

Evaluation of Tests To Assess Stripping Potential of Asphalt Concrete Mixtures

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Stress pedestal, boil, and indirect tensile tests were evaluated for assessing the stripping potential of asphalt concrete mixtures. The tests were applied to surface and base-binder mixtures that included five aggregate combinations, asphalt cement from two sources, and three antistripping agents. The field performance of mixes with the five aggregate combinations ranged from good to poor, and the asphalt cements and antistripping agents are representative of those used in Alabama. The boil and indirect tensile tests were most promising, although neither they nor the stress pedestal test accurately predicted the expected performance of all mixes. They did, however, produce consistent, although at times apparently incorrect, predictions. There was also reasonably good correlation between boil test and indirect tensile test values, which improves their credibility as predictors of stripping when applied to specific mixes. Use of the tests for general evaluation of material sources is not recommended; they must be applied to specific material combinations. Variability in aggregate drying, gradation, and asphalt content may be an important factor affecting stripping potential. Additional testing to establish the influence of these factors is recommended.

The destructive influence of moisture in asphalt concrete has been extensively investigated. Numerous test procedures have been developed and are continually evolving to evaluate asphalt concrete mixtures and possible remedies that could reduce stripping. Materials alone present thousands of variables that may influence stripping (1). Kennedy et al. (2) in 1983 investigated the stripping potential of selected materials from Texas using three different tests. Stuart (3) in 1986 investigated the stripping potential of material selected from several states with several techniques. These two independent studies, and many more, have concluded that there is no generally applicable way to reliably evaluate the water susceptibility of proposed aggregate-asphalt combinations.

The quantification of stripping potential during material selection and mixture design has remained difficult. Conventional specifications for asphalt mixtures do not totally evaluate the asphalt-aggregate bond (4). A possible approach that would consider stripping with other mixture requirements could be achieved by following the conventional design method first, then evaluating the proposed mixture by conducting moisture susceptibility tests.

Because of this problem, this study was initiated in 1984 to develop or recommend, or both, a test procedure to assess the stripping potential of Alabama asphalt concrete mixtures and to

study the effectiveness of antistripping additives. The study incorporated five aggregate combinations (two limestone and three gravel), asphalt cement from two sources, and three antistripping agents representative of materials used in Alabama. The stripping potential of mixtures designed with the Marshall method was evaluated with boil tests, stress pedestal tests, and indirect tensile tests.

DEVELOPMENT OF TEST PROGRAM

The testing program was initiated by evaluating the boiling and stress pedestal tests on surface course mixes with the five aggregate combinations and asphalt cement from two sources. The results of these tests were generally better than expected and showed lack of strong correlation with field performance. Indirect tensile tests were then run on asphalt cement from one source. These test results showed similar correlation with field performance.

Further review revealed that coarser and leaner base-binder mixtures may be more vulnerable to stripping than are finer and richer surface mixtures. Field experience reinforced this belief. Cores taken from pavements constructed with some of the aggregates under study showed that stripping generally began and was concentrated in bottom layers of pavements. A significant exception to this has been stripping in surface mixes that have been overlaid. At this stage, the decision was made to evaluate base-binder mixtures and to eliminate the stress pedestal test. The remaining tests were performed with all five aggregate combinations and asphalt cement from two sources. The effectiveness of antistripping agents was studied at all stages of the testing program.

MATERIALS

Properties of the component materials and mixes have been previously described (5) and will only be summarized here.

Asphalt Cement

Asphalt cements were obtained from two sources and were labeled AC1 and AC2. Both were viscosity grade AC-20 meeting Alabama Highway Department specifications. The manufacturers mix crude from various sources, but at the time of sampling the majority of the crude oil was from the Gulf of Mexico.

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Aggregate

Aggregate combinations were selected, after consultation with Alabama Highway Department central laboratory and division personnel, to provide a range of field performance from good to poor. The characterization of an aggregate combination is subjective and based on experience of field personnel with asphalt-aggregate mixes containing the aggregate. The characterization is, therefore, general in nature rather than specific and relates to the potential for stripping rather than to the performance of a particular mix. A reasonable characterization would be that a mix of "A" materials would be less likely to strip than a mix of "B" materials. As results presented later will verify, factors other than aggregate composition (gradation and asphalt content) influence test results.

Five typical aggregate combinations of from three to five individual aggregates each were selected and arbitrarily labeled A through E. Aggregates were combined to produce mixes that met either surface or base-binder course specifications. Therefore, for each aggregate combination, there will be a surface mix and a base-binder mix. The gradations and design asphalt contents were those obtained by the Marshall mix design procedure.

Combination A

These are basically limestone mixes that have good reported performance with few signs of pavement distress attributable to stripping. Surface Mix A contains 85 percent crushed limestone and 15 percent natural sand and has an asphalt content of 5.5 percent. It has been used primarily for shoulder paving and leveling. Base-Binder Mix A contains 100 percent crushed limestone and has an asphalt content of 4.25 percent. The limestone is dense (specific gravity ≈ 2.8) dolomitic material with an absorption of about 1 percent.

Combination B

These are basically gravel mixes with variable reported performance. Before the use of antistripping additives, stripping damage was severe. Antistripping additives have improved performance; however, some stripping problems are still reported. Both surface and base-binder mixes contain 10 percent limestone screenings and 90 percent siliceous sand and gravel. The surface mix has an asphalt content of 7.5 percent and the base-binder mix 4.5 percent. The gravel and sand are from the same source and are described as "cherty" materials (specific gravity ≈ 2.5) with relatively high absorption (3 percent). The surface mix contains crushed gravel and the base-binder mix contains uncrushed gravel.

Combination C

These are siliceous gravel mixes with moderate reported performance. Even before the use of antistripping additives, only minor stripping problems were reported. Both the surface and the base-binder mixes contain 15 percent fine sand and 85 percent coarse sand and gravel from a primary source. Asphalt contents are 6.25 and 4.55 percent for the surface and base-binder mixes, respectively. The coarse sand and gravel are

predominantly sound quartz and quartzite materials (specific gravity ≈ 2.6) with relatively low absorption (1 percent).

Combination D

These are siliceous gravel mixes with poor reported stripping performance. The use of antistripping additives has improved performance, but gravels from this region of the state continue to be regarded as particularly susceptible to water damage. The mixes contain 10 and 15 percent fine sand and 90 and 85 percent washed sand and gravel from a primary source. Asphalt contents are 6.25 and 4.9 percent for the surface and base-binder mixes, respectively. The washed sand is primarily sound quartz, but the coarser particles tend to be similar to the gravel. The gravel is a highly variable cherty material (specific gravity ≈ 2.5) including light and porous particles. Absorption is relatively high at about 2.7 percent.

Combination E

These are basically limestone mixes with good reported stripping performance. Both the surface and the base-binder mixes contain 10 percent natural sand and 90 percent crushed limestone from a primary source. Asphalt contents are 5.5 and 4.15 percent for the surface and base-binder mixes, respectively. The limestone has a relatively high calcium carbonate content (approximately 90 percent), a specific gravity of about 2.6, and absorption of about 1 percent.

Antistripping Additives

Three antistripping additives were used: hydrated lime and two proprietary chemical agents. The hydrated lime (HL) is high calcium and was applied at a rate of 1 percent by weight of aggregate. One proprietary liquid agent, labeled BA, is a metalloamine (or polyamine) with a recommended dosage rate of 0.5 percent by weight of asphalt cement. The second proprietary liquid agent, labeled KB, is an amidoamine with a recommended dosage rate of 0.5 to 1 percent by weight of asphalt cement.

TEST PROCEDURES

Aggregates were combined according to the job mix formulas, and sieved on eight sieves to produce portions with particle sizes ranging from passing 1½ in. to No. 200. Required aggregate from each portion was then combined to meet required gradations. After this stage, sample preparation and testing were dependent on the type of test.

Indirect Tensile Test

Samples were prepared in accordance with ASTM D 1559. Mixing and compaction temperatures were selected on the basis of asphalt cement viscosity. Compaction levels were varied to meet the 6 to 8 percent voids requirement. Two testing procedures were used (Table 1).

Boil Test

Samples for boil test were prepared and tested in accordance with ASTM D 3675 except for the following variations:

TABLE 1 INDIRECT TENSILE TEST PROCEDURES

Treatment	Procedure 1	Procedure 2
Mix aging	No aging	15 hr at 140°F
Compacted specimen curing	No curing	24 hr at room temperature
Initial saturation (%)	60–80	60–80
Freezing	No freezing	15 hr at 0 ± 4°F
Soaking	24 hr at 140°F	24 hr at 140°F
	3 hr at 77°F	3 hr at 77°F
Age of specimen at testing (days)	2	4
Voids range (%)	6–8	6–8
Loading strips (width in in.)	1/2	1/2
Rate of loading (in./min)	2	2
Testing temperature (°F)	77	77
Similar procedure	Tunnicliff and Root (1)	Modified Lottman (6)

1. Boiling time was 10 min,
2. Samples were stirred three times during boiling, and
3. Specimens were cooled to room temperature before the water was drained.

Details of the test procedure are given elsewhere (7).

Stress Pedestal Test

The test procedure is an adaptation of a test proposed by the Laramie Energy Technology Center (8). The test was performed according to procedures recommended by Kennedy et al. (9).

DISCUSSION OF TEST RESULTS

Indirect Tensile Test

Results from indirect tensile tests are summarized in Table 2 and plotted in Figures 1 and 2. The following can be inferred from these data:

1. Test Procedure 2 is more severe than Procedure 1 (except for Aggregate Combination B). This may be the result of differences in aging of the mixture, curing of the compacted specimen, and specimen conditioning. The aging and curing for Procedure 2 may enhance adhesion and result in a higher mechanical strength. The cycle of freezing for Procedure 2 may result in larger loss of strength than does only soaking in Procedure 1. In general, the larger strength loss more than compensates for the strength increase due to aging and curing. However, Aggregate Combination B has porous cherty gravel of high absorption. The aging and curing may have increased asphalt absorption and adhesion enough to offset the more detrimental effects of freezing. The net result is that Procedure 2 gave higher strength ratios for this particular aggregate combination.

2. From Figure 2 it appears that mixtures with AC2 are somewhat less susceptible to water damage than are those with AC1, although the differences are not large. Standard physical tests indicate no dramatic differences in asphalt cement properties, and retained strength differences are thought to be the result of asphalt-aggregate interaction.

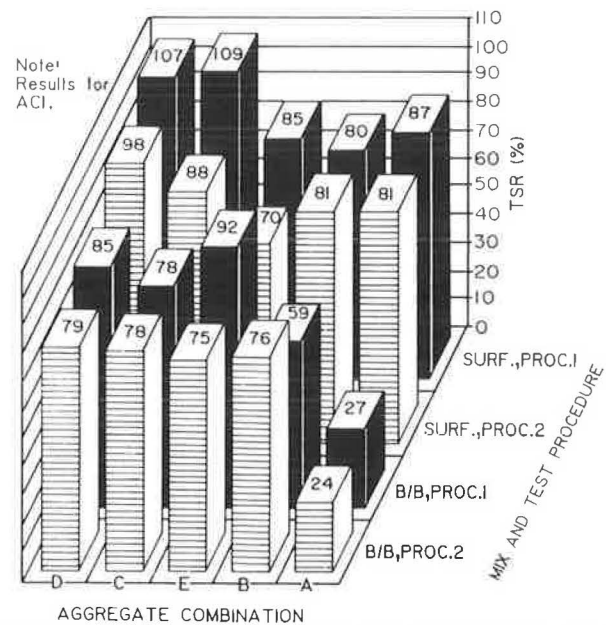


FIGURE 1 Effect of test procedure and type of mixtures on TSR.

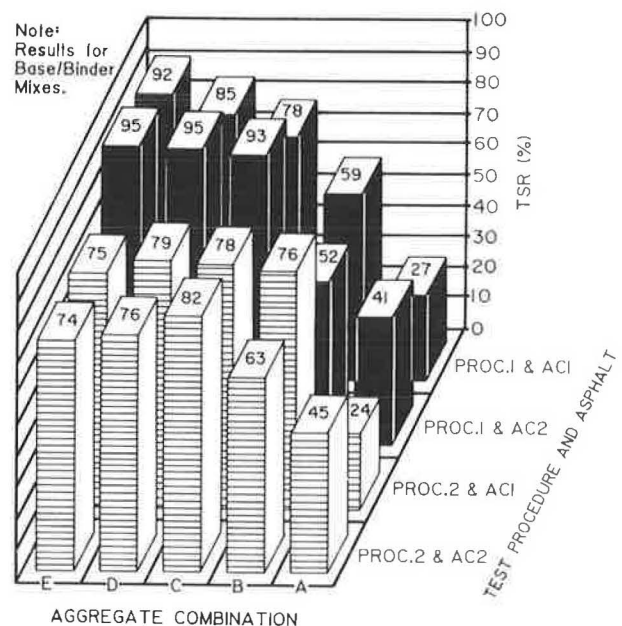


FIGURE 2 Effect of test procedure and source of asphalt cement on TSR.

3. Figure 1 shows that base-binder mixtures are more vulnerable to water damage than are surface mixtures. Speculation is that the differences in tensile strength ratios (TSRs) are due to the coarser gradation and lower asphalt content of the base-binder mixtures. Asphalt content of base-binder mixtures is compensated for somewhat by coarser gradation, but generally these mixtures are "leaner" than surface mixtures. Gradation will also affect the nature of the voids in a mix. Although void content was controlled at 6 to 8 percent, coarser gradation will produce fewer but larger voids. These larger voids will permit easier access to water and, thus, increase the potential for stripping. This phenomenon was apparent during vacuum saturation. During the trial-and-error attempts to achieve 60 to

TABLE 2 INDIRECT TENSILE TEST RESULTS, NO ADDITIVES

Aggregate Combination	Asphalt Content (%)	Procedure 1 ^a				Procedure 2 ^a			
		Initial Voids (%)	Final Saturation (%)	TSR (%)	SMR (%)	Initial Voids (%)	Final Saturation (%)	TSR (%)	SMR (%)
Asphalt Cement 1									
A									
Surface	5.5	6.5	89	87	—	6.2	91	81	58
B/B	4.25	7.4	94	27	11	7.7	89	24	10
E									
Surface	5.5	6.4	82	85	59	7.4	96	70	56
B/B	4.15	7.0	88	92	90	6.8	88	75	47
C									
Surface	6.25	7.3	80	109	—	6.9	82	88	72
B/B	4.55	6.9	89	78	45	6.7	85	78	55
B									
Surface	7.5	7.0	101	80	—	6.2	101	81	53
B/B	4.5	6.6	100+	59	30	6.4	100+	76	60
D									
Surface	6.25	7.4	88	107	76	7.5	93	98	71
B/B	4.9	6.6	97	85	47	6.6	98	79	44
Asphalt Cement 2									
A, B/B	4.25	6.7	100+	41	17	6.4	100+	45	23
E, B/B	4.15	6.5	85	95	83	6.9	88	74	43
C, B/B	4.55	7.2	93	93	68	6.7	83	82	68
B, B/B	4.5	7.7	100+	52	29	7.2	100+	63	55
D, B/B	4.9	6.9	95	95	54	7.2	100	76	46

NOTE: B/B = base-binder.

^aAverage of at least three specimens.

80 percent saturation, less intense partial vacuums and much smaller times were required with base-binder mixtures.

Table 3 gives a summary of a three-way analysis of variance to determine the overall effect of test parameters on tensile strength and TSR for different mixtures. In this table, the aggregate combinations are grouped into three subgroups in relation to reported field performance as follows:

- Nonstripping mixtures: Aggregate Combinations A and E,
- Stripping mixtures: Aggregate Combinations B and D, and
- Variable mixture: Aggregate Combination C.

Analysis of variance was conducted on all mixtures as well as on stripping and nonstripping subgroups at the 5 percent level of significance. Table 3 can be interpreted as follows:

1. Aggregate mineralogy is the dominant factor affecting tensile strength and TSR.
2. Test procedure and source of asphalt cement affect both conditioned and unconditioned strengths with a resulting insignificant effect on TSR.
3. There is no relationship between the combined effect of test parameters and the individual effect of each parameter. For example, if the source of asphalt produces a significant effect and the type of aggregate also produces a significant effect, the combined effect may or may not be significant.

The effectiveness of antistripping agents was studied by using them to improve mixtures that had low TSR. In accordance with this criterion, antistripping agents were used in base-binder mixtures for Aggregate Combinations A and B only.

Figure 3 shows the sensitivity of the tested mixtures to antistripping agents. It can be seen from the figure that the agents increased TSR values above the 70 to 80 percent range only for Aggregate Combination B. A possible reason is that the agents were formulated for siliceous material not limestone. However, an extenuating circumstance is the lower TSR values for Combination A without additives. The percentage increases in TSR are similar for both combinations.

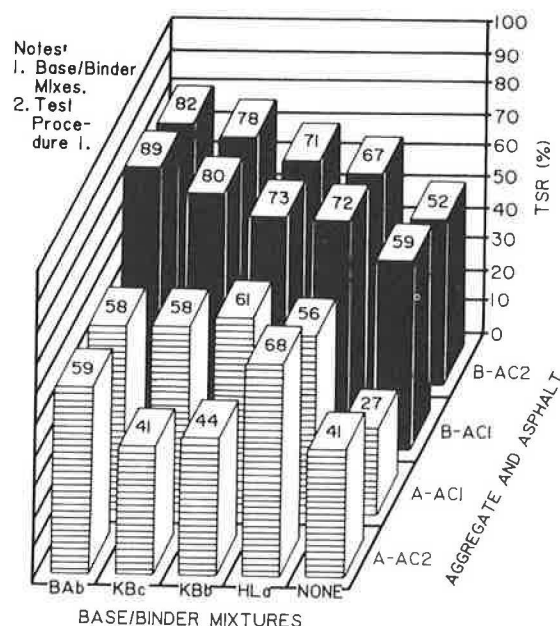


FIGURE 3 Effect of additives on TSR for Aggregate Combinations A and B.

TABLE 3 EFFECT OF TEST PARAMETERS (significance table)

		Test Parameters						
Test Variable	Type of Mixture	Asphalt Cement Source (A)	Test Procedure (T)	Aggregate Type (M)	Combinations of Test Parameters			
					AT	AM	TM	ATM
TSR	All	N	N	S	N	S	S	—
Unconditioned strength	Nonstrip	N	N	S	N	N	N	—
	Strip	N	N	S	N	N	N	—
	All	S	S	S	S	N	N	S
	Nonstrip	S	N	N	N	N	N	N
Conditioned strength	Strip	S	S	S	N	N	N	N
	All	S	S	S	N	S	S	S
	Nonstrip	S	N	S	N	N	S	S
	Strip	N	S	N	S	N	N	S

NOTE: S = significant at 5 percent level ($\alpha = .05$), N = not significant at 5 percent level ($\alpha = .05$), and dashes = not tested.

The Duncan multiple range test, at the 5 percent significance level, was used to rank the additives according to their improvement of TSR. For Limestone Mix A, all of the additives fell at the same rank. For Gravel Mix B, at the 5 percent level of significance, antistripping agents BA and KB at 1 percent dosage were the first ranked, KB at 0.5 percent dosage was the second, and the hydrated lime was third.

Boil Test

Boil test results are tabulated in Table 4. Values without antistripping additives are plotted in Figure 4. Comparison of coating retention for AC1 and AC2 indicates little difference. Coating retention differences for surface and base-binder mixtures can be noted in Figure 4. Base-binder Mixtures A and B retain much less asphalt after boiling than do surface mixtures. The differences are much less pronounced for Aggregate Combinations C, D, and E, which is consistent with indirect tensile test results.

The effect of additives on coating retention was also investigated for Aggregate Combinations A and B. The data in Table 4 indicate greater improvement in coating retention for liquid agents than for hydrated lime. When lime is used, a white powdery coating (assumed to be due to unbound lime) often

results. This tends to reduce the luster and intensity of the black coating, which in turn reduces perceived coating retention and, therefore, the rating.

This observation suggests that the boiling test may not adequately judge the effectiveness of lime as an antistripping agent. Hazlett (6) has also suggested that the boil test more favorably evaluates liquid antistripping agents. The data in Table 4 also indicate that the antistripping agents improved coating retention more for Aggregate Combination B than for Aggregate Combination A. This is consistent with the indirect tensile test results.

Stress Pedestal Test

A limited study was performed with surface mix aggregate proportions only. Asphalt cement from both sources and three antistripping agents were used in testing the five aggregate combinations.

Test results are given in Table 5. No significant difference between AC1 and AC2 could be detected. Lime increased cycles for cracking above 25 [suggested limit in Kennedy et al. (9)] for Aggregate Combinations A, B, and C. With the exception of Agent BA at 0.5 percent dosage, liquid antistripping agents did not increase cycles to cracking. Unlike the boil test, the stress pedestal test favorably evaluates lime.

TABLE 4 BOIL TEST RESULTS WITH AND WITHOUT ADDITIVES

Aggregate Combination	Mix Type	Percentage of Asphalt Coating Retained									
		Asphalt Cement 1 with Antistripping Agent					Asphalt Cement 2 with Antistripping Agent				
		None	HL ^a	BA ^b	KB ^b	KB ^c	None	HL ^a	BA ^b	KB ^b	KB ^c
A	Surface	70	80	95	95	—	70	90	85	80	—
	Base	25	50	60	60	—	35	50	60	50	55
E	Surface	95	—	—	—	—	90	—	—	—	—
	Base	90	—	—	—	—	90	—	—	—	—
C	Surface	95	—	—	—	—	75	—	—	—	—
	Base	80	—	—	—	—	85	—	—	—	—
B	Surface	55	70	90	60	85	60	75	90	50	80
	Base	25	65	95	70	80	35	55	90	75	80
D	Surface	95	—	—	—	—	95	—	—	—	—
	Base	90	—	—	—	—	95	—	—	—	—

^a1 percent hydrated lime (based on aggregate weight).

^b0.5 percent antistripping agent (based on asphalt weight).

^c1 percent antistripping agent (based on asphalt weight).

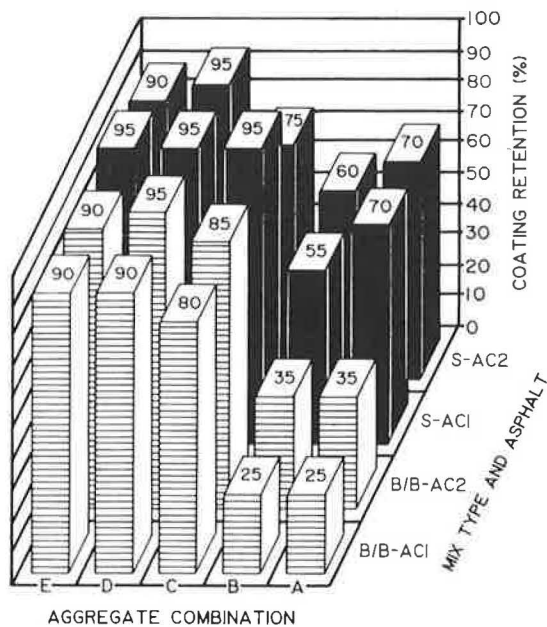


FIGURE 4 Effect of type of mixture and source of asphalt on coating retention.

Comparison of Boil and Indirect Tensile Tests

Both the indirect tensile and the boiling tests express the moisture damage to the mix as a ratio. A correlation of these results is shown in Figure 5 in which TSR for Test Procedures 1 and 2 are considered separately. Both least-squares linear regression equations fall to the right of the line of equality, indicating that the TSR percentage is greater than the coating retention percentage. The coefficients of determination indicate a much stronger correlation with Procedure 1. The freezing in Procedure 2 may introduce additional variability. The positive nature of the correlations, combined with the reasonably strong coefficient of determination for Procedure 1, indicates that both tests are, at least in part, measuring similar phenomena.

The test results are plotted in Figures 6 and 7 for surface and base-binder mixtures, respectively. If 70 percent TSR and 90 percent coating retention are used as criteria for separating stripping and nonstripping, Figure 6 indicates that both tests correctly characterize Mixture E as a nonstripper and incorrectly characterize Mixture D as a stripper. Moreover, the indirect tensile test results indicate that all of the surface mixtures are nonstrippers, and the boiling test predicts only Mixtures A and B as strippers.

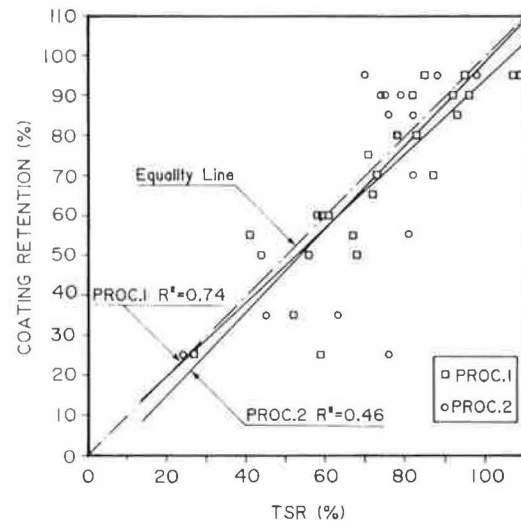


FIGURE 5 Relationship between indirect tensile and boil test results.

Figure 7 shows that, for base-binder mixtures, a strong correlation exists between the boiling and indirect tensile tests. Both tests correctly characterize Mixture E as a nonstripper and incorrectly characterize Mixture D as a nonstripper. Both tests also incorrectly characterize Mixture A as a stripper and correctly characterize Mixture B as a stripper. The boiling test indicates that Mix C is a stripper, and the indirect tensile test indicates that Mix C is a nonstripper.

MATERIAL EVALUATION

The five aggregate combinations, the asphalt cement from two sources, and the two tensile test procedures were evaluated using indirect tensile and boiling test results. Table 6 gives the ranking of the five aggregate combinations based on tensile strengths and stripping resistance as indicated by TSR and coating retention. Each mean value of strength, TSR, and coating retention for a specific type of mix, source of asphalt cement, and type of test procedure was assigned a number of points from one to five. For example, the lowest mean unconditioned strength value for Aggregate Combinations A through E for each test procedure was given one point, the second lowest was given two points, and so on until the highest value was given five points. The number of points for each aggregate combination in each case was totaled. The aggregate combination that had the highest total points was given the highest rank (i.e., one).

TABLE 5 RESULTS OF STRESS PEDESTAL TEST ON SURFACE MIXTURES

Aggregate Combination	Asphalt Cement 1 with Antistripping Agent					Asphalt Cement 2 with Antistripping Agent				
	None	HL ^a	BA ^b	KB ^b	KB ^c	None	HL ^a	BA ^b	KB ^b	KB ^c
A	15	—	—	—	—	13	>25	>25	11	—
E	>25	—	—	—	—	>25	—	—	—	—
C	15	—	—	—	—	18	>25	13	14	—
B	16	>25	13	9	9	17	>25	17	6	7
D	>25	—	—	—	—	>25	—	—	—	—

^a1 percent hydrated lime (based on aggregate weight).

^b0.5 percent antistripping agent (based on asphalt weight).

^c1 percent antistripping agent (based on asphalt weight).

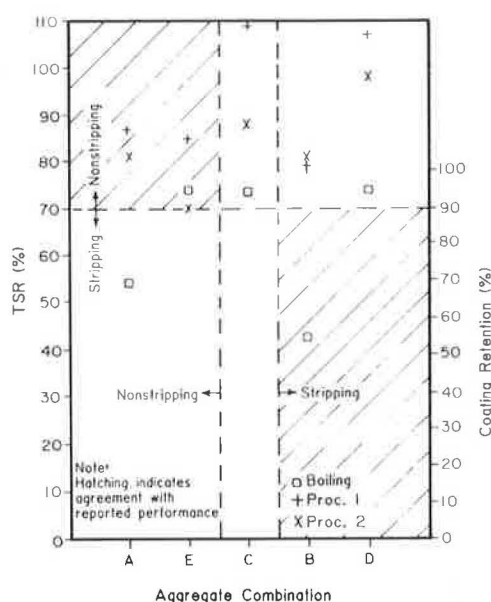


FIGURE 6 Comparison of boil and indirect tensile test results for surface mixtures.

It can be seen from the table that, in terms of unconditioned strength, Mix E has the highest rank and Mix D has the lowest. After conditioning, the table indicates that Mix C has the highest strength and that Mix A has the lowest.

The data in the table indicate that the indirect tensile and the boiling tests are well correlated in ranking the material in terms of stripping resistance as indicated by TSR and coating retention. The ranking indicates that Mixtures D and E are more resistant to water damage than are Mixtures A and B; Mixture

C is in the middle. This is consistent with reported field performance for Mixtures B, C, and E but inconsistent for A and D.

Evaluation of test procedures and asphalt cement sources was based on mean values. Table 7 gives mean values for tensile strength, TSR, and coating retention. AC2 consistently produced higher strength, TSR, and coating retention than did AC1. Although the differences are not large, because of their consistency it may be inferred that mixes with AC2 would

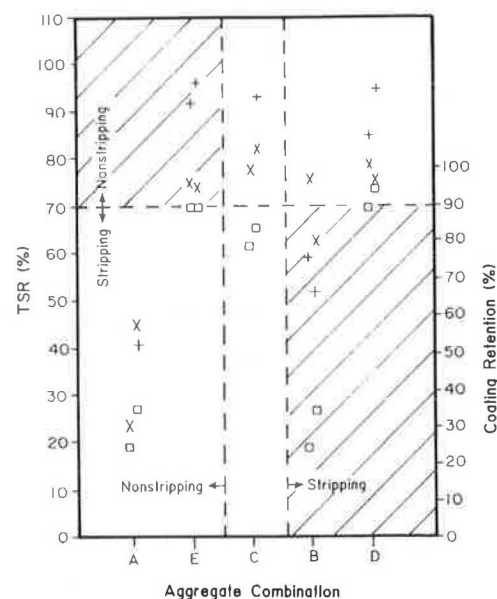


FIGURE 7 Comparison of boil and indirect tensile test results for base-binder mixtures.

TABLE 6 RANKING OF AGGREGATE COMBINATIONS

		Points Based on Means ^a							
		Surface AC1 Procedure		Base-Binder AC1 Procedure		Base-Binder AC2 Procedure		Total	Rank ^b
	Aggregate Combination	1	2	1	2	1	2		
Unconditioned strength	A	4	3	5	2	4	4	22	2
	B	2	1	3	4	2.5 ^c	5	17.5	3
	C	1	4	2	5	2.5 ^c	2	16.5	4
	D	3	2	1	1	1	1	9	5
	E	5	5	4	3	5	3	25	1
Conditioned strength	A	3	3	1	1	1	1	10	5
	B	1	1	2	4	2	3	13	4
	C	2	5	4	5	4	5	25	1
	D	4	4	3	2	3	2	18	3
	E	5	2	5	3	5	4	24	2
TSR	A	3	2.5 ^c	1	1	1	1	9.5	5
	B	1	2.5 ^c	2	2.5 ^c	2	2	12	4
	C	4.5 ^c	4	3	4	3	5	23.5	2
	D	4.5 ^c	5	4	5	4.5 ^c	4	27	1
	E	2	1	5	2.5 ^c	4.5 ^c	3	18	3
Coating retention	A		2		1.5 ^c		1.5 ^c	5	4
	B		1		1.5 ^c		1.5 ^c	4	5
	C		3		3		3	9	3
	D		5		4.5 ^c		4	13.5	1.5
	E		4		4.5 ^c		5	13.5	1.5

^aPoints = 1 (lowest mean) to 5 (highest mean).

^bRank = 1 (highest total) to 5 (lowest total).

^cEqual means.

TABLE 7 EVALUATION OF TEST PROCEDURES AND ASPHALT CEMENT FROM TWO SOURCES

	Mean Unconditioned Strength (psi)	Mean Conditioned Strength (psi)	Mean TSR (%)	Mean Coating Retention (%)
AC1	142	103	72	72
AC2	146	109	78	73
Procedure 1	133	104	70	—
Procedure 2	153	111	73	—

have somewhat greater resistance to detrimental effects of moisture.

Finally, the data in the table indicate that Test Procedure 2 produces higher strengths but lower TSRs than does Procedure 1. This is as expected, because aging of the mix and curing of the specimens increase strengths in Procedure 2. However, freezing in Procedure 2 produces larger strength reductions that more than compensate for the larger unconditioned strength. This results in lower TSRs for Test Procedure 2.

Numerous factors including aggregate composition, asphalt content, and gradation influence boil and indirect tensile test results. These, combined with the subjective nature of the characterization of the stripping propensity of the mixes, result in the not totally unexpected poor correlation with test results. This should not be interpreted as an invalidation of the test procedures or performance. Rather it indicates that additional refinement of test procedures and applications to specific mixes will be necessary to improve test result–performance correlation.

An extension of this research will provide the data for improving these correlations. Material and mix samples will be taken during construction and subjected to laboratory tests to study the effects of incomplete drying and segregation (gradation). Differences between complete laboratory drying and incomplete field drying may be primary contributors to lack of correlation for porous gravels such as those in Combination D. Cores will be taken immediately after construction and periodically thereafter to study the effects of compaction (voids) and to develop mix-specific performance data.

CONCLUSIONS

Measurement of moisture damage is a complex problem that is sensitive to discrepancies between laboratory and field conditions. Ideal testing and handling of materials, which can be achieved in the laboratory, can hardly be achieved in the field. On the other hand, field environmental conditions can only be approximately simulated in the laboratory. Conclusions include the following observations:

1. A pass-fail criterion, according to which all reported moisture-susceptible mixtures fail and all reported moisture-resistant mixtures pass, could not be developed for any of the tests evaluated.
2. The tests correctly categorized Aggregate Combinations B, C, and E as reported by field performance, but they did not correctly characterize Aggregate Combination A as a nonstripper or D as a stripper.

This weak correlation with field performance, coupled with the strong correlation between test results, led to the following conclusions:

1. The tests may not be valid indicators of stripping, or the subjective reported field performance may not be valid for specific mixes.
2. Variability in gradation, asphalt content, drying, mixing, and compaction may significantly affect stripping potential. Standard laboratory tests on samples with carefully controlled gradation and asphalt content, according to mix design, may not be sufficiently severe. Field sampling and testing should be conducted to establish the influence of construction variability on stripping potential and to establish correlations between laboratory tests and specific mix performance.

Given the assumption that the tests are valid indicators of stripping, the material tested can be described as follows:

1. Limestone Aggregate Combinations A and E have different stripping potential although they possess high tensile strength. Base-binder mixes with Aggregate Combination A have much higher stripping potential than do similar E mixes.
2. Cherty gravel Aggregate Combinations B and D also have different stripping potential; Mix D has lower strength but a higher retained ratio than Mix B.
3. Aggregate Combination C possesses moderate stripping potential.
4. Base-binder mixtures are more susceptible to moisture damage than are surface mixtures made up of the same constituents. This is attributed to differences in asphalt content (film thickness) and the nature of the voids resulting from differences in gradation.
5. AC2 is somewhat more resistant to moisture damage than is AC1.
6. The tests measure improvements when antistripping agents are added. The stress pedestal test assesses the effect of lime favorably, but the boil test assesses its effects unfavorably.

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