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Evaluating Moisture Susceptibility of Asphalt Mixtures Using the Texas Boiling Test

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ABSTRACT

A description of the development and use of the Texas boiling test to evaluate stripping of materials susceptible to moisture damage is presented. Based on a review and comparison of boiling tests currently in use by several agencies and a limited test evaluation program, a tentative test procedure was prepared and used for all subsequent testing. Tests were performed on eight mixtures, of which five had stripped in the field and three had not. Each mixture and its individual aggregate components were tested to determine if the results could be used to differentiate between stripping and nonstripping mixtures. Because antistripping additives are commonly used in stripping-prone mixtures, a few additives and aggregate combinations were tested to determine if test results were affected by the presence of these additives. Test results indi-

cate that valuable information is provided by the Texas boiling test. The test is simple and easy to perform; it can be performed either in the laboratory during mixture design or on field-mixed mixtures. Evaluation of known aggregates and various antistripping additives indicates that the Texas boiling test generally can be used to detect moisture-susceptible mixtures.

Water-induced damage of asphalt mixtures has produced serious distress, reduced performance, and increased maintenance for pavements in Texas as well as in other regions of the United States. Moisture-induced damage produces several forms of distress, including localized bleeding, rutting, shoving, and ultimately complete failure because of permanent deformations and cracking. This damage occurs because of stripping of asphalt from aggregate and in some cases possibly because of softening of the asphalt matrix.

Stripping, which is of primary concern, is the physical separation of the asphalt cement and aggregate produced by the loss of adhesion between the asphalt cement and the aggregate surface primarily due to the action of water or water vapor. Stripping is accentuated by the presence of aggregate surface coatings and by smooth surface-textured aggregates. Softening is a general loss of stability of a mixture that is caused by a reduction in cohesion due to the action of moisture within the asphalt matrix.

Field and laboratory experience to date (1-10) indicates that stripping is primarily an aggregate problem, but the type of asphalt is also important. Thus it is important to evaluate both the asphalt and the aggregate that is proposed for use. In addition, attempts to reduce the magnitude of the problem often have centered on introducing various antistripping additives to asphalt mixtures. Unfortunately, there has been no generally accepted, reliable way to evaluate proposed aggregate-asphalt combinations to determine their water susceptibility.

In response to this problem, the Center for Transportation Research and the Texas State Department of Highways and Public Transportation, through their cooperative research program, initiated a research project to study water-induced damage to asphalt mixtures in Texas. This study included an evaluation of proposed test methods for ascertaining the water susceptibility of asphalt mixtures and the effectiveness of antistripping agents.

As a result of the study, three tests were identified and were found to provide significant information with respect to distinguishing between stripping and nonstripping mixtures. These tests are the Texas freeze-thaw pedestal test, the Texas boiling test, and the wet-dry indirect tensile test.

The Texas boiling test is a rapid method to evaluate the moisture susceptibility of an aggregate-asphalt mixture before using the mixture in the field. The Texas freeze-thaw pedestal test is described elsewhere (2,3,8,10), and the wet-dry indirect tensile test is described by Kennedy and Anagnos (9). In this paper the development of the Texas boiling test procedure and the findings of studies to evaluate its effectiveness are summarized.

TEXAS BOILING TEST AND EVALUATION

The Texas boiling test is a rapid method to evaluate the moisture susceptibility, or stripping, of aggregate-asphalt mixtures, with and without antistripping agents, and is a composite of procedures that are described in other publications (11-14). In this test a visual observation is made of the extent of stripping of the asphalt from aggregate surfaces after the mixture has been subjected to the action of boiling water for a specified time. After reviewing the various test methods and performing a preliminary evaluation, the best features of each procedure were synthesized to produce a test procedure that would minimize potential field problems while minimizing the difficulty and cost of performing these laboratory tests. The standard procedure used in this study was designed for evaluating both the potential stripping mixtures and the effect of adding antistripping additives. The standard procedure is included in the Appendix and is summarized in the following sections.

Aggregate

Aggregate mixtures can contain several materials that are blended naturally or by the contractor to satisfy grading requirements. These individual mate-

rials and the total mixture vary in size, shape, surface texture, and chemical composition. The test method allows the individual materials and the total mixture to be evaluated.

Individual Aggregates

When an individual aggregate is to be evaluated, the proposed Texas boiling test permits testing of individual component materials in a range of sizes such as

1. Passing 3/8-in. retained on No. 4,
2. Passing No. 4 retained on No. 10,
3. Passing No. 10 retained on No. 40, and
4. Passing No. 40 retained on No. 80.

Additional size ranges can also be tested if needed.

Total Aggregate Mixture

When evaluating the total mixture, the sample should have the same gradation as proposed for construction; aggregates greater than 7/8 in. are normally eliminated. Care should be taken in the evaluation to ensure that a proper determination is made of the amount of asphalt retained on the aggregate because the fine aggregates have a significant effect on the visual appearance of the mixture.

Asphalt Cement

Both the type and amount of asphalt cement influence stripping and test results.

Type and Source

The asphalt cement should be the same as that proposed for use during construction. It is recommended that the asphalt-aggregate mixture be retested if the source or type of asphalt changes.

Asphalt Content

To evaluate the total aggregate mixture, the aggregates should be blended according to the specified project gradation, and the asphalt content should be that determined by Tex-204-F (15) or other design procedures. When the individual components of the mix are evaluated, a constant asphalt content can produce different film thicknesses because the design asphalt content varies with the size, shape, absorption, and surface area (16) of the aggregate being tested. To produce an asphalt film thickness for an individual aggregate that approximates the film thickness for the total mixture, the asphalt content should be increased or decreased until the proper film thickness, as determined visually, is secured. This can be done by visually ensuring that all particles are coated and that excess asphalt is not left in the mixing pan. Future refinements should consider the surface area of the individual aggregates in order to produce uniform film thicknesses.

Mixture Preparation

The asphalt cement, with or without an antistripping agent, is heated at $325^{\circ} \pm 5^{\circ}\text{F}$ for 24 to 26 hr, which allows the heat stability of the additive to be considered. For the evaluation of the total ag-

gregate mixture, 300 g of aggregate should be used; for the evaluation of an individual aggregate component, 100 g of material should be used. The dry aggregate is heated at $325^{\circ} \pm 5^{\circ}\text{F}$ for 1 to 1.5 hr. The asphalt cement is added to the aggregate and mixed manually on a hot table. The mixture is allowed to cool at room temperature for at least 2 hr before testing.

Test Procedure

A 1000-mL beaker or other suitable container is filled one-half full (approximately 500 cc) with distilled water and heated to boiling. The prepared aggregate-asphalt mixture is added to the boiling water, which will temporarily lower the temperature below the boiling point. The heat should be increased so that the water reboils in approximately 2 to 3 min. The water should be maintained at a medium boil for 10 min, stirring with a glass rod at 3-min intervals. During and after boiling the stripped asphalt should be skimmed away from the surface of the water with a paper towel to prevent recoating of the aggregate. The mixture is then allowed to cool to room temperature while still in the beaker. After cooling, the water is drained from the beaker and the wet mixture is emptied onto a paper towel and allowed to dry.

Evaluation and Reporting

The amount of stripping is determined by a visual rating, expressed in terms of the percentage of asphalt retained (scale 0 to 100 percent retained). Such a rating is subjective and will vary with time and for different operators. To standardize the evaluation, a standard rating board (Figure 1) has been developed with 10 intervals from 0 to 100 percent retained. This scale is constructed by using a set of specimens that have been selected to provide visual examples of varying degrees of stripping that can be compared with the test specimen to obtain a test value. A photograph should not be used because of textural differences. The mixture should not be evaluated until air-dried because laboratory results have demonstrated that stripping of the fines in some mixtures is not as apparent if the mixture is wet.

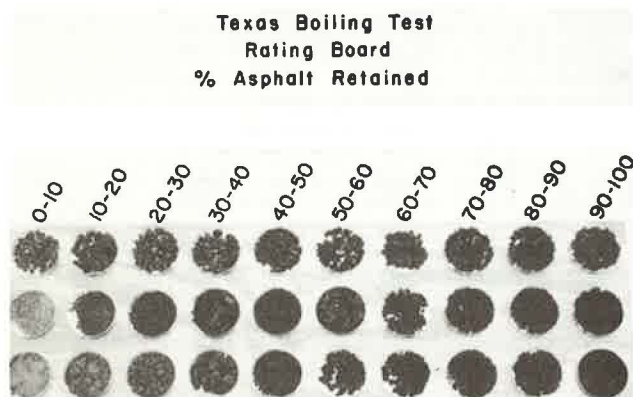


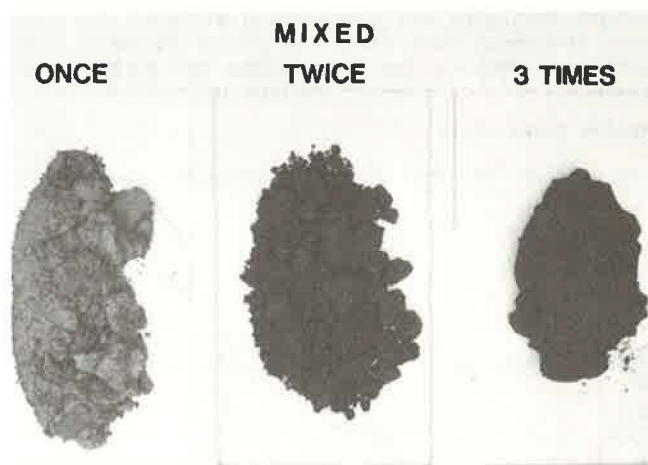
FIGURE 1 Texas boiling test rating board.

Analysis of Critical Test Variables

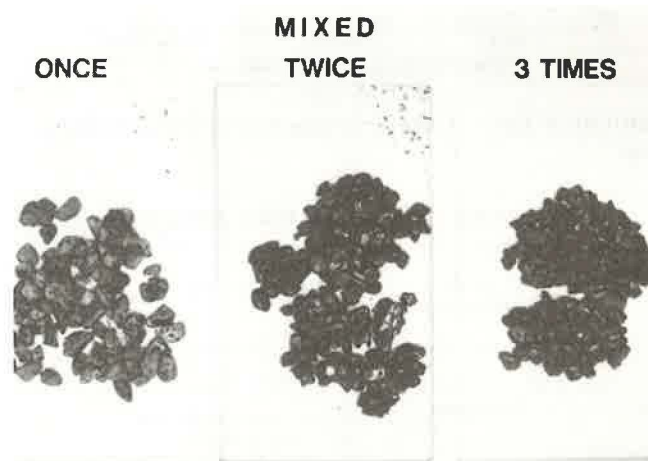
Initial laboratory evaluation of the test method indicated that test results were sensitive to three test variables: the number of times the asphalt and aggregate were mixed, the temperature to which the aggregate was heated before mixing, and the type of water used to boil the mixture. Thus these variables were evaluated to determine their effects, and the results were used to establish the test procedure.

Number of Times Mixed

Results of the boiling test indicated that reheating and remixing the asphalt-aggregate mixtures dramatically increased the amount of asphalt retained (Figure 2). A set of specimens, prepared from seven individual aggregates and one mixture, was prepared by mixing the aggregates and asphalt once; a second set of specimens was prepared where the specimens were mixed, reheated, and mixed again; and a third set of specimens was prepared where the specimens were



FINE FIELD SAND(9E)



COARSE RIVER GRAVEL(13A)

FIGURE 2 Effect of number of times mixed on Texas boiling test.

TABLE 1 Summary of Effect of Number of Times Mixed

Field Performance	Individual Aggregates and Mixture	Aggregate Size	Asphalt Content %	Asphalt Retained, %		
				Mix Once	Mix Twice	Mix 3 Times
Stripping	River gravel, 9D	-3/8 + 4	2.3	45	65	95
	Washed sand, 9F	-10 + 40	6.3	15	35	85
	Field sand, 9E	-40 + 80	6.3	15	75	95
	Coarse river gravel, 13A	-3/8 + 4	3.0	5	75	75
	Coarse field sand, 13C	-10 + 40	7.0	15	75	75
	Combined mixture, 13A & C		6.0	35	65	85
Nonstripping	Coarse crushed limestone, 14I	-3/8 + 4	3.4	75	75	85
	Limestone screening, 14K	-4 + 10	3.4	75	85	95

mixed three times. The results are summarized in Table 1 and Figure 3. As shown, the amount of retained asphalt was greater for mixtures that were reheated and remixed. In addition, the separation between stripping and nonstripping mixtures was best when specimens were mixed once. The standard procedure, therefore, involves mixing the asphalt and aggregate only once before cooling and boiling.

Mixing Temperature

The effect of the initial aggregate temperature

(mixing temperature) was also evaluated. A series of boiling test specimens were prepared with aggregates heated to either 200°, 250°, or 325°F and then mixed with asphalt cement at 325°F. After mixing and cooling, each mixture was boiled and the amount of asphalt retained was determined. The results indicated that a greater amount of asphalt was retained when the aggregate and resulting mixing temperatures were higher (Table 2 and Figures 4 and 5). Therefore, in the standard boiling test procedure both the aggregates and the asphalt cement are heated to 325°F before mixing.

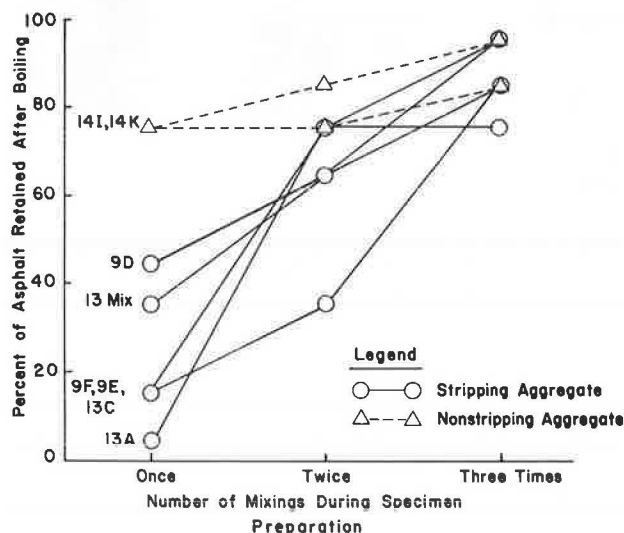


FIGURE 3 Effect of number of times mixed on Texas boiling test.

Water for Boiling

A comparison of test results obtained by using distilled water and tap water indicated that dramatically different results can be obtained and that the type of water also produces effects (Figure 6). Similar effects were also reported by personnel of the Alabama Department of Transportation. Thus the standard procedure uses distilled water.

TEXAS BOILING TEST TO EVALUATE MATERIALS

A series of tests on mixtures with and without anti-stripping additives was conducted to evaluate the ability to distinguish between known stripping and nonstripping mixtures and to evaluate the effect of antistripping additives.

Materials

Eight mixtures from actual projects were selected for use in this study. Of these eight mixtures, five previously exhibited stripping in the field and

TABLE 2 Summary of Effect of Initial Aggregate Temperature

Field Performance	Individual Aggregate	Aggregate Size	Asphalt Content %	Asphalt Retained, %		
				200°F	250°F	325°F
Stripping	Field sand, 9E	-40 + 80	6.3	15	15	55
	Coarse field sand, 13C	-10 + 40	7	25	25	65
	Gem sand, 13M	-3/8 + 4	3	5	5	26
	Coarse sand, 13N	-10 + 40	7	15	25	65
Nonstripping	Sandstone, 13L	-3/8 + 4	3	35	35	85
	Field sand, 13D	-40 + 80	7	85	65	85

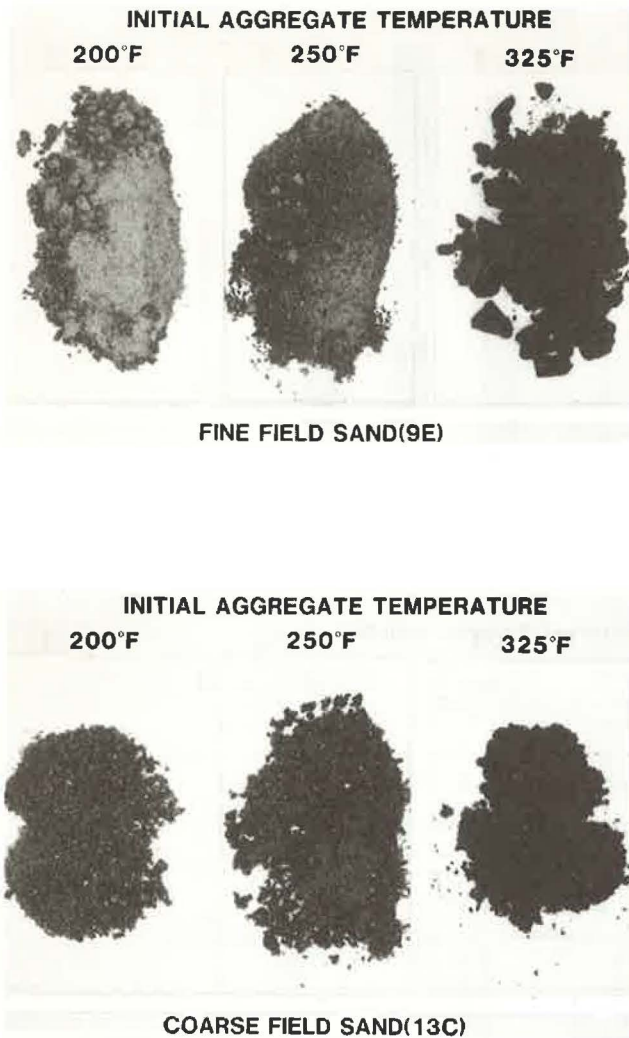


FIGURE 4 Effect of initial aggregate temperatures on Texas boiling test.

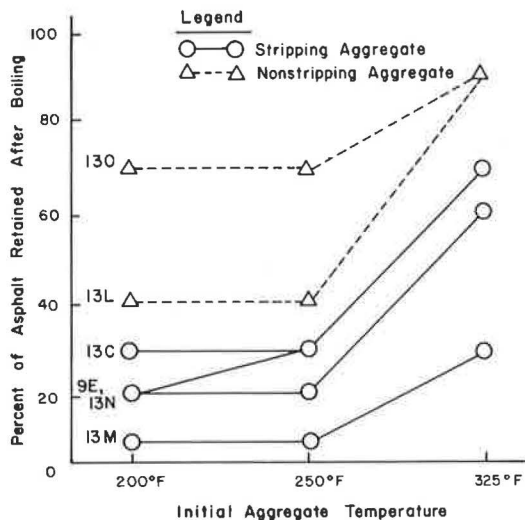


FIGURE 5 Effects of initial aggregate temperatures on Texas boiling test.

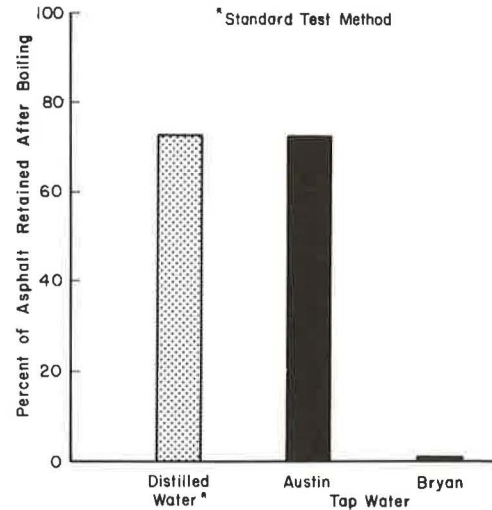


FIGURE 6 Effects of type of water on the Texas boiling test.

three did not. The major components of these stripping mixtures were silicious river gravel and sand. The major components of the nonstripping mixtures were crushed limestone, caliche, or slag. The composition of each mixture by aggregate type and percentage is reported elsewhere (6).

The gradations of aggregates used for the boiling test were the same as those used in construction. Two materials met the requirements of grade 1 flexible base item 238 (processed gravel) and item 232 (caliche), respectively (17). Gradations of the other six materials met the requirements of type D surface course paving mixtures.

The asphalt cements included in the testing program were the same as those used in pavement constructions.

Evaluation of Mixtures

Results for each of the eight mixtures are shown in Figure 7. All mixtures that experienced stripping in the field retained less than approximately 60 percent asphalt after boiling. The nonstripping mixtures retained more than 75 percent.

By using these data as well as other test results as a base, it is currently recommended that 70 percent of asphalt retained after boiling be the division between stripping and nonstripping mixtures. Based on this study and other experience, aggregates that retain more than 85 percent are judged to be moisture resistant. Those between 70 and 85 percent are borderline and would benefit from treatment. Thus the Texas boiling test offers a quick method of detecting asphalt-aggregate mixtures that are susceptible to stripping and moisture in the field. Because this test can be performed quickly in either the laboratory or the field, and because the results provide a satisfactory indication of stripping, it is recommended for use in evaluating mixtures during both design and construction.

Evaluation of Individual Aggregates

The boiling test has also been used to evaluate the individual components of these aggregate mixtures to determine their water susceptibility. Test results for each of the individual aggregates included in the eight project mixtures are given in Tables 3 and

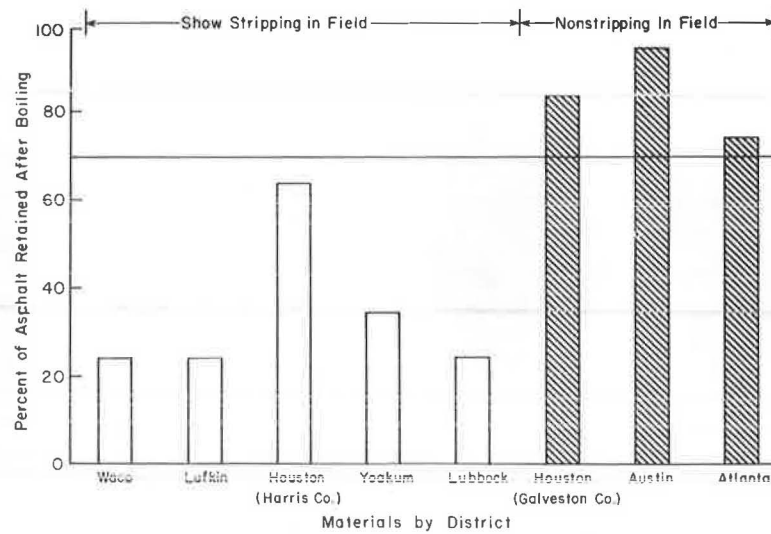


FIGURE 7 Texas boiling test results for stripping and nonstripping mixtures.

TABLE 3 Texas Boiling Test Results for Individual Aggregates and Stripping Design Mixtures

District	Individual Aggregate and Design Mixture	Aggregate Size Tested	Asphalt Content, %	Percent of Asphalt Retained After Boiling
5 Lubbock	Crushed caliche (5A)	all gradation	9.0	25
9 Waco	Coarse gravel (9D)	-3/8 + 4	2.3	45
	Washed sand (9F)	-10 + 40	6.3	15
	Field sand (9E)	-40 + 80	6.3	15
	Design mixture	all gradation	4.3	25
11 Lufkin	Crushed limestone (11C)	-3/8 + 4	5.0	35
	Pea gravel (11D)	-3/8 + 4	3.0	35
	Coarse field sand (11E)	-3/8 + 4	7.0	15
	Local field sand (11F)	-40 + 80	7.0	15
	Design mixture	all gradation	5.0	25
12 Houston (Harris Co.)	Gravel screenings (12B)	-3/8 + 4	2.3	35
	Crushed limestone (12A)	-3/8 + 4	4.3	85
	Local field sand (12C)	-40 + 80	6.3	95
	Design mixture	all gradation	4.3	65
13 Yoakum	Coarse river gravel (13A)	-3/8 + 4	3.0	5
	Fine river gravel (13B)	-3/8 + 4	5.0	25
	Coarse field sand (13C)	-10 + 40	7.0	15
	Fine field sand (13D)	-40 + 80	8.0	85
	Design mixture	all gradation	5.0	35

4. In general, when a major component of the mixture retains less than 50 percent asphalt, the mixture itself strips significantly. However, there were anomalies that occurred between results for individual aggregates and for mixtures of the aggregates.

Evaluation of Antistripping Additives

Several techniques have been proposed in the technical literature or have been demonstrated in the field to limit the water damage to asphalt concrete mixtures. These include pretreatment or elimination of stripping-prone aggregates, design control, and construction control. However, the most commonly used procedure is to treat the aggregate or asphalt with an antistripping additive. To evaluate the effectiveness of these additives in reducing moisture susceptibility, a limited study was performed.

Antistripping Additives

During recent years various antistripping additives have been incorporated into asphalt mixtures to reduce the magnitude of the stripping problem. The most common categories of additives that have been used and judgments of their effectiveness have been summarized by Majidzadeh and Brovald (18). These additives are either mixed with the binder or applied to the aggregate surfaces. Some test results indicate that the effectiveness of the additives may be better when applied directly on the aggregate than when added to the binder (19,20). However, blending the additive with the binder is easier, more economical, and is the current practice with liquid chemical additives. These chemical antistripping additives are usually added at a rate of 0.5 to 1.0 percent by weight of the asphalt (21).

Hydrated lime has been used quite successfully in

TABLE 4 Texas Boiling Test Results for Individual Aggregates and Nonstripping Design Mixtures Materials

District	Individual Aggregate and Design Mixture	Aggregate Size Tested	Asphalt Content, %	Percent of Asphalt Retained After Boiling
12 Houston (Galveston Co.)	Crushed limestone (12E)	-3/8 + 4	5.0	85
	Limestone screenings (12F)	-10 + 40	5.0	85
	Field sand (12G)	-40 + 80	7.0	55
	Design mixture	all gradation	6.0	85
14 Austin	Crushed limestone (14 I&J)	-3/8 + 4	3.4	95
	Limestone screenings (14K)	-4 + 10	4.4	75
	Local field sand (14L)	-40 + 80	7.4	75
	Design mixture	all gradation	5.4	95
19 Atlanta	Coarse slag (19A&B)	-3/8 + 4	5.5	95
	Field sand (19C)	-40 + 80	7.5	85
	Local field sand (19D)	-10 + 80	6.5	65
	Design mixture	all gradation	7.5	75

the past as an antistripping additive (2-7,10). Usually, 1 to 2 percent hydrated lime is applied directly to the aggregate in slurry form (10). However, it has also been added to the asphalt and to the aggregate in dry form, but test results have not been as dramatic as those from slurry applications.

Effectiveness of Antistripping Additives

A limited laboratory study was designed to evaluate the effectiveness of several antistripping additives using results from the Texas boiling test. Two groups of specimens were prepared with antistripping additives for the purposes of

1. Evaluating the effectiveness of adding antistripping additives to the stripping materials, and
2. Detecting any adverse effect of antistripping additives in the nonstripping materials.

Eleven different liquid chemical antistripping additives, representing five antistripping categories and a lime slurry, were used as additives in specimens prepared for this study. The lime slurry

was added directly to the aggregate while the liquid antistripping additives were added to the asphalt before mixing. The amount of liquid agents was 1 percent by weight of asphalt. The lime slurry was prepared with 1 percent hydrated lime and 3 percent water by weight of the aggregate. After applying the selected treatment, the asphalt mixture was prepared, the mixture boiled, and the amount of stripping estimated after cooling.

The three individual aggregates selected for use in this investigation were a coarse aggregate river gravel, rhyolite from west Texas, and crushed limestone. The coarse river gravel was a silicious aggregate with crushed faces and is a stripping-prone aggregate. The rhyolite was a gray, rough, subangular material that has exhibited severe moisture-related problems in both asphalt mixtures and seal coats. The crushed limestone was a rough, subangular, porous material; it is a nonstripping aggregate. Two asphalt cements from different Texas refineries were selected.

Test results are summarized in Figure 8 for the silicious river gravel. The antistripping additives were grouped by classification as obtained from each

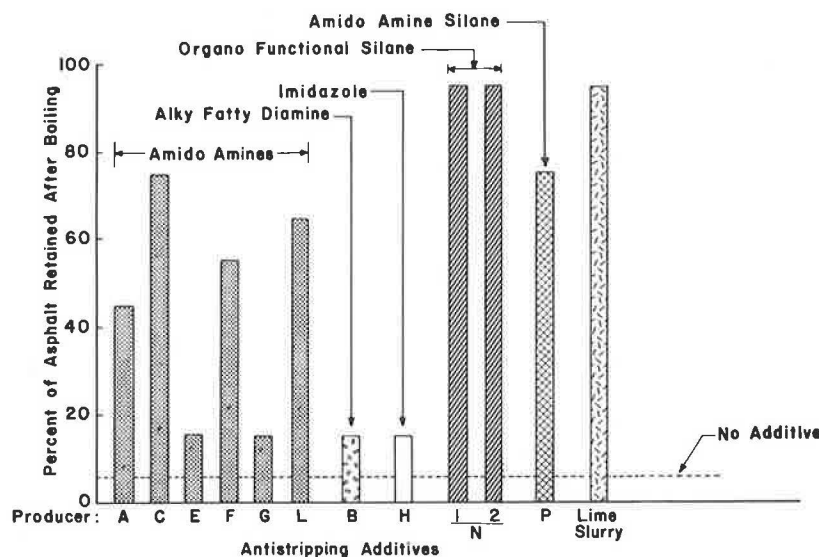


FIGURE 8 Texas boiling test results on mixtures of coarse river gravel with various antistripping additives.

producer. In general, the results from the Texas boiling test indicated positive benefits for lime slurry and selected chemical antistripping additives, depending on the aggregate. Other unreported test results suggest that some of these additives are more effective when sprayed directly on the aggregate rather than being added to the asphalt.

It was observed that there is significant interaction between additives, asphalt, and aggregate (i.e., the magnitude of test results may be affected if any one of these three factors is changed). Thus each combination of asphalt, aggregate, and antistripping additive must be evaluated to determine whether the combination provides increased resistance to stripping.

For the nonstripping aggregates, no differences between test results were detected when the antistripping additives were used and when they were not used. This indicates that no adverse effects occurred due to the presence of the various antistripping additives for the quantities used and for the aggregates included in this test program.

Because the effectiveness of antistripping agents is dependent on the aggregate and asphalt used, evaluation should be conducted on the actual asphalt cement-aggregate combination to be used in the field. Consideration should also be given to treating the aggregates with chemical additives in a water-soluble form rather than adding the additive directly to the asphalt.

CONCLUSIONS

Results from the Texas boiling test provide valuable information that can differentiate between asphalt mixtures that are known to strip in the field and those that do not strip. Specific conclusions are as follows.

1. The number of mixing times affects the test results significantly. The best differentiation between stripping and nonstripping mixtures occurred when the specimen was mixed only once. Therefore, in the standard procedure the specimen is prepared by mixing once.
2. The mixing temperature produced a significant effect on test results: the higher initial aggregate temperature produced less stripping. Test results, however, indicated that when aggregates were heated to 325°F, the results more consistently differentiated between stripping and nonstripping mixtures. Therefore, 325°F was incorporated in the standard boiling test procedure.
3. Aggregates that retain less than 70 percent asphalt are tentatively judged to be moisture susceptible; aggregates that retain more than 85 percent are believed to be moisture resistant. Those between 70 and 85 percent are probably borderline and would benefit from treatment.
4. A rating board (Figure 1) should be used to make the visual estimates of the amount of asphalt retained to ensure uniformity of results. A photograph should not be used.
5. Based on a limited evaluation, the results of the Texas boiling test appeared to be useful in evaluating the effectiveness of antistripping additives. Based on these test results, the lime slurry and silanes appeared to be the most effective.

RECOMMENDATIONS

Results from this study indicate that the Texas boiling test can detect asphalt mixtures that exhibit stripping tendencies in the field. The test is

rapid and can be conducted with a minimum amount of special equipment. Thus the test offers a method for the field control of aggregates and asphalts to ensure moisture-resistant asphalt mixtures and a means to evaluate proposed antistripping additives.

Because of the potential offered by this test, the following recommendations are offered.

1. The Texas boiling test should begin to be used to evaluate the moisture susceptibility of asphalt-aggregate mixtures proposed for use in construction and as a quality control test.
2. In the event that a stripping mixture is detected, the proposed antistripping additive can be tested by using the Texas boiling test to evaluate its effectiveness in improving the adhesion between the asphalt cement and each aggregate in the mixture.
3. If any component of a mixture is changed, the mixture should be reevaluated because stripping is dependent on the asphalt as well as on the aggregate and because the effectiveness of some antistripping agents appears to be aggregate and asphalt dependent.
4. Other tests such as the Texas freeze-thaw pedestal test and the wet-dry indirect tensile test should also be conducted if time allows.
5. Consideration should be given to evaluating chemical additives in their water-soluble form as aggregate pretreating agents.

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APPENDIX: TEXAS BOILING TEST--STANDARD TEST PROCEDURE

Scope

The method is used as a screening device to evaluate the moisture susceptibility of an asphalt concrete mixture by visually estimating the degree of stripping after boiling in distilled water. The procedure can also be used to evaluate the effectiveness of

antistripping additives added to moisture-susceptible mixtures.

Apparatus

1. Oven--an electric oven capable of maintaining a temperature of $163^{\circ} \pm 2.8^{\circ}\text{C}$ ($325^{\circ} \pm 5^{\circ}\text{F}$) to heat the asphalts and to heat or dry the aggregates;
2. Sample mixing apparatus--suitable equipment for hand mixing the aggregate and asphalt; includes round mixing pans of various sizes, small masonry pointed trowels, and spatulas;
3. Balance--a balance with a capacity of 5 kg that is sensitive to at least 0.1 g;
4. Hot table--an electric hot table capable of maintaining a temperature during mixing;
5. Beaker--a 1,000-mL beaker capable of being heated;
6. Source of heat--a heat source that consists of a burner or an electric heater, with beaker support or an oil bath with an internal chamber capable of holding 500 cc of distilled water and the sample; and
7. Miscellaneous apparatus--stop watches, scoops, glass rods, gloves, paper towels, and aluminum foil.

Preparation of Specimen Mixture

1. Selection of asphalt content: Determine the optimum asphalt content for the asphalt-aggregate mixture according to test method Tex-204-F (15) or other design method. For individual aggregates, a trial mixture of asphalt and aggregate should be prepared. If some of the aggregate is not coated well or if the mixture appears rich, increase or decrease the asphalt cement content, respectively, until a satisfactory mixture is secured (i.e., all aggregates are coated and no excess asphalt is left on the mixing bowl). Future refinements should consider surface area in order to ensure a relatively uniform film thickness.
2. Preparation of aggregates: If a mixture is to be evaluated, the mixture must have components representative of each of the aggregate sources and sizes. All materials should be combined in the specimen mixture in the same gradation that they occur in the field mixture. If an individual aggregate is being evaluated, use the fraction passing the 9.52 mm (3/8 in.) and retained on the 4.76 mm (No. 4) sieves. If the predominance of the material is smaller than the No. 4 sieve, a finer fraction can be tested.
3. Adding antistripping additives: If an antistripping additive is to be evaluated, it must be either blended with the asphalt or placed on the aggregate before final mixing. In case of blending with the asphalt, the asphalt needs to be preheated at 135° to 149°C (275° to 300°F). Pour 100 g of asphalt into a 6-ounce can. Add the desired amount of antistripping additives as a weight percent of the asphalt. Immediately stir the two materials with a small spatula for approximately 2 min.
4. Preparation of mixtures: Weigh out 300 g of the aggregates mixture or 100 g of an individual aggregate. Heat the asphalt cement or asphalt cement plus chemical additive at $163^{\circ} \pm 2.8^{\circ}\text{C}$ ($325^{\circ} \pm 5^{\circ}\text{F}$) for 24 to 26 hr, and heat the aggregate at $163^{\circ} \pm 2.8^{\circ}\text{C}$ for 1 to 1.5 hr. After both materials are at $163 \pm 2.8^{\circ}\text{C}$, pour the required asphalt cement into the preweighed aggregate, which is in a metal container on the hot table. Mix the aggregate and asphalt by hand as thoroughly and rapidly as possi-

ble. Transfer the mixture to a piece of aluminum foil and allow to cool at room temperature for 2 hr.

Test Procedure

1. Boiling mixture in water: Fill a 1000-mL beaker one-half full (500 cc) with distilled water and heat to boiling. Add the mixture to the boiling water. Addition of the mixture will temporarily cool the water below the boiling point. Apply heat at a rate such that the water will reboil in not less than 2 or more than 3 min after addition of the mixture. Maintain the water at a medium boil for 10 min, stirring with a glass rod three times during boiling, then remove the beaker from the heat. During and after boiling dip a paper towel into the beaker to skim any stripping asphalt from the surface of the water. Cool to room temperature, drain the water from the beaker, and empty the wet mix onto a paper towel and allow to dry.

2. Visual observation: Visually estimate the percentage of cement retained after boiling by comparing the specimen with a standard rating scale (Figure 1). A photograph should not be used. The

mixture should also be examined on the following day after it has been allowed to dry because stripping of the fines is not as apparent when the mixture is still wet.

[Note: The standard rating scale (Figure 1) consists of samples that represent various degrees of stripping selected to provide examples at 10 percent intervals ranging from 0 percent to 100 percent retained asphalt cement.]

Report

The percentage of asphalt retained after boiling should be based on a comparison with the standard scale, not a photograph. Select the specimen nearest in appearance to the test specimen and report that as the test result.

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Analysis of Asphalt Concrete Test Road Sections in the Province of Quebec, Canada

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ABSTRACT

Data were collected from test road sections in the Province of Quebec, Canada, for the purpose of evaluating the effects of materials and in situ conditions on the performance of asphalt concrete pavements. These pavements were tested in 1980 to determine rutting, ride, and deflection characteristics. In situ conditions were determined by sampling and test measurements. Asphalt concrete cores were obtained for indirect tensile strength tests and for recovery of asphalt for conventional consistency tests (penetration, viscosity, and softening point). These data were compiled along with information contained in the original construction records and pavement crack surveys. Statistical analyses were conducted and various relationships were developed that relate to factors that influence asphalt binder properties, tensile strength, and transverse cracking. The most significant findings include (a) a verification of greater age hardening when in-service asphalt concrete pavements have air voids in excess of 4.0 percent, (b) a tentative test method

that incorporates the work of Goode and Lufsey to evaluate the age hardening of binders, and (c) mathematical relationships developed from statistical analyses by using recovered asphalt penetration and traffic level for the prediction of transverse cracking. Results of other analyses are presented that define those variables that have an effect on consistency parameters, mix tensile strength, rutting, and ride quality. Dynaflect deflection basins were analyzed by using an elastic layer computer program, which resulted in the development of relationships between subgrade moduli and the fifth-sensor deflection.

Data were collected from 3-km-long test road sections for evaluation of the effects materials and in situ conditions have on pavement performance. Analyses were conducted to develop relationships (a) between asphalt consistency measurements, (b) for in situ differences in asphalt and mix properties, and (c) for differences in pavement performance. Twenty-three test sections were used as the data base. These sections were located throughout the Province of Quebec, including areas in Montreal, Sherbrooke, Trois Rivières, Rimouski, and Lake St. Jean.