Criteria for Accepting Precoated Aggregates for Seal Coats and Surface Treatments

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One of the most common causes of seal coat failures is the presence of dust on the cover aggregate, which prevents good adhesion between the applied bituminous binder and the aggregate. Precoating the aggregate with a thin film of bituminous binder usually solves the dust problem and provides good adhesion. This research was undertaken (*a*) to evaluate the adhesion of aggregates precoated to varying degrees so that the optimum precoating requirement can be established, and (*b*) to develop an end-result type test in lieu of the subjective visual test for accepting precoated aggregates. Five AASHTO No. 8 aggregates of different mineralogical compositions and absorptive characteristics were used. These aggregates were precoated with MC-30 cutback asphalt to varying degrees (from a salt-and-pepper effect to 90 percent or more coating). The Pennsylvania Aggregate Retention Test developed in this study was used to evaluate the effect of precoating on aggregate retention loss. Immediate adhesion of the cover aggregate with the bituminous binder was best obtained at 90 percent or greater precoating. The agreement (reproducibility) between different evaluators who made subjective visual evaluations of the percent precoating was also by far the best at a level of 90 percent or more. Of the three end-result type tests attempted, dry gradation test of the precoated aggregate was determined to be most appropriate with an acceptance criteria of 0.5 percent maximum minus 200 (dust). It has been recommended to use AC-20 asphalt cement as a precoating material in lieu of MC-30 cutback asphalt, because it can be mixed at higher temperatures in a hot-mix asphalt (HMA) plant, does not need any curing, and will cause better aggregate retention.

The Pennsylvania Department of Transportation (PennDOT) is responsible for the maintenance of 43,000 mi of roadway. PennDOT's projected maintenance program for 1987 included placing seal coat applications over 5,000 mi of roadway requiring more than 14 million gal of emulsified asphalt. One of the most common causes of seal coat failures is the presence of dust on the cover aggregate, which prevents good adhesion between the aggregate and the applied bituminous binder. Precoating the aggregate with a thin film of bituminous binder usually solves the dust problem and provides good adhesion. PennDOT recommends the use of precoated aggregates in seal coats and surface treatments on roads carrying average daily traffic (ADT) of more than 1,500 vehicles.

The current PennDOT specifications require that "at least 90 percent of the total visible area of the aggregates shall be coated with a bituminous film—any thin, brownish, translucent areas will be considered full coated." Questions have been raised about the minimum degree of precoating required and its subjective determination. Some people believe that a lesser degree of coating (even a salt-and-pepper effect) will be as effective as 90 percent coating. A need was felt to develop an end-result type test in lieu of the subjective visual test for accepting the precoated aggregates for department work.

The objectives of this research were (*a*) to evaluate the adhesion of aggregates precoated to varying degree so that the optimum precoating requirement could be established, and (*b*) to develop an end-result type test in lieu of the subjective visual test for accepting precoated aggregates.

REVIEW OF LITERATURE AND CURRENT PRACTICES

PennDOT uses a rational design method (*1,2*) to establish the application rates of bituminous binder and cover aggregate. This was done in 1975 to have a uniform practice throughout the state and to minimize failures resulting from improper application rates. However, the specification allowed up to 2 percent of minus 200 material (dust) in the cover aggregate. This was considered excessive for applications on high-volume roads and, therefore, specifications for precoated aggregates were developed in 1980 based on the experience in other states and overseas (particularly in Australia, New Zealand, and the United Kingdom).

Literature Review

Before commencing this research, a review of literature on precoated aggregates was conducted. The existing literature on this subject was summarized in 1968 in Special Report 96 of the Highway Research Board (*3*). It was mentioned that "one cannot overemphasize the importance of the physical condition (dusty) of the cover aggregate, the success or failure of a particular surface treatment might well depend solely upon the condition of the cover material." Research of Benson and Gallaway (*4*) indicated that for the presence of 1 percent dust there was a loss in aggregate retention of 12 percent by weight per unit area. One method of dealing with the dust problem is washing and drying the aggregate by mechanical means before application, which solves the problem almost entirely. The other methods include coating the aggregate with either a bituminous material or a kerosene film before application. Precoating with a bituminous material al-

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most guarantees good adhesion. Longer life experienced with precoated aggregates justifies the increased cost.

Harris (*5*) recommended the use of precoated aggregates in 1955, mentioning that "on heavily travelled roads, the trend is definitely towards the use of precoated aggregates, and probably as much as one hundred thousand tons will be used in Texas during 1955." Parr (*6*) reported on a surface treatment project more than 33 mi long in Michigan, which gave 17 years of service without maintenance. The aggregate was precoated with an SC-1 oil (approximately 1 percent). Although the cost is something to be considered, the long life of the surface treatment more than paid for the extra cost of precoating.

The Asphalt Institute (*7*) recommends that precoating the aggregate with a thin film of asphalt usually solves the dust problem and provides good adhesion of the asphalt to the aggregate. The aggregate is run through a hot-mix asphalt (HMA) plant dryer, cooled to under 200°F, then mixed in the pugmill with about 1 percent MC-70 to coat each particle thoroughly. The small amount of asphalt does not change the aggregate from a free flowing material, which can still be applied with aggregate spreaders. The precoating adds to the cost of the aggregate, but the additional cost is often justified by the better results obtained.

The Transport and Road Research Laboratory (TRRL) of the United Kingdom also suggests the use of precoated chippings to overcome the problem of dust (*8*). Compared with dry, uncoated chippings, coated chippings adhere immediately to the binder, especially when the binder viscosity is relatively high. The most common technique is to heat the chippings to between 220°F and 300°F and to coat them with more normal grades of tar or bitumen. The high temperature hardens the coating and makes the chippings easy to handle. A binder content of about 0.75 to 1 percent by weight of the chippings is suitable.

McLeod (*9*) stated that rapid development of good adhesion between cover aggregate and bituminous binder is highly desirable. To achieve this, the National Roads Board of New Zealand requires that all cover aggregates on state roads be washed to remove dust and then precoated. Precoating is done by a special cationic emulsion or cutback asphalt at the rate of 1 gal/yd^3 of chips. In Australia, to promote adhesion, stone chips are often similarly precoated with diesel fuel oil at the rate of 1 to 2 gal/yd^3 of cover stone or with 1 percent of MC-30 or MC-70.

Precoated sandstone cover aggregate was used successfully on Interstate 81 in Pennsylvania in FHWA Demonstration Project 55 (*10*). The seal coat job was completed in August 1980 using MC-30 cutback as a precoating material, and CRS-2 (Pennsylvania Designation E-3) emulsified asphalt as the application binder.

Epps et al. (*11*) prepared a field manual on design and construction of seal coats. They stated that "precoated aggregates are more expensive than untreated aggregates but have been utilized to reduce the effect of a dusty aggregate, to reduce automobile glass damage due to flying stone and to promote bond with asphalt."

Current Practices

A questionnaire was sent to all 50 United States and various highway agencies in Australia, New Zealand, and the United Kingdom. Australia and New Zealand are considered to be leading countries in obtaining most successful seal coat jobs in the world.

The questionnaire and the summary of the responses of 44 responding United States and other foreign countries on general seal coat practices such as most commonly used aggregate gradation and applied bituminous materials, tests and specifications for minus 200 material (dust) in the cover aggregate are given elsewhere (*12*). Only six states (Illinois, Oregon, Pennsylvania, Texas, Utah, and Virginia) use precoated aggregates.

MATERIALS

Aggregates

Five AASHTO No. 8 (PennDOT 1B) cover aggregates of different mineralogical compositions and absorptive characteristics were used in this study. Table 1 presents the sources and properties of these aggregates. Table 2 presents the specified and as-received gradations. Two gradations (graded and single-size) shown in Table 2 were used in the study for all five aggregates. These gradations were held constant to eliminate gradation as a variable. The gradation of AASHTO No. 8 aggregate was based on the average of 425 samples of aggregates in Pennsylvania.

Precoating Bituminous Material

PennDOT specifications permit the use of MC-30 and MC-70 cutback asphalts and AC-20 asphalt cement as precoating bituminous materials. MC-30 cutback asphalt (AASHTO M82), which is most commonly used in Pennsylvania, was used. The test properties of MC-30 such as kinematic viscosity at 140°F, distillate volumes at various temperatures, percent asphalt, and asphalt residue viscosity at 140°F are provided elsewhere (*12*).

Application Bituminous Materials

PennDOT specifications permit the use of AASHTO RS-2 (PA E-2) and CRS-2 (PA E-3) emulsified asphalts and AC-2.5 asphalt cement as the application bituminous material in seal coats. However, CRS-2 (PA E-3) emulsified asphalt, the most commonly used in Pennsylvania, was used in this study. The test properties of this cationic emulsion such as Saybolt Furol viscosity at 122°F, percent asphalt, and residue penetration are provided elsewhere (*12*).

TEST PROCEDURES

Tests on Aggregates

Bulk specific gravity and percent water absorption were determined in accordance with AASHTO T85. Flakiness index measures the tendency of an aggregate particle toward particle flatness, and it represents the percentage by weight of flat particles having a least dimension smaller than 60 percent of the mean size (*13*).

TABLE 1 SOURCES AND PROPERTIES OF AGGREGATES USED

	Aggregate Number				
	1	2	3	4	5
Producer	New Enterprise Stone & Lime Co. Ashcom	Obtained from Dist. 5-0	Wyoming Sand & Stone Co. Eaton Twp.	Columbia Asphalt Corp. Bloomsburg	State Aggregates Clifford
Type	Limestone	Limestone	Gravel	Siltstone	Sandstone
Bulk Sp. Gr.	2.795	2.758	2.559	2.678	2.639
% Water Absorption	0.31	0.97	1.95	1.69	1.66
Flakiness Index	27.2	54.2	15.9	28.0	16.0
Median Size, Inch	0.26	0.26	0.26	0.26	0.26
Average Least Dimension, in.	0.185	0.15	0.20	0.185	0.20
Particle Index (ASTM D3398)	15.9	---	12.3	14.7	13.9

TABLE 2 GRADATION OF AGGREGATES

Sieve	Specification	Aggregate Gradation as Received					Gradation Used in Study	
		1	2	3	4	5	Graded*	Single-Size
% Pass.								
1/2"	100	100	100	100	100	100	100	100
3/8"	85 - 100	94	84	91	93	97	90	100
No. 4	10 - 30	27	15	26	30	27	18	0
No. 8	0 - 10	4.2	6.0	3.0	2.8	5.1	2.5	0
No. 200	0 - 2.4	0.2	1.4	0.6	0.4	1.0	Variable	Variable

* Based on the average of 425 samples of aggregates in Pennsylvania.

Median size and average least dimension (ALD) of the aggregates were also determined according to the procedures given in the Asphalt Institute's Manual Series No. MS-19. These parameters and flakiness index are generally used for designing seal coats and surface treatments.

The particle index, which is a quantitative measure of aggregate particle shape and texture characteristics, was also measured in accordance with ASTM D3398.

Incorporation of Varying Dust Contents

Before the precoating phase of this study, it was believed necessary to study the effect of varying dust contents in the uncoated aggregate on aggregate retention. The aggregates were thoroughly washed with water to eliminate the minus 200 (dust) material completely. Then, varying amounts of dust (1, 2, 3, 4, and 5 percent by weight of the dry aggregate) were added to the aggregate. Water was added to the clean aggregate-dust mixture and thoroughly mixed to disperse the dust uniformly in the wet mixture. The mixture was then dried to constant weight. This procedure was used to simulate, as much as possible, the naturally occurring dust coatings on mineral aggregates.

Precoating Procedures

Aggregates containing 3.0 percent dust (establishment of this threshold value is discussed later) were precoated with MC-30 cutback asphalt to obtain the following five conditions:

1. No coating,
2. Salt-and-pepper effect,
3. Less than 50 percent coating,
4. More than 50 percent (but less than 90 percent) coating, and
5. More than 90 percent coating.

Any thin, brownish, translucent areas were considered to be coated. The percentage of coating was based on the total visible area of the precoated aggregate material. Individual particles were not considered.

A mechanical mixer was used to mix the aggregate and MC-30 cutback asphalt. Both materials were mixed at ambient temperature. Mixing time was approximately 6 min. Different percentages of MC-30 were used to obtain the required precoating conditions from a salt-and-pepper effect to 90 percent or greater coating. This required varying the percentage of MC-30 (by weight of the aggregate) from 0.4 to 1.1. All samples were cured in a flat pan for 2 days and were considered to be free flowing. Figure 1 shows an aggregate with five different precoating conditions.

Pennsylvania Aggregate Retention Test

This simple test method was developed by trial and error during this study. The testing equipment needed is available in most highway materials testing laboratories. The equipment consists primarily of 8-in. sieves, 8-in. pans, a sieve shaker (sifter), rubber pads, a compression machine, and a balance.

The procedure is described below:

1. Application of bituminous material: The emulsified asphalt (CRS-2) was poured on the back side of an 8-in. separator pan to obtain an application rate of 0.25 gal/yd^2. The emulsion was applied at 140 ± 5°F, and its weight was 36.8 g to give the desired application rate in an 8 in.-diameter pan.

2. Application of cover aggregate: It was established by trials that 300 g of aggregate is sufficient to obtain a single particle layer in the 8-in. diameter pan. This corresponds to 17.4 lb/yd^2. The aggregate is applied in the field by a chip spreader, which is difficult to simulate in the laboratory. However, an attempt was made to mechanize the process to minimize the variation in applications.

A Mary Ann laboratory sieve shaker (or sifter) was used. It can take an unclamped stack of 8-in.-diameter × 2-in.-deep standard laboratory sieves and pans. These are laid on a pair of 45°-inclined, rubber-covered, power-driven rollers, which revolve the stack. The pan bottom rests on a free-wheeling turntable. The aggregate is tumbled, mixed, and passed as it is carried up on the revolving inclined screen wire. To encourage clearing the openings, the sieve frames are tapped laterally (from below) by hardwood-faced aluminum hammers. These cam-cocked and spring-thrown hammers are pivoted on a nylon sleeve bearing.

For this study, the sieve shaker was inclined at an angle of 60° instead of 45°. Attempts to make it more to vertical were unsuccessful because the unclamped sieve stack fell out.

The pan containing applied emulsion was placed at the bottom of 5 inverted ½-in. sieves. A retainer or collar (sieve with no screen) was placed on the top. Figure 2 shows the complete assembly and feeding of aggregate from the top. The screen mesh in each ½-in. sieve was rotated 45° from the adjacent top or bottom sieve so that 2 consecutive sieve meshes did not have the same orientation.

After the sieve assembly was placed on the shaker and the shaker was turned on, 300 g of aggregate was poured into the retainer at the top. After 1 min, the pan containing emulsion and applied aggregate was removed and tapped to spread the aggregate evenly on the emulsion film.

3. Compaction and curing: Within 15 min, the pan was covered with a 7½-in.-diameter × ¾-in.-thick Neoprene bearing pad (of 50 durometer hardness) and placed under a compression machine to apply a load of 2,000 lb for 5 sec. This is equivalent to a pressure of 40 to 50 psi, which is normally used in pneumatic-tired rollers for seal coats. After compaction, the bearing pad was removed and the pan containing emulsion and aggregate was cured at the ambient temperature for 23 to 25 hr. The weight of pan + emulsion + aggregate was obtained after curing.

4. Initial retention loss: After the 24-hr curing, the pan containing the seal coat was inverted to allow the aggregate particles (which did not develop initial adhesion to the binder) to fall. These aggregate particles were weighed to determine the initial loss in grams. The percentage of initial loss is determined as follows:

$$\text{Percent initial loss} = B/A \times 100$$

where A is the weight of total aggregate (300 g), and B is the initial loss in grams.

5. Knock-off loss: After the initial loss was determined, the pan containing emulsion and aggregate was placed upside down at the top of the five ½-in. sieves (used for filling only), and a pan was placed at the bottom of the assembly to collect the knock-off loss. This complete assembly was placed in the Mary Ann sieve shaker described earlier and subjected to the shaking and tapping action for 5 min. The knock-off loss of the aggregate, which was collected in the bottom pan, was weighed (C). The percentage of knock-off loss was determined as follows:

$$\text{Percent knock-off loss} = [C/(A - B)] \times 100$$

where C is the knock-off loss in grams. It is realized that this knock-off test does not simulate the action of traffic in dislodging the aggregate from the seal coat. Nonetheless, it was used to give comparative results for uncoated aggregates containing varying dust contents and the precoated aggregates with different conditions of precoating.

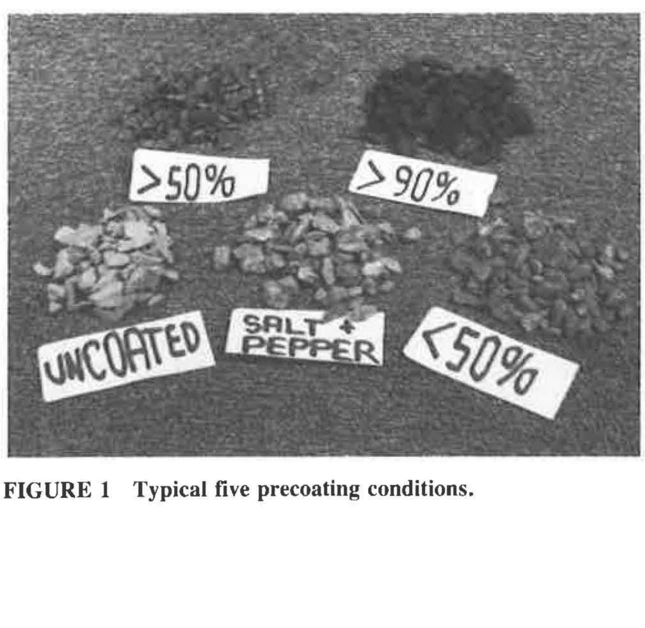

FIGURE 1 Typical five precoating conditions.

FIGURE 2 Complete assembly for applying aggregate.

6. Total loss: The total loss (initial loss + knock-off loss) was calculated as follows:

Percent total loss = $D/A \times 100$

where D is the total loss in grams ($B + C$). It should be noted that three aggregate retention tests were run for each sample type and the results averaged.

TEST RESULTS AND DISCUSSION

Aggregate Test Results

As mentioned earlier, the five aggregates (AASHTO No. 8 size) had different mineralogical compositions and absorptive characteristics. Tables 1 and 2 present the properties of the aggregates used. Limestone, gravel, siltstone, and sandstone aggregates ranged in water absorption from 0.31 to 1.95 percent. The flakiness index ranged from 15.9 percent (Aggregate 3, gravel) to 54.2 percent (Aggregate 2, limestone). The National Association of Australian State Road Authorities specifies 35 as the maximum permissible flakiness index for surface treatment. The median size of 0.26 in. was same for all aggregates because the same gradation was used. The ALD determined from the median size and flakiness index ranged from 0.15 to 0.20 in. The particle index ranged from 12.3 (Aggregate 3, gravel) to 15.9 (Aggregate 1, limestone).

Effect of Dust Contents on Aggregate Retention

Before precoating all aggregates, it was believed necessary to establish the dust content to be used consistently throughout the study. Therefore, varying amounts of dust (1, 2, 3, 4, and 5 percent) were added to the aggregates as described earlier.

The single size (⅜ in., No. 4) gradation instead of the total (½ in., No. 8) gradation was used to obtain better and more consistent results. The Pennsylvania Aggregate Retention Test described earlier was used.

Figure 3 shows the plots of percent dust content versus percent knock-off loss for all aggregates. The following trends were observed in this figure:

1. The rate of increase in knock-off loss with increasing dust contents (slope of the percent dust content versus percent knock-off loss line) becomes significantly greater after about 3 percent dust content in most cases. Therefore, this was considered a threshold value for all practical purposes and was used before precoating in the next phase of this study.
2. Most states specify a maximum of 2 percent (or 2.4 percent rounded off to 2) dust for unwashed aggregates. This appears to be reasonable for low-volume roads, particularly if the cost of washing or precoating the aggregate is high.
3. No correlation was observed between the percent knock-off loss and percent water absorption or particle index of the aggregate. However, a good relationship was observed when the flakiness indices of the aggregates and the corresponding aggregate retention losses were ranked (*12*). It shows the trend that the aggregate retention loss increases with increasing values of the flakiness index. It is quite possible that the flaky (flat) particles did not get pressed down well into the bituminous binder when compressed with the Neoprene bearing pad (pneumatic-tired roller in the field) because of the surrounding protruding cubical particles. Therefore, when the percentage of flat particles in the sample (or flakiness index) increases, the corresponding retention loss also increases.

Effect of Degree of Precoating on Aggregate Retention

All aggregates containing 3.0 percent dust contents were precoated to obtain five different conditions as described earlier in precoating procedures. Ten evaluators made subjective visual determinations of the percentage of coating on all aggregates for three conditions: less than 50 percent, more than 50 percent (but less than 90 percent), and more than 90 percent. The data are given in Table 3. It should be noted from the average data that it was difficult to achieve the condition of less than 50 percent precoating in actual practice because then the precoated aggregate tended to border on the salt-and-pepper effect. The average observed coating obtained for this condition actually ranged from 45 to 54 percent. This can reasonably be considered about 50 percent, although the tables will indicate it to be less. Table 3 presents the mean and standard deviations of percent coating on 15 precoated aggregate samples observed by 10 evaluators. It is quite evident

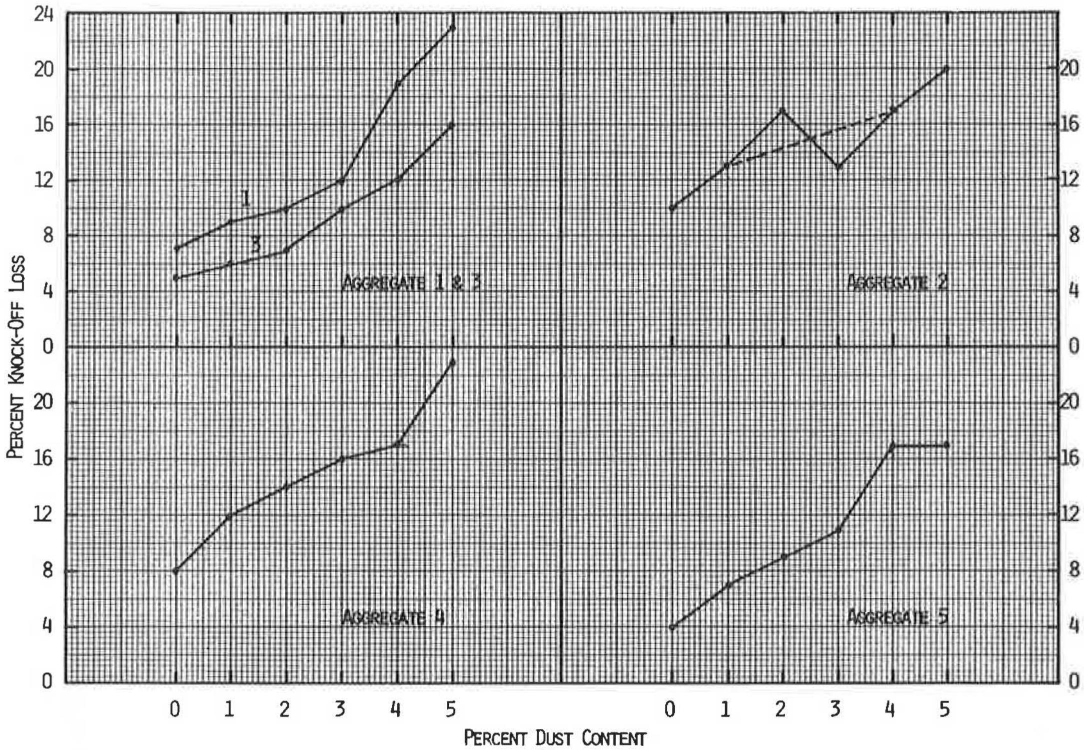

FIGURE 3 Percent dust content versus knock-off loss (all aggregates/one size).

from the data that the standard deviation decreases as the percentage of coating increases. In other words, the agreement between different evaluators becomes increasingly better when the percentage of coating is increased from 50 to 90 or more, the best agreement being for 90 percent or greater coating. It should be noted that the current PennDOT specifications require 90 percent or greater precoating and few, if any, problems have been experienced in judging this specified minimum percentage of precoating. It has been recognized by ASTM on the basis of cooperative tests that only at 95 percent level can a reasonable degree of the reproducibility be obtained when rating the same sample by visual estimation.

TABLE 3 SUBJECTIVE EVALUATION OF PERCENT COATING (10 EVALUATORS)

Evaluator	Percent Coating By Observation														
	Aggregate 1			Aggregate 2			Aggregate 3			Aggregate 4			Aggregate 5		
	<50	>50	90+	<50	>50	90+	<50	>50	90+	<50	>50	90+	<50	>50	90+
1	60	80	95	50	90	98	50	80	98	50	80	98	60	90	98
2	50	75	99	35	75	99	40	65	99	35	65	99	80	90	99
3	40	70	98	40	80	95	30	50	98	30	50	92	40	80	97
4	50	75	95	60	80	98	50	70	98	50	75	98	60	75	98
5	60	75	98	55	85	98	65	85	99	55	75	97	50	75	97
6	55	70	98	60	80	99	50	80	99	45	80	99	55	85	99
7	50	80	100	60	90	100	55	75	97	45	70	94	50	85	98
8	40	60	97	40	70	98	40	55	99	40	65	97	40	70	98
9	50	70	96	30	60	98	50	60	97	40	65	96	40	65	95
10	65	75	100	65	70	96	75	85	98	60	70	92	60	75	93
$\bar{X}$	52	73	98	50	78	98	50	70	98	45	70	96	54	79	97
Std. Dev.	8.2	5.9	1.8	12.4	9.5	1.4	12.8	12.6	0.8	9.1	9.0	2.7	12.5	8.4	1.9

Note: It was difficult to obtain less than 50 percent coating because then it approached salt & pepper effect.

ASTM specifies 95 percent level in ASTM D 1664-80, Coating and Stripping of Bitumen-Aggregate Mixtures, as a go-no-go test because the precision is not satisfactory for applications at lower levels.

All five aggregate precoated to different degrees were subjected to the Pennsylvania Aggregate Retention Test. Table 4 presents the aggregate retention loss data in percentages. Figure 4 shows the plots of percent precoated surface versus percent initial retention loss. The following observations were made:

1. Considering the percent initial loss, the 90 percent or greater precoating is by far the best. This means that immediate adhesion of the cover aggregate with the bituminous binder is best obtained with 90 percent or greater precoating. The primary function of precoating is to obtain immediate adhesion as discussed earlier in the literature review.
2. Increasing the percentage of precoating decreased the initial aggregate retention loss. A salt-and-pepper condition is better than uncoated aggregate, and so forth.
3. Initial aggregate retention loss was reduced by as much as 80 percent when the uncoated aggregate (containing 3 percent dust) was precoated with 90 percent or more coating.

It should be noted that 90 percent or greater coating gave poor results in the knock-off test. More than 50 percent coating gave the best results for Aggregates 3, 4, and 5. The precoating on Aggregate 2 did not help at all. It is suspected that the MC-30 cutback asphalt used as the precoating material in this study did not cure completely in two days. Although the initial adhesion was immediate and good, it appears that the cutback asphalt film around the aggregate was too soft (thus weakening the bond between the aggregate and emulsion residue) for the severe knock-off test. Therefore, it

TABLE 4 EFFECT OF PRECOATING ON AGGREGATE RETENTION LOSS (PERCENT)

	Coating	Aggregate Number				
		1	2	3	4	5
% Initial Loss						
$= \frac{B}{A} \times 100$	No Coating	21	34	18	21	18
	S. & P.	18	30	14	17	12
	Less than 50%	15	24	10	11	11
	More than 50%	13	15	10	10	9
	90% +	4	10	4	3	4
% Knock-Off Loss						
$= \frac{C}{A - B} \times 100$	No Coating	12	13	10	16	11
	S. & P.	10	19	10	15	7
	Less than 50%	10	17	7	10	5
	More than 50%	11	19	6	8	4
	90% +	15	27	9	13	8
% Total Loss						
$= \frac{D}{A} \times 100$	No Coating	31	43	26	34	27
	S. & P.	26	44	22	29	19
	Less than 50%	23	37	17	21	16
	More than 50%	22	31	15	17	13
	90% +	18	31	13	16	12

Notes: 1. A = Wt. of total aggregate (300 grams), B = Initial loss in grams, C = Knock-off loss in grams, and D = Total loss in grams (B + C).

2. S. & P. = Salt & Pepper effect.

3. All aggregates (uncoated and precoated) contained 3.0% dust.

4. Above results are based on an average of 3 tests. Therefore, the initial loss and the knock-off may not add up exactly to the total loss.

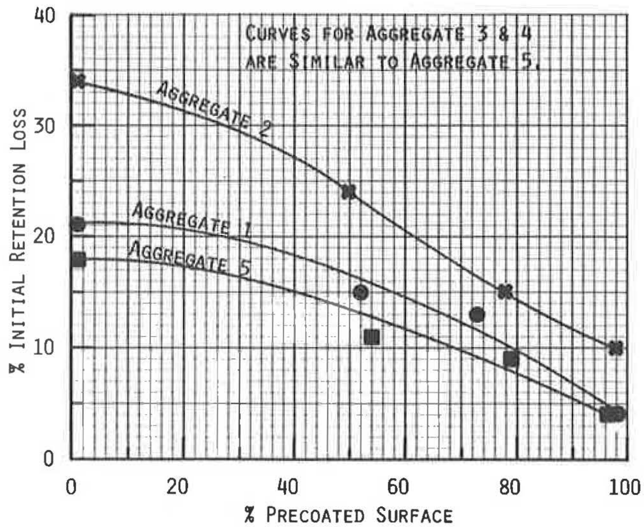

FIGURE 4 Percent coating versus initial retention loss.

is recommended to use AC-20 asphalt cement as the precoating material because it can be mixed with the aggregate at high temperatures in an HMA plant and does not require any curing. If MC-30 or MC-70 cutback asphalt must be used, the surface coating must cure completely.

It is also known that the rate of setting (breaking) of applied emulsified asphalts is slower with precoated aggregates compared with uncoated aggregates. The latter absorb water readily from the emulsified asphalt and thus accelerate the breaking process. This has been documented by TRRL in Road Note No. 39 (*14*), thus "the use of lightly-coated chippings when bitumen emulsions are used may lead to delay in the break of emulsion." Most experience in the past with the precoated aggregate in the United States and abroad has been with asphalt cements and cutback asphalts as application bituminous materials. Texas does not recommend the use of precoated aggregate with emulsions because the latter breaks and cures slowly (responses to questionnaire on durable asphalt emulsion seal coats, 1987). Undoubtedly, traffic control will be required for longer periods of time when precoated instead of uncoated aggregates are used with emulsified asphalts. Nonetheless, the importance of obtaining immediate and good adhesion that results from the use of precoated aggregates cannot be ignored.

If the total aggregate retention loss (initial loss and knock-off loss) is considered (Table 4), the benefits of precoating are apparent, and the 90 percent or more precoating is still the best.

Single Size Versus Total Gradation

So far, the reported data and discussion pertained to the single size (⅜ in., No. 4) aggregate gradation. Because AASHTO No. 8 aggregate (½ in.) is used by PennDOT for seal coats and surface treatments, it was necessary to verify whether similar results are obtained when the total gradation is used. This was attempted on Aggregates 4 and 5. The detailed data are given elsewhere (*12*).

These two total aggregates (½ in., No. 8) were also precoated to different degree and were evaluated by 9 observers. Similar to the single size aggregates, the standard deviation of the observed percent coating decreased as the coating increased. Again, the best reproducibility was obtained at precoating levels of 90 percent or greater.

Dust contents varying from 0 to 5 percent were also attempted on the total gradation of Aggregates 4 and 5. The comparative test data (single size versus total gradation) are given elsewhere (*12*). The following observations were made:

1. Aggregate retention loss (initial as well as knock-off) increased with increasing dust contents.
2. The rate of increase in knock-off loss with increasing dust contents became significantly greater after about 3 percent dust content in both cases.
3. As expected, the aggregate retention loss at all dust content levels was greater for the total aggregate compared with the single size. The former contains additional smaller particles that tend to fill the voids between large particles and thus may not get effectively embedded into the applied binder.

The above observations are similar to the observations of uncoated single size aggregates reported earlier. The following observations were made based on the test data obtained on precoated total gradations of Aggregates 4 and 5:

1. Considering the percent initial loss, the 90 percent or greater precoating is by far the means that immediate adhesion of the cover aggregate with the bituminous binder is best obtained with 90 percent or greater precoating of the total aggregate similar to the single size aggregate.
2. Unlike single size aggregates, the total aggregates had higher initial retention loss when precoated less than 50 percent compared with uncoated aggregates. Only when the percent coating exceeded 90 percent was a drastic reduction in the retention loss realized. Increasing the precoating of Aggregate 4 from 76 to 97 percent reduced the initial retention loss by about 50 percent. This observation is important because the results of this study are to be applied to the total aggregate (AASHTO No. 8) used by PennDOT and not to the single size aggregate. It appears that increased precoating is required to effectively bind the dust to the graded aggregate particles. This will be more evident when the end-result test data are discussed later.

End-Result Tests

It has been demonstrated in the previous sections that the subjective visual evaluation test is suitable and reasonably reproducible for 90 percent or greater precoated aggregates. However, the following end-result type tests were attempted on the precoated total aggregate (½ in., No. 8) to eliminate the subjective evaluation for final acceptance:

1. Dry gradation test: Because the precoated aggregates were free flowing, the samples were subjected to dry gradation test using ½-in., ⅜-in., No. 4, No. 8, No. 16, No. 30, No. 50, No. 100, and No. 200 sieves (sieving time was 10 min). This was attempted in order to quantify the presence of unbound

fine material (passing No. 8) and dust (passing No. 200) in the sample. The dry gradation data for all five aggregates precoated to different degree are given elsewhere (*12*).

It was evident from the data that a substantial amount of fine material (passing No. 8) and dust (passing No. 200) remains unbound (or loose) until the precoating level of 90 percent or more is reached. This unbound dust is quite likely to fall off in the chip spreader during field operations and interfere with the initial adhesion of the precoated aggregate to the bituminous binder. The previously discussed laboratory test data using the Pennsylvania Aggregate Retention Test support this observation. It was noted that 90 percent or greater precoating reduces the unbound dust (minus 200) to less than 0.1 percent, which ensures the development of good initial adhesion. If the dry gradation is used as an acceptance (or referee) test, it appears reasonable and practical to establish 0.5 percent maximum minus 200 as the acceptance criterion.

2. Wash test: The precoated aggregate samples were subjected to a wash test (with and without detergent) to determine the minus 200. Because the water containing detergent (sodium tripolyphosphate) started to strip the coating, the wash tests were performed under running tap water only. Two sieves (No. 16 and No. 200) were used. The unbound dust contents obtained by wash test and dry gradation test were comparable (*12*). Again, 90 percent or greater precoating reduced the dust content by the wash test to 0.3 percent.

After running several wash tests, it was concluded that the reproducibility of this test may not be satisfactory because it involves physical manipulation (stirring) of the sample by the operator and because of the likelihood of some partial stripping.

SUMMARY AND CONCLUSIONS

One of the most common causes of seal coat failures is the presence of dust on the cover aggregate, which prevents good adhesion between the applied bituminous binder and the aggregate. Precoating the aggregate with a thin film of bituminous binder usually solves the dust problem and provides good adhesion. This research was undertaken (*a*) to evaluate the adhesion of aggregates precoated to varying degrees so that the optimum precoating requirement could be established, and (*b*) to develop an end-result type test in lieu of the subjective visual test for accepting precoated aggregates.

Five AASHTO No. 8 aggregates of different mineralogical compositions and absorption characteristics were used. Two gradations, single-size (⅜ in., No. 4) and total (½ in., No. 8), were used. MC-70 cutback asphalt and CRS-2 (PA E-3) emulsified asphalt were used as the precoating and application bituminous materials, respectively.

The Pennsylvania Aggregate Retention Test was developed for this study to evaluate the initial adhesion loss and knock-off loss. Uncoated aggregates with 0 to 5 percent dust contents were also evaluated. Precoating of aggregates was varied from a salt-and-pepper effect to 90 percent or greater coating. On the basis of the preceding review of literature, test results, and discussions the following conclusions were drawn:

1. The rate of increase in knock-off loss with increasing dust contents in uncoated aggregates was generally observed to be significantly greater for more than 3 percent dust content. Therefore, 3 percent is considered to be a threshold value for all practical purposes.
2. A good relationship was observed between the flakiness indices of the aggregates and the corresponding aggregate retention losses. The latter increase with increasing values of the flakiness index.
3. Increasing the percentage of precoating decreased the initial aggregate retention loss. This loss was reduced by as much as 80 percent when the uncoated aggregate was precoated with 90 percent or more coating.
4. Considering the percent initial retention loss, the 90 percent or greater precoating was observed to be by far the best. This means that immediate adhesion of the cover aggregate with the bituminous binder is best obtained with 90 percent or more precoating.
5. Use of AC-20 asphalt cement (in lieu of MC-30 cutback asphalt) as a precoating material is recommended because it can be mixed with hot dry aggregate in a HMA plant, does not need any curing, and will cause better aggregate retention. If MC-30 or MC-70 cutback asphalt must be used it should be ensured that the coating has cured completely before the precoated aggregate is used.
6. Effects of dust content and extent of precoating on the aggregate retention loss were similar for the two gradations [⅜ in., No. 4 (single size) and ½ in., No. 8 (total)]. However, the corresponding retention losses were greater in the latter gradation, as expected, because it contained additional smaller particles.
7. Ten observers made 150 subjective visual examinations of the precoated aggregate samples. The agreement between different evaluators becomes increasingly better when the percentage of coating is increased from 50 to 90 or more, by far the best agreement (reproducibility) being for 90 percent or greater coating. The current PennDOT specifications require 90 percent or greater coating. Few, if any, problems have been experienced in judging this specified minimum coating except during the first 2 years when the precoated aggregate specifications were introduced in 1980.
8. Two simple end-result type tests: dry gradation test and wash test were attempted on the precoated aggregates in this study. The dry gradation test was determined to be more appropriate with an acceptance criteria of 0.5 percent maximum minus 200 (dust).

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