation

Dynaflect testing was accomplished with three tests at each site. A temperature deflection adjustment procedure was applied to each section, converting all deflections to their equivalent deflection at 60°F. Mean deflection data and corresponding structural number are included in Table 8.

The data seems to indicate two levels of performance on this roadway. However, these levels are not distinguishable as conventional versus experimental. For the Chemkrete sections, A and F demonstrate higher deflections and lower structural numbers (SN) than C and D. Referring to Figure 2 (page 7), it is found that these paired sections are separated by approximately three miles. Inherent in the SN and maximum deflection would be the amount of support provided by the subgrade and the soil cement base. Certainly, there could be differences in the uniformity of the mixed-in-placed soil cement base between these two areas. Also, the subgrade modulus indicates a lower level of performance for sections A and F. It is noted that A and F are located in an area subject to flooding so that moisture could be affecting the performance of these sections.

TABLE 8
STRUCTURAL ANALYSIS

Dynaflect Property	Corrected Maximum Deflection (in)			Subgrade Modulus of Elasticity (psi)			Structural Number		
Eval. Year	1	2	3	1	2	3	1	2	3
Section									
A	0.88	.096	0.95	5500	5733	5667	3.7	3.3	3.4
C	0.47	0.60	0.55	9000	9167	11100	5.0	4.1	4.2
D	1.34	0.65	0.67	6000	6633	6333	4.4	4.7	4.6
F	0.99	0.92	1.04	5200	5200	4733	3.4	3.7	3.5
B	0.54	0.47	0.52	8567	9567	8833	4.6	4.8	4.5
E	-	0.68	0.85	-	7500	6366	-	4.1	3.5

The conventional sections performed similarly to the Chemkrete sections with B providing lower deflections and higher SN than E. Subgrade modulus indicates a difference in the level of support which, along with the possibility of nonuniformity of the soil cement base, seems to account for the differences.

Roadway Cores

On six-inch diameter roadway core was taken at each site during each evaluation. The specific gravity of each core was determined and then the asphalt cement was extracted. The binder content was determined and gradations were run on the aggregate samples. An Abson process was used to recover the binder for viscosity (140°F), penetration (77°F) and ductility (77°F) testing.

Specific gravities and extraction analysis results are presented in Table 9. The specific gravities obtained after year one are greater than those achieved immediately after pavement construction (Table 6, page 16) confirming the additional densification noted by the distress ratings. Unlike most Louisiana mixes no further densification due to traffic was noted in years two and three. This lack of additional densification may be caused by excessive binder hardening as found during binder properties testing in both control and experimental sections.

All of the Chemkrete sections approach the design air void content with the exception of C. It is noted that the gradations obtained for C are finer than the other sections with a binder content on the low side of the job mix formula. This factor could contribute to the higher void level. The same reasoning would apply to the conventional sections, where low binder contents were found in three of the four extractions presented. Also, it is noted that the original construction compaction level was lower (Table 6) for the conventional mix.

TABLE 9
ROADWAY CORE ANALYSIS

Section	A			C			D			F			B			E		
Eval. Year	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
U.S. Sieve Size (% Passing)																		
1 inch	100	100		100	100		100	100		100	100		100	100		100	100	
3/4 inch	100	99		99	97		100	100		100	97		100	94		95	100	
1/2 inch	88	87		90	87		90	86		92	87		91	83		86	92	
No. 4	53	57		63	62		54	53		54	55		62	52		54	63	
No. 10	40	44		49	46		42	41		41	42		46	39		40	46	
No. 40	22	31		31	29		28	27		26	27		28	26		26	28	
No. 80	16	14		15	13		13	13		12	12		13	12		12	13	
No. 200	8	8		8	7		7	7		7	6		7	7		8	8	
% AC	5.5	5.3		5.3	5.1		5.3	5.2		5.2	5.7		4.9	5.1		4.2	4.3	
Specific Gravity	2.31	2.31	2.30	2.28	2.30	2.27	2.35	2.33	2.32	2.33	2.32	2.32	2.27	2.26	2.28	2.24	2.16	2.21
% Air Voids	4.9	4.9	5.3	6.2	5.3	6.6	3.3	4.1	4.5	4.1	4.5	4.5	6.6	7.0	6.2	7.8	11.1	9.1

Table 10 presents the properties of the recovered binder including results from loose mix and roadway cores sampled during construction. The properties obtained from the binder recovered from the loose mix sample taken from the haul truck at the plant and field cores was representative of mix placed from the particular lot containing each sample site. The lack of construction properties for the conventional mix was due to miscommunication and the delayed construction of those sections.

Sites A, C, and F provides values which would be consistent with laboratory experience of the Chemkrete additive in that large increases in viscosity and decreases in penetration and ductility were observed. Certainly, the 200,000+ poise viscosity attained by the third evaluation would be consistent for a Chemkrete binder. There does appear to be some unaccountable variation in binder properties during the earlier evaluations. For instance, the AC-30 plus Chemkrete would be expected to have aged faster than those blends with AC-20, while at site D the viscosity is much lower after the first year and much higher after the second year than the other sections with supposedly the same binder. Such findings lead to suspicion of inadequate blending at the plant which was supported by the lower than anticipated manganese content found in binder samples tested during construction.

An unexpected hardening was found in the binder extracted from the conventional sections. In fact, the AC-30 from sites B and E hardened at a rate which was atypical for Louisiana asphalts and was greater than the Chemkrete materials. The excessive oxidation of this AC-30 is most likely due to one of the crudes used in its blend.

It is known that Texaco was utilizing a Maya crude source during this time period. The actual percentage of Maya utilized was not known. Several experimental field installations constructed with an AC-30 which was composed of 100 percent Maya crude (by a different refiner) have demonstrated a similar tendency. However, to our knowledge, blends of Maya and other crude sources

TABLE 10
BINDER PROPERTIES

Section	A	C	D	F	B	E
Viscosity (140°F) (Poise)						
Loose Mix	5,451	2,048	2,048	1,840	-	-
Field Core	3,501	2,077	2,077	2,066	-	-
Year 1	25,059	30,052	10,361	25,016	47,887	54,911
Year 2	53,163	63,567	119,246	81,091	200,000+	200,000+
Year 3	200,000+	200,000+	200,000+	200,000+	200,000+	200,000+
Penetration (77°F) (0.1mm)						
Loose Mix	57	88	88	87	-	-
Field Core	65	87	87	83	-	-
Year 1	31	27	41	29	23	19
Year 2	22	21	18	18	12	15
Year 3	15	15	12	11	14	12
Ductility (77°F) (cm)						
Loose Mix	150+	150+	150+	150+	-	-
Field Core	150+	150+	150+	150+	-	-
Year 1	26	21	134	31	14	12
Year 2	8	12	7	9	6	6
Year 3	7	7	6	6	7	6

utilized in Louisiana have not oxidized as quickly as the AC-30 encountered on this project.

It is not known whether or not the AC-20 blended with the Chemkrete also utilized Maya as a blend stock. If so, then the hardening of the binder in the Chemkrete sections could be attributed to the asphalt and possibility only partially to the Chemkrete. Such assumptions would be consistent with the lower than expected manganese content found in the binder sampled during construction.

General Discussion

To date the Chemkrete sections are performing as well as the conventional hot-mix control section. No differences in performance have been noted. There are, however, several inconsistencies noted during the conduct of this study which could preclude the use of this field trial as justification for implementing the use of the Chemkrete product at this time.

Demonstration projects utilizing Chemkrete additive constructed prior to this installation displayed extensive cracking and ravelling which in some cases resulted in additional overlays.(6) Such was not the case in the Louisiana field trial. The cracking that occurred on this project is typical reflected shrinkage cracking observed whenever a flexible surfacing is placed on soil cement. The crack width, though, was greater than that seen on pavements of this type and age. However, this was true for both the control and the experimental mix. The excessive hardening found in the conventional AC-30 binder would contribute to such a state. Likewise, a loss of surface fines could also be attributed to hardened asphalt cement. An assumption that the AC-20 used in the Chemkrete sections was derived from the same crude sources as the AC-30 and the finding of low manganese content in the construction samples would confuse conclusions with respect to the cause of distress in the Chemkrete sections.

Due to the increase in binder consistency in both the Chemkrete and control sections, it is also difficult to assess the manufacturer's claim that Chemkrete will provide additional pavement strength. The structural analysis indicates two levels of performance on this project which cannot be relegated to a Chemkrete/conventional difference. Generally, the two distinct levels of deflection and SN can be attributed to subgrade support. Chemkrete sites C and D (log mile 9.0 - 9.5) have markedly higher elastic moduli than Chemkrete sections A and F (log-mile 5.5 - 6.0). Likewise, the control sections demonstrated two levels of SN (at the same magnitudes as the Chemkrete sections) which seem to be related to a difference in subgrade support. It could be argued, though, that the Chemkrete mix does provide greater strength as those sections were constructed at 2.5-inches thickness as opposed to the 3.0-inch thick control section; ie., discounting the affect of subgrade support the higher level Chemkrete sites C and D and control site B with similar SN's of 4.2 - 4.6 would indicate that on a per inch basis, the Chemkrete mix would have a higher structural coefficient. The same situation occurs at the lower level SN, 3.4 - 3.5 (sites A, F, and B). This point could be confounded by the air void analysis as it was found that generally, the conventional mix was not as dense as the Chemkrete mix. Such a disparity in air void content could act to nullify the apparent strength advantage attributed to Chemkrete.

ECONOMIC ANALYSIS

For this particular project the plan change involved an increase in cost of $4.46/ton for the Chemkrete modified hot mix (from a bid of $25.00/ton each for the planned 1.5-inch binder and 1.5-inch wearing course to $29.46/ton for the 2-1/2-inch modified asphaltic concrete). This bid was accepted as very reasonable considering the base cost of the Chemkrete modifier was $4.42/ton of mix ($1200/ton of modifier x 5.5% A.C. x 6.97% Chemkrete addition rate). On balance, after a rebate for the conventional binder and wearing course, a net savings was obtained due to the reduction in section thickness for the Chemkrete modified mix. Of course, such economic parity (created by reduction of section design to counter the increase in materials cost) is predicated on equivalent performance over the life cycle of the pavement system.

While reduction in section design may achieve economic parity, consideration needs to be given to the other aspects of Chemkrete modified mix as claimed by the manufacturer. The increase in mix strength properties could be used in equivalent thickness design to produce a stronger material for systems such as urban interstate, or Chemkrete's improved temperature susceptibility characteristics could improve mix durability providing an increase in life cycle. To examine these aspects for equivalent design thickness from an economic viewpoint, an annual cost comparison was evaluated. This analysis on a first cost only basis provided estimated life spans for equal annual costs. The bid prices from the La. 10 project were used assuming an 8.0 percent capital rate of return and no maintenance costs. According to this evaluation, a Chemkrete mix would have to provide more than an additional three years of life for a conventional mix listing ten years as follows:

Mix	FIRST COST ($/Ton)	LIFE FOR EQUAL ANNUAL COST (Years)			
Type Wearing Course	$25.00	4	6	8	10
Chemkrete Modifier	$29.42	4.9	7.5	10.2	13.0

An economic analysis of life cycle costs was also undertaken. Certainly such an examination can prove a useful management tool depending on the extent of hypothesis of maintenance data. Access to maintenance record keeping can provide excellent predictions. For the following scenario, a typical Louisiana design providing for 2 inches of hot mix over 8 1/2 inches of cement stabilized base was used. A records search indicated that such a system may have minor maintenance performed in years 7 through 9 with seal coat coming in year 10. A 1 1/2 inch overlay would be placed in year 15 with again some minor maintenance toward the end of the 20 year design. Allowing for this situation and the first cost analysis findings, the hypothetical scenario for a Chemkrete modified hot mix delays the maintenance actions for three years. For this evaluation, first costs were converted to price per square yard. Considering an 8.0 percent rate of return, the following results presented in Table 11 indicate that for this particular hypothesis the Chemkrete system would cost approximately $.02 per square yard more on an annualized cost basis than a conventional system:

TABLE 11

LIFE CYCLE COST ANALYSIS

Year	Conventional Mix Cost ($\$/Yd^2$)	 Present Worth ($\$/Yd^2$)	Chemkrete Modified Mix Cost ($\$/Yd^2$)	 Present Worth ($\$/Yd^2$)
1	2.75	2.75	3.24	3.24
2				
3				
4				
5				
6				
7	.05	.029		
8	.10	.054		
9	.25	.125		
10	.40	.185	.05	.023
11			.10	.043
12			.25	.099
13			.40	.147
14				
15	2.48	.782		
16				
17				
18			2.48	.621
19	.10	.023		
20	.15	.032		
Total Present Worth		3.98		4.17
Capital Recovery Factor		0.10185		0.10185
Uniform Annual Cost		.405		.425

CONCLUSIONS

1. After three years of age, there was no discernable difference in the performance parameters investigated between the Chemkrete modified and control sections. Various factors addressed in other conclusions leave doubt as to the value of this project for assessing the benefits of Chemkrete modified asphaltic concrete.

2. Binder samples tested during construction indicated that the Chemkrete additive was either non-uniformly blended or was present at a lower than expected concentration since the major component, soluble manganese, was found at 0.1 of the projected level.

3. Excessive hardening of the binder was found in both the Chemkrete and control sections. The cause of this hardening in the conventional AC-30 is probably due to one of the crude feed stocks which has previously demonstrated similar characteristics. Laboratory experience with Chemkrete modified binders showed that this type of accelerated hardening is characteristic of the additive. However, as the feed stocks for the AC-20 used to blend with the Chemkrete were probably the same as those that produced the AC-30 and in light of the lower than expected concentration of manganese in the binder samples, the hardening of the Chemkrete modified binder cannot necessarily be attributed to the Chemkrete.

4. Wider than expected reflective cracks and loss of surface fines were probably the manifestation of the excessively hardened binder for both modified and control sections.

5. Normal control and acceptance testing may need modification to accommodate the inherent "curing" properties of Chemkrete modified mix.

6. Greater than normal Marshall strengths were attained in Chemkrete modified asphaltic mixtures upon curing.

RECOMMENDATIONS

Since the construction and evaluation of the Chemkrete modified asphaltic concrete project, Lubrizol has ceased active marketing of the product. As this study demonstrated, no discernable difference in performance between the Chemkrete modified and control sections was observed and, therefore, its further use cannot be economically justified.

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