SPRINKLE TREATMENT EXPERIMENTAL PROJECT
CONSTRUCTION AND THREE YEAR EVALUATION

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DEMONSTRATION PROJECT NO. 50
RESEARCH REPORT NO. 219

Conducted by
LOUISIANA DEPARTMENT OF TRANSPORTATION
AND DEVELOPMENT
Louisiana Transportation Research Center
In Cooperation With
U. S. Department of Transportation
FEDERAL HIGHWAY ADMINISTRATION

JUNE 1989

ABSTRACT

This report documents the construction of a Sprinkle Treatment field trial on a high speed/high volume roadway (55 mph/8520 ADT) and presents the performance data obtained for three years after construction. Normal plant and roadway production rates were maintained during the construction of the 3.1 mile Sprinkle Treatment section. Sprinkle chip spreading was accomplished with a Bristowes Mk V Chip spreader which remained immediately behind the paver throughout laydown operations. The precoated chips were uniformly placed at rates of 7 lb/yd^2 and 10 lb/yd^2. The only problem occurring during construction was related to the densification of the wearing course mix. Less than the 95% specification requirement was achieved.

Performance evaluations were conducted on an annual basis which included Pavement Condition Ratings, structural evaluation, skid resistance, critical hydroplaning speeds, and aggregate retention. In addition, roadway cores were obtained to determine densification due to traffic, roadway gradation and binder content and properties of the asphalt cement including viscosity penetration and ductility. The study demonstrated that both Sprinkle Treatment sections were performing as well as an asphaltic concrete friction course utilized as a control section.

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INTRODUCTION

Background

Louisiana developed an open-graded friction course in the late 1960's and early 1970's in order to provide a skid resistant surfacing (1). Also, due to the open texture of this material water spray was reduced and critical hydroplaning speeds were increased. While the state's native chert gravel could produce acceptable skid resistance initially in dense-graded wearing courses, it was found that skid numbers declined rapidly (2). Thus, the development of an open-graded friction course utilizing a locally produced expanded clay aggregate or other imported non-polishing aggregates such as stone and slag, filled a void just prior to the initiation of the Federal Highway Safety Program Management Guide, Highway Safety Program 12, and Instructional Memorandum 21-3-73 of 1973 dealing with the establishment of a Skid Accident Reduction Program.

Many miles of friction course were placed, and by the late 1970's it had become the standard for high speed, high volume roadways (3). By 1980, however, some of these surfacings reached end of life, which was manifested by severe ravelling and an ensuing decrease in serviceability. This, in conjunction with a number of friction course failures either in the construction stage or shortly thereafter led to a moratorium on its use, in 1980. Use was continued after revisions were made to specifications. Severe winter weather conditions in 1982 and 1983 led to an inordinate amount of ravelling of friction courses regardless of age. The decrease in serviceability of these roadway was vocalized by the driving public, and the construction of open-graded friction course was suspended in 1984.

The Department's Research Section recognized the need for alternatives to the friction course materials. One such alternative which appeared promising was Sprinkle Treatment. Sprinkle Treatment, initiated in 1977 by the Federal Highway

Administration (FHWA) under the auspices of Demonstration Project No. 50, was developed in England where it has been widely utilized to provide skid resistant wearing surfaces. Sprinkle Treatment is the application of a properly graded, pre-coated, non-polishing aggregate to a hot asphaltic concrete wearing course immediately behind the paving machine. The "sprinkled" chips are embedded into the mat with the initial rolling operation. By embedding costly imported, non-polishing aggregates only in the wearing course surface, rather than using it in the entire mix, a substantial conservation of materials and cost could be realized.

The success of Demonstration Project No. 50 and the Department's problems with open-graded friction course led to the approval of an experimental project to examine Sprinkle Treatment. In May 1984 a plan change was issued to an ongoing contract to include the use of the Sprinkle Treatment process for approximately 3.0 miles on La. 20 from Chacahoula to Schriever. An agreement with the Demonstration Projects Division of FHWA provided for the use of a Bristowes Mk V chip spreader. This report documents the construction and presents performance data for the first three years of the Sprinkle Treatment field trial.

LOCATION AND SECTION DESIGN

An agreement was made whereby the construction of the trial section was made part of an ongoing contract with Louisiana Paving Co., Inc., Kenner, Louisiana. This 6.1-mile project on La. 20 in Terrebonne Parish extended from Chacahoula to Schriever, as shown in Figure 1. This roadway was scheduled for cold planing (2-inch average), 3-1/2-inch overlay and the application of a 5/8-inch asphaltic concrete friction course (ACFC). The change substituted Sprinkle Treatment for approximately one-half of the scheduled friction course. The existing roadway was composed of Portland cement concrete which had been overlaid twice with asphaltic concrete, adding approximately 6 inches to the cross section. Figure 2 presents the design typical section.

Traffic and Accident Data

In 1984 the average daily traffic (ADT) was 8520, with 18 percent truck traffic. Accident data was obtained for the period 1980 through 1987 with a summary of accidents by type as classified by property damage only, injury excluding fatalities, and fatalities. This information is presented in Table 1 along with the total number of injuries or fatalities. Wet weather accidents have also been extracted and are indicated in parentheses.

TABLE 1 **TRAFFIC AND ACCIDENT DATA**

YEAR/ ADT	TOTAL ACCIDENTS	PROPERTY DAMAGE ONLY	INJURY	FATALITY	NUMBER OF INJURIES	NUMBER OF FATALITIES
1980 7538	60 (12)*	22 (4)	36 (4)	2 (1)	68 (10)	2 (1)
1981 7116	45 (7)	29 (4)	15 (2)	1 (0)	24 (2)	1 (0)
1982 7572	57 (13)	35 (10)	21 (0)	1 (0)	43 (0)	1 (0)
1983 6284	46 (7)	31 (6)	15 (1)	0 (0)	24 (1)	0 (0)
1984 8520	56 (8)	33 (5)	21 (2)	2 (0)	52 (4)	2 (0)
1985 9550	36 (9)	21 (7)	15 (2)	0 (0)	32 (2)	0 (0)
1986 6710	23 (2)	5 (0)	18 (2)	0 (0)	37 (4)	0 (0)
1987 6790	29 (7)	17 (2)	12 (3)	0 (0)	18 (4)	1 (0)

* All data in parentheses refer to wet weather accidents.

EXPERIMENTAL FIELD PROJECT

Materials and Mix Design

The Special Provisions for this plan change, found in Appendix A, required that the sprinkle aggregate be either slag or stone graded such that most of the material passed the 1/2-inch screen and was retained on the No. 4 screen. The aggregate chosen for use was a slag from Godwin, Tennessee, supplied by Southern Stone. According to the specification, this material was required to possess a polish value greater than 35. Test results on material sampled from the stockpile representing 300 tons of aggregate are presented in Table 2 along with the gradation requirements. It was noted that the stockpile material was slightly outside specification requirements.

TABLE 2

SPRINKLE AGGREGATE PROPERTIES

Gradation U.S. Sieve Size	Specification (% Passing)	Stockpile (% Passing)
1/2 inch	100	99
3/8 inch	20 - 55	42
No. 4	0 - 5	8
No. 200	0 - 1.5	0
Polish Value	35 min.	38
Specific Gravity		2.51

The Type 3 (high stability) wearing course used on the conventional section design was modified to create room in the mix matrix for the sprinkle aggregate so that a satisfactory level of embedment could be attained. A necessary criterion for proper embedment established through other Demonstration Project No. 50 field trials was the requirement that a minimum of 50 percent of the total aggregate should pass the No. 10 screen. The job mix formulas (JMF) submitted and approved for this project are provided in Table 3.

Three Rivers Rock Co. of Smithland, Kentucky, was the source of the limestone coarse aggregate and screenings for the modified wearing course. Normally this material source is prohibited from use in wearing surfaces where the average daily traffic per lane exceeds 1000 vehicles because of its low polish value. The sources of coarse and fine sands were Pearl River Sand and Gravel and Weber Pit, respectively. Sunshine Oil Co. supplied the AC-30 asphalt cement that was utilized to both pre-coat the slag sprinkle aggregate and in the asphaltic concrete. Southern Stone also supplied the slag aggregate used in the ACFC.

TABLE 3

PROJECT JOB MIX FORMULAS

Sequence No.	49	87	03	01
Mix Use	Type 3 Binder	Type 3 Wearing	Type 3 Mod Wearing	ACFC
Recommended Formulas				
Percent Passing				
U.S. Sieve Size				
1 inch	100	100	100	
3/4 inch	91	99	100	
1/2 inch	76	85	91	100
3/8 inch	-	-	-	95
No. 4	50	57	70	43
No. 10	41	44	54	14
No. 40	27	27	30	
No. 80	13	14	15	
No. 200	8	8	9	3
% AC	4.5	4.2	5.1	6.5
Mix Temp.	315	300	300	
Marshall Properties (75 blow design)				
Specific Gravity	2.40	2.43	2.38	
Theoretical Gravity	2.50	2.52	2.48	
% Theoretical	96.0	96.4	96.0	
% Voids	4.0	3.6	4.0	
% V.F.A.	72.4	73.3	75.0	

Marshall Stability	2130	2280	1820
Flow	9	9	10

PLANT PRODUCTION

Louisiana Paving Co. utilized its 5-ton screenless batch plant located at Bayou Blue in Houma, Louisiana, for mix production on this job. The plant was located approximately 17 miles from the project site. There were no modifications required to normal plant operations for the production of either the pre-coated aggregate or modified Type 3 mix.

In March of 1984, Type 3 binder course material was placed in six lots, numbers 21 through 26, between the 16th and the 30th of March. There were 8697 tons of binder course produced. The contractor ceased work on this project at that point.

In September, work on the roadway was resumed. The Type 3 wearing course for the control section (JMF No. 87) was placed in three lots, Nos. 55 through 57, between the 10th and the 13th of the month (4137 tons). The asphaltic concrete friction course (JMF No. 01) was placed over the control section from the 24th to the 26th. Two lots (Nos. 62 and 63) were produced, totaling 1202 tons.

All of the sprinkle aggregate was pre-coated at the plant approximately two weeks prior to production of the modified wearing course. This material was stockpiled according to the special provisions at the contractor's yard.

The modified Type 3 wearing course for the Sprinkle Treatment section (JMF No. 03) was produced from the 27th to 29th, in lots 64 through 66. There were 3321 total tons placed on the roadway. Table 4 presents the production data for the project.

TABLE 4

PLANT PRODUCTION

Lot No.	Date	Mix Type	Tonnage	Mean Temp. (°F)
21	3/16	Binder	1481	314
22	3/19	Binder	1486	313
23	3/22	Binder	1385	307
24	3/23	Binder	1511	301
25	3/28	Binder	1519	317
26	3/30	Binder	1315	299
55	9/10	Wearing	1312	307
56	9/11	Wearing	1406	306
57	9/13	Wearing	1419	317
62	9/24	ACFC	661	249
63	9/25	ACFC	541	252
64	9/27	Mod. Wearing	1515	313
65	9/28	Mod. Wearing	1522	319
66	9/29	Mod. Wearing	284	312

CONSTRUCTION

Perhaps one of the most critical aspects to a successful treatment is the uniform dispersion of the sprinkle aggregate in a timely manner so that the breakdown roller can embed the chips while the mat is still hot. It is thus important that the chip spreader be able to keep a fully charged hopper holding a sufficient quantity of material in order to keep up with the paving machine. As part of the special provisions the FHWA provided a Bristowes Mk V chip spreader which fulfilled these requirements.

The Bristowes Mk V chip spreader is the culmination of fifteen years of chip spreader development. This self-propelled, variable speed spreader completely spans the newly paved mat (Figure 3) and can spread the chips along the full 12-foot width.

Figure 3. Bristowes Mk V Chip Spreader.

As indicated in the figure there are two separate hoppers. The charging hopper is a powered self-trimming transversing hopper which operates on command. The spreading hopper lays the chips behind the spreader such that the aggregate's speed of fall is commensurate with the forward speed of the spreader thus reducing the tendency of the chips to roll on the mat. Distribution rate is set by gates.

In addition to the chip spreader and operator, two trucks holding the pre-coated aggregate, a front-end loader and three operators were used on this project. Figures 4 and 5 depict the process of loading the aggregate into the chip spreader. Note that extension plates were welded onto the charging hopper to accommodate the size of the loader bucket.

Figure 4. Haul truck and front end loader.

Figure 5. Fully charged hopper.

Figures 6 and 7 portray the paving train in operation. The modified Type 3 wearing course was placed through a standard paving machine. It is observed that the Bristowes chip spreader maintained a position immediately behind the paver. This was the case throughout production. The uniform distribution of the sprinkle aggregate should also be noted. This uniform placement occurred during the entire course of construction. An occasional exception happened when the paving train would stop due to lack of haul trucks. However, with a slight overlap the operator could correct the uniformity. Generally, the breakdown roller followed immediately behind the spreader, as shown, thereby compacting the mix at the same temperature as in a conventional operation.

Two separate experimental sections were attempted during the field trial with the rate of application of the sprinkle aggregate providing the distinction. For approximately 1.2 miles a chip spread rate of 7 pounds per square yard was applied. This rate was recommended by personnel of the FHWA as an optimum rate in order to provide good skid resistance and reduce the amount of aggregate loss. The second section attempted utilized a spread rate of 10 pounds per square yard. It was reasoned that if this rate could be embedded, the surface macrotexture would behave similar to an open-graded friction course such that the critical hydroplaning speed could be increased.

Application rates for the sprinkle aggregate were checked by district laboratory personnel using a portable scale and a one square yard cloth. The cloth was placed on the freshly laid hot mix prior to spreading the chips. After the chips were placed, the cloth was gathered and the aggregate was emptied into a tared can. Several locations were checked both longitudinally and transversely. Gate settings were established at the beginning of each test section. The actual application rates for the 7 pound per square yard section ranged between 6.5 and 8.5 while the 10 pound per square yard section was found to range from 7.5 to 11.

Figure 6. Chip spreading operation.

Figure 7. Initial compaction and embedment.

Despite this overlap in measured application rates there was a visual difference in the spread rates.

Quality Control

Several samples of the pre-coated slag aggregate were taken from the roadway to the research laboratory for gradation and asphalt content analysis. As is observed in Table 5, the aggregate did not meet the proposed specification and the asphalt content was higher than the 1.0 to 1.5 percent required. There were, however, no problems associated with these discrepancies at the roadway.

TABLE 5

SPRINKLE AGGREGATE EXTRACTED PROPERTIES

Sample No.	1	2	3
US. Sieve Size (% Passing)			
1/2 inch	98	99	99
3/8 inch	40	37	38
No. 4	12	10	11
No. 8	3	3	3
% Asphalt Cement	2.2	2.2	2.1

Marshall stability (75 blow design) was used for acceptance testing and other Marshall properties were used for mix control. Table 6 presents all Marshall data for this project. Table 7 contains the gradations and asphalt cement content from extracted loose mix samples. With the exception of two briquettes in lot 64 which exceeded VFA and air void control criteria, all mix properties concurred with specifications. The low asphalt content on the lot 24 binder course was not found in a verification sample which indicated a 4.6 percent asphalt content.

TABLE 6

MARSHALL TESTS FOR PLANT SPECIMENS

Lot No.	Specimen Number	Stability (Lbs)	Flow (0.01 In)	Specific Gravity	VFA (%)	Voids (%)
			TYPE 3 BINDER COURSE			
21	1	2099	13	2.40	72	4.0
	2	2025	13	2.40	72	4.0
	3	2281	14	2.40	72	4.0
	4	2140	12	2.40	72	4.0
22	1	2198	9	2.40	72	4.0
	2	2257	9	2.40	72	4.0
	3	2343	8	2.40	72	4.0
	4	2168	9	2.40	72	4.0
23	1	2227	9	2.40	72	4.0
	2	2374	10	2.40	72	4.0
	3	2183	9	2.39	70	4.4
	4	2198	9	2.40	72	4.0
24	1	2140	9	2.39	70	4.4
	2	2124	9	2.40	72	4.0
	3	2388	10	2.40	72	4.0
	4	2083	10	2.40	72	4.0
25	1	2169	9	2.40	72	4.0
	2	2163	10	2.40	72	4.0
	3	2661	8	2.41	74	3.6
	4	2054	9	2.40	72	4.0
26	1	2225	9	2.40	72	4.0
	2	2169	9	2.40	72	4.0
	3	1955	8	2.39	70	4.4
	4	2113	9	2.40	72	4.0

TABLE 6 (CONTINUED)

MARSHALL [illegible] PLANT SPECIMENS

Lot No.	Specimen Number	Stability (Lbs)	Flow (0.01 In)	Specific Gravity	VFA (%)	Voids (%)
		TYPE 3 WEARING COURSE				
55	1	2100	8	2.42	71	4.0
	2	2135	10	2.44	76	3.2
	3	2096	10	2.42	71	4.0
	4	2192	9	2.42	71	4.0
56	1	1758	8	2.44	76	3.2
	2	1898	9	2.43	73	3.6
	3	1782	8	2.42	71	4.0
	4	1733	10	2.42	71	4.0
57	1	1901	7	2.45	78	2.8
	2	1930	8	2.42	71	4.0
	3	2079	9	2.44	76	3.2
	4	2029	9	2.43	73	3.6
		MODIFIED TYPE 3 WEARING COURSE				
64	1	1831	8	2.41	81	2.8
	2	1742	10	2.41	81	2.8
	3	2032	8	2.39	77	3.6
	4	1837	10	2.39	77	3.6
65	1	1877	9	2.40	79	3.2
	2	1782	9	2.38	77	3.6
	3	1732	8	2.39	77	3.6
	4	1756	8	2.40	79	3.2
66	1	1831	10	2.40	79	3.2

TABLE 7

EXTRACTED GRADATION AND ASPHALT CEMENT CONTENT

Mix Type	Type 3 Binder Course					
Lot No.	21	22	23	24	25	26
Date Laid	3/14	3/16	3/19	3/22	3/23	3/28
Gradation % Passing						
1 inch	100	100	100	100	100	100
3/4 inch	90	94	94	96	94	94
1/2 inch	74	80	74	80	78	80
No. 4	50	52	49	53	52	53
No. 10	42	42	40	43	42	44
No. 40	27	26	26	28	28	28
No. 80	13	12	13	14	15	12
No. 200	8	7	6	7	8	8
% Asphalt	5.1	5.1	4.8	3.1	4.8	4.8

Mix Type	Type 3 Wearing Course			Mod. Wearing Course		
Lot No.	55	56	57	64	65	66
Date Laid	9/10	9/11	9/13	9/27	9/28	9/28
Gradation % Passing						
1 inch	100	100	100	100	100	100
3/4 inch	100	100	100	100	100	100
1/2 inch	92	88	86	94	94	94
No. 4	59	56	56	70	72	73
No. 10	45	44	42	54	56	56
No. 40	28	28	25	30	30	30
No. 80	12	12	12	14	12	12
No. 200	8	8	8	8	8	7
% Asphalt	4.4	4.4	4.6	5.2	5.3	5.7

The normal density requirement of 95 percent of design compaction was waived for this project as there was concern that the coarse surface texture imparted by the partially embedded sprinkle aggregate could mask the true compactive effort. Table 8 provides the specific gravities and percent compaction for each of the roadway samples. As the contractor was achieving good although inconsistent compaction on his conventional binder and wearing courses, no changes were made to his rolling pattern. The first day's production of the Sprinkle Treatment seemed to demonstrate that the modified Type 3 mix could also be readily compacted and that the surface texture did not interfere in the density determination. By the time the second day's production was sampled and tested, the short third day's production had already been laid, and, as can be seen did not meet the normal densification requirement. A short section of modified mix was placed during the first day of laydown without the sprinkle aggregate. It was believed that this section would demonstrate the ability to compact the modified mix. Unfortunately, two specimens indicated 95.4 and 93.3 percent compaction leaving in doubt whether the low densities were due to the sprinkle aggregate or the contractor's inability to compact the modified mix.

TABLE 8

ROADWAY DENSITIES AND PERCENT OF PLANT DENSITIES

Mix Type	Type 3 Binder Course					
Lot No.	21	22	23	24	25	26
Date Laid	3/14	3/16	3/19	3/22	3/23	3/28
Specific	2.28	2.39	2.36	2.31	2.34	2.30
Gravity	2.29	2.28	2.31	2.31	2.34	2.33
	2.30	2.36	2.32	2.35	2.36	2.25
	2.29	2.32	2.30	2.28	2.35	2.31
	2.35	2.30	2.32	2.30	2.37	2.34
Mean	2.30	2.33	2.32	2.31	2.35	2.31
% of Plant	95.9	97.1	96.8	96.3	98.0	96.3

Mix Type	Type 3 Wearing Course			Mod. Wearing Course		
Lot No.	55	56	57	64	65	66
Date Laid	9/10	9/11	9/13	9/27	9/28	9/28
Specific	2.31	2.39	2.31	2.34	2.27	2.24
Gravity	2.32	2.37	2.34	2.32	2.21	2.28
	2.31	2.38	2.32	2.32	2.27	2.26
	2.33	2.31	2.31	2.35	2.25	2.25
	2.28	2.39	2.35	2.31	2.29	2.30
Mean	2.31	2.37	2.33	2.33	2.26	2.27

% of Plant	95.5	97.4	95.3	97.0	94.5	94.4

PERFORMANCE EVALUATION

The Sprinkle Treatment 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 based on severity and intensity of the distress. The total quantity of deduct points forms a pavement distress rating (PDR) by subtracting from 100 percent, weighting 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. Roadway cores were examined for further densification due to traffic and the quality of the asphalt cement.

The skid resistance of both experimental sections and the open-graded friction course were examined. Also, critical hydroplaning speeds were determined from texture depths obtained by sand patch testing. Finally, aggregate retention was monitored at selected locations on the project.

Figure 8 defines the experimental sections and identifies each evaluation site by log mile from the Chacahoula end of the project. There were nine sites chosen, each encompassing approximately 200 feet, with 3 sites in each of the two experimental sections and 3 sites in the conventional section.

Figure 8. Evaluation sites.

An initial evaluation was conducted in November 1984 shortly after construction. Yearly evaluations were completed for three years after construction..

Serviceability

A sample Pavement Condition Rating form is provided in Appendix B and actual deduct points for the distress modes found for each section are presented in Table 9. Table 10 presents the Pavement Condition Ratings and also incorporates the Pavement Distress ratings and Mays ride meter values in terms of present serviceability index (psi) for each section / evaluation period.

Figures 9 through 11 depict mean rutting measurements, Mays serviceability and pavement condition ratings, respectively, for each evaluation.

Generally, very little distress was observed at the test site during the three year evaluation period. With the exception of the last evaluation, the rut depths are less than one-quarter inch and are consistent with additional traffic densification routinely found in Louisiana mix types. The slightly lower rut depths found during the third evaluation may have been due to a faulty measuring device.

There is a minor decline in the serviceability data for each section after the first year (Figure 10) which coincides with the incidence of distress in the form of transverse and longitudinal cracking reflecting from the underlying Portland cement concrete pavement. The 10 lb/yd^2 section has a lower serviceability than either the 7 lb/yd^2 of ACFC sections. There is no justification for this in the distress factors. It is noted, however, that sections 2, 3 and 4, all in the eastbound roadway, had initial serviceabilities lower than the other sections, indicating that paving operations may have created a rougher ride.

The Pavement Condition Ratings (Figure 11) followed the same trends as the serviceability. There was a decrease during the first year due to increased incidence of longitudinal and transverse cracking.

TABLE 9

PAVEMENT DISTRESS RATING DEDUCT POINTS

		Sp. Treat. 7 LBS/YD^2			Sp. Treat. 10 LBS/YD^2			ACFC		
SECTION		4	5	6	2	3	7	1	8	9
Rut	11/84	0.12	0.12	0.08	0.10	0.10	0.07	0.15	0.12	0.15
	11/85	0.13	0.11	0.11	0.08	0.10	0.10	0.10	0.11	0.15
	11/86	0.20	0.19	0.12	0.13	0.14	0.13	0.20	0.17	0.20
	11/87	0.09	0.08	0.03	0.02	0.05	0.06	0.11	0.06	0.08
Lng	11/84	0	0	0	0	0	0	0	0	0
	11/85	0	0.8	0	0.8	2	0	1.6	0	0
Crk	11/86	0	0.8	2	1.6	2	0	2	0	0
	11/87	0.8	2	2	2	1.6	0.8	6	0.8	1.6
Tnv	11/84	0	0	0	0	0	0	0	0	0
	11/85	1.6	0	0.8	0	1.6	0.4	2	0.8	2
Crk	11/86	1.6	0.4	2	2	2	1.6	2	1.6	2
	11/87	1.6	1.6	2	2	2	2	2	2	2

TABLE 10

PAVEMENT CONDITION RATING

		Sp. Treat. 7 LBS/YD^2			Sp. Treat. 10 LBS/YD^2			ACFC		
SECTION		4	5	6	2	3	7	1	8	9
PDR	11/84	24.25	24.27	24.27	24.25	24.25	24.27	24.25	24.27	23.50
	11/85	23.85	24.05	24.05	24.05	23.35	24.15	23.35	24.05	23.75
	11/86	23.85	23.65	23.25	23.35	23.25	23.85	23.25	23.55	23.45
	11/87	23.65	23.35	23.25	23.25	23.35	23.55	22.25	23.55	23.35
MRM	11/84	3.2	3.8	3.8	3.2	3.2	3.8	3.8	3.8	3.8
	11/85	3.0	3.3	3.3	3.0	3.0	3.3	3.6	3.4	3.4

	11/86	3.4	3.7	3.7	3.2	3.2	3.5	3.6	3.4	3.4
	11/87	3.4	3.7	3.4	3.1	3.2	3.4	3.6	3.6	3.4
PCR	11/84	40.25	43.25	43.25	40.25	40.25	43.25	43.25	43.25	42.50
	11/85	38.85	40.55	40.55	39.05	38.35	40.65	41.35	41.05	40.75
	11/86	40.90	42.20	42.80	39.40	39.30	41.40	41.30	40.60	40.50
	11/87	40.60	40.40	40.20	39.70	39.90	40.10	42.20	43.60	43.40

Figure 9. Rutting.

Figure 10. Serviceability.

Figure 11. Pavement Condition Rating.

~~Structural Evaluation~~

The Dynamic Deflection Determination System (Dynaflect) was used to evaluate the relative strength of both the conventional and sprinkle treated pavements. A temperature correction was applied, converting all deflections to their equivalent deflection at 60 degrees Fahrenheit. Deflection data and corresponding structural numbers are included in Table 11.

The data in Table 11 indicates very little change in the structural strengths within each section since the April 86 evaluation. There is a difference between the initial evaluation (conducted approximately six weeks after construction) and the April 86 evaluation. This difference is attributed to an increase in the strength of the upper pavement layers as evidenced by the surface curvature index. The surface curvature index is the difference between the first and second sensor. A decreasing (smaller) number represents an increase in strength. An increase in the strength of the asphaltic concrete overlay is a reasonable assumption due to increased densification from traffic. Also, a contribution is added from the increase in the consistency of the asphalt cement.

There are some noticeable differences in structural number and maximum deflection between sections. Generally, the 7 lb/yd^2 sections are performing at a slightly higher level than the 10 lb/yd^2 sections which in turn are slightly higher than the control section. These differences can be attributed to the slight difference in subgrade support between sections indicated by the modulus of elasticity values. It is noted that there is virtually no difference between sections in the performance of the upper pavement as provided by both the surface curvature index and the percent spread (a measure of the total stiffness of the structure with higher number indicating higher stiffness in the upper layers). The similarity in the upper pavement strength between the Sprinkle Treatment sections and the control indicating that the change in mix design to a finer gradation did not affect the overall stiffness of the modified asphalt concrete.

TABLE 11

STRUCTURAL ANALYSIS

		Sp. Treat. 7 LBS/YD^2			Sp. Treat. 10 LBS/YD^2			ACFC		
SECTION		4	5	6	2	3	7	1	8	9
Cor	11/84	0.82	0.73	0.72	0.82	0.99	0.71	0.88	0.93	0.96
Max	4/86	0.68	0.65	0.69	0.84	0.84	0.64	0.78	0.82	0.92
Def	11/86	0.60	0.61	0.67	0.85	0.81	0.66	0.76	0.77	0.82
in*	11/87	0.61	0.66	0.71	0.79	0.85	0.71	0.88	0.82	0.96
%	11/84	86	87	88	90	85	88	89	91	93
Spd	4/86	90	92	90	94	89	89	90	93	94
	11/86	88	90	89	89	90	90	92	92	92
	11/87	90	94	88	92	90	90	93	94	92
Sur	11/84	0.07	0.02	0.05	0.03	0.11	0.04	0.05	0.04	0.03
Cur	4/86	0.04	0.04	0.02	0.02	0.05	0.02	0.02	0.03	0.02
Inx	11/86	0.04	0.03	0.04	0.05	0.04	0.02	0.02	0.02	0.03
	11/87	0.02	0.01	0.02	0.02	0.03	0.02	0.01	0.01	0.03
Sgd	11/84	4700	5000	4900	4500	4000	5000	4300	4000	3800
Mod	4/86	5000	4900	4900	4200	4400	5400	4500	4300	3800
Els	11/86	5933	5533	5133	4333	4400	5233	4500	4433	4033
psi	11/87	5367	4833	4933	4433	4233	4800	3933	4300	3633
	11/84	4.6	4.8	4.9	4.8	4.3	5.0	4.7	4.6	4.6
Str	4/86	5.2	5.4	5.1	5.0	4.8	5.3	4.9	5.0	4.8
No.	11/86	5.3	5.4	5.1	4.8	4.9	5.2	5.1	5.1	5.0
	11/87	5.4	5.4	5.0	5.1	4.8	5.2	4.9	5.1	4.7

* Inches x 10^{-3}

Field Samples

Samples in the form of roadway cores were taken from each section shortly after construction and then on an annual basis for three years. Six inch diameter cores were used in order to obtain a sufficient quantity of binder for additionally testing. Specific gravities were determined for the wearing course layer in each case

(the ACFC was removed from the cores taken in the conventional sections). This material was then subjected to extraction and asphalt cement recovery by the Abson process. Binder content and gradations were determined (gradation was determined for the first evaluation only). The recovered asphalt cement was tested for viscosity (140^{0}F), penetration (77^{0}F) and ductility (77^{0}F). Table 12 presents the data from the roadway samples.

As anticipated, the two experimental sections and the control sections have densified under traffic. Typically, Louisiana mix types experience densification resulting in air void content of

3 - 4 percent over a period of 2 - 3 years after construction (5). After three years under traffic the air void contents were 6.1 and 5.3 percent for the 7 lb/yd^2 and the 10 lb/yd^2 sections, respectively, while the conventional mix has an air void content of 6.3 percent.

The extracted cores had gradations and asphalt contents which were substantially the same as those obtained during production testing (see Table 7 P.18)

With respect to binder quality indicators, typical traits were observed. The viscosities of the asphalt cements increased with time while penetrations and ductilities decreased. No overall differences in performance were found between the experimental and conventional sections. However, sections 7 and 8 show much less of an aging trend than the other sections. This difference can probably be attributed to the higher densification found in these areas. It is observed that overall the aging of the asphalt cement is much higher than that found in historical data for

TABLE 12

ROADWAY CORE ANALYSIS

		Sprinkle Treatment 7 LBS/YD^2			Sprinkle Treatment 10 LBS/YD^2			ACFC		
SECTION		4	5	6	2	3	7	1	8	9
Spec Grav	11/84	2.304	2.267	2.301	2.304	2.290	2.348	2.340	2.349	2.317
	3/86	2.348	2.277	2.339	2.343	2.337	2.394	2.322	2.355	2.356
	11/86	2.322	2.280	2.308	2.300	2.337	2.351	2.346	2.390	2.381
	11/87	2.321	2.319	2.347	2.322	2.335	2.388	2.344	2.357	---
US Seive Size (%)	1"	100	100	100	100	100	100	100	100	100
	3/4"	100	99	100	100	100	100	100	99	97
	1/2"	91	95	94	95	93	90	87	85	82
	No 4	67	73	68	70	72	65	55	53	52
	No 10	52	58	52	54	56	50	42	40	41
	No 40	30	35	29	27	32	28	28	25	26
	No 80	12	14	12	11	12	13	13	10	12
	No200	7	9	8	7	8	9	9	7	8
Asph Cont (%)	3/86	5.3	5.2	5.3	5.2	5.8	5.5	4.6	3.8	5.1
	11/86	5.7	5.3	4.8	5.9	5.1	5.4	4.5	4.2	3.9
	11/87	4.9	4.9	4.7	5.1	5.4	5.3	3.9	4.5	4.2
Visc 140^{0}F Poise	3/86	35487	38155	36386	52232	25836	23444	73715	29347	22494
	11/86	38210	55540	56650	40172	32162	38569	75478	20589	52463
	11/87	50117	85193	64948	65115	75800	27363	81208	30964	79005
Pen 77^{0}F	3/86	25	26	25	24	29	29	23	25	24
	11/86	25	22	22	21	22	24	18	33	22
	11/87	22	21	22	19	20	29	19	29	18
Duc 77^{0}F	3/86	22	18	22	13	40	66	10	35	69
	11/86	21	10	12	18	28	19	22	51	12
	11/87	12	7	9	12	45	24	8	30	12

Louisiana (5). This higher oxidation rate is characteristic of a crude source used which has been utilized over the last several years by refiners supplying the state.

Friction Numbers and Critical Hydroplaning Speeds

A primary measure of the performance of the Sprinkle Treatment section is their ability to maintain an adequate level of friction for the life of the pavement. Friction of the experimental sections and the ACFC was measured shortly after construction and for years after by the Department's skid truck according to ASTM E 274-85 procedures.

Average friction numbers are presented in Table 13 and depicted in Figure 12. Historical data provides that a difference in a friction number of three represents a significant different. With that criteria, the sprinkle treated sections are performing similarly to the ACFC. The data confirms that 7 lb/yd^2 is a sufficient rate to provide frictional properties.

TABLE 13

FRICTION NUMBERS

	7 LBS/YD^2	10 LBS/YD^2	ACFC
11/84	41.4	42.4	40.0
3/85	41.7	44.4	42.4
11/86	41.4	41.5	44.2
11/87	43.1	41.2	40.6

FIGURE 12. Friction Numbers.

Critical hydroplaning speed is defined as the speed at which a vehicle will begin hydro-planing, or riding on a film of water instead of the pavement surface. The speed is calculated using measured texture depths of the pavement's surface and other factors such as tire tread depth, rainfall intensity, tire pressure, spin down, and pavement gradients. FHWA Report No. FHWA-RD-75-11, was used as the basis for the critical hydroplaning speed analysis (4). A rainfall intensity of 2 inches per hour was assumed as being typical of Louisiana conditions along with a pavement cross slope of 0.025 and a longitudinal gradient of 0.0. A worst case scenario was used for the vehicle characteristics including tire pressure of 18 psi, spin down of 10 percent and tire tread depth of 2/32 inch. The pavement texture depth was measured using a sand patch. Table 14 contains the texture depth measurements and the hydroplaning speeds developed according to these assumptions. Because of these assumptions the speed numbers are not definitive, but relative.

TABLE 14

CRITICAL HYDROPLANING SPEEDS

		Sp. Treat. 7 LBS/YD²			Sp. Treat. 10 LBS/YD²			ACFC		
SECTION		4	5	6	2	3	7	1	8	9
Tex	11/84	0.036	0.039	0.030	0.052	0.049	0.042	---	---	---
Dpt	11/85	0.050	0.039	0.039	0.053	0.050	0.045	0.047	0.048	0.053
	11/86	0.040	0.039	0.047	0.044	0.050	0.048	0.044	0.039	0.055
in.	11/87	0.035	0.041	0.034	0.051	0.044	0.043	0.045	0.039	0.050
Hpn	11/84	52	54	47	75	66	56	--	--	--
Spd	11/85	75	54	54	75	75	58	61	62	75
	11/86	54	54	61	57	75	63	57	54	75
mph	11/87	52	55	51	75	57	56	58	54	75

Hydroplaning speeds are tabulated in Table 14 and presented graphically in Figure 13. Three years after construction, it is observed that the 10 lb/yd² section is performing similarly to the ACFC which was the intention of the increased quantity of sprinkle chips. The 7 lb/yd² section is somewhat less efficient in increasing critical hydroplaning speeds. If the 10 lb/yd² section continues to retain the chips, such rates could be utilized on those facilities where hydroplaning is a concern.

FIGURE 13. Critical Hydroplaning Speed.

Aggregate Retention

In order to examine loss of the sprinkle aggregate in the experimental sections, photographic logs were established in the wheel paths and in the middle of each lane were established within each evaluation site. A box grid was used to assist in evaluating the aggregate loss. Each picture location was outlined so that the exact spot could be found at subsequent evaluations. Figure 14 provides a sample photo. Visual inspections of each section were conducted on a year-by year basis and compared for aggregate losses. Pop-out of aggregate were discovered. As observed in Table 15, the aggregate retention after three years was excellent.

TABLE 15

AGGREGATE RETENTION

SITE		CONSTRUCTION	YEAR 1	YEAR 2	YEAR 3
Sp. Treat.	4	100*	99	98	97
(7 lbs/yd^2)	5	100	99	98	97
	6	100	99	99	98
Sp. Treat.	2	100	99	98	98
(10 lbs/yd^2)	3	100	99	98	98
	7	100	100	100	99

* Average of three locations

FIGURE 14. Aggregate photo log.

Traffic and Accident Reduction

Average daily traffic and accident was collected for this project for a period of eight years (four leading up to construction, the year of construction and three year performance period). Figure 15 shows average daily traffic as having only minor annual changes from 1980 to 1983. One year before the construction of the study section (1983), a rise in average daily traffic began and continued through the following two years. An inspection of the data in Figure 16 shows that moderate levels of total annual accidents, injuries, fatalities and property damage occurred four years prior to (1984) the construction of the Sprinkle Treatment sections. In spite of the 1983 to 1985 increase in average daily traffic, the study section maintained annual declines in total accidents and property damage. Although the number of injuries were only slightly reduced after the first year of service, the mortality rate on this roadway was reduced to zero.

In trying to assess changes in accident rates due to the various treatments, "accident densities" were calculated by dividing the annual number of accidents in each section by the section's length. The results presented in Figure 17 show the ACFC to have a predisposition to higher accidents but with reconstruction in 1984, the accident densities were drastically reduced. The two Sprinkle Treatment sections, on the other hand, possessed noticeably lower accident level prior to construction. The accident densities in subsequent years were moderately reduced and approximated the same level through 1987.

FIGURE 15. Average daily traffic.

FIGURE 16. Annual Accidents.

FIGURE 17. Accident densities.

ECONOMIC ANALYSIS AND MATERIALS CONSERVATION

As per the special provisions in Appendix A there were three pay items associated with the experimental section along with rebates for the conventional asphaltic concrete and asphaltic concrete friction course. The unit cost for these items were bid as follows:

ITEM	DESCRIPTION	UNIT	COST
501(1)	Asphaltic Concrete	Ton	32.00
501(1)X	Modified Asphaltic Concrete	Ton	36.50
502(1)	Asphaltic Concrete Friction Course	SYD	0.95
S-1	Pre-Coated Sprinkle Aggregate	Ton	42.50
S-2	Handling and Spreading	SYD	0.25

The additional cost bid for the modified asphaltic concrete is related to an increase in asphalt cement content and the use of stone screenings. Converting this difference in price to a square yard basis the total cost of the Sprinkle Treatment would be:

Pre-Coated Sprinkle Aggregate (10 lbs/yd)	= $0.21
Handling and Spreading	= 0.25
Modified Asphaltic Concrete	= 0.38
	$0.84/yd

Thus, on a first cost basis, the Sprinkle Treatment provided a savings of $.11 per square yard or $1550 per mile of roadway. More typical bids for asphaltic concrete friction course in Louisiana average about $1.50 per square yard, however, which would provide cost savings in the neighborhood of $9300 per mile of roadway. Of course until the life cycle of the Sprinkle Treatment can be established long term savings cannot be addressed.

Perhaps a much larger savings is realized in the area of materials conservation. Using an application rate for the slag friction course of 56 lbs/yd^2 and the design asphalt content of 6.5%, one mile of two lane roadway would consume 25.6 tons of asphalt cement and 368.6 tons of slag aggregate. A Sprinkle Treatment of 10 lbs/yd^2 would utilize approximately 68.9 tons of slag aggregate. Considering the actual percentage of asphalt cement used on this project for sprinkle aggregate coating (2.2%) and the 0.7% additional asphalt in the modified wearing course, the asphalt cement required was 1.5 tons per mile and 8.1 tons per mile, respectively. Thus an overall savings in material of approximately 16 tons per mile of asphalt cement and 300 tons per mile aggregate was realized.

CONCLUSIONS

1. After three years of evaluation the Sprinkle Treatment sectionsat both 7 lb/yd^2 and 10 lb/yd^2 spread rates, are performing as well or better than the asphaltic concrete friction course control section. The performance factors include serviceability, structural integrity, pavement distress, friction numbers and hydroplaning criteria.

2. The Sprinkle Treatment sections retained virtually all of the aggregate placed at both the 7 lb/yd^2 and 10 lb/yd^2 spread rates.

3. Both Sprinkle Treatment sections provided friction properties which were similar to the asphaltic concrete friction course.

4. A 10 lb/yd^2 spread rate Sprinkle Treatment can provide anti-hydroplaning characteristics similar to an asphaltic concrete friction course.

5. On a first cost basis Sprinkle Treatment provided a small savings for this first project. When compared to typical costs for asphaltic concrete friction course savings of approximately $10,000 per mile could be realized.

6. Normal plant and roadway operations were maintained throughout the construction of the Sprinkle Treatment sections; there were

no delays due to the chip spreader operation.

7. Specification density requirements were not met for two of the three lots representing the modified type 3 wearing course. Whether this lack of densification was due to the unfamiliarity of the contractor in compacting the modified mix or to the open surface texture imparted by the sprinkle aggregate could not be determined.

RECOMMENDATIONS

The experimental project reported herein demonstrates that the Sprinkle Treatment technique, at both a 7 lb/yd^2 and 10 lb/yd^2 spread rate can perform as well as an asphaltic concrete friction course with respect to friction properties. The 10 lb/yd^2 Sprinkle Treatment section has anti-hydroplaning properties similar to the ACFC.

Until the 1984 moratorium placed on their use, asphaltic concrete friction course was utilized on roads with greater than 4000 average daily traffic and which also had paved shoulders. Since 1984, a blended aggregate wearing course, type 8, which incorporates a minimum of 30 percent by weight high quality, non-polishing aggregate, has been used to obtain adequate friction numbers in wearing surfaces. The dense-graded type 8 mix, however, provides little in the way of anti-hydroplaning characteristics.

On the basis of the results obtained in this study, it is recommended that Sprinkle Treatment be considered as an alternate for either ACFC or type 8 wearing course mixes. It is envisioned that alternates could be established in the Skid Accident Reduction Program (EDSM I.1.1.5) along the following guide lines.

(1) A 7 lb/yd^2 Sprinkle Treatment could be used on those roadways where frictional properties are needed but anti-hydroplaning is not a concern. Such an alternate could save approximately $10,000 per mile as a substitute for ACFC or reduce the quantity of high quality, non-polishing Class I aggregate currently being used in type 8 mixes by seven fold (50 tons/mile sprinkle chips vs. 350 tons/mile of Class I aggregate).

(2) A 10 lb/yd^2 Sprinkle Treatment could be used as an alternate for ACFC on those roadways where anti-hydroplaning characteristics are desirable.

It is further recommended that prior to full implementation, several additional projects be constructed at each of the two spread rates recommended herein. In this manner, the Sprinkle Treatment technique could be introduced to the construction industry while gaining additional data to establish traffic volume levels for the different spread rates.

REFERENCES

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4. Galloway, B.M., et. al., Tentative Pavement and Geometric Design Criteria for Minimizing Hydroplaning, Federal Highway Administration Research Report No. FHWA-RD-75-11, Washington D.C., February 1975.

5. Shah, S.C., Asphalt Cement Consistency Study, Research Report No. 107, Louisiana Department of Highways, Baton Rouge, LA., April 1977.

APPENDIX

SPECIAL PROVISIONS

SPECIAL PROVISIONS

SPRINKLE TREATMENT

DESCRIPTION: Sprinkle Treatment is the application of a properly graded, precoated aggregate on the surface of a wearing course immediately following laydown and prior to initial rolling in order to provide a skid resistant wearing surface.

MATERIALS:

Sprinkle Aggregate: The aggregate shall be slag or stone conforming to section 1003.06(b) of the Standard Specifications for Roads and Bridges, 1982 Edition, and meeting the following gradation:

U.S. Sieve Size	Percent Passing
1/2	100
3/8	20 - 55
No. 4	0 - 5
No. 200	0 - 1.5

Asphalt: The asphalt cement used to precoat the sprinkle aggregate shall be AC-30 with properly proportioned anti-strip additive.

Modified Type 3 Wearing Course: The aggregate used in the wearing course mix shall have a minimum of 50 percent passing the No. 10 sieve. The gradation requirements for the modified type 3 wearing course shall be:

U.S. Sieve Size	Percent Passing
3/4	100
1/2	80 - 100
No. 4	60 - 85
No. 10	50 - 70
No. 40	20 - 45
No. 80	10 - 25
No. 200	2 - 12

A job mix formula for the modified type 3 wearing course shall be submitted for approval prior to construction.

Modified type 3 wearing course shall meet all control and acceptance requirements of the Standard Specifications for Roads and Bridges, 1982 Edition, except as herein modified. Density requirements shall be waived for the modified type 3 wearing course.

EQUIPMENT: The equipment used for spreading the precoated aggregate shall be a Bristowes Mk V Hydrostatic Pre-coated Chip Spreader. This equipment and operator shall be furnished by the Federal Highway Administration.

EQUIPMENT: The equipment used for spreading the precoated aggregate shall be a Bristowes Mk V Hydrostatic Pre-coated Chip Spreader. This equipment and an operator shall be furnished to the contractor by the Federal Highway Administration.

PRECOATING THE SPRINKLE AGGREGATE: The sprinkle aggregate shall be dried at a temperature of 250-300ºF and precoated with asphalt cement at 1.0-1.5 percent by weight. Freshly coated aggregate shall be stockpiled no higher than three (3) feet until sufficient cooling has occurred to preclude coking of the asphalt. The precoated aggregate shall be stored to prevent contamination and deterioration. Storage for an extended period of time may require the stockpile to be covered. Wetting down the precoated aggregate and manipulation of the stockpile should prevent crusting. Generally, the sprinkle aggregate should be precoated several days prior to use in order to allow for complete cooling.

CONSTRUCTION: The precoated aggregate material shall be uniformly applied to the surface of the wearing course as soon as possible after laydown and prior to initial breakdown rolling. The application rate shall be as directed by the engineer with a target rate of 10 pounds per square yard. This rate may be adjusted up or down; however, 12 pounds per square yard shall be the maximum application rate.

Rolling shall begin immediately behind the aggregate spreader with a steelwheel roller according to the established rolling pattern. The use of pneumatic-tired rollers will not be permitted.

Traffic shall not be permitted on the surface until the pavement has cooled to such an extent that the precoated aggregate does not ravel under tire traffic. A water truck may be required by the engineer to facilitate surface cool-down.

MEASUREMENT AND PAYMENT: The precoated sprinkle aggregate shall be measured by the ton at the time of precoating and payment shall be made under Item S-1.

Handling and spreading of the precoated sprinkle aggregate shall be measured by the square yard of completed and accepted surfacing, and payment shall be made under Item S-2.

Modified type 3 wearing course shall be measured by the ton at the time of processing, and payment shall be under Item S-3.

Item S-1, Precoated Sprinkle Aggregate, per ton.
Item S-2, Handling and Spreading of Precoated Sprinkle Aggregate, per square yard.
Item S-3, Modified Asphaltic Concrete, 501(1)(X), per ton.
Item S-4, Rebate, Asphaltic Concrete Friction Course, 502, per square yard.
Item S-5, Rebate, Asphaltic Concrete, 501(1), per ton.

APPENDIX B

SAMPLE PAVEMENT CONDITION RATING FORM