SPRINKLE TREATMENT

FOR

SKID RESISTANT SURFACES

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"Sprinkle Mixes for Skid Resistance Surfaces"
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16. Abstract

Sprinkle treatment for improved skid resistance involves the procedure of applying and embedding non-polishing aggregates into the surfaces of newly placed hot-mix asphalt concrete pavement, and freshly placed Portland cement concrete pavement. This addition of skid resistant aggregate prior to compaction of the hot-mix and/or before the set of Portland cement concrete enables embedment and retention of the skid resistant material. By the utilization of low skid quality aggregate for structural requirements of the pavement and reserving high quality non-polishing aggregates for the wearing surface, improved skid resistance of the roadway can be realized and valuable aggregate resources conserved.

Reports of detailed investigations of Great Britain, Belgium and Virginia as well as reference material complementary to this study are included in Volume II.

A 20 minute slide/tape and 15 minute narrative motion picture have been produced which describe the investigation and detail recommendations for successful sprinkle treatment construction.

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METRIC CONVERSION FACTORS

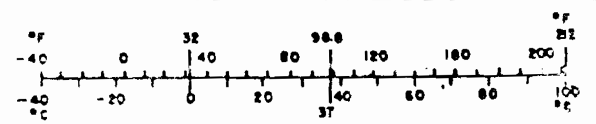
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
	ounces	28	grams	g
	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



METRIC CONVERSION FACTORS

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ABSTRACT

Successful sprinkle treatment construction technology in this country, as well as in Great Britain and Europe, is presented to enable immediate user implementation. Sprinkle treatment for improved skid resistance involves the procedure of applying and embedding non-polishing aggregates into the surfaces of newly placed hot-mix asphaltic concrete pavement and freshly placed Portland cement concrete pavement. This addition of skid resistant aggregate prior to compaction of the hot-mix and/or before the set of Portland cement concrete enables embedment and retention of the skid resistant material. By the utilization of low skid quality aggregate for structural requirements of the pavement and reserving high quality non-polishing aggregate for the wearing surface, improved skid resistance of the roadway can be realized and valuable aggregate resources conserved.

A questionnaire survey was conducted of current sprinkle treatment construction practices in the United States and foreign countries. A detailed direct investigation of sprinkle treatment procedures in Great Britain, Belgium, and Virginia was also conducted and reports on that investigation are included in Volume II of this study.

A 20 minute slide/tape and 15 minute narrated motion picture have been produced which describe the investigation and recommendations for successful sprinkle treatment construction. Both desirable techniques and recommendations for improvements are emphasized to assist the user in development of a systematic program for improved construction.

The report should assist the user in material selection, personnel training, construction procedures, and finished roadway evaluation to assure optimum success of the technique of sprinkle treatment for improved skid resistance.

SUMMARY

Sprinkle treatment for improved skid resistance has consistently demonstrated advantages in pavement construction in this Country, Great Britain and Europe. Consistency of results to be expected from trained personnel utilizing this procedure make it a viable option when any program of construction for improved skid resistance is considered. Attention to selection, coating, and application of sprinkle aggregate materials to the roadway as described in this report should enable the engineer to develop procedures applicable to unique environmental conditions.

The following recommendations and conclusions are offered to aid in the design and placement of sprinkle treatment:

1. Sprinkle mix aggregate can be effectively placed hot (270° F. to 300° F.) or cold (below 90° F.).

2. Effective aggregate spreading equipment is available for both hot and cold placement of sprinkle aggregate.

3. Sprinkle mix aggregate should be coated with sufficient asphalt to aid in sticking the aggregate in the mat. Although coating of the aggregate with asphalt has been successfully accomplished in the maintenance yard with emulsion, plant coating is recommended for a more uniform particle coverage. AC-20 has been used on numerous occasions for plant coating and is recommended for general use. The desired range in residual asphalt is 2.5% to 8% by volume and 1.7% to 3.1% by weight depending upon the aggregate's specific gravity and absorption characteristics.

4. Stockpiling of coated aggregate at elevated temperatures for eventual cold placement can result in coking the asphalt on the aggregate particles. When sprinkle aggregate is plant precoated, it should not be stockpiled in depths greater than 2 1/2 to 3 feet nor at temperatures in excess of 300° F.

5. Stockpiled coated aggregate which is scheduled for cold placement is frequently wetted with water at the plant to promote cooling. Occasional wetting of the stockpiles at the job site may also prove beneficial in preventing balling of the material when in the spreader.

6. Rolling should be accomplished with steel wheel rollers. Care in the use of rubber tire rollers should be exercised to insure that pick up of the sprinkle aggregate does not occur. If pick up of the sprinkle aggregate occurs, use of the rubber tire roller should be terminated. Where the pavement is opened to traffic while pick up conditions are prevalent, wetting the finished mat with water to promote cooling may also be required.

7. The contractor should have the option of selecting either hot or cold placement of sprinkle aggregate. A specification should allow adequate inspection, require polish resistant aggregate, provide for acceptable rates of asphalt coating for the sprinkle material and establish minimum and desirable application rates.

CHAPTER I

INTRODUCTION

Pavement surfaces with adequate skid resistance are of primary concern to the highway engineer. Vehicle control for wet conditions is directly dependent upon vehicle speed, condition of tires and the frictional quality of the driving surface. A dramatic reduction in numbers and severities of all accident types can be expected if road surfaces are constructed and maintained to insure high frictional coefficients over their service life. A pavement which displays good anti-skid properties is one in which:

1. Good drainage exists
2. Good texture is evident
3. Non-polishing aggregate in the pavement-tire interface is maintained

The first factor, good drainage of surface water from the pavement surface, is instrumental in preventing a build-up of water under the vehicle's tires. Unfortunately, most motorists tend to ignore or are not aware of the hazard of surface water even though the concept of hydroplaning may be fairly well understood. Even the thinnest film of accumulated water under a tire can produce a hydroplaning condition where speeds are excessive and tire conditions are poor. Partial, if not complete loss of vehicle control can readily occur under these conditions as evasive maneuvers are initiated. The second factor, good texture in pavements as well as suitable tread depth and pattern on vehicle tires provides passageways for free moisture on the pavement surface to escape upon passage of the vehicle tire. Pavement surfaces having good texture can consequently accommodate heavier rainfall intensities with reduced potential for vehicle hydroplaning. Texture on pavements also provides better tire-roadway surface contact. This better contact acting on tires enables greater control during wet and dry driving conditions. The third factor in providing a safe driving environment is frictional resistance of the pavement material which is in contact with the vehicle's tire, i.e., the tire-pavement interface. Materials which are susceptible to accelerated polishing under traffic should be closely examined and their use discouraged.

Through the years, concern over skid resistant pavements has been instrumental in bringing about the development of pavements which perform excellently. Such measures as synthetic aggregate seal coats and open-graded friction courses are able to provide renewed friction to otherwise structurally adequate roadways. On new construction and on existing roadways needing resurfacing where a course of hot-mix asphaltic concrete is warranted, the traditional use of skid resistant aggregate throughout the mat is subject to economic concern. The scarcity of suitable natural aggregate to attain safe coefficients of friction has prompted investigation into procedures of conserving this scarce and valuable resource.

Fortunately, attainment of a pavement surface with the optimum requisities of good drainage, good texture, and good skid resistance can be achieved through the sprinkle treatment procedure. Sprinkle treatment involves the distribution of non-polishing aggregates only to the surface of newly placed hot-mix asphaltic concrete pavements prior to compaction and to the surface of freshly placed Portland cement concrete pavements. The purpose of this investigation was to develop guidelines for successful utilization of sprinkle treatment with regard to design, construction, testing, performance, maintenance, and economics.

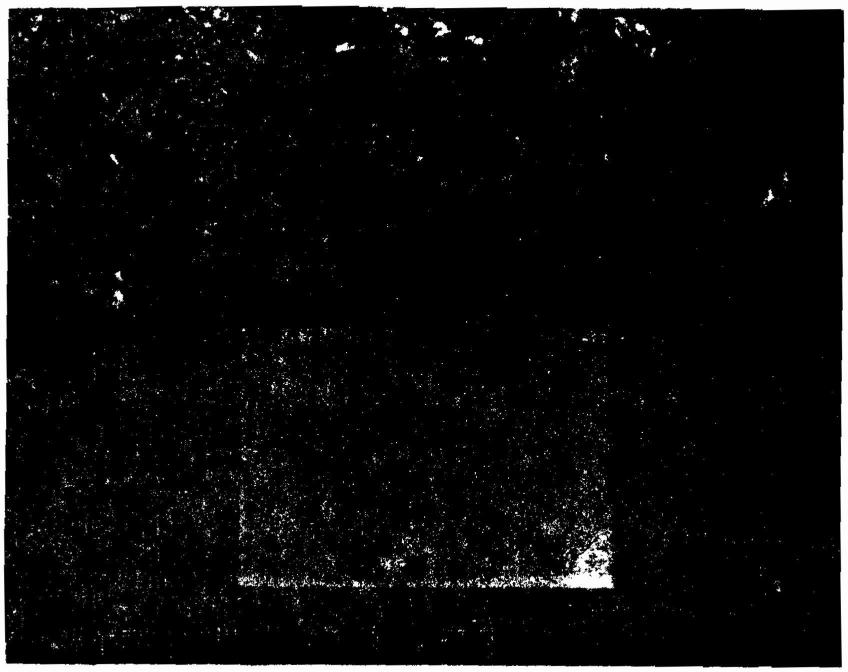

Figure 1
Hot-Mix Asphaltic Concrete
Sprinkle Treated Roadway

CHAPTER II

SURVEY

Investigation into the sprinkle treatment procedure for skid resistance was initiated with a survey of current experience in this procedure both in this Country and in Europe. Exhibit I illustrates a tabulation of responses to a questionnaire to all states, Great Britain, Belgium, Netherlands and Norway.

Experience with sprinkle treatment on asphaltic pavement in the United States, with the exception of Virginia and Texas, has largely been confined to short experimental sections. Only Belgium and Ohio,with 18.6 miles and 1 mile respectively, of the group surveyed indicated any experience with sprinkle treatment of Portland cement concrete. Procedures for asphaltic concrete sprinkle treatment utilized in the United States largely reflect those developed and in current use in Virginia. Other states using sprinkle treatment have utilized similar aggregate gradations, aggregate application rates, and construction procedures. Although residual asphalt percentages are also similar for given aggregate types, some variation does exist in asphalt coating procedures and types of asphalt to coat the sprinkle aggregate. Also, sprinkle aggregate placement techniques, involving both hot and cold placement and equipment utilized, indicated the need for further investigation into these aspects of this procedure.

Based upon the indicated relative experiences of the respondents to the questionnaire, a visitation program was initiated to observe and record the detailed sprinkle treatment procedures from Great Britain, Belgium, and Virginia with reported asphaltic concrete pavement sprinkle treatment experiences of 10,563 miles, 1,864 miles and 200 miles respectively. Reports produced from these visitations are:

1. "Sprinkle Treatment of Asphaltic Concrete in England or 'Chipping Asphalt'"

2. "Sprinkle Treatment of Both Asphaltic and Portland Cement Concrete in Belgium"

3. "Sprinkle Mix Experience in the State of Virginia"

These three reports are included in this report as Appendix A in Volume II - Supplementary Information.

EXHIBIT I

	PAVEMENT	SPRINKLE MATERIAL					
	LANE MILES	AGGREGATE TYPE	AGGREGATE GRADATION	APPLICATION RATES	POLISH VALUE	ASPHALT MATERIAL	ASPHALT RATE (% by wt.)
FOREIGN							
BELGIUM	1,864 18.6 PCC	Norway Stone	6-10 = 1/4"-3/8" 10-14 3/8"-1/2" 13-19 1/2"-3/4"	9.2 (lbs/yd^2) 12.9 " 11.1-14.7 "	0.50* to 0.70	plant coated bitumen	0.5 1.5
ENGLAND	10,563	crushed rock	14-20 9/16"-3/4"	14.7-22.1 " (refer to BS 594)	0.50* to 0.75	plant coated bitumen (refer to BS 594)	1.5 ± .3
NETHERLANDS	590	quartzite	2-5 = 1/16"-3/16"	3.7-5.5 (lbs/yd^2)	0.55*	not coated	n/a
NORWAY	301	high class	4-8 = 1/8"-5/16" 8-12 5/16"-1/2" 12-16 = 1/2"-5/8"	5.5-7.4 (lbs/yd^2) 7.4-11.1 " " 11.1-14.7 " "	0.50* to 0.60	plant coated AC 80 to 100 pen 60 to 70 pen (same as in pavement)	1.0 to 1.5 AC with 1.0 to 1.5 filler

* Test Method Used Is Of Shorter Duration Than ASTM.

	LANE MILES	AGGREGATE TYPE	AGGREGATE GRADATION	APPLICATION RATES	POLISH VALUE	ASPHALT MATERIAL	ASPHALT RATE (% by wt.)
DOMESTIC							
CALIFORNIA	0.5 (mi) PCC	crushed slag, concrete agg., quartz	3/8" X #8	up to 9 lbs/yd^2	n/a	none	none
COLORADO	0.5 (mi)	pea gravel & burned shale	between #10 and #4	5 lbs/yd^2	n/a	spray with emulsion	n/a
FLORIDA	0.2 (mi)	expanded clay	100% pass 3/8" 65% pass #4 4% pass #10	5 lbs/yd^2	LA 32	AC-20 @ 280° F in batch plant	6.5% by wt. 4% by vol.
GEORGIA	2 (mi)	granite	#78 & #7 stone	5-7 lbs/yd^2	n/a	AC-20 plant	2.0%
ILLINOIS	2.3 (mi)	slag traprock	pass 1/2" 100% pass 3/8" 90-100% pass #4 5-15% pass #8 0-5%	15 lbs/yd^2(slag) 20 lbs/yd^2(trap)	dense non-polishing	MC 70 MC30 in batch plant	3-4% (slag) 1% (trap)
IOWA	4.0 (mi)	quartzite limestone expanded shale	3/8" cover aggregate	1-5 lbs/yd^2	n/a	85-100 pen AC in batch plant	0.5% to 1.0% by wt.
LOUISIANA	.01 (mi)	expanded clay	minus 1/2"	3 lbs/yd^2	n/a	CMS-2 asphalt emulsion in batch plant	6%
MICHIGAN	10 (mi)	siliceous sand	3 CS Mich. Spec.	0.5 to 2 lbs/yd^2	n/a	AC in batch plant	0.5 to 1.5 % by wt.
OHIO	1 (mi) PCC	fine silica sand coarse silica sand colorcron	sand	n/a	n/a	n/a	n/a
TEXAS	80 (mi)	lightweight sandstone	grade 4	1 cu. yd. to 400 sq. yd. -600 sq. yd.	35-40	AC 10-20, emulsions, plant mix & hand sprayed	0.75% to 3% by wt.
VIRGINIA	200 (mi)	good skid resistant	#8 & #78 specifications	5-7 lbs/yd^2 regular 3-5 lbs/yd^2 lightweight	n/a	AC-20 in batch plant	2%

MEASUREMENTS		MISCELLANEOUS			REMARKS
SKID	SOUND	CLOSED SEASON	SPECS. AVAILABLE	PUBLISHED REPORTS	
0.50 - 0.65 @ 50 mph odoliograph or stradographe	n/a	10/15 to 3/1 PCC days of frost	yes	yes	For PCC aggregate water sprinkle to have material wet at time of spreading.
SFC 0.40 - 0.80 SCRIM (refer to LR 504, LR 510, SR 103)	76-79 dB(a) @ 7.5m & 70 km/m (refer LF 577, mic & mag tape)	air temp. below 0^{o} C (refer BS 594)	yes	yes	
(see report)	n/a	11/1 to 3/1	yes	yes	Surface temperature ACP shall be at least 90^{o} C.
μ_{60} (wet) 0.60 - 0.80 Mμ-meter	71-73 dB(A) 50-70 km/m mic dist 7.5m, Brüel & Kjoer	Oct. to May	yes	no	12-16 (mm) aggregate used where ACP coarse aggregate (+3/8") is <35%, 8-12 (mm) aggregate used where ACP coarse aggregate (+3/8") is 35 - 40%, 4-8 (mm) aggreg. used where ACP coarse aggregate (+3/8") is > 40%, material spread by mechanical spreader or by hand & pressed about half way into ACP.
0.35 - 0.45 Calif. skid test trailer	none	n/a	no	no	
0.80 on burned shale skid trailer	none	n/a	no	no	
0.60 @ 40 mph ASTM E274-70	n/a	temp. below 40^{o} F	no	no	Sprinkle rock transported directly to road from batching operation SN_{40} 0.52 3 X 10^6 cumulative traffic 0.40 5 X 10^6 cumulative traffic.
n/a	n/a	n/a	no	no	Applied to road hot in accordance with Virginia's method. Roughness Index 714 avg. Wisconsin roadmeter.
0.44 @ 40 mph 0.22 after 1 year ASTM trailer	n/a	n/a	yes	no	Sprinkle rock stockpiled & protected after batching. Area to be covered between 50 - 75% of surface. Sprinkle rock to be dry at time of placement. Coating temperature 200^{o} F.
n/a ASTM	n/a	same as ACP	no	n/a	Process aggregate is advance & stored in open stockpile.
n/a	n/a	not specified as of this date	yes (tentative)	n/a	Stockpile aggregate after mix and allowed to cure.
0.40 - 0.65 Skid trailer		not permitted after 9/15	yes HRR 341 1970	yes	
.53 - .57 @ 40 mph 6-10 no.s higher than control	n/a	n/a	n/a	yes	
0.35 - 0.50 ASTM E274	60-70 dB(A)	same as ACP	yes	yes	All placement with cold aggregate ACP coarse aggregate factors 50 - 70% retained on #10 sieve texture 0.030 by sand patch.
0.40 - 0.50 ASTM trailer & vehicle stopping distance	n/a	same as ACP in temperature nomograph	yes	yes	Coated aggregate must be placed hot.

CHAPTER III

MATERIAL

Successful sprinkle treatment construction necessitates the selection of sprinkle aggregate and asphaltic materials compatible with the sprinkle equipment and the road surface. Sprinkle aggregate with non-polishing characteristics are essential to achieve optimum skid resistance. These non-polishing characteristics may be provided by hard, durable aggregate such as quartzite, gabbro, basalt, sandstone, etc., or by synthetic lightweights which abrade under traffic to continually produce a high friction surface. Successful skid properties have been achieved with aggregates having polish values of 35 and above when tested in accordance with Test Method TEX-438-A (see Volume II, Appendix B). However, in the interest of upgrading overall skid performance to more desirable levels, a minimum polish value of 37 is recommended for all new sprinkle treatment construction.

Sprinkle rock gradations utilized are closely associated with the type hot-mix asphaltic concrete used. In Great Britain, a hot-mix design is composed of 30% to 40% coarse aggregate retained on the #8 sieve. This relatively low amount of coarse aggregate enables their two commonly used sprinkle mixes having predominately 3/4" and 1/2" size aggregates to be easily embedded into the mat. In Belgium, sprinkle treatment design is quite similar to Great Britain's, except that due to the heavier axle loads of 14.3 tons, gradation of coarse aggregate in ACP is being increased to 45% to 55% retained on a #10 sieve. Good success is achieved with either a 3/8" to 1/2" or a 1/4" to 3/8" sprinkle rock. Although the former gradation produces greater texture since all sprinkle rock is imported, the latter gradation is preferred as good skid resistance can be produced using less material. Virginia's hot-mix design is also predominately coarse graded with 15% to 30% passing the #30 sieve. Sprinkle aggregate used with this hot-mix is predominantly a #4 sieve size rock. Sprinkle aggregate gradation in Texas patterns closely after Virginia's with the hot-mix coarse aggregate between 50% to 70% retained on the #10 sieve and utilizes a sprinkle rock which is also predominately #4 sieve size.

Typical asphaltic concrete and sprinkle rock gradations are as follows:

GREAT BRITAIN

Asphaltic Concrete Pavement

(1 3/8" mat thickness)

Coarse Aggregate (retained on #8 sieve)

Size	% Pass
3/4"	100
9/16"	85-100
3/8"	0-100
1/4"	0-60

Sprinkle Aggregate

Size	3/4" size % Pass	1/2" size % Pass
1"	100	
3/4"	90-100	100
1/2"	0-25	90-100
3/8"	0-4	0-30
1/4"		0-4
#200	0-2	0-2

GREAT BRITAIN (CONTINUED)

Fine Aggregate (passing a #8 sieve)

Size	% Pass
2.36 mm	95-100
600 μm	75-100
212 μm	15-60
75 μm	0-5

Plus Mineral Filler

BELGIUM

ACP

Size	%
Pass 1/2"	100
Pass 1/2" Retained #10	35
Pass #10 Retained #200	53
Pass #200	12

Sprinkle Aggregate

Size
1/4" - 3/8" and 3/8" - 1/2"

VIRGINIA

ACP

S-5

Size	% Pass
1/2"	100
#4	50-70
#30	15-30
#200	2-10

Sprinkle Aggregate

(Size 78)

Size	% Pass
3/4"	min. 100
1/2"	95 ± 5
3/8"	60 ± 20
#4	max. 20
#8	max. 8
#16	max. 3

TEXAS

ACP

(Type D Hot Mix)

Size	%
Passing 1/2"	100
Passing 3/8"	95-100
Passing 3/8" Retained #4	20-50
Passing #4 Retained #10	10-30
Total Retained #10	50-70
Passing #10 Retained #40	0-30
Passing #40 Retained #80	4-25
Passing #80 Retained #200	3-25
Passing #200	0-6

Sprinkle Aggregate
Grade 4 (Lightweight)

Size	%
Retained 5/8"	0
Retained 1/2"	0-5
Retained 3/8"	20-40
Retained #4	95-100
Retained #10	98-100

Grade 3 (Natural Stone)

Size	%
Retained 3/4"	0
Retained 5/8"	0-2
Retained 1/2"	20-35
Retained 3/8"	85-100
Retained 1/4"	95-100
Retained #10	99-100

Although uncoated aggregates have been used with some measure of success in a few instances in this country, optimum retention of sprinkle aggregate to the hot mix surface is achieved through a thorough coating of each aggregate particle with asphalt. Clean aggregate plays a major part in an adequate asphalt coating. A variety of asphaltic materials may be used in coating the aggregate: Slow-cure emulsions (SS-1), medium-cure cutback asphalts (MC 30 and MC 70), and asphalt cements (AC 10 and AC 20). They have all been used with success. Where asphalt cements are used, the same asphalt cement used in the hot mix may be convenient to use for coating the sprinkle aggregate. Plant coating the aggregate with emulsion may require special handling due to the high percentage of water or emulsifying agent. Successful plant coating of the aggregate with emulsion has been achieved by initially combining 1/2 of the emulsion with the aggregate. After a short mixing, the remaining emulsion is added and mixing resumed until the aggregate is fully coated with asphalt. Specifications governing emulsions and asphalt cements utilized are described in the Texas Specification, Item 300, "Asphalts, Oils and Emulsions", found in Volume II - Appendix C.

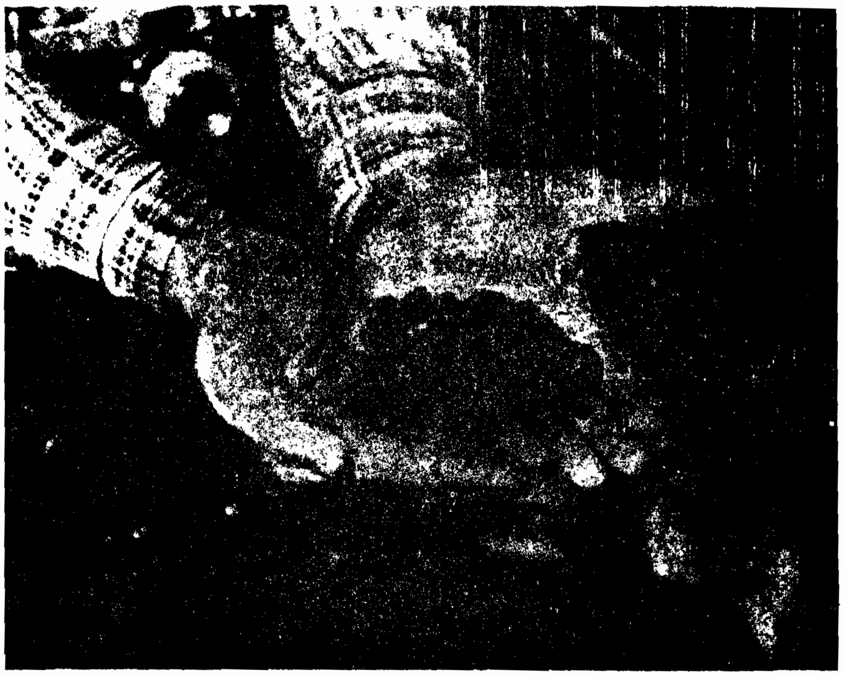

Figure 2
Texas Grade 4 Asphalt Coated
Lightweight Sprinkle Aggregate

CHAPTER IV

CONSTRUCTION METHODS

Asphaltic Concrete Pavements

Sprinkle treatment construction involves preparation of the sprinkle aggregate, placement of the sprinkle aggregate on the freshly laid asphaltic concrete mat, and compaction of the completed surface. Preparation of the sprinkle aggregate to assist in sticking the rock to the pavement generally consists of an asphalt coated material. A sprinkle aggregate coated with 2.5% to 8% by volume of residual asphalt is recommended or 1.7% to 3.1% by weight. Uncoated sprinkle aggregates have been used in a few instances as exhibited in this picture; however, their use is not recommended.

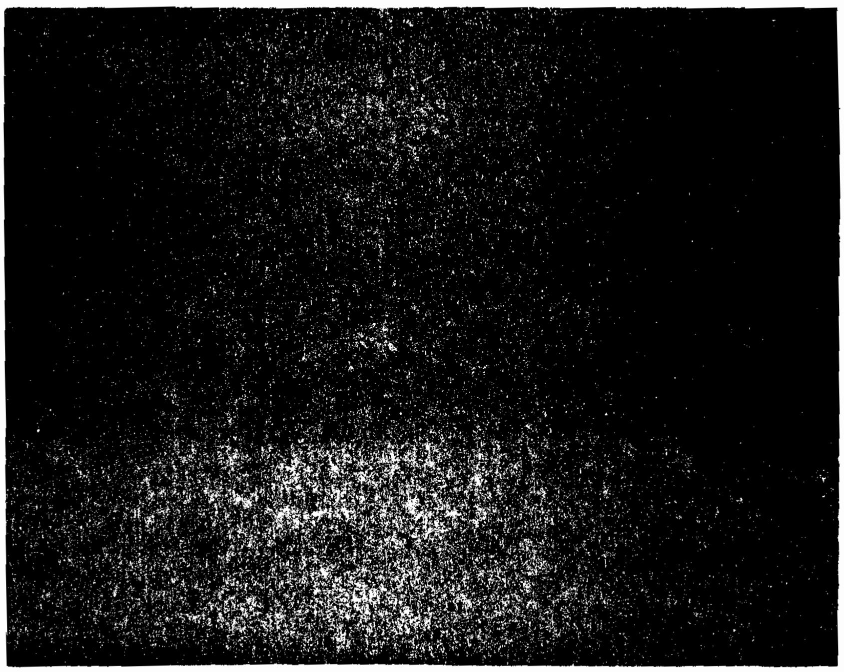

Figure 3
Sprinkle Treatment with Texas
Type D Hot-Mix Coarse Aggregate Fraction

Although initial skid numbers were increased from 23 to 44 by means of this uncoated sprinkle rock (Texas type D hot-mix aggregate sandstone), only about 35% of the applied material was retained on the road surface after opening to traffic.

Two basic means of achieving precoating have been used: namely, blade mix and plant mix operations. Through blade mix operations, the aggregate to be coated is placed on a clean surface in an equipment storage yard and asphalt added by a distributor truck or hand sprayed. Either an emulsion or cutback asphalt is utilized for blade mixing. Curing the material is assisted by aeration of the stockpile with a maintainer. Usually this operation requires several applications of asphalt to attain the desired asphalt residual on the sprinkle aggregate particles, as too heavy a single application can result in balling and matting of the aggregate. This process is ideally suited to maintenance operations where coated material must be available when needed.

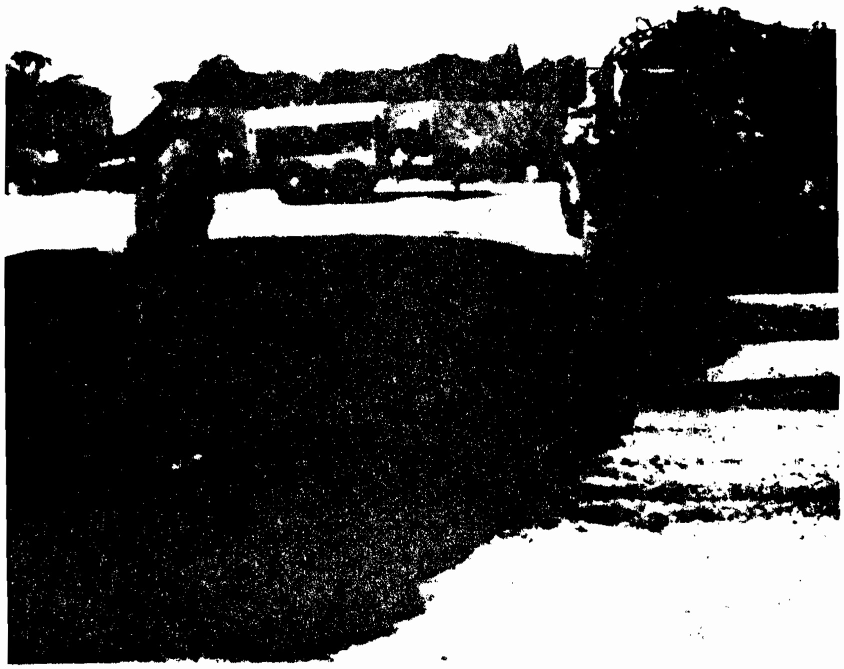

Figure 4
Asphalt Application Blade
Mix Sprinkle Aggregate

Plant mixing with asphalt is the other and preferred option available for coating the sprinkle aggregate. Although emulsions and cutbacks have also been applied successfully through a plant, care should be exercised due to their critical temperature ranges. Asphalt cement AC-20 is more commonly used as a plant mix coating material and the coated aggregate can be placed on the road hot or cold. Stockpiled aggregate can be subsequently "sweetened" with additional asphalt using an emulsion as described in the blade mix procedure if desired or needed. Great Britain practices plant batching of their sprinkle aggregate and prompt wetting of the stockpile with water to prevent crusting of the aggregate and coking of the asphalt. Additional sprinkling of the stockpiles of aggregate with water at the job site is sometimes practiced to reduce the tendency toward crusting as the material is spread on the roadway.

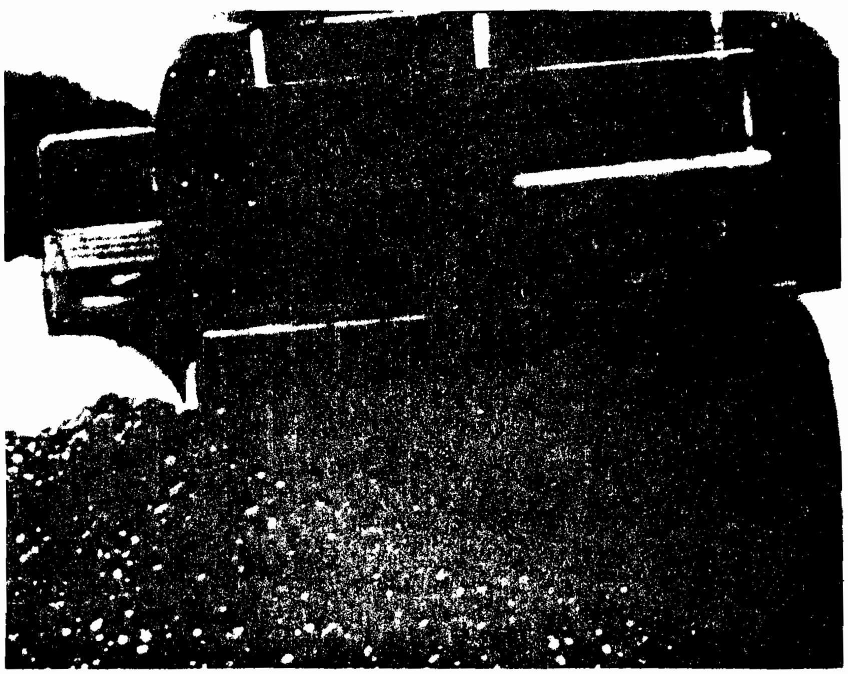

Figure 5
Watering Stockpile

Batching operations of the sprinkle aggregate through a conventional hot-mix asphaltic concrete plant can be accomplished with little difficulty through utilization of a conventional batch plant having an additional cold stone bin for the sprinkle aggregate. Batching of seven ton loads of sprinkle rock with asphalt cement can be accomplished with less than five minutes delay to the asphaltic concrete operation. When a batch of coated material is required, hot-mix operations are temporarily suspended and contents of the hot bin are discharged into a waste truck.

Figure 6
Discharging Hot Bins

There is virtually no delay in starting the hot-mix operation as the sprinkle aggregate remaining in the hot bins is mixed into the subsequent batch of hot-mix asphaltic concrete. In batching the sprinkle mix, the aggregate is heated to approximately 275° to 325° F. and the asphalt applied. When the asphalt coated material is to be placed hot on the road, it is recommended that it be hauled in insulated trucks and covered to prevent excessive heat loss.

When the coated aggregate is to be stockpiled for future use, it is important that batching temperature be no hotter than required to secure a uniform covering. Great Britain reports that the aggregate temperature of 390° F., is apt to cause coking of the asphalt on the aggregate particles in about four hours. The coking or burning of the asphalt results in a very hard oxidized asphalt layer on the aggregate. Where coking has occurred, the asphalt is no longer tacky, even at temperatures of 212° F. Also, in this regard, Great Britain recommends that stockpiles of precoated material not exceed three feet in height and a temperature of 320° F. Due to a heat rise within stockpiles, cooling of the stockpile with water after plant batching is recommended. Where stockpile temperature is less than 300° F., water cooling may be eliminated.

Hot placement of the sprinkle rock should be accomplished immediately after laydown of the asphaltic concrete pavement. A minimum mat temperature between 270° F. and 300° F. is recommended. The combination of hot asphaltic pavement and asphalt coating of the sprinkle rock permits a slight softening of the asphalt and a tight bond to be developed. A minimum rate of application of Texas Grade 4 sprinkle aggregate (95-100% retained on the #4 sieve) to achieve 25%-30% coverage of the surface area is recommended.

A rate of application to achieve this coverage will require one cubic yard of sprinkle aggregate per 450 square yards of pavement surface. In Great Britain and Europe, an optimum rate of application for sprinkle material is to cover approximately 75% of the surface area. This rate of coverage is at a rate of one cubic yard per 250 and 300 square yards of pavement surface for their 3/4" and 1/2" aggregate respectively. To accommodate the greater application rates and larger sizes of sprinkle aggregate, it may be necessary to reduce the plus 10 aggregate factor for the asphaltic concrete pavement to 35% to 40% as is practiced in these countries.

Continual inspection as the work progresses should be exercised to insure that desired application rates are being secured. Since rates of coverage are difficult to estimate, Virginia has prepared 18-inch square specimen boards to aid their inspectors in recognizing recommended application rates (see Volume II - Appendix A-3, page 83). Where a variety of aggregate types are utilized, an estimate of the rate of coverage can be a useful training tool. In this regard, Volume II - Appendix D contains full size photographs illustrating coverage rates of 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 50%, 60%, 70% and 100% respectively. These photographs may be placed directly on the sprinkle roadway surface for a quick comparison of rates of application. A periodic quantative check should also be made to insure that proper rate of application is being achieved.

Virginia has devised a simple method to measure the rate of aggregate application. A 2-square yard canvas cloth is laid directly on the hot-mix surface in advance of the spreader, and the material subsequently deposited on the sample cloth is then weighed.

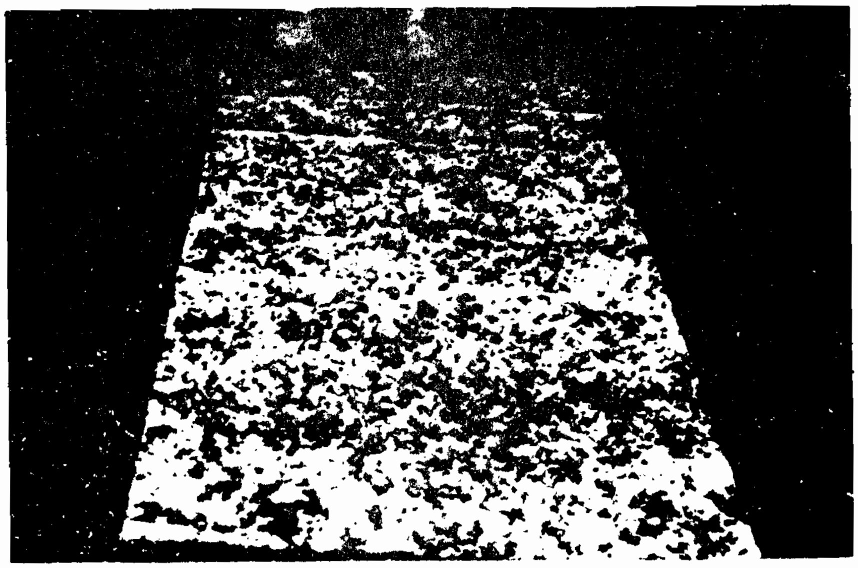

Figure 7
Sprinkle Aggregate
2-Yard Sample Cloth

After application of the sprinkle rock to the pavement surface, breakdown and compaction rolling should be initiated as soon as possible. Occasionally, due to the type of hot-mix asphaltic concrete, a slight delay in compaction rolling may be necessitated if shoving of the asphaltic concrete is encountered. Approximately three complete coverages each of the road surface by three wheel and tandem steel wheel rollers are usually sufficient to obtain the desired hot-mix density. Nuclear density measurements are unaffected by the sprinkle mixture and are utilized by Virginia to verify that asphaltic concrete densities have been achieved.

Although pneumatic rollers are not recommended, if they are utilized, care in their use should be exercised to insure that the sprinkle aggregate is not picked up by the tires.

After daily completion of the paving operation, care should be exercised in restoring traffic to the roadway. If pick up of the aggregate should occur, consideration should be given to wetting the pavement surface with water to reduce the pavement temperature.

Portland Cement Concrete Pavements

The sprinkle treatment procedure has also been extended to the application of skid resistant aggregate to Portland cement concrete pavements. In Belgium, this operation is being utilized as formed concrete pavements are being placed. Sprinkle aggregate takes the place of brooming or grooving the concrete pavements to provide texture and skid resistant qualities. Sprinkle aggregate is placed by a machine specially designed to travel on the concrete forms and uniformly deposits sprinkle aggregate. The machine is equipped with a wooden tamper which partially embeds the aggregate into the surface of the fresh concrete. The final operation performed by the machine is to spray the pavement surface with curing compound.

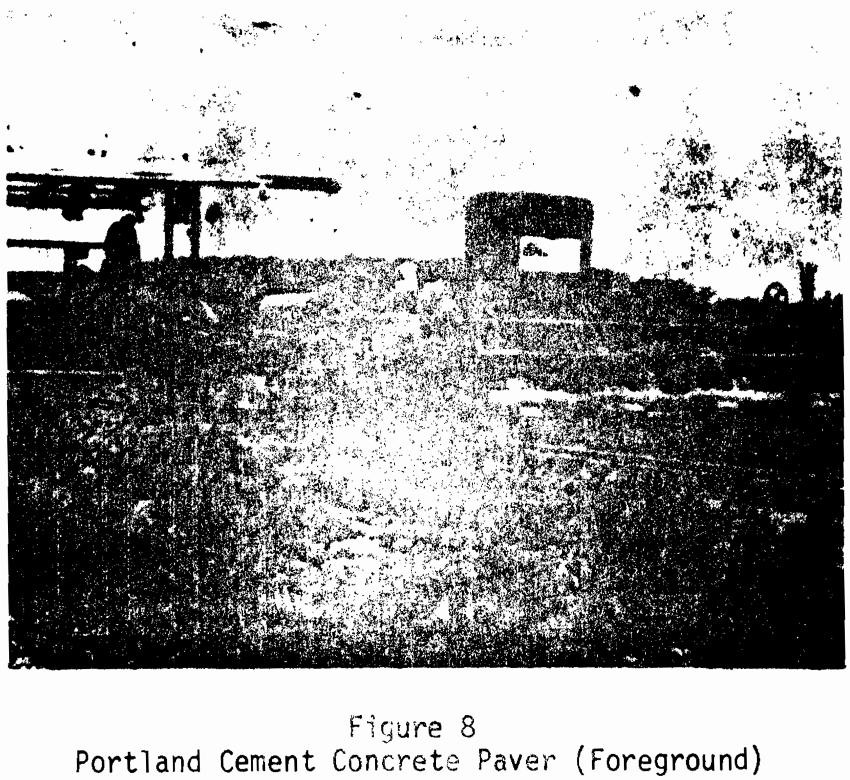

Figure 8
Portland Cement Concrete Paver (Foreground)
and Sprinkle Aggregate Spreader (Background)

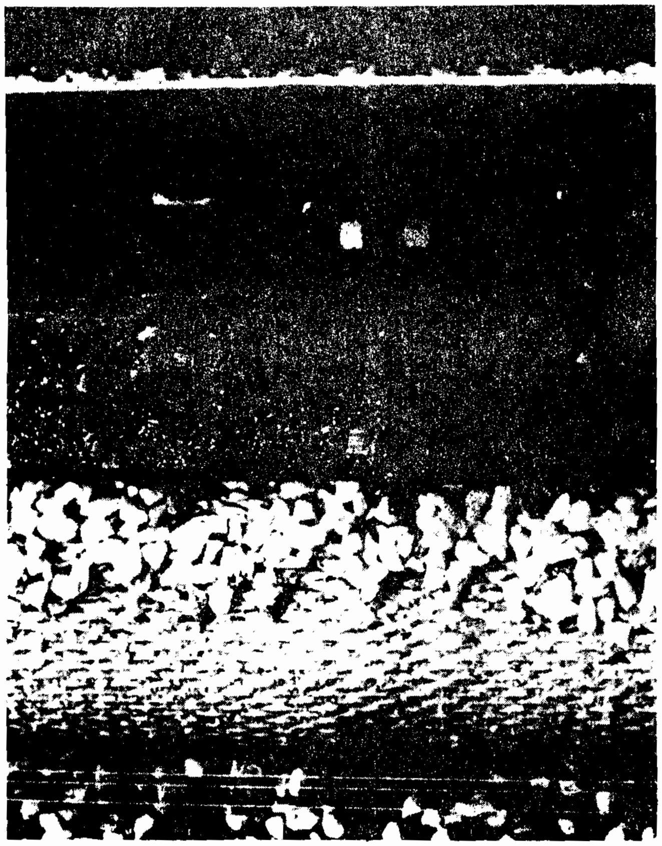

Figure 9 - Portland Cement Concrete
Sprinkle Aggregate Dispersed through Wire Grid

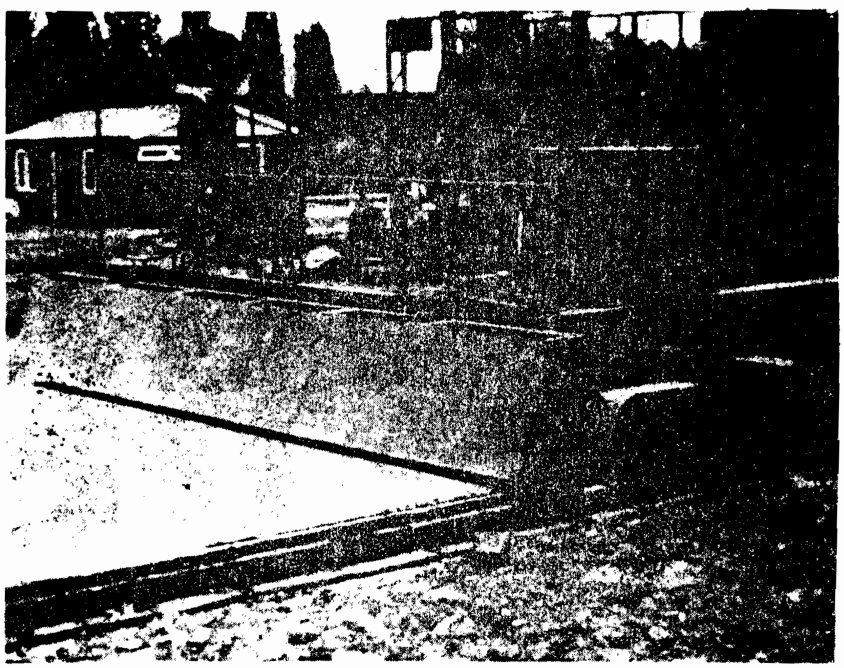

Figure 10 - Sprinkle Aggregate Spreader - Application of Curing Compound to Portland Cement Concrete in Belgium

CHAPTER V

EQUIPMENT

Application of the sprinkle aggregate to the freshly placed hot-mix surface necessitates the use of sprinkle equipment which will provide uniformity of distribution and permit application immediately after laydown while pavement temperatures are high. Successful applications have been achieved both where material has been spread by hand, using shovels, and where highly sophisticated machines which span the road surface were used.

In early efforts with sprinkle treatment construction, where specialized equipment was not available, conventional one and two spinner salt spreaders, which were attached to dump trucks, have been used with success. Two basic disadvantages of the salt spreaders, however, are their uneven rate of distribution and loss of aggregate during application. Consistency of performance between salt spreaders, even of the same type, has been difficult to achieve. These characteristics have tended to discourage their further use. Additionally, the swirled pattern of aggregate and the wheel tracks left in the pavement also detract from the appearance of the completed roadway.

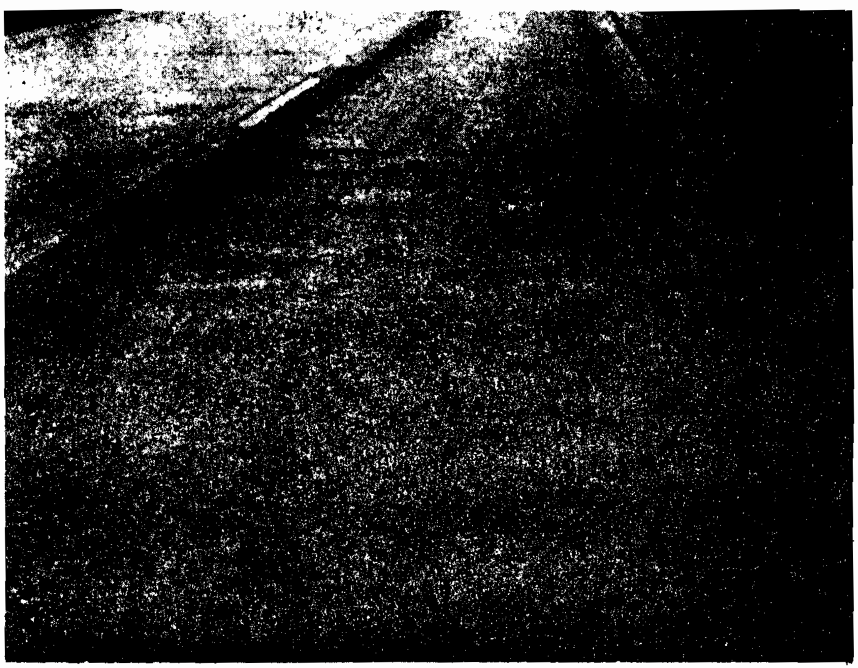

Figure 11
Salt or Sand Spreader
Swirled Distribution & Wheel Tracks

In an attempt to improve the evenness of distribution and reduce loss of aggregate, the conventional chip spreader has also been used with success. Wheel tracks in the finished pavement are again a problem with this type of spreader. Although the wheel tracks left by spreaders which travel the uncompacted mat were generally only cosmetic in nature and were largely ironed out by traffic, their undesirable appearance was a contributing factor in the development of straddle wheel spreaders.

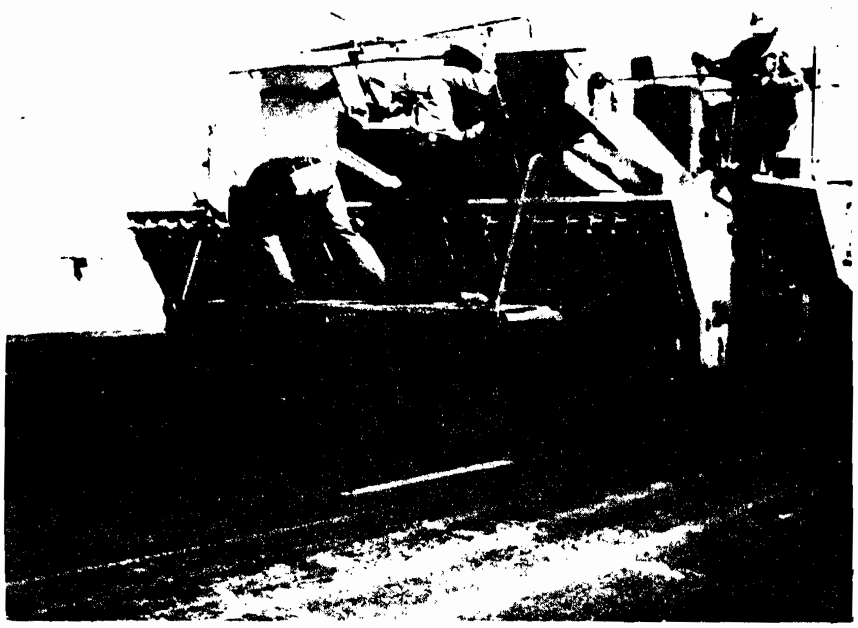

Figure 12
Coated Texas Grade 4 Lightweight Sprinkle Aggregate Applied Cold Through a Conventional Chip Spreader

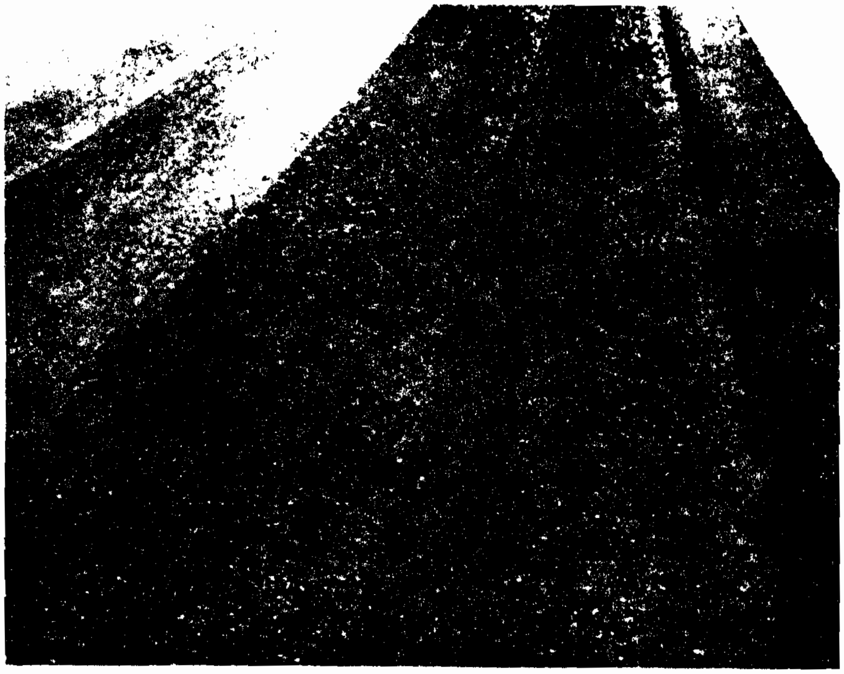

Figure 13
Wheel Tracks from Conventional
Chip Spreader Prior to Compaction Rolling

The straddle wheel spreader locates the wheels of the spreader entirely off the hot-mix mat. Several straddle spreaders have been constructed to accomplish aggregate placement. The Bristowes spreader made in Great Britain is the only known commercially available spreader for sprinkle treatment construction. This spreader has a grooved roller which assists in metering stone to the roadway. It is also equipped with a series of hammers which vibrate the spreader hopper and sprinkle aggregate to reduce crusting and sticking of the sprinkle rock in the machine.

Figure 14
Great Britain's Commercially Available Bristowes Spreader

The Virginia Department of Highways and Transportation has also produced a self-propelled spreader which has been constructed from components of an old Dodge truck.

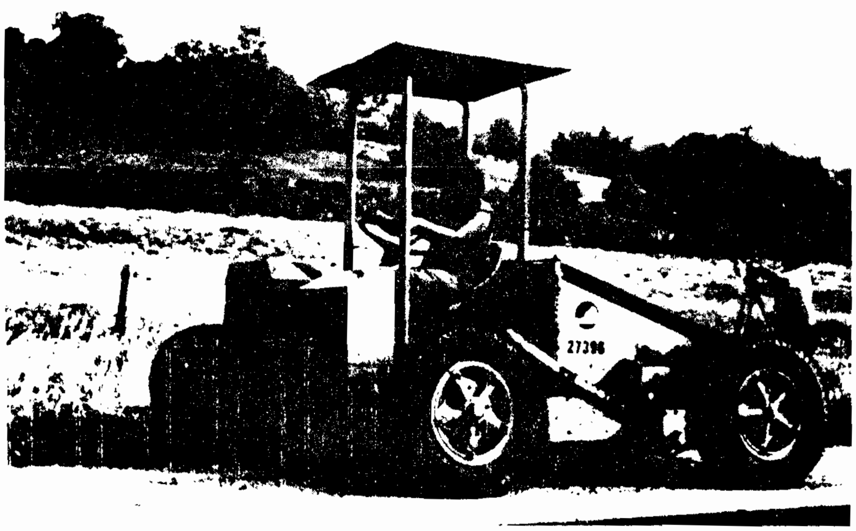

Figure 15
Virginia's Hot Sprinkle Aggregate Spreader

The roller, which meters aggregate to the road surface, is interconnected to the drive wheels of the spreader. In this manner, a constant rate of application of material to the roadway is insured whenever the spreader is in operation. Where sprinkle rock is placed hot, as it is in Virginia, aggregate spreaders must be designed so that when the hopper loads are discharged, cooled aggregate remaining in the spreader can be removed in a minimum of time. Refilling the Virginia spreader is accomplished in several steps: (1) as the contents of the hopper are depleted, the spreader is driven off the pavement onto a shoulder, (2) the remaining aggregate is removed in order to prevent crusting of the material in the machine, (3) a release agent is utilized to free the crusted aggregate, (4) when the hopper is relatively clean, it is filled with hot sprinkle aggregate from a covered dump truck which empties its contents directly into the spreader hopper.

At the beginning of the sprinkle run, the spreader operator begins sprinkling as the machine first backs over the already sprinkled surface for a distance of approximately two to three feet. Immediate commencement of the forward roll of the machine insures that all irregularities of sprinkle rock application have been eliminated by the time the machine reaches the beginning of the unsprinkled surface.

Texas has also produced a variation of a spreader which straddles the pavement surface.

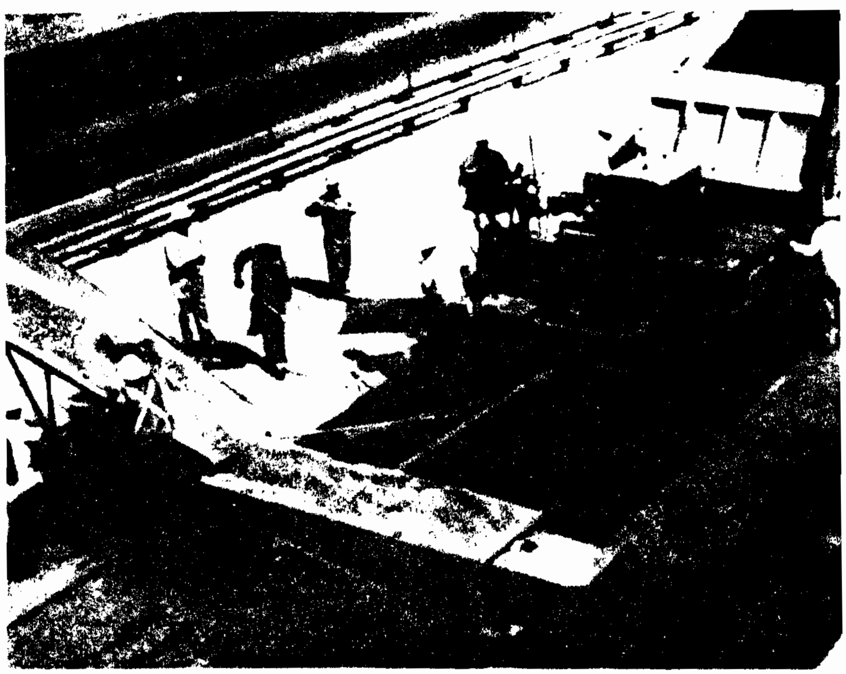

Figure 16
Texas State Department of Highways & Public Transportation
Towed Sprinkle Aggregate Spreader

Unlike the British and Virginia units which require an operator, the Texas spreader is attached directly to the laydown machine. With this spreader the operator is free from the duty of driving the spreader and can devote full attention to charging the hopper and achieving an even rate of aggregate distribution. The attachment of the spreader directly to the laydown machine also insures the application of sprinkle rock immediately after placement of asphaltic concrete pavement.

Rollers utilized for compaction of the hot-mix asphalt concrete and sprinkle aggregate are conventional steel three wheel rollers weighing not less than ten tons and tandem steel wheel rollers weighing not less than eight tons. Pneumatic tired rollers are not recommended on sprinkle treatment construction because they tend to pick up sprinkle aggregate if care is not devoted to keeping tires clean and lubricated and if the pavement mat is not sufficiently cool.

CHAPTER VI

SPECIFICATION

A sample specification to assist users in implementation of the sprinkle treatment procedure is illustrated as Exhibit II. This specification is a synthesis of the experience and findings of this research effort which embraces both users in this Country as well as Great Britain and Europe.

Specific requisities of this specification which are necessary to insure satisfactory and economical sprinkle treatment construction projects are:

1. Plant mixing of the sprinkle aggregate with a suitable asphalt

2. Use of any suitable aggregate having a minimum polish value

3. Provision for stockpiling coated aggregate to avoid coking of asphalt on the coated particles

4. Procedure for wetting the stockpile with water to cool the materials and to prevent clumping of the mixture

5. Provision for use of straddle wheel spreaders

6. Provision for either hot or cold placement of the sprinkle aggregate

EXHIBIT II

SAMPLE SPECIFICATION *

ITEM ____

SPRINKLE TREATMENT

(For Asphaltic-Concrete Pavement)

1. DESCRIPTION - This item shall consist of a special precoated aggregate applied to the surface of hot-mix asphaltic concrete pavement, immediately after laydown, for the purpose of providing a skid resistant wearing surface.

2. MATERIALS

(1) Asphalt - The asphalt used to coat the aggregate shall be AC-20 or the grade used in the asphaltic concrete pavement to be sprinkle treated and shall meet the requirements of the Item, "Asphalts, Oils and Emulsions."

(2) Aggregate - The sprinkle aggregate shall meet the requirements of the Item "Aggregate for Surface Treatments (Class A)," Grade 4 or the Item "Aggregate for Surface Treatments (Lightweight)," Grade 4 unless otherwise specified in the plans. In addition the aggregate shall have a polish value of not less than 37 when tested in accordance with Test Method TEX-438-A.

Expect as otherwise specified herein, precoating of the aggregate shall be in accordance with the requirements of the item "Aggregate for Surface Treatment" (precoated) (Class B) and except that flux oil will not be permitted. Aggregate shall be mixed at a temperature between 275° F. and 325° F. and shall have a uniform coating of asphalt in the amount of 2.5 to 8.0 percent by volume of the aggregate. The amount of coating required will be determined by the engineer as sufficient to provide a workable mix, uniformly coated to allow proper distribution of the aggregate and without excess binder drainage from the aggregate. If the asphalt coated hot sprinkle aggregate is to be stockpiled, it shall be stockpiled in depths not exceeding three feet. The coated aggregate stockpiles shall be cooled with water and/or manipulated if stockpile temperature is over 300° F. after being stockpiled for 15 minutes.

3. CONSTRUCTION METHODS - The sprinkle aggregate shall be uniformly applied with a mechanical spreader before initial rolling of the asphaltic concrete. The spreader shall be one that completely spans the lane to be spread or a self propelled aggregate spreader equipped with smooth tread tires. These types or any other type spreader approved by the engineer shall not mar nor rut the surface of the finished asphaltic concrete pavement. If the tire marks of the self propelled aggregate spreader are not removed by compaction equipment, its use shall be discontinued. The sprinkle aggregate may be spread hot or cold. Where aggregate is to be

placed hot directly from the batching operation or cold from a stockpile, the sprinkle aggregate mixture shall be maintained at temperatures sufficient to insure its workability as it is applied to the surface of the asphaltic concrete mat. Cold placement may require wetting the aggregate with water in insure workability.

The sprinkle aggregate shall be applied to the surface of the asphaltic concrete pavement as soon as possible after laydown of the pavement. The sprinkle aggregate shall be applied at a rate to insure 30% to 75% coverage of the surface area or as directed by the engineer.

Rolling shall be in accordance with the requirements of the Item, "Hot-Mix Asphaltic Concrete Pavement." Rolling shall commence immediately after application of the sprinkle aggregate unless otherwise directed by the engineer. Initial rolling shall be done with steel three wheel and steel tandem rollers. Pneumatic tire rollers will not be permitted until the mat has cooled to such a level that the sprinkle aggregate will not pick up under the tires.

Traffic will not be permitted on the finished surface until the pavement has cooled to such a level that the sprinkle aggregate will not pick up under the tires. Sprinkling the pavement surface with water may be required as directed by the engineer to promote cooling of the pavement prior to opening the roadway to traffic.

4. MEASUREMENT - Sprinkle treatment will be measured by the cubic yard of asphalt coated aggregate in vehicles as applied on the road.

5. PAYMENT - The work performed and the materials furnished as prescribed by this item and measured as provided under "measurement" will be paid for at the unit price bid for "Sprinkle Treatment", which price shall be full compensation for furnishing all materials, including asphalt to precoat the sprinkle aggregate; for all hauling, uniform placement of the precoated aggregate and for all manipulation, labor, tools, equipment and incidentals necessary to complete the work. Asphaltic concrete pavement and all rolling required shall be paid for under the Item, "Hot-Mix Asphaltic Concrete Pavement."

* NOTE: Specifications and test methods cited in this sample specification may be found in Volume II - Supplementary Information.

CHAPTER VII

DATA COLLECTION AND EVALUATION

The resultant noise and skid resistance of any roadway surface are two of the roadway characteristics that must be considered by any pavement surface designer. When a new or different surfacing technique is introduced these factors become important to everyone concerned.

In order to determine these characteristics for the relatively new concept of sprinkle treatment and to compare this type surfacing with hot-mix asphaltic concrete and penetration surfaces, tests were performed on various Texas roadways. The tests performed were noise measurement, skid and sand patch texture tests.

Detailed results of testing can be found in Exhibit III, page 33.

NOISE MEASUREMENTS AND ANALYSIS

All sound measuring and recording instrumentation used on this project was manufactured by the Gen Rad Company and consisted of a detached microphone-preamplifier, sound level meter and graphic level recorder. Each piece of equipment, and therefore the entire system, has been rated as equal to or greater than "type 2" accuracy as defined in ANSI S1.4-1971. The major components (microphone, sound level meter and graphic level recorder) were factory calibrated less than one year prior to this project. Acoustical and electronic field calibrations were performed before and after the measurements at each site.

The microphone-preamplifier was mounted on a tripod approximately 4 1/2 feet above ground level and connected to the sound level meter via a 100 foot cable. Care was exercised to insure that all sites were relatively equal in free-field and ground attenuation conditions and that no unusual reflecting surfaces or obstructions existed which might alter the sound measurements to a significant degree.

The microphone-preamplifier was located at a distance of 50 feet from the center line of the traveled lane. Markers were established at 50 feet either direction along the traveled lane from the perpendicular of the microphone location to create a site length for the vehicle test run of 100 feet. In the site layout plans, reference was made to the standard site layouts contained in: (1) "Proposed Standards for Medium and Heavy Duty Trucks", Federal Register of October 30, 1974, Volume 39, Number 210, page 38362, (2) "Interstate Motor Carrier Noise Emission Standards", Federal Register of September 12, 1975, Volume 40, Number 178, pages 42432 through 42441, (3) "Measurement of Truck Tire Noise", ASE-J57 and (4) "Guide for the Measurement of Tire-Roadway Noise on Various Friction Courses", Texas Department of Highways and Public Transportation.

One of the primary purposes in using the instrumentation chain as described above was to eliminate as much of any "human error" as possible in determining peak noise levels. By utilizing the graphic level recorder and detached microphone-preamplifier system it is possible to remove the possible human error of reading a moving needle. There is less possibility for error in reading a permanent record (the recorder's paper tape). Therefore the choice of instrumentation becomes a measurement technique.

A vehicle was chosen for its availability and tire pattern from those in the Department's pool. Since no attempt was to be made to isolate the tire-roadway noise itself because of impracticability, consistency was made the goal and relative noise levels became the result. The same vehicle was used throughout the tests. Its tire tread pattern can best be described as "standard ribbed."

The original plan called for two vehicle pass-bys in each direction, a total of four runs per speed per site. But very early in the trial runs it became evident that any more than two runs served no useful purpose so long as the difference in noise level between the first two runs in the same direction did not exceed one dB(A). It is interesting to note that no runs had to be voided or repeated because of a noise level difference in excess of one dB(A). Funds and time were not available for the construction of special test tracks; therefore, sites had to be chosen along in-use facilities. Fortunately, sufficient facilities were available in areas of low vehicular volumes which allowed the data to be acquired when no other traffic except the test vehicle was within the range of the microphone. Under these conditions the peak noise level of each run was evidenced by the recorder's trace, and the influence of undesirable or unrelated noise was readily noticed.

As indicated by Exhibit III, a total of 31 sites were investigated. Ten of these sites involved sprinkle treatment, 10 sites involved seal-coat treatment, and 11 sites involved hot-mix treatment. A total of 189 individual measurements was recorded.

The following information compares the dB(A) range and average peak noise levels on the three types of surface treatments. The number in parentheses indicates vehicle pass-bys.

RANGE OF PEAK NOISE LEVELS
IN dB(A)

Speed (MPH)	40	50	60
Sprinkle	63-71 (21)	66-75 (21)	69-78 (21)
Hot-Mix	65-70 (22)	67-75 (22)	70-77 (22)
Seal Coat	65-73 (20)	68-76 (20)	71-78 (20)

AVERAGE OF PEAK NOISE LEVELS
IN dB(A)

Speed (MPH)	40	50	60
Sprinkle	68	72	75
Hot-Mix	68	71	74
Seal Coat	69	72	76

From an analysis of the above, it is apparent that no significant differences in the noise levels of a single vehicle pass-by exist for the three types of surface treatments. The range of values, as well as the averages, indicates no pattern which would support any other conclusion. On the contrary, the surprising consistency of the data recorded tends to dispute earlier concerns that one type of friction course produced more or less noise than another type of asphaltic surface. Certainly there would be no difference in the noise levels as far as the human ear can detect. The predictable variation in levels experienced in any one of the surface types (almost $\pm$ 5 dB(A)) would indicate that if a difference in noise levels did exist, that difference would have to be on the order of a 100% increase or decrease in intensity to be perceptable to the human ear.

Other studies in this Country and in Europe support this conclusion. The Transport and Road Research Laboratory of the Department of the Environment in England conducted tests which indicated a range of only 3 dB(A) for texture depths from 0.1 mm to 3.0 mm on "Rolled Asphalt, Asphaltic Concrete, Surface Dressing and Open Textured Macadam" pavement. (Reference 1 - Volume II)

SKID TESTS AND ANALYSIS

Skid testing was performed at the previously mentioned test sites with care being taken to perform each skid test as closely as possible between the markers established in the noise measurement portion. All tests were taken by a totally automated skid measurement system which conforms to the standards set forth in ASTM E-274. The test tire was the standard skid test tire conforming to ASTM E-501. The skid measurement system had been calibrated and correlated less than one year earlier at the Federal Highway Administration sponsored Central Field Test Center located at The Texas Transportation Institute. Daily on-roadway calibrations were performed by equipment operators along with calibration checks performed before and after data collection on each test section.

Initial skid testing was performed at each site to clean the pavement, thereby allowing skid readings to "level out" prior to any testing for record. This initial testing was performed to statistically reduce the pavement variance. The technique had been emphasized by Field Test Center personnel in an attempt to aid in the determination of skid measurement system variance.

Upon completion of this "level out" testing, five skid tests were performed in the test site at each test speed of 40, 50 and 60 miles per hour. These test speeds were chosen to achieve an expected operating range over which to calculate speed gradients.

RANGE (SN)

Speed (MPH)	40	50	60
Sprinkle Treatment	*25-57	*24-52	*22-47
Hot-Mix	20-51	19-49	18-44
Seal Coat	37-61	32-60	29-58

* The low values were obtained on a sprinkle treatment section which was placed with non-precoated aggregate. This aggregate had, to a large extent, been whipped off by traffic.

AVERAGE (SN)

Speed (MPH)	40	50	60
Sprinkle Treatment	*39	37	33
Hot-Mix	33	31	28
Seal Coat	48	45	43

* Two sections of sprinkle treatment contained non-precoated aggregate. Without the two sections included, the 40 mph average skid number is raised to a 42.

Prediction of skid numbers at any speed has become an item of major importance to highway engineers. This prediction has most frequently been accomplished by the calculation of skid speed gradients; i.e., the change in skid number per mile per hour speed change.

$$\text{Speed Gradient} = \frac{SN_{40} - SN_{60}}{20 \text{ mph}}$$

SPEED GRADIENTS SN/MPH

Surface Type	Min.	Avg.	Max.
Sprinkle Treatment	0.10	0.32	0.60
Hot-Mix	0.05	0.27	0.50
Seal Coat	0.00	0.22	0.55

Little analysis can be performed on the above skid speed gradients unless the 40 mph skid number is known in advance. Also, the location of the 40 mph skid test on the skid or y-axis affects the speed gradient; i.e., the lower the 40 mph test, the flatter the gradient must be.

In an attempt to remove this inherent problem with speed gradients, a "percentage speed gradient" has been calculated using the data collected in Texas. This will allow the calculation of skid numbers at any speed without calculating a negative skid number at the higher speeds.

$$\text{Percentage Speed Gradient} = \frac{SN_{40} - SN_{60}}{SN_{40}} \times 100$$

This calculation gives the percentage change in skid numbers over the speed range of 40 to 60 mph. From this figure skid numbers at any speed can then be calculated.

PERCENT SPEED GRADIENTS (%)

Surface Type	Min.	Avg.	Max.
Sprinkle Treatment	4.8	16.4	23.1
Hot-Mix	5.0	16.0	24.0
Seal Coats	0.0	9.2	19.0

As shown earlier, sprinkle treatment surfaces exhibit 5 to 6 skid numbers increase over hot-mix control sections. These average percent speed gradients then show that skid numbers of sprinkle treatment surfaces remain higher than those of their hot-mix counterparts at any speed.

TEXTURE TESTS AND ANALYSIS

Sand patch texture readings were taken at two locations in each test section according to the test methods shown in Appendix B - Volume II. These two texture readings were then averaged and the average value used as the texture reading for that section.

Surface Type	Texture Range(in./in.)
Sprinkle Treatment	0.0205 ---- 0.0540
Hot-Mix	0.010 ---- 0.040
Seal Coats	0.0380 ---- 0.1240

Surface Type	Average Texture (in./in.)
Sprinkle Treatment	0.0366
Hot-Mix	0.0256
Seal Coats	0.0735

The average increase in texture of sprinkle treatment surfaces over hot-mix surfaces, as shown above, contribute to the increase in skid numbers. This macrotexture is a major contributor, but the microtexture of the sprinkle treatment aggregate is also a major contributor to increased skid resistance.

SUMMARY OF TEST ANALYSIS

1. Sprinkle treatments do not adversely affect the noise produced by vehicle pass-by.

2. Sprinkle treatments do exhibit higher skid numbers than their hot-mix counterparts.

3. Sprinkle treatments have more macrotexture than normal hot-mix, therefore increasing the hysteresis contribution to skid resistance.

EXHIBIT III

Sprinkle Treatment & Control
Texture, Skid Numbers & Noise Measurements

TEST SECTION	Text. #1	Text. #2	Avg. Text.	SN_{40}	SN_{50}	SN_{60}	NOISE MEASUREMENTS 40mph	50mph	60mph
Jarrell (Sprinkle)	.022	.021	.0215	52	46	40	63, 63, 64	66, 67, 68	70, 69, 69
Jarrell (HMAC)	.032	.032	.032	44	40	36	66, 65	68, 67	70, 70
IH-35 (Lightweight Seal)	.038	.038	.038	61	60	59	72, 73	75, 75	78, 77
IH-35 @ 19th (Sprinkle)	.051	.057	.054	57	52	47	70, 70	75, 74	76, 77
IH-35 @ 19th (Lightweight HMAC)	.025	.021	.023	51	49	44	68, 69	72, 72	74, 74
IH-35 @ Dilley, Outside Lane (Seal Coat)(Slightly Flushed)	.063	.065	.064	40	34	31	69, 70	72, 73	76, 76
IH-35 @ Dilley, Inside Lane (Seal Coat)	.161	.086	.124	52	51	52	70, 71	75, 76	77, 78
FM 140 Pearsall #1 Eastbound (Seal)	.094	.094	.094	57	51	50	70, 70	74, 73	77, 77
FM 140 Pearsall #2 Westbound (Seal)	.063	.059	.061	58	53	47	67, 66	71, 71	74, 74
US-90 Hondo (Sprinkle)	.035	.035	.035	37	35	32	68, 69	73, 73	76, 76
US-281 Pleasanton (Sprinkle)	.051	.045	.048	33	27	26	70, 71	74, 74	78, 78
US-281 Campbelton (HMAC)	.030	.030	.030	36	33	30	69, 70	74, 73	77, 77
IH-35 South of San Antonio (Seal)	.057	.071	.064	42	42	42	65, 65	69, 69	71, 72
IH-35 Devine (HMAC)	.040	.040	.040	28	25	24	68, 68	73, 73	75, 74
IH-35 Lytle (HMAC)	.026	.021	.0235	27	25	23	67, 66	70, 70	72, 72
IH-35 San Antonio (HMAC)	.034	.026	.0305	25	22	20	67, 67	70, 70	73, 73
US-181 Floresville (HMAC)	.026	.021	.0235	31	28	25	68, 68	72, 71	74, 73
FM 1516 Martinez (Seal)	.039	.050	.0445	42	37	35	66, 65	68, 69	73, 72
FM 2696 #1 San Antonio (Seal)	.074	.077	.0755	51	43	43	67, 68	73, 72	78, 78
FM 2696 #2 San Antonio (Seal)	.094	.098	.096	46	45	45	69, 69	72, 72	75, 76
FM 1604, Eastbound #1 (HMAC)	.019	.015	.017	32	29	28	67, 66	71, 70	73, 73
FM 1604, Eastbound #2 (Sprinkle)	.044	.050	.048	42	41	40	70, 69	74, 74	76, 75
FM 1604, Eastbound #3 (Sprinkle)	.032	.034	.033	39	38	35	68, 68	72, 71	74, 75
FM 1604, Westbound #1 (Sprinkle)	.036	.031	.0335	44	42	40	68, 68	71, 71	74, 74
FM 1604, Westbound #2 (Blended HMAC)	.019	.022	.0205	42	36	32	68, 69	71, 72	74, 75
FM 1604, Westbound #3 (HMAC)	.009	.011	.010	35	31	25	67, 68	71, 70	73, 72
IH-10 #1, Gevers St. (Sprinkle)	.031	.032	.0315	29	27	27	69, 69	72, 72	76, 75
IH-10 #2, Roland Ave.(Sprinkle)	.024	.017	.0205	27	24	22	67, 68	72, 71	74, 74
SH 14 Mexia (Sprinkle)	.035	.050	.0425	31	28	27	70, 70	74, 74	76, 76
SH 14 Mexia (HMAC)	.029	.033	.031	20	19	19	71, 70	74, 75	77, 77
SH 320 Lott (Seal)	.068	.077	.0725	37	32	30	71, 70	74, 74	76, 76

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

Investigation of sprinkle treatment in this Country, Great Britain and Europe has indicated this procedure to be one which can be expected to consistently produce tangible benefits in improved skid resistant properties for road surfaces. Where non-polishing aggregates are in short supply and costly, the sprinkle treatment procedure offers the opportunity to economically construct a pavement with no reduction in driver safety.

Any comparative economic assessment of this procedure should consider both the qualitative improvement to the roadway and the associated quantitative costs needed to attain this level of performance. Since quantitative values will be affected by geographical location, their evaluation should consider the following factors:

1. availability of polish resistant aggregate
2. quantity requirements
3. haul distances
4. additional labor, experience, and equipment required

Where successful sprinkle aggregate retention has been achieved utilizing the procedures detailed in this study, significant improvement to skid resistance has occurred. Improved texture may also be expected with sprinkle treatments to provide an added benefit of permitting passageways to reduce water buildup as well as increased mechanical contact between tire and pavement. Measurement of vehicle-pavement noise production on sprinkle treatment surfaces compared to control hot-mix asphaltic concrete and seal coats indicates that the variation is of no statistical significance.

Through this investigation which has surveyed the current practices in the United States, Great Britain and Europe, confirmation of the efficacy of this construction procedure is indisputable. Accommodation to the sprinkle treatment operation in a hot-mix asphaltic concrete pavement construction can be accomplished with little difficulty. A simplified introduction to the sprinkle treatment procedure is anticipated through the use of a 15-minute sound 16 mm motion picture and 20-minute slide/tape presentation. This documentation was produced to provide viewers with general and specific concepts involved in the operation and can be secured on a loan basis from the FHWA, DOT, Washington, D.C. A formalized course of training for personnel to accommodate to the procedures of this operation is recommended to enable development of the necessary skills and confidence. In Appendix E - Volume II, a training course outline developed by the State of Virginia provides an excellent means for developing a systematic and effective instructional program.

Through the use of these media (motion picture, slide/tape and the training school) and a thorough study of the detailed investigations from Great Britain, Belgium and Virginia (Appendix A - Volume II), successful sprinkle treatment projects may be expected. The sample specification (Exhibit II) represents a synthesis of the findings of this study and should permit immediate implementation of the sprinkle treatment operation to asphaltic concrete pavement construction. Essential aspects of this study which are embraced in the sample specification are:

1. Sprinkle aggregate can be effectively placed hot or cold. Hot placement should be accomplished with the sprinkle aggregate at a temperature between 270° F. to 300° F. Cold placement involves material which has been previously stockpiled. A recommended temperature for the aggregate for cold placement is below 90° F. These temperature limitations should be closely observed since difficulty in securing an even rate of spread may be encountered due to balling of the mix.

2. Effective aggregate spreading equipment design is available for both hot and cold placement of the sprinkle aggregate. Conventional chip spreaders with the smooth tires are acceptable. Although slight wheel tracks are frequently left by spreaders which travel on the uncompacted mat, no objectionable pavement performance has been encountered as these blemishes are only cosmetic in nature and are largely ironed out under traffic. However, spreaders which straddle the pavement are recommended for optimum operation. Both the Bristowes self-propelled spreader and the Texas towed spreaders have proved effective in the application of cold sprinkle aggregate. Virginia's self-propelled spreader has also achieved success with hot sprinkle aggregate placement. The overall simplicity of the straddle spreaders and their minimal cost virtually insures their availability if specifications require their use on construction projects.

3. Sprinkle mix aggregate should be coated with sufficient asphalt to aid in sticking the aggregate in the mat. A variety of asphaltic materials may be used for this purpose ranging from asphalt cements, emulsions and cutbacks. To insure optimum aggregate coating,plant precoating is recommended. An AC-20 has been used on numerous occasions for plant precoating and is recommended for general use. The desired range in residual asphalt is 2.5% to 8% by volume and 1.7% to 3.1% by weight depending on the aggregate's specific gravity and absorption characteristics.

4. Stockpiling of coated aggregate at elevated temperatures can result in coking of the asphalt on the aggregate particles. Once coking occurs, sticking of the aggregate to the hot-mix mat is impaired. Therefore, when sprinkle aggregate is plant precoated, it should not be stockpiled in depths greater than 2½ to 3 feet, nor at temperatures in excess of 300° F.

5. As stockpiles are constructed, temperature of the stockpile within the acceptable limits can be achieved by wetting the stockpile with water. Occasional wetting of the stockpiles at the job site may also prove beneficial in preventing balling of the material and sticking in the spreader.

6. Rolling should be accomplished with steel wheel rollers to attain usual asphaltic concrete density. Nuclear density measurements are unaffected by the sprinkle treatment application and are used by Virginia to verify pavement densities. Rubber tire rollers are not recommended for compaction unless the mat has cooled sufficiently to prevent aggregate pullout by the tires. Where the pavement is opened to traffic while pick up conditions are prevalent, wetting of the finished mat with water to promote cooling may also be required.

7. The contractor should have the option of selecting either hot or cold placement of the sprinkle aggregate. Job control may be achieved with specifications which will allow adequate inspection, require polish resistant aggregate, provide for acceptable rates of asphalt coating for the sprinkle aggregate material, and establish a minimum application rate for sprinkle aggregate of one cubic yard per 450 square yards of pavement surface. The optimum rate of application for sprinkle material in Great Britain and Europe is to cover approximately 75% of the surface area which would be an application rate of one cubic yard per 250 to 300 square yards of pavement surface for 3/4" or 1/2" aggregate respectively. To accommodate the greater application rates and larger sizes of sprinkle aggregate, it may be necessary to reduce the plus 10 aggregate fraction of the asphaltic concrete pavement to 35%-40%.

Sprinkle treatment for Portland cement concrete, although utilized on all roadways in Belgium, requires a further long term evaluation to assess its benefits over conventional PCC texturing techniques. Wear to most concrete pavements in this Country rarely progresses to the point where coarse aggregate is exposed to tire contact. Skid resistant properties of the coarse aggregate utilized are therefore not usually a factor in the successful performance of the pavement as compared to the aggregate of an asphaltic concrete. With the development and use of transverse texturing equipment and attention to fine aggregate quality, suitable frictional resistances can be obtained at minimal costs. The costs and specialized PCC sprinkle equipment (which presently can only be utilized with formed pavements) are additional factors which need to be considered in the overall assessment of this procedure.

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