Auburn University

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Summary Report

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sponsored by

The State of Alabama Highway Department
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ABSTRACT

An earlier laboratory study with representative Alabama materials illustrated the difficulties inherent in predicting field stripping performance with available laboratory testing procedures. A part of the problem appeared to be the inability to accurately model construction conditions in the laboratory. This study examined and modified laboratory conditions to better simulate construction conditions, particularly residual aggregate moisture.

Six asphalt-aggregate mixes were selected and a sampling and testing program conducted. Moisture content of aggregate and mix was measured during construction. Hot mix, aggregate and asphalt cement (without antistrip additives) were sampled during construction. Samples for wet-dry tensile and boil tests were prepared with field mix, mix prepared with standard laboratory procedures and mix prepared with controlled residual aggregate moisture content.

Cool and rainy construction conditions result in higher aggregate and mix moisture content. Larger aggregate particles have higher residual moisture than finer particles.

Residual aggregate moisture increased conditioned tensile strength and TSR for dolomitic limestone mixes, but decreased these parameters for siliceous sand-gravel mixes. Values for field mixes were generally higher than values for comparable laboratory mixes.

The wet-dry tensile test is a conservative method for designing and controlling mixes comprised primarily of dense dolomitic limestones. However, the unusual and, at this state, unexplained response of these mixes justifies a cautious and conservative approach.

The wet-dry tensile test does a reasonably good job of designing and controlling mixes comprised primarily of siliceous sand-gravel. However, additional testing should be conducted to further develop procedures for including residual aggregate moisture during mix design.

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INTRODUCTION

The process of stripping in asphalt concrete is most often thought of as a loss of adhesion between asphalt binder and aggregate. This was first considered to be an adhesion problem in 1932 (1). Researchers still consider adhesion to be the dominant failure mode; however, some have added that stripping may also be a result of a loss of cohesion (2). The Asphalt Institute defines stripping as "the breaking of the adhesive bond between the aggregate surface and the asphalt cement." The one factor common in all proposed stripping mechanisms is the presence of water.

Adhesion improving additives may be added to the asphalt or aggregate to overcome poor adhesion between the asphalt binder and aggregate surfaces. Many tests have been developed to evaluate the properties that affect stripping and to evaluate the effectiveness of adhesion improving additives. However, stripping is a complex phenomenon, influenced by many factors, and no test has been universally accepted as a predictor of stripping. A completed laboratory study (3) with representative Alabama materials illustrated the difficulties inherent in predicting field stripping performance with available laboratory testing procedures.

A part of the problem appears to be the inability to accurately model construction conditions in the laboratory, particularly incomplete drying and partial coating of aggregate. For saturated aggregate, the excess moisture in and on the particles will tax the drying system. According to Lottman (4) when saturated aggregate is heated by hot gases, escaping water vapor consumes some of the heat energy and prevents the aggregate from reaching optimum drying temperature. Larger particles, which contain the greater percentage of total moisture, give off large amounts of vapor and are slower to reach a uniform temperature. However, the fine aggregates heat up and dry out faster due to their larger surface area to mass ratio. If the dryer retention time is too short, internal moisture will remain in the pores of larger particles.

Release of internal moisture during and after particles have been coated can lead to conditions conducive to stripping. Energy expended vaporizing residual moisture will result in lower mixing temperature and poorer aggregate coating.

Moisture escaping from pores can impeded asphalt-aggregate bond development and leave the mixture vulnerable to stripping. Steam escaping from pores of coated aggregate will cause ruptures or blisters in the asphalt coating, providing an avenue for water to enter between the asphalt film and aggregate surface.

Existing laboratory models do not account for the effect of residual moisture. Test procedures usually begin with heating of the aggregates in a convection oven overnight. This essentially assures that all moisture will be driven off. This modeling inconsistency may contribute to poor correlations with known field performance for some absorptive aggregate.

DESCRIPTION OF STUDY

This study will examine laboratory tests for quantification of stripping potential with emphasis on the influence of residual moisture on and/or in the aggregate. Objectives were

1. To examine the influence on stripping test results of differences between laboratory specimen preparation conditions and field conditions,
2. To develop modifications to existing laboratory test procedures in order to better simulate field conditions and improve their reliability as predictors of stripping propensity of asphalt-aggregate mixtures, and
3. To examine criteria for separating stripping from nonstripping mixes with emphasis on consideration of aggregate material type (siliceous or carbonate) as a factor in the criteria.

To accomplish project objectives six asphalt-aggregate mixes were selected and a program of sampling and testing conducted. Tests were conducted on aggregate constituents and on asphalt-aggregate mixtures.

In a completed study of stripping of Alabama mixes (3), the wet-dry indirect tensile and boil tests indicated potential for stripping opposite from observed field performance for two mixes. A gravel mix from the northwest part of the state gave high retained tensile strength and coating, although this and similar mixes have a reputation for severe stripping. A dolomitic limestone mix gave low retained tensile strength and coating, although this and similar mixes apparently have no history of stripping problems in Alabama.

Speculation was that the inconsistent behavior was caused by a failure of test procedures to duplicate field conditions. For the gravel mix, which contained porous gravel, the most likely specific cause seemed to be residual moisture in the aggregate. For the dolomitic limestone mix no specific causes were apparent, although inconsistent results for similar materials has been observed by others.

To study the influence of construction conditons on the predictability of the test procedures, materials with characteristics similar to those that exhibited inconsistent behavior in the completed study were chosen. A mix with the same dolomitic limestone and a mix with a similar dolomitic limestone were sampled and tested.

Mix A is essentially the same as the base/binder Mix A in the completed study (3). The source of the dolomitic limestone is the same, but 10% natural coarse siliceous sand was used in lieu of 100% dolomitic limestone. Mix J is a similar base/binder mix with dense dolomitic limestone from the Birmingham area. The dolomitic limestone for mixes A and J are from the same geologic formation. Similar mixes have no history of stripping problems.

Mixes F, H and I contain porous siliceous gravel from the northwestern part of the state and have a history of stripping problems. The materials are similar to Mix D from the completed study which produced high coating and tensile strength retention. Mix F is a binder and H and I are surface mixes.

Mix G contains siliceous gravel from the southwestern part of the state. This material tends to be less porous than the gravel for Mixes F, H and I and does not have the reputation for severe stripping. Stripping and raveling are occasionally observed for this and similar materials which leads to the classification as a moderate stripper.

Mix, aggregate and asphalt cement were sampled during mix production. Mix and aggregate moisture contents were measured during field sampling. Specimens for wet-dry indirect tensile tests were fabricated in the field, and samples for boil tests were secured and sealed.

Laboratory mixes were prepared with constituent asphalt and aggregate using standard procedures and a procedure to produce a "wet" mix (5). The "wet" mix procedure resulted in a mix with residual moisture and simulated partial drying.

Wet-dry indirect tensile and boil tests were the basic tests utilized for evaluating mix stripping propensity. Tests were conducted on field mixes, standard laboratory mixes and "wet" laboratory mixes. Moisture content measurements were also an integral part of the laboratory testing program since the influence of residual aggregate moisture was a major consideration.

A microwave oven was used to dry samples for moisture content determination. This procedure provided quick and consistent results without the cumbersome apparatus and hazardous solvents used in the distillation procedure: Moisture or Volatile Distillates in Bituminous Mixtures (ASTM D1461).

For the wet-dry indirect tension test, conditioning and testing followed procedures suggested by Tunnecliff and Root (6). The boil test procedure used is an adaptation of several procedures including ASTM D3625, but most closely resembles the procedure by Kennedy, Roberts and Lee (7).

ANALYSIS OF RESULTS

The only standardized method for measuring moisture content of asphalt-aggregate mixtures is the distillation procedure (ASTM D1461). This procedure is time consuming, requires toxic materials, and is generally not suited for field or routine production testing. However, the alternative, heating of the mixture either by conventional or microwave ovens to remove moisture, has not been generally accepted. This is primarily because of concern that heat will drive off volatiles from the asphalt. In the course of this study, data on the various methods were accumulated and analyzed. Based on this analysis, the microwave method was selected for moisture content determination.

Hot bin aggregate and mix moisture contents were measured for five of the six mixes. The hot bin aggregate moisture contents confirmed the concentration of residual moisture in coarse particles. These aggregate moisture contents and mix moisture contents indicated a strong correlation between residual mositure and weather conditions; with cool rainy weather resulting in higher residual moisture. There was some evidence to indicate that plant start up results in higher residual moisture and that moisture is lost during mix hauling and spreading.

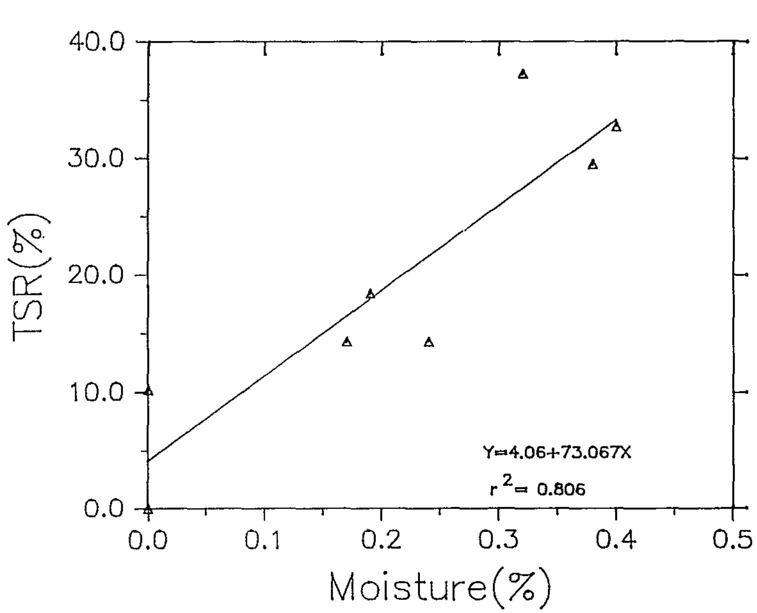
The wet-dry indirect tension test results for the dolomitic limestone mixes (A and J) unexpectedly show that retained tensile strength, as measured with TSR, increases as moisture content increases. As illustrated in Figure 1, this was a result of decreasing unconditioned strength but increasing conditioned strength.

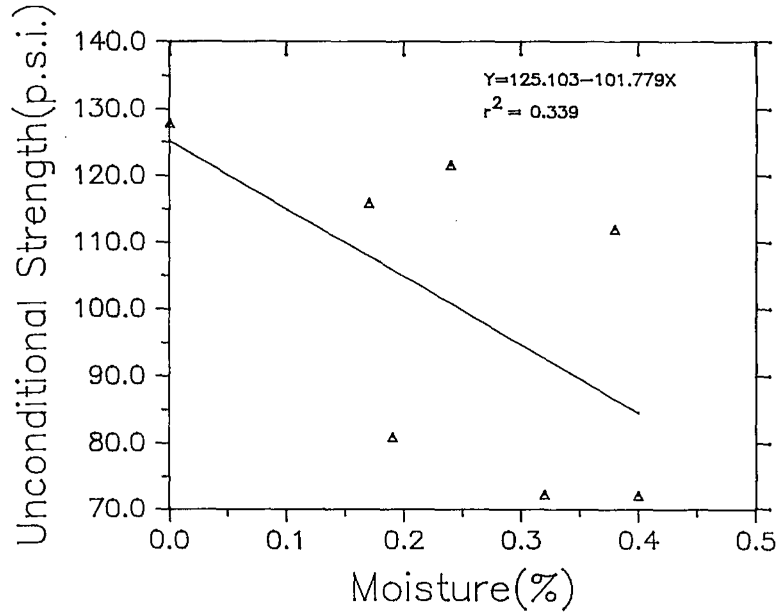
The causes or reasons why residual aggregate moisture in the dolomitic limestones produces asphalt-aggregate bonds that are more resistant to the detrimental effects of water is not known. However, the evidence, increasing TSR and conditioned strength for two aggregate and three asphalt cement sources, strongly suggests that the observed trends are real. The explanation is likely a surface chemistry phenomenon resulting from unusual chemical composition and/or crystal structure of the dolomitic limestone.

However, residual moisture does not provide a complete explanation of differences between observed and predicted performance of the dolomitic limestone mixes. Even with residual moisture, TSR values for Mixes A and J are well below the widely used criteria of 70 to 80% for separating stripping and nonstripping mixes. In addition, conditioned strengths for Mixes A and J are not dramatically different from conditioned strengths of the four siliceous gravel mixes that are considered prone to stripping. Other factors, including field mixing and possibly storage, may also affect field performance.

The wet-dry indirect tension test results for the siliceous gravel mixes (F, G, H and I) expectedly show that TSR decreases as moisture content increases. As illustrated in Figure 2, this was a result of conditioned strength decreasing faster than unconditioned strength.

The cause or reasons why residual aggregate moisture in siliceous gravel is detrimental to the development of strong moisture resistant asphalt-aggregate bonds are well established. It is generally accepted that the mineralogy produces acidic surfaces which are hydrophilic in nature and are, thus, susceptible to interference of bond development during mixing (decreasing unconditioned strength with increasing moiture content) and to loss of bond during subsequent exposure to moisture





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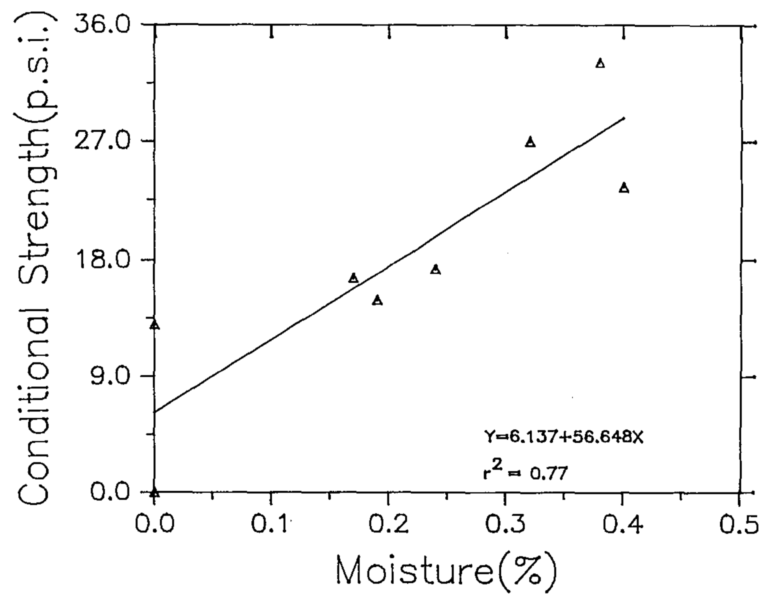
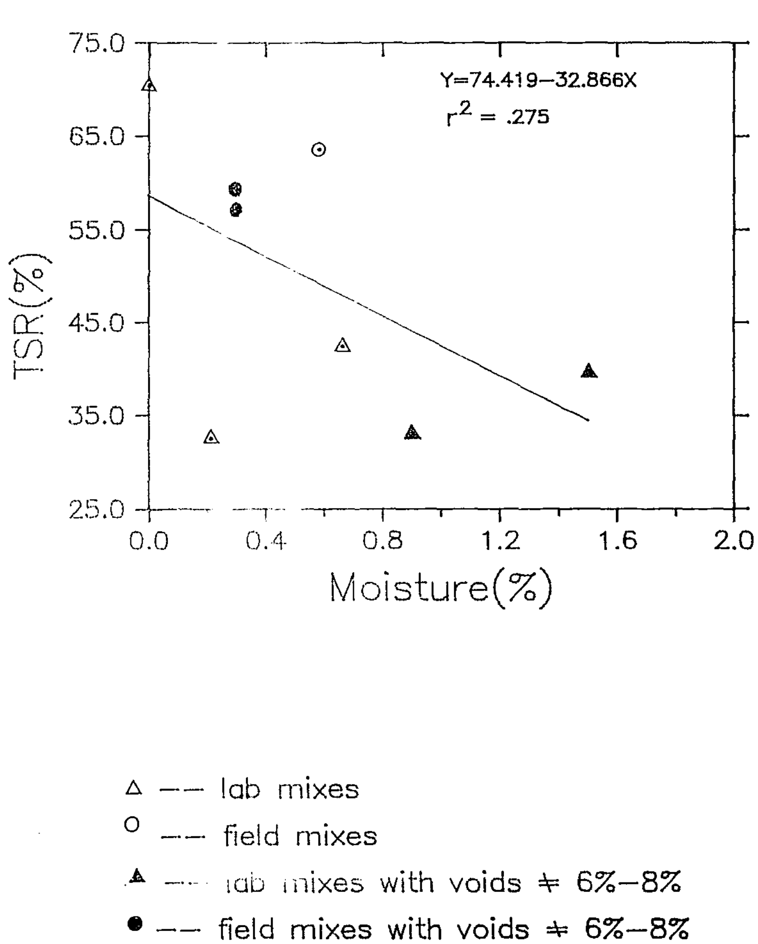
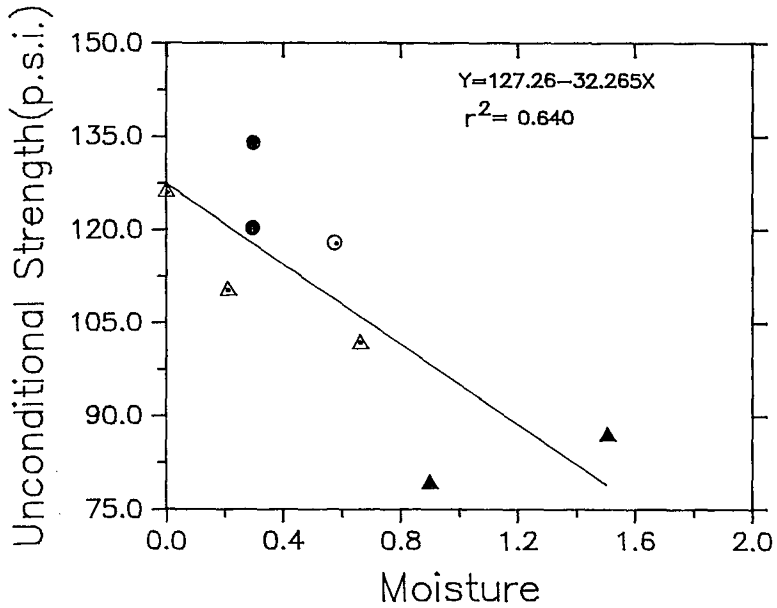


Figure 1. Example Wet-Dry Tension Test Results for Dolomitic Limestone Mix.





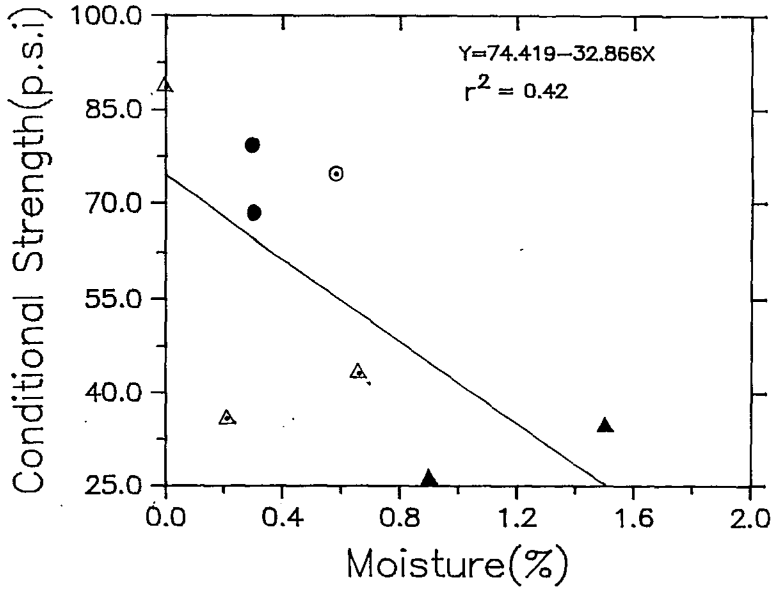


Figure 2. Example Wet-Dry Tension Test Results for Siliceous Gravel Mix.

(decreasing conditioned strength with increasing moisture content).

With a 70% TSR acceptance criteria, mixes A and J were incorrectly categorized as having high stripping potential, even with the apparent beneficial effects of residual moisture. Mixes F, H and I were correctly categorized as susceptible to stripping with and without consideration of the effects of residual moisture. Mix G, which based on field performance would be characterized as moderately susceptible to stripping, was categorized as a stripper.

Unlike the earlier study (3), a poor correlation between TSR from wet-dry tensile tests and percent coating from boil tests was obtained. This appeared to be due, in part, to operator error on a portion of the boil tests. However, the unusual behavior of the dolomitic limestone mixes (A and J) could also have been a factor.

CONCLUSIONS AND RECOMMENDATIONS

Mix production conditions can affect stripping propensity. Residual aggregate moisture is a major factor, but mixing and possibly storage may also contribute. Lack of simulation of field conditions in standard laboratory tests can lead to poor correlation between observed and predicted mix performance.

Aggregate and mixture moisture contents were measured during production. Comparison of several methods for measuring moisture content lead to the adoption of the microwave oven method. Moisture contents were dependent on environmental conditions (temperature and rainfall) with higher moisture contents during cool rainy conditions. Moisture contents also appeared to be higher during plant startup, and although not measured, rate of production will also influence aggregate drying. Residual moisture is higher in coarse particles than in fine particles.

A procedure was developed for preparing mix with controlled aggregate residual moisture. The moisture content that can be realistically maintained during mix preparation is dependent on aggregate absorption. Higher residual moisture can be obtained with higher absorptive aggregate.

Wet-dry tensile test results indicated that residual moisture affects dolomitic limestone mixes differently than siliceous gravel mixes. Residual aggregate moisture increases conditioned strength and TSR for dolomitic limestone mixes, but decreases these parameters for siliceous sand-gravel mixes. Values for field mixes were also generally higher than values for comparable laboratory mixes. This difference is one of the reasons for poor correlation between predicted and observed stripping propensity.

The wet-dry tensile test does a reasonably good job of evaluating mixes comprised primarily of siliceous sand-gravel with a history of moderate to severe stripping problems. High retained strength ratios obtained with standard test conditions for some mixes indicate a need for modifications to consider the influence of residual moisture during mix design. Implementation of a modified testing procedure during mix design will require 1) selection of a realistic moisture content range for testing, 2) refinement of the laboratory mix preparation procedure for controlling residual aggregate moisture content, and 3) additional testing and field observations to verify the apparent influence of residual moisture. Development of a procedure for including residual moisture would identify problems during mix design rather than after production begins.

The influence of residual moisture on retained tensile strength accentuates the need for routine testing during mix production. Residual moisture content will vary during production and routine testing will indicate when conditions are developing that could lead to unacceptable retained tensile strength levels. A set of retained tensile strength samples should be tested for each 5000 tons of mix produced. Should daily moisture content measurements indicate moisture content 0.1% larger than the previous days measurements, a set of retained tensile strength samples should be immediately prepared and tested.

The unusual and, at this state, unexplained response of mixes containing dense dolomitic limestone provides justification for caution and conservatism during mix design and construction. While there are no perceived performance problems, and while residual moisture has an apparently beneficial effect on retained tensile strength; the continued use of current mix design and construction control procedures is recommended until a more refined procedure that includes the influence of residual moisture is developed and verified. During mix design this approach may occasionally lead to the overuse of antistripping additives, but lack of knowledge vindicates the conservative approach.

The boil test is simple and easy to perform, but consistent testing techniques and sample evaluation are difficult to maintain. The boil test should only be considered as a field control test to indicate changes during mix production.

REFERENCES

1. Nicholson, V., "Adhesion Tension in Asphalt Pavements, Its Significance and Methods Applicable in Its Determination," Proceedings, Association of Asphalt Pavement Technologists, Vol. 13, 1932.

2. Fromm, H.J., "The Mechanisms of Asphalt Stripping from Aggregate Surfaces," Proceedings, Association of Asphalt Paving Technologists, Vol. 43, 1974.

3. Parker, F., "Stripping of Asphalt Concrete - Physical Testing," Report #1, Project 930-111, Alabama Highway Department, Montgomery, Alabama, January, 1987.

4. Lottman, R.P., "Aggregate Heating and Drying Variations in Asphalt Plants," Proceedings, Association of Asphalt Paving Technologists, Vol. 30, 1961.

5. Sonderegger, P.E., "Residual Moisture in Asphaltic Concrete," Proceedings, Association of Asphalt Paving Technologists, Vol. 30, 1961.

6. Tunnicliff, D.G. and R.E. Root, "Use of Antistripping Additives in Asphaltic Concrete Mixtures," National Cooperative Highway Research Program, Report No. 274, Transportation Reserach Board, 1984.

7. Kennedy, T.W., F.L. Roberts, and K.W. Lee, "Evaluation of Moisture Susceptibility of Asphalt Mixtures Using the Texas Boiling Test," Transportation Research Record 968, 1984.