ENGINEERING ECONOMY AND ENERGY CONSIDERATIONS

SPRINKLE TREATMENT - HOW, WHY AND WHERE

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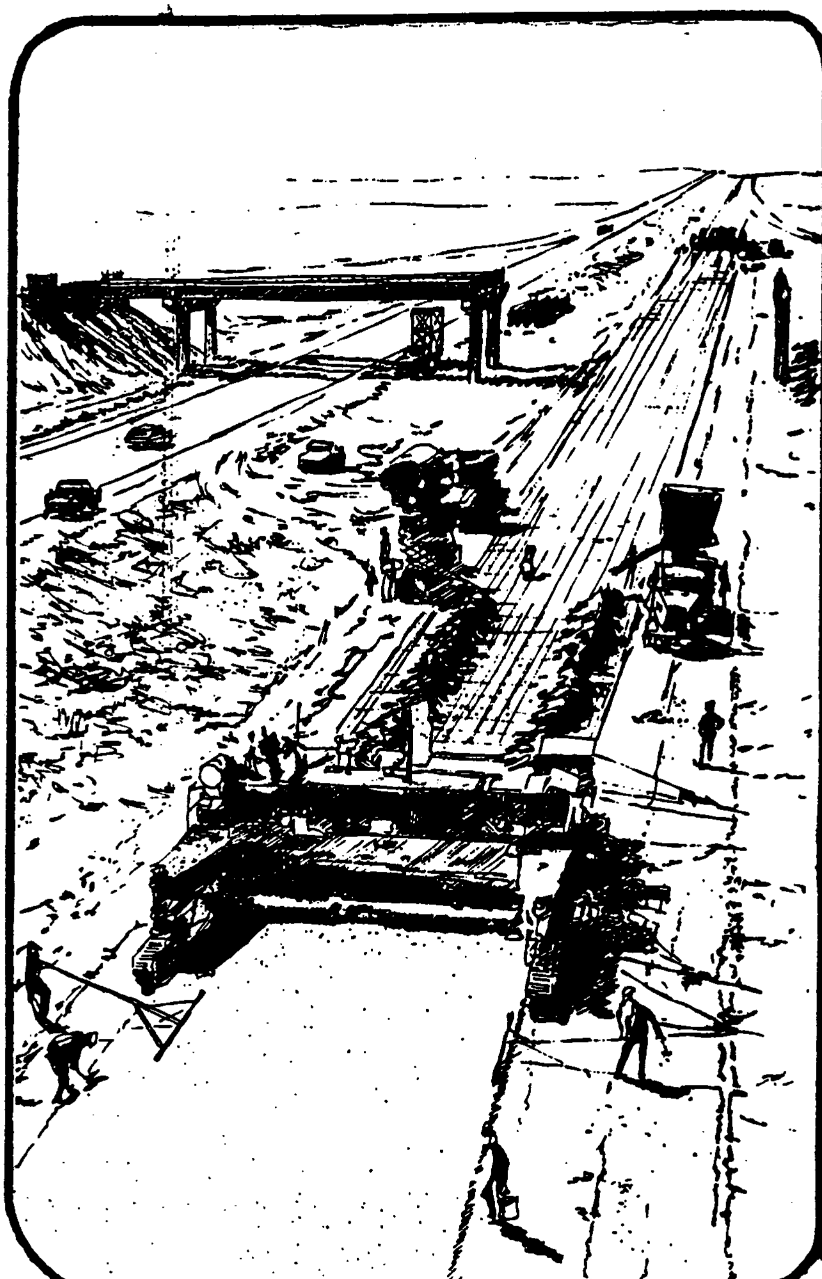

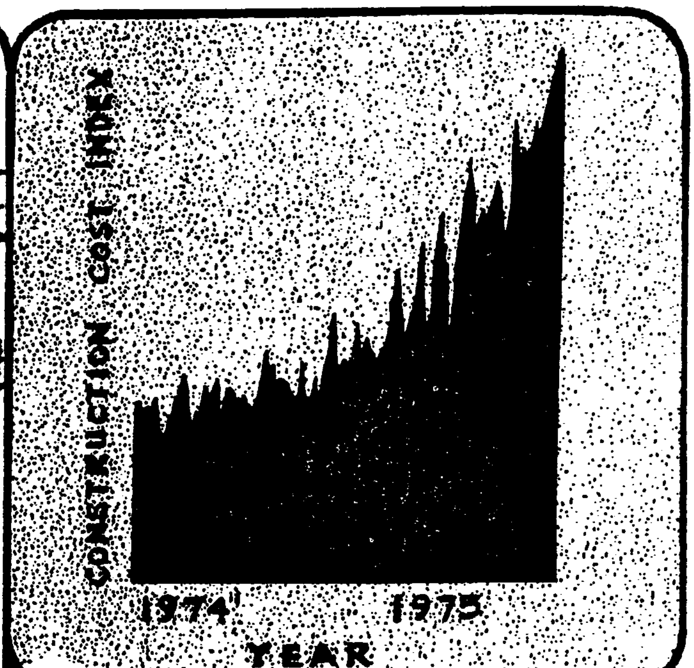

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"ENGINEERING, ECONOMY AND ENERGY CONSIDERATIONS IN DESIGN, CONSTRUCTION AND MATERIALS"

TEXAS STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

AND

TEXAS TRANSPORTATION INSTITUTE
TEXAS A&M UNIVERSITY

SPRINKLE TREATMENT - HOW, WHY AND WHERE

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Introduction

The highway engineer must provide among other things a pavement surface that will have a high initial coefficient of friction as well as a surface that will maintain a satisfactory level of friction throughout its design life. Research has identified materials that will provide acceptable friction. Seal coats, dense graded asphalt concrete, open graded asphalt concrete mixtures, sprinkle treatment and other mixtures made with polish resistant aggregate are presently utilized as surface courses to provide road surfaces with the desired skid resistance. This report will be concerned with only one of the treatments to provide skid resistance--sprinkle treatment.

Sprinkle treatment involves the application of a precoated, non-polishing aggregate to the surface of newly placed asphalt concrete pavement prior to initial rolling. The purpose of this construction technique is to provide the desired level of friction with a minimum amount of non-polishing aggregate. By utilizing this construction process, polishing aggregates, which are often purchased at a low price, may be used for the asphalt concrete mixture and the non-polishing aggregates, which are often purchased at an elevated price, can be utilized as sprinkle aggregate. A cost savings will result with the use of sprinkle treatments in many areas of Texas due to the limited availability of non-polishing aggregates. Examples of cost analysis are covered in the report together with a suggested specification.

History of Sprinkle Treatment

The process of spreading material onto a pavement to provide high skid resistance is not new and has been used on both bituminous and Portland cement concrete pavements. The British have utilized the sprinkle treatment concept on bituminous pavement for over 10 years (1, 2). Virginia efforts with sprinkle treatment dates to 1968 and continues to the present (3, 4, and 5). Experimental sections were first placed in Texas in 1972 (6). Additional experimental sections have been placed in Texas in 1975 (7, 8, 9, 10 and 11). A review of the use of sprinkle treatment in Virginia and Texas is presented below. This information has served as background information for the development of the suggested specifications for sprinkle treatment contained in Appendix A. A limited bibliography is contained in Appendix B for those interested in pursuing the subject in greater depth. The Appendix is arranged to correspond to the reference numbering system utilized in the report.

Virginia Experience

The first sections were placed in Virigina in 1968 on an experimental basis. In 1969, more experimental work was conducted by Virginia personnel. In 1970, three jobs were performed by contract forces. Since 1970, sprinkle treatment has become a popular method of providing skid resistant surfaces in areas where polish resistant aggregates are in short supply. Over 100 miles of pavements have been sprinkle treated since 1968.

1968 Experience Following a limited laboratory program to determine a suitable aggregate precoating material, Virginia place approximately 1.2 miles of sprinkle treatment in August of 1968. This experimental section contained seven different types of sprinkle aggregate; granite, crushed gravel, concrete sand, slag, slag sand, lightweight aggregate and fine lightweight aggregate. All aggregates were coated with MC-70 and broadcast with a spin type spreader normally normally used to apply deicing chemicals. The spreaders backed along the pavement immediately behind the laydown machine to broadcast the aggregate at a rate of from 2.2 to 5.2 pound per square yard depending upon the size and gradation of the sprinkle aggregate. Adequate skid resistance has been maintained on this facility which carries 1500 vehicles per day on two lanes.

Additional limited investigation prior to the experiment indicated that a tailgate spreader did not give a uniform spread at the low aggregate spread rate required in the sprinkle treatment method. Laboratory tests utilizing visual observation indicated that MC-70 was a preferred precoating material as opposed to RC-250 and MC-250.

1969 Experience In September 1969, slag sand and 3/8-inch slag were used in a sprinkle mix adjacent to the 1968 test sections. Seven percent MC-70 was mixed with the slag sand and 4 percent MC-70 was used with the 3/8-inch slag. The MC-70 was mixed with the aggregate approximately 3 months prior to the aggregate being utilized. Spin type spreaders and steel wheel compaction were employed on the job.

The asphalt concrete utilized on the 1968 experimental section was somewhat coarser than that used on the 1969 experimental section. The sprinkle mix particles appeared to be more firmly embedded in the finer asphalt concrete mixtures utilized in the 1969 project. Adequate skid resistance has been maintained on the facility.

1970 Experience The three projects placed in 1970 were placed by contract forces. MC-70 was utilized to precoat the aggregate on all jobs except for one truck load where an 85-100 penetration asphalt cement was employed to precoat the stone. The precoated aggregate was applied hot and appeared to adhere better than the MC-70 precoated stones.

On one job, an uneven distribution of the sprinkle material was obtained. The spreader selected by the contractors for use on this job was a farm-type lime spreader. The spreader mechanism operated from a power take off, which provided poor rate control. The width of spread was poorly regulated due to lack of central fins around the whirly blade.

A section placed in 1970 on Interstate 81 which carries 8400 vehicles per day on four lanes has retained an adequate skid number to date. A lightweight aggregate was utilized on this section.

Experience since 1970 Sprinkle treatment has been used on several jobs since 1970. Experiments utilizing cationic emulsion and AC-20 asphalt cement as aggregate precoat materials have resulted in the elimination of medium curing cutbacks as precoating materials. AC-20 asphalt cement is the only precoat material that is currently specified by Virginia. A test method has not been established to determine the design precoat material quantity; however, quantities in the range of 1 to 3 percent by weight are commonly specified.

The asphalt concrete mixtures specified for use with sprinkle treatment has a maximum size of one-half inch and is similar to the Texas, Item 340, Type D asphaltic concrete mixture. Improved sprinkle aggregate retention has been achieved with the use of the finer asphalt concrete mixture. This confirms British findings of several years ago.

Aggregate distribution equipment is not specified in detail. Spin type spreaders, self-propelled chip spreaders, and specially manufactured self-propelled, straddle spreaders have been used. Probably the most satisfactory results have been gained with the straddle spreader (Figure 1). Uniform distribution of the sprinkle aggregate can be obtained and since the tires are

FIGURE 1: SELF PROPELLED STRADDLE SPREADER

FIGURE 2: DETERMINATION OF AGGREGATE SPREAD QUANTITIES

FIGURE 3: DETERMINATION OF AGGREGATE SPREAD QUANTITIES

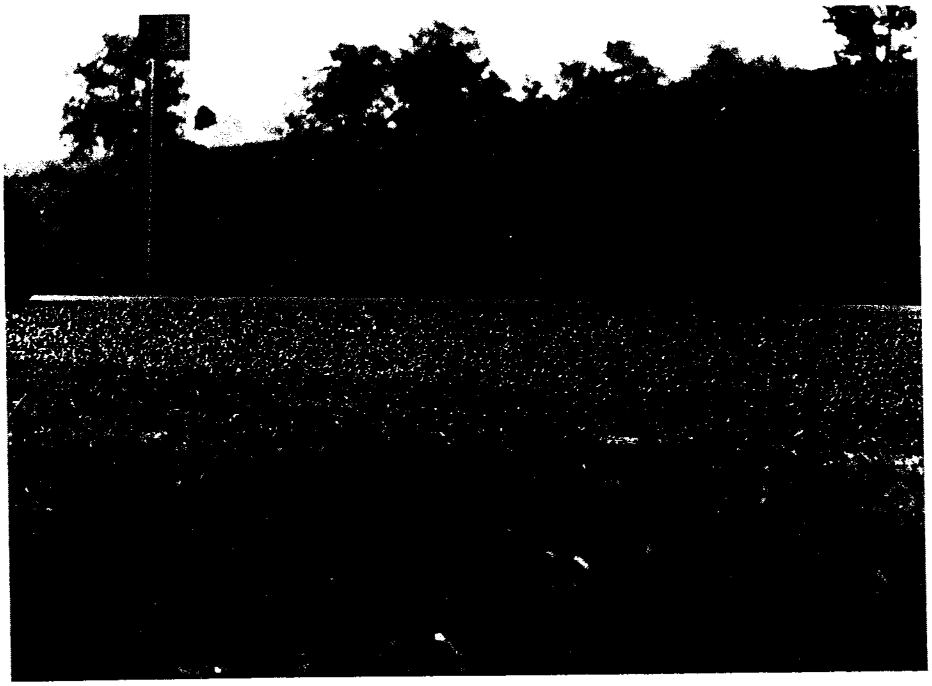

FIGURE 4: AGGREGATE SPREAD RATE OF 5 POUNDS PER SQUARE YARD (ABOUT 1 CUBIC YARD TO 400 SQUARE YARDS)

not on the hot asphalt concrete mat, the surface is not marred. Self-propelled chip spreaders give satisfactory results provided tires without treads are utilized and the spreader does not rest in one place on the mat for an extended period of time. Spin type spreaders give adequate distribution but sprinkle stone waste is increased and a somewhat non-uniform surface appearance is created.

The quantity of the aggregate placed on the surface is determined by placing a two square yard canvas on the asphalt concrete prior to sprinkle stone distribution (Figure 2). The quantity spread on the canvas is determined by weight (Figure 3). Typically, 3 to 5 pounds per square yard is required for lightweight aggregate and 5 to 7 pounds per square yard for normal weight aggregate (Figure 4). A laboratory test is not utilized to determine spread quantities. The maximum size of the sprinkle stone utilized by Virginia is 3/4 inch with 90 to 100 percent passing on the 1/2-inch sieve, 40 to 80 percent passing the 3/8 inch sieve and a maximum of 20, 8 and 3 percent passing on the NO. 4, 8, and 16 mesh sieves respectively.

The compacting process and the seating of the sprinkle aggregate into the hot asphalt concrete mat can be best accomplished by use of a 10 to 12 ton, three wheel steel roller followed by a tandem 10-ton wheel roller. Pneumatic rolling was avoided as it dislodged the sprinkle stone.

Experience gained in Virginia suggest that the sprinkle stone precoated with AC-20 asphalt cement must be placed hot to achieve even distribution and proper adherence to the asphalt concrete mat. Ideally the sprinkle stone should be applied at a temperature of about 275 to 300^{o}F and about 1 to 5 minutes behind the laydown machine.

Sprinkle treatment can be placed under environmental conditions which allow the placement of asphalt concrete. Virginia has developed a weather and seasonal limitations specification for the placement of asphalt concrete. The limitations are based on laydown temperatures, mat thickness, base temperatures and number of breakdown rollers.

Payment for sprinkle treatment in Virginia is based on an optional bid concept. The contractor is allowed to provide the state either an asphalt concrete with an acceptable non-polishing aggregate or an asphalt concrete that may contain a polishing aggregate together with a non-polishing aggregate sprinkle treatment. Only one item appears on the bid sheet and it is at the contractor's option to supply an acceptable surface. Payment is based on tons of asphalt concrete in place. The sprinkle aggregate is not paid for separately.

Prices for the sprinkle treatment operation are approximately $20 per ton while prices for asphalt concrete without sprinkle treatment are typically $18 per ton. In-place costs to the contractor for asphalt concrete are approximately $11 to $12 per ton. In-place costs to the contractor for a precoated sprinkle aggregate are typically $11 to $12 per ton. For one inch mats, the contractor costs for sprinkle treated asphalt concrete mixtures in-place are about $13 to $14 per ton of hot mix placed.

Sprinkle treatment is expected to be utilized in Virginia as economics dictate. Sprinkle treatments have been successfully placed on 4-lane Interstate facilities carrying 14,000 vehicles per day. Non-polishing aggregates, which are specified by source, are required on all highways carrying in excess of about 500 vehicles per day per lane.

Texas Experience

District 9 Texas experience with sprinkle treatment began in 1972 when District 9 (Waco) placed a 0.9 mile section on State Highway 14 north of Mexia (6).

A Grade 4 synthetic aggregate precoated with emulsified asphalt (EA-11M) was utilized and spread with a twin type turntable and spreader at a rate of 2.5 pounds per square yard. A vibratory steel roller was utilized to seat the sprinkle stone and compact the asphalt concrete. The added cost for the sprinkle treatment of this section was approximately 4 1/3 cents per square yard. A summary of skid numbers for the control and sprinkle section are shown in Table 1. The control section is asphalt concrete made with a siliceous river gravel. The skid numbers for the sprinkle treated section are about 38 while the control section has a value of 24 after being open to traffic for 38 months.

A second experimental section has been placed in District 9 on Loop 363 in Temple. Satisfactory results have been obtained to date.

<u>District 15</u> District 15 (San Antonio) placed their first sprinkle treatment experimental sections in January 1975 (7). Various types of precoating materials, amounts of precoating material, types of aggregate, aggregate spread quantities and aggregate spreading and compaction equipment have been investigated to date (7, 8, and 11). Lightweight limestone rock asphalt and sandstone sprinkle aggregate has been utilized. Precoating materials have included an AC-10 asphalt cement and No. 6 precoat oil. Those sprinkle aggregates precoated with AC-10 asphalt cement were applied both hot (after mixing) and cold (after stockpiling). Quantities of precoat binder materials have ranged from 3.2 to 5.0 percent by dry weight of aggregate. Some aggregates were placed without precoating material. Aggregate spread rates have varied from 1:337 (1 cubic yard to cover 337 square yards of road surface) to 1:515. Compaction with steel wheel vibrating rollers, three wheel steel rollers and pneumatic rollers has been utilized. Aggregate has been spread by a specially designed sprinkle treatment spreader (11), a "whirley bird" spreader and a Flaherty

TABLE 1: Skid Numbers for Expermental Sprinkle Section Placed on State Highway 14 in District 9.

Date of Skid Measurement	Months after Construction	Skid Number at 40 mph*	
		Control Section	Sprinkle Section
Sept. 1972	2	37	52
July 1973	12	32	46
April 1974	22	26	42
July 1974	24	30	44
Sept. 1975	38	24	38

*measured with a locked wheel skid trailer

TABLE 2: Skid Numbers for Experimental Sprinkle Sections Placed in District 5

Date of Skid Measurements	Months after Construction	Skid Number at 40 mph*		
		Control Section	Sprinkle** Section No. 1	Sprinkle Section No. 2
April 1975	2	32	32	33
May 1975	3	38	39	40
Aug. 1975	6	33	40	42

*measured with a locked wheel skid trailer
** Sprinkle section number 1 has a sprinkle aggregate spread rate of 1:600 and section number 2 a rate of 1:475.

self-propelled aggregate spreader.

Results of the tests sections in District 15 indicated the following:

1. The preferred precoat material is an AC-10 asphalt cement;
2. Grade 4 stone is preferred over Grade 5 stone;
3. Sprinkle aggregate spread rates of 1:450 are appropriate;
4. Pneumatic rolling caused sprinkle stone "pick up" and should be avoided;
5. Vibratory steel wheel rolling caused some aggregate breakdown;
6. Three wheel rollers are the preferred breakdown rollers;
7. Aggregate spreading equipment that does not mark the mat is preferable; and
8. Initial skid numbers are at acceptable levels.

District 5 In February of 1975 two sprinkle treatment sections were placed on U.S. Highway 87 in District 5 (Lubbock) (9). Lightweight aggregate precoated with an EA-11M emulsion was spread from a single fan, salt spreader mounted on a dump truck. The aggregate was precoated by mixing the emulsion and aggregate with a blade. A three-wheel steel roller was utilized for breakdown rolling followed by a tanden steel wheel roller and a pneumatic roller. Skid numbers taken two and three months after placement of the experimental sections showed little difference between the sprinkle treated sections and the control sections. Aggregate spread rates were 1:630 and 1:475 for the two test sections. Skid numbers for these sections are shown in Table 2.

District 14 A conventional self-propelled chip spreader was utilized to distribute two precoated synthetic sprinkle aggregates on Interstate Highway 35 near Austin (10). The method of precoating the aggregate consisted of plant mixing the AC-3 asphalt cement, petroleum primer and water; followed by field mixing with emulsion and water periodically over a 40 day period. The residual asphalt contents were 3.2 and 3.4 percent by weight for the two lightweight aggregates. Rolling was accomplished with a three-wheel steel roller followed by a steel tandem roller and a pneumatic roller.

District 8, 17 and 20 Districts 8, 17, and 20 have experimented with sprinkle treatment. Lightweight aggregates were utilized in both Districts 8 and 17. District 20 sprinkled limestone rock asphalt on a relatively short section of hot-mixed asphalt-stabilized sand. District 8 placed three 1200 feet sections on U.S. 84 north of Snyder. The aggregate was precoated with EA-11M by mixing with a maintainer. A double fan type salt spreader was utilized to distribute the aggregate. The District 17 sprinkle aggregate was precoated with EA-HVMS emulsion and placed on top of a mat processed by a heater-planer operation. A sand type spreader was utilized to distribute the sprinkle aggregate.

Recommendations

Sprinkle treated asphalt concrete mixtures will provide an economical skid resistant surface. Construction methods are available to satisfactorily place sprinkle treatments under environmental conditions which allow the placement of asphalt concrete mixtures. Recommended practices for the selection of the materials to be utilized for sprinkle treatment and construction practices which will result in a minimum of performance problems are reviewed below. These recommended practices were formulated based on a review of the literature and on-site visits to construction projects utilizing sprinkle treatments in both Texas and Virignia and a workshop meeting in which representatives of Districts 1, 5, 9, 14, 15, 20 and Divisions 6, 8, 9, and 10 participated.

Sprinkle Aggregate

Selection of the aggregate to be utilized as the sprinkle stone should be based on established field performance indicating the aggregate to be non-polishing. In absence of and in addition to established field performance data, a "Polish Value", as determined with Test Method Tex-439-A, of 37 or above is recommended. As field performance data becomes available the "Polish Value" may have to be altered for traffic volume, environment, etc. considerations. Grade 4 aggregate as specified in Items 301, 302 or 303 is recommended. The maximum size of this aggregate is near the top size of Texas Type D hot mix asphalt concrete.

Aggregate spread quantities of 1 cubic yard to 450 square yards of pavement surface appear reasonable. This quantity is approximately 2 to 3.5 pounds per square yard for lightweight aggregates and about 4.5 to 5.5 pounds per square yard for normal weight aggregates. Adequate sprinkle stone coverage is approximately 25 to 35 percent of that required for a conventional surface treatment or seal coat.

Since a formal design method has not been established for determining sprinkle aggregate spread rates, a conventional seal coat design method could be used (board test). Approximately 25 to 35 percent of the aggregate required for the conventional seal coat aggregate would be required for the sprinkle treatment. Field control of sprinkle aggregate quantities can be accomplished on a weight basis as practiced by Virginia (Figures 2 and 3), or on a volume basis utilizing those techniques commonly practiced in Texas for control of surface treatment and seal coat aggregate quantities.

Asphalt for Precoating

Both plant mixing and road mixing techniques have been utilized to precoat the sprinkle aggregate. Emulsions, petroleum primers, precoating oil and asphalt cements have been utilized as the precoating material for the majority of the projects. With one minor exception, all of the sprinkle treatments in Texas have been placed when the sprinkle stone was cold. Virginia's initial sprinkle treatments utilized cutbacks and some emulsions in applying these materials cold. However, all recent sprinkle treatments recently placed in Virginia have utilized AC-20 asphalt cement mixed hot and placed hot to provide the greatest opportunity for the sprinkle stone to adhere to the asphalt concrete mat.

For hot mixing and hot application of coverstone, AC-20 asphalt cement or the asphalt utilized in the asphalt concrete mat as specified by Item 300 is the preferred precoat material because of the uncertainties introduced by curing of solvents and/or evaporation of water. The likelihood of successfully placing a sprinkle treatment is improved by use of an asphalt cement as a precoat material. The sprinkle aggregate should be placed prior to the loss of sufficient heat to render the mix unworkable. Normally, this temperature will be above 225° F. A formal design method has not been established for determining asphalt precoat quantities. Quantities between two and four percent have been utilized with success. It is normal practice to establish asphalt precoat quantities in the field. The asphalt content is adjusted to preclude excessive binder drainage from sprinkle stone. Mixing temperature, haul distance, environmental conditions and aggregate characteristics must also be considered in this selection of the precoat asphalt content.

The use of emulsions as precoat material should not be discouraged for certain types of projects. Additional experimental work with emulsion as a precoat agent mixed in-place or at a central plant is warranted at this time.

Asphalt Concrete

Type D asphaltic concrete hot mix as specified by Item 340 is recommended; however, some field experience exists where type C asphalt concrete has been successfully utilized. Evidence exists which suggests that the maximum size of the aggregate in the sprinkle stone should be about the same size or slightly coarser than the maximum size aggregate in the asphalt concrete mixtures. Conventional mixture design methods and construction procedures can be utilized for the asphalt concrete. Polishing aggregates can be used as the fine and coarse aggregate fraction of the hot mix.

Where both the asphalt concrete and precoated aggregate must be mixed and placed hot, it is important that proper plant coordination is maintained. A convenient method to provide both the asphalt concrete and precoated coverstone from the same plant is to have an extra cold feed bin (over and above that required for the production of asphalt concrete). This cold feed bin can be utilized for the sprinkle aggregate.

Environmental conditions, surface course thickness, spread rate of the sprinkle aggregate, and truck size will determine the frequency at which the production of asphalt concrete must be interrupted to precoat the sprinkle aggregate if a hot mixing and hot placing operation is utilized. If six cubic yard haul units are utilized on the job, one load of sprinkle aggregate should be prepared for about 10 loads of asphalt concrete, assuming a one-inch lift.

Distribution of Sprinkle Aggregate

The sprinkle aggregate should be applied in a uniform manner with a mechanical spreader. A spreader that completely bridges the lane to be spread is preferred (Figure 1). A self-propelled aggregate spreader equipped with tires without treads has been used successfully. Spin or fan type spreaders commonly used to distribute deicing chemicals can be used; however, a more non-uniform appearing surface normally results. Care should be taken to insure that the sprinkle aggregate distribution equipment does not mar or rut the pavement.

If the sprinkle aggregate is to be mixed and placed hot, it should be precoated with asphalt cement at a temperature between 275 and 325°F or at a temperature below 275°F if satisfactory mixing can be achieved. Except for tender mixtures of asphalt concrete, the sprinkle aggregate should be applied to the surface of the asphalt concrete mat when the mat when temperature is between 250°F and 300°F and should be rolled into the surface of the asphalt concrete pavement within about five minutes after laydown of the pavement. The hot mix sprinkle aggregate should be delivered and applied to the mat prior to the loss of sufficient heat to render the mix unworkable. Elevated temperatures during placement and compaction of the sprinkle treated asphalt concrete are necessary to achieve desired compaction and "sticking" of the precoated sprinkle stone.

Compaction

Breakdown rolling should begin immediately after placement of the sprinkle aggregate. Three wheel steel rollers should be used for breakdown followed by a steel tandem roller. Pneumatic rolling should not be allowed until the mat has cooled to such a level that the sprinkle aggregate will not pick up.

Traffic should not be allowed on the pavement until the mat has cooled sufficiently for the sprinkle aggregate to adhere to the mat. On hot days it may be necessary to lightly sprinkle the surface with water to promote cooling prior to reuse of the facility by high speed traffic.

Measurement and Payment

Measurement and payment for sprinkle treated pavement surfaces can be accomplished by a number of methods. An approach that is recommended is to use an alternate bid where prices for supplying an asphalt concrete with a specified polish value aggregate and prices for supplying an asphalt concrete with no polish requirement together with a specified polishing aggregate sprinkle treatment are obtained. Ideally, the asphalt concrete should be paid for by the cubic yards to allow for a direct comparison of mixtures containing lightweight aggregates and mixtures containing a normal weight aggregate both of which may be non-polishing. In absence of payment on a volume basis for hot mix, the asphalt concrete should be paid for by the ton of "asphalt" and "aggregate" as specified in Item 340.

Sprinkle aggregate ideally should be paid for by the cubic yard in-place. A separate pay item should be included for the precoating asphalt material and paid for by the ton. A second approach would be to pay for both the sprinkle aggregate and precoat material combined and by the cubic yard in-place.

Evaluation of Sprinkle Treatment

Detailed evaluation of sprinkle treatments will be necessary to determine the suitability of various types of sprinkle aggregates and construction techniques under a variety of environmental and traffic conditions for prolonged service life. The appearance of the pavement surface from an aesthetic point of view should be noted. Marring of the surface by construction equipment is of particular importance as is the streaking effect that may be evident when spin type spreaders are utilized.

Retention of sprinkle stone is also of importance to the engineer. Ideally, all sprinkle aggregate that is applied should adhere to the asphalt concrete mat. An estimate of the percent retention should be made and recorded.

Skid resistance should be monitored on a continuous basis. Relatively low skid numbers during the first 4 to 8 months should be expected on new sprinkle treatment and/or asphalt concrete jobs. As the asphalt cement wears off of the non-polishing aggregates, the skid number will increase to a point and then may begin a slow, long term decrease. The relationship between skid number and time is dependent upon traffic volume, aggregate type and the environment, among other factors.

Economic Considerations

Sprinkle treated asphalt concrete mixtures must compete on an economic basis with other construction operations that will provide the same desired engineering result. An alternative treatment which must be considered under almost all conditions is an asphalt concrete mixture containing, as a portion of its coarse aggregate fraction, a polish resistant aggregate.* Other conditions may dictate that an economic comparison be made between sprinkle treated asphalt concrete, non-polishing asphalt concrete mixtures, open graded plant mix friction courses, seal coats, and perhaps, a heater-planer-remix operation.

An economic comparison between sprinkle treated asphalt concrete and asphalt concrete containing a non-polishing aggregate is presented below. Two non-polishing aggregates are considered: a non-polishing normal weight aggregate, and a non-polishing lightweight aggregate. The data shown compares only normal weight non-polishing sprinkle aggregate with non-polishing

*Data are presented for mixtures containing 20, 30, 40, 50 and 60 percent non-polishing aggregate expressed as a fraction of the total aggregate volume. Blends with approximately 40 to 60 percent non-polishing aggregate have performed successfully in Texas as nearly the entire coarse aggregate fraction is a non-polishing aggregate. Mixtures containing aggregate blends less than approximately 40 percent non-polishing aggregate have only recently been utilized and detailed performance data is presently not available.

blended asphalt concrete mixtures and lightweight non-polishing sprinkle treatment with lightweight non-polishing blended asphalt concrete mixtures. No comparison is made between normal weight non-polishing sprinkle treatment and lightweight aggregate blends of asphalt concrete.

Figures 5 can be used to determine the cost difference between placing a non-polishing asphalt concrete mixture and placing a sprinkle treated asphalt concrete mixture. The difference in cost is expressed in terms of dollars per cubic yard of asphalt concrete and can be determined for a variety of haul distances. Information is presented for 3/4-inch, 1-inch and 2-inch overlays and with asphalt concrete mixtures containing 20, 30, 40, 50 and 60 percent by volume non-polishing aggregate. Other assumptions utilized in the solution are given below:

1. Sprinkle aggregate is spread at a rate of 1:4000 and has a dry loose unit weight of 90 pounds per cubic foot for normal weight aggregate and 50 pounds per cubic foot for lightweight aggregate.
2. The cost of asphalt cement precoat material is $80 per ton.
3. Three percent precoat material by weight is required for the normal weight sprinkle aggregate and 5.4 percent by weight is required for the lightweight aggregate.
4. Haul costs are 6 cents per cubic yard per mile for normal weight aggregate.
5. The price of non-polishing normal weight aggregate is $6.00 per cubic yard, non-polishing lightweight aggregate $9.00 per cubic yard and polishing aggregate $5.00 per cubic yard.
6. The asphalt concrete contains 14.0 percent by volume asphalt cement and 6 percent by volume air expressed as a percentage by total volume of the mixture.

7. The cost of mixing at a batch plant, hauling to the job site and placing the sprinkle aggregate is $5.00 per cubic yard.
8. Haul distance utilized in the calculations are based on differences between the haul distances of the competing aggregates.
9. Cost comparisons are based on either the use of normal weight or lightweight aggregate being available for the non-polish stone in the blended asphalt concrete or sprinkle aggregate.

The information shown in Figure 5 and summarized on Table 3 and Table 4 affords some very interesting observations. For example:

1. The distance at which it becomes more economical to utilize a sprinkle treated asphalt concrete mixture than asphalt concrete blend containing non-polishing aggregate varies depending upon the type of non-polishing aggregate utilized and the amount of aggregate to be blended.
2. For two-inch overlays it is more economical to utilize lightweight aggregate sprinkle treated asphalt concrete than asphalt concrete containing a lightweight aggregate as the non-polishing material with the exception of mixtures containing 25 percent or less non-polishing aggregate.
3. For haul distances greater than 100 miles, it becomes more economical to utilize lightweight aggregates than normal weight aggregates for sprinkle treatments. The observed difference is due to freight cost differences.
4. When comparing asphalt concrete blends containing 40 percent non-polishing with sprinkle treated asphalt concrete mixtures a cost saving of from $0.76 to $4.63 can be achieved for 300 mile hauls depending upon the type of aggregate utilized and the thickness of

TABLE 3: COST DIFFERENCES

Thickness of Overlay, Inches	Type of Aggregate	Percent Non-Polishing Aggregate	Cost Differences Dollars per Cubic Yard of Asphalt Concrete			
			Haul Distance, Miles			
			0	100	200	300
3/4	Normal Weight	20	-1.15	-0.98	-0.80	-0.63
		30	-1.09	-0.56	-0.02	0.51
		40	-1.02	-0.14	0.76	1.65
		50	-0.97	0.28	1.54	2.79
		60	-0.91	0.70	2.32	3.93
	Lightweight	20	-1.07	-0.98	-0.89	-0.80
		30	-0.82	-0.56	-0.29	-0.02
		40	-0.58	-0.14	0.31	0.76
		50	-0.35	0.28	0.90	1.54
		60	-0.11	0.70	1.51	2.32
1	Normal Weight	20	-1.11	-0.70	-0.28	0.13
		30	-1.03	-0.14	0.76	1.65
		40	-0.95	0.42	1.80	3.17
		50	-0.87	0.98	2.84	4.69
		60	-0.79	1.54	3.88	6.21
	Lightweight	20	-0.91	-0.70	-0.49	-0.28
		30	-0.59	-0.14	0.31	0.76
		40	-0.27	0.42	1.11	1.80
		50	0.05	0.98	1.91	2.84
		60	0.37	1.56	2.71	3.88
2	Normal Weight	20	-0.47	0.21	0.90	1.59
		30	-0.39	0.82	1.98	3.11
		40	-0.32	1.33	2.98	4.63
		50	-0.23	1.89	3.98	6.09
		60	-0.16	2.45	5.06	7.67
	Lightweight	20	-0.13	0.21	0.56	0.90
		30	0.19	0.77	1.36	1.94
		40	0.50	1.33	2.15	2.98
		50	0.82	1.89	2.93	3.98
		60	1.14	2.45	3.75	5.06

TABLE 4: HAUL DISTANCE AT WHICH IT BECOMES ECONOMICAL TO UTILIZE SPRINKLE TREATED ASPHALT CONCRETE

Thickness of Overlay, Inches	Type of Aggregate	Percent Non-Polishing Aggregate (1)	Haul Distance Miles (2)
3/4	Normal Weight	20	650
		30	200
		40	110
		50	75
		60	55
	Lightweight	20	900
		30	300
		40	125
		50	55
		60	10
1	Normal Weight	20	270
		30	115
		40	70
		50	50
		60	35
	Lightweight	20	425
		30	125
		40	40
		50	5
		60	0
2	Normal Weight	20	70
		30	35
		40	20
		50	10
		60	5
	Lightweight	20	35
		30	0
		40	0
		50	0
		60	0

(1) Sources utilized in Table 4 of draft.
(2) Sources as utilized in Table 4 of draft.

the asphalt concrete overlay.

5. The thicker the asphalt concrete mat required for the overlay the more economical it becomes to utilize the sprinkle treatment approach.

A cost comparison between an open graded plant mix friction course and a sprinkle treatment is shown on Figures 5a and 5b. The assumptions utilized for the calculations are stated below:

1. The aggregate utilized for the open graded plant mix friction course has the same cost and unit weight as the aggregate utilized as the non-polish aggregate in the asphalt concrete blend and non-polishing sprinkle aggregate.
2. The plant mix seal will be 3/4 inch thick and will contain 65 percent by volume aggregate, 14 percent by volume asphalt and 20 percent by volume air.
3. A $2.00 premium per cubic yard will be paid to mix, haul and place an open graded plant mix seal as compared to a conventional asphalt concrete mixture.
4. All other assumptions utilized for the comparison between sprinkle treatment and blended asphalt concrete mixtures are valid.

For the above assumptions, Figures 5a and 5b illustrated that sprinkle treatment is a more economical solution than plant mix friction course. In some instances, open graded plant mix seals have been placed as thin as 5/8 inch. If a 5/8-inch open graded plant mix seal friction course is compared with 3/4-inch sprinkle treatment mat. The cost comparison will vary somewhat.

The engineer should be aware that the above economic comparisons are based on initial costs only. If the service life and maintenance costs of the two alternatives compared above are nearly identical, then the relative comparisons made above are valid. Limited data collected to date indicate that equal service lives and maintenance costs can be expected, provided proper design and construction procedures are utilized.

From an engineering point of view, sprinkle treated aspahlt concrete and asphalt concrete blends containing non-polishing aggregate serve nearly the same function on the roadway. They can be utilized to improve the riding quality of a roadway, to provide skid resistance, somewhat seal the roadway surface and structurally improve the roadway (provided sufficient thickness is utilized) among other factors. It is therefore logical to compare these alternatives on a cost basis for a wide variety of uses.

A comparison between open graded plant mix friction course and sprinkle treated asphalt concrete may be subject to criticism because of the suitability of the two treatments for particular uses. For example, open graded plant mixes do not seal the roadway surface and do not provide a significant structural improvement. Open graded plant mix seals do, however, reduce the potential for hydroplaning no afforded to the same degree by sprinkle treated asphalt concrete.

The use of sprinkle treated asphalt concrete is encouraged where econmical. However, the engineer should be aware that additional field evaluation will be necessary over a prolonged period to determine the service life of sprinkle treated asphalt concrete as compared to other alternative treatments to insure that the economic comparisons made herein are valid.

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*Data are presented for mixtures containing 20, 30, 40, 50 and 60 percent non-polishing aggregate expressed as a fraction of the total aggregate volume. Blends with approximately 40 to 60 percent non-polishing aggregate have performed successfully in Texas as nearly the entire coarse aggregate fraction is a non-polishing aggregate. Mixtures containing aggregate blends less than approximately 40 percent non-polishing aggregate have only recently been utilized and detailed performance data is presently not available.

APPENDIX A

SUGGESTED SPECIFICATION FOR SPRINKLE TREATED ASPHALT CONCRETE SURFACE COURSE*

1.0 DESCRIPTION. This item establishes the requirements for applying pre-coated aggregate to the finished riding surface of newly placed Asphaltic Concrete Pavement, prior to its initial rolling, to improve the skid resistance of the pavement.

2.0 MATERIALS.

2.1 Cover Aggregate. The cover aggregate used shall be Grade 4 and meet the requirements of Item 301, "Aggregate for Surface Treatments[2] (Class A)", Item 302, "Aggregate for Surface Treatments (Class B)", or Item 303, "Aggregate for Surface Treatments (Lightweight)". In addition to these requirements, the aggregate shall have a "Polish Value" of not less than 37 when tested in accordance with Test Method Tex-438-A.

2.2 Asphalt. The asphalt cement used to coat the aggregate shall be AC-20 as specified by Item 300, "Asphalts, Oils and Emulsions".

2.3 Asphaltic Concrete Pavement. The asphaltic concrete pavement up n which the sprinkle treatment is to be placed shall be Type D and meet the requirements of Item 340 "Hot Mix Asphaltic Concrete Pavement".

3.0 CONSTRUCTION METHODS.

3.1 Precoating the Sprinkle Aggregate. The sprinkle aggregate shall be run through an approved dryer, thoroughly dried and then mixed with asphalt cement. The amount of asphalt cement shall be determined by the engineer. The mixing temperature shall be between 275°F and 300°F.

*Data are presented for mixtures containing 20, 30, 40, 50 and 60 percent non-polishing aggregate expressed as a fraction of the total aggregate volume. Blends with approximately 40 to 60 percent non-polishing aggregate have performed successfully in Texas as nearly the entire coarse aggregate fraction is a non-polishing aggregate. Mixtures containing aggregate blends less than approximately 40 percent non-polishing aggregate have only recently been utilized and detailed performance data is presently available.

Drying and mixing operations shall conform to those specified in Item 340, "Hot Mix Asphaltic Concrete Pavement".

3.2 Distribution of the Sprinkle Aggregate. The sprinkle aggregate shall be applied in a uniform manner with a mechanical spreader. The spreader shall be one that completely bridges the lane to be spread or a self-propelled aggregate spreader equipped with tires without patterned treads. These types, or any other spreader approved by the engineer shall not mar or rut the surface of the asphaltic concrete pavement. Except for tender mixtures, the sprinkle aggregate shall be applied at a temperature between 250^{o}F and 300^{o}F and shall be rolled into the surface of the asphaltic concrete pavement within five minutes after laydown of the pavement. For tender mixtures the engineer shall determine the roller delay time. The aggregate spread rate shall be at a rate of one cubic yard per 450 square yards of as directed by the engineer.

3.3 Asphaltic Concrete Pavement. The asphaltic concrete pavement shall be constructed according to Item 340, "Hot Mix Asphaltic Concrete Pavement", except the sprinkle aggregate shall be uniformly distributed over the pavement surface prior to initial rolling. Compaction of the sprinkled mat shall begin immediately after placement of the sprinkle aggregate and shall be accomplished with a three-wheel steel roller for breakdown and a steel tandem roller. Pneumatic rolling will not be allowed until the mat has cooled to such a level that the sprinkle aggregate will not pick-up.

4.0 MEASUREMENT AND PAYMENT.

Asphaltic Concrete Pavements shall be paid for by the ton of "asphalt" and "aggregate" as specified in Item 340, "Hot Mix Asphaltic Concrete

Pavement". Sprinkle aggregate will be paid for by the ton of "asphalt" and cubic yard of "aggregate" as applied on the road, which shall be full compensation for furnishing, hauling, and uniform placement of the precoated aggregate and for all manipulation, labor, tools, equipment and incidentals necessary to complete the work.

APPENDIX B

ANNOTATED BIBLIOGRAPHY ON SPRINKLE TREATMENTS

1. Findley, I.B. "The Influence of Precoated Chippings on the Skid Resistance of Hot Rolled Asphalt", The Surveyor and Municipal Engineer, pp. 27-30, November 13, 1965.

   Data is presented on a field test of the effectiveness of spreading precoated chips of various crushed granite on newly constructed asphalt concrete pavement to increase skid resistance.

2. Green, E.H. and F.V. Montgomery, "Coated Chippings for Rolled Asphalt", Transport and Road Research Laboratory, TRRL Report LR 456, 1972.

   This report describes laboratory tests and field experiments conducted to investigate the hardening of the asphalt cement used as precoat material on sprinkle treatment aggregate. Problems of adhesion of the precoated sprinkle treatment stone were responsible for this research. Fifty to seventy penetration bitumen has been utilized in England. 1.3% plus or minus 0.3% by weight is the usual range of asphalt content.

   Test methods are described to control the hardening of the asphalt on the sprinkle treatment aggregate. Gradiations of sprinkle treatment stone are given below. Field experiments were conducted as a part of this study.

BS Sieve	20 mm Nominal Sieve	14 mm Nominal Sieve
28 mm	100	---
20 mm	90-100	100
14 mm	0-25	90-100
10 mm	0-4	0-10
6.3 mm	---	0-4
75 mm	0-2	0-2

   The use of sprinkle treatments in England is popular.

3. Mahone, D.C. and R.K. Shaffer, "Corrective Programs for Improving Skid Resistance", HRB Record, No. 376, 1971.

   This paper describes the major elements to consider when establishing a corrective program for improving skid resistance.

   The blending of aggregates has been considered and utilized on maintenance programs in Virginia. Blends of polish-resistant aggregates (granites, sandstones, light weight) have bee utilized with polish-susseptable materials.

   Sprinkle treatment utilizing 3 to 5 lbs per square yard of aggregate have been utilized in Virginia with success. One hundred percent limestone was utilized for the hot mixes.

4. Maupin, G.W. "Sprinkle Treatment Increases Highway Skid Resistance", ASCE Civil Engineering, February 1972.

This one page article reviews Virginia Highway Department procedure. The sprinkle treatment consists of spreading approximately 5 lbs. per square yard of precoated skid-resistant aggregate on a freshly placed bituminous hot mix and then compacting the pavement by normal procedure. MC-70 has been utilized as the precoating material. Types of aggregates include slag, synthetic aggregate, sand, crushed gravel and granite. A spin-type chemical spreader normally used to apply deicing chemicals is used for spreading the sprinkle material.

Treatments first placed in 1969 and by 1972 65 miles of equivalent two-lane road has been placed including Interstate 81 carry approximately 8,500 vehicles per day.

5. Dillard, J.H. and G.W. Maupin, Jr. "Use of Sprinkle Treatment to Provide Skid Resistant Pavements", Association of Asphalt Paving Technologists, February 1971.

This paper summarizes Virginia laboratory and field results to date. Several cutbacks (MC-70, RC-250, MC-250) were utilized in laboratory experiments to determine the best precoating materials. The MC-70 seemed to be the best for the aggregates utilized on the projects. An 85-100 asphalt cement was utilized on one small field project.

Sprinkling the aggregate was performed by use of a salt spreader and farm type lime spreader on the field sections. The lime spreader mechanism operated from a power take-off which provided pour rate control and the width of spread was poorly regulated due to lack of control fins around the whirly blade.

The rate of application of the sprinkle material averaged 2.2 to 5.2 lbs. per square yard depending upon specific gravity and gradation.

6. Tyler, R.L. and T.R. Kennedy. "Sprinkle Treatment for Achieving Skid Resistant Pavement in Texas", Texas Highway Department, Special Study No. 20.0, August 1974.

The paper describes sprinkle treatments placed in District 9 of the State Department of Highways and Public Transportation. A grade 4 synthetic aggregate precoated with EA-11M anionic emulsion was placed as the sprinkle treatment aggregate on State Highway 14 north of Mexia, Texas. The 0.9 mile two-lane section was placed in the summer of 1972 and has been subjected to about 2,700 vehicles per day. A spin type spreader (the type which is used to broadcast sand or deicing chemicals) was used to spread the aggregate at a rate of 2.5 lbs. per square yard. The aggregate was rolled into the hot mixed asphalt concrete with a vibratory power roller. About 3/4 of the aggregate placed was retained.

The aggregate gradation is given on the following page.

Sieve Size	Accumulative % Retained
5/8	0
1/2	0-2
3/8	5-25
No 4	85-100
No 10	98-100

7. Frye, Donald J. "Test Sections of Various Asphaltic Mixtures and Sprinkle Treatments, District 15, Texas State Department of Highways and Public Transportation, 1975.

The paper describes both sprinkle treatment and aggregate blending projects performed in District 15. Lightweight aggregate was precoated with different materials and quantities of materials and spread at the rates shown below.

Precoat Material	Percent Precoat	Spread Rate Cubic yds: Square Yds.	Type of Spreader
No. 6 Precoat Oil	3.5	1:515	Flaherty Aggregate Spreader
No. 6 Precoat Oil	3.2	1:288	Flaherty Aggregate Spreader
No. 6 Precoat Oil	3.5	1:400	Chat Spreader
No. 6 Precoat Oil	5.0	1:511	Flaherty Aggregate Spreader
AC-10	4.0	1:400	Flaherty Aggregate Spreader
No. 6 Precoat Oil	5.0	1:337	Flaherty Aggregate Spreader
No. 6 Precoat Oil	5.0	1:415	Flaherty Aggregate Spreader
None		1:400	Flaherty Aggregate Spreader

Pneumatic rolling tended to remove the sprinkle stone from the mat while some crushing problems were experienced with steel vibratory rollers. Sprinkle stone precoated with AC-10 was retained somewhat better than the stone treated with the precoat oils. Initial skid tests show a high coefficient of friction. The cost of applying the sprinkle treatment was $2.41 per ton of hot mix that was treated.

8. Magers R.H. and R.M. Harle. "Test Sections of H.M.A.C. (class A) Type D with Sprinkle Treatment Surface," Texas State Department of Highways and Public Transportation, Report Number: 601-1, June 1975.

The report describes a sprinkle treatment project in District 15. A Flaherty Aggregate Spreader was utilized to distribute a precoated limestone rock asphalt (Item 304, Type PE, Grade 4) as type of a Type D hot mix at a rate of 1 cubic yard per 400 square yards. Rolling was accomplished by use of a Tampo Vibratory Double Drum Roller. A portion of this trial section was placed with a limestone rock asphalt that was not precoated.

9. Johnston, J.T. "Test Sections of Type "C" ACP with Sprinkle Treatment Surface," Texas State Department of Highways and Public Transportation, Report Number: 603-1, July 1975.

A Grade 4 synthetic aggregate was precoated with a mixture of 1/3 emulsion (EA-11M) and 2/3 water. Approximately six hundred gallons of emulsion-water mixture was used to coat the aggregate in two separate applications. Mixing was accomplished with a blade.

A single fan, salt spreader mounted on a dump truck was utilized to spread the aggregate at a rate of one cubic yard to 630 square yards and one cubic yard to 475 square yards on the two test sections. Compaction was performed by a three-wheel steel roller followed by tandem steel wheeled roller and a pneumatic roller. Skid measurements made about two months after construction showed little difference between those sections with and without sprinkle treatments.

10. Gallatin, G.L. "Precoating Aggregates for Sprinkle Treatment," Texas State Department of Highways and Public Transportation, Report Number: 605-1, July 1975.

A chip spreader was utilized to place two precoated synthetic aggregates (Grades 4 and 5) on Interstate Highway 35. Rolling was accomplished with a three-wheel steel roller, a steel tandem roller and a pneumatic roller.

The method of precoating the aggregate consisted of plant mixing aggregates with AC-3, petroleum primer and water, followed by field mixing with emulsion and water over a period of 40 days.

11. "Innovations in Precoating and Distributing Sprinkle Treatment Aggregates," The Research Reporter, Number 17-75, Texas State Department of Highways and Public Transportation, August 1975.

A Grade 4 lightweight aggregate was precoated with 2 percent AC-10, allowed to cool and then distributed with a straddle spreader is a modified Grace spreader box. The spreader was charged with aggregate from the side with a front-end loader. Sprinkle stone distribution rate of one cubic yard to 450 square yards was most desirable.

12. Maupin, G.W. Personal conversation with J.A. Epps on 20 November 1974.

Sprinkle treatments have been utilized in Virginia since 1968. Contractors have been placing sprinkle treatments since 1970 and specifications have been prepared.

Some problems have been encountered in applying the sprinkle treatment stone with the salt type spreaders. Uniformity of spread due to the material not being in a free flowing condition is responsible for part of the difficulties.

Medium curing cutbacks are no longer utilized as a precoating material. Jobs placed with MC's as precoating material have been variable. Loss of stone under traffic is one of the problems when utilizing MC materials.

Asphalt cement is the only material that will be utilized in the 1975

construction season as better stone retention has been obtained under traffic. The asphalt cement utilized is the same grade that is normally used in hot mix. When asphalt cements are used they must be somewhat warm to maintain the free flowing conditon; thus, some type of hot or warm storage is necessary.