Overview

Historically, engineers have recognized the importance of providing good surface and subsurface drainage from pavements. Structural design either minimized the potential for water entry or allowed for a reduction in structural support resulting from the periodic variation in water table and soil moisture. In some situations it was found to be advantageous to use full depth-thick lift asphalt pavements over clay subgrades where improvement in drainage conditions was not feasible. The performance of these asphalt mixtures in the presence of moisture appears to be excellent. In fact, asphalt paving mixtures used in the facing of dams and for pond linings seem to exhibit no major problem with deterioration caused by water. However, in recent years the problems of water damage to asphalt pavement has directed attention toward the phenomenon called "stripping." This term is applied to paving mixtures that exhibit separation of asphalt films from aggregate surfaces due primarily to the action of water.

The severity and extent of stripping is primarily related to environmental conditions, materials, and adequacy of mix design and construction. In South Carolina severe stripping was observed on 8.1% of pavements sampled throughout the highway system by Bushing et al. Florida has experienced some stripping problems in the past and consequently now specifies the use of approved antistripping agents in all friction course and recycled mixtures. Stripping is most prevalent in eastern Texas where high water table or high rainfall conditions or both exist. This combined with siliceous river, rhyolite, and certain limestone aggregates that are susceptible to moisture damage tends to promote stripping unless treated with lime or other suitable antistripping agents. Oregon has found it necessary to use antistripping agents in over 20% of its construction projects since 1983.

The papers contained in this special technical publication (STP) provide considerable insight into the severity of stripping, test methods for evaluation, and relative effectiveness of using antistripping additives to minimize in-service stripping potential. However, the mechanism of stripping in precise physical-chemical terms and the effect of asphalt characteristics are not discussed. In general the authors have emphasized the effectiveness or ineffectiveness of antistripping agents as evaluated by various laboratory test methods.

The evaluation of stripping potential and effectiveness of antistripping agents are generally performed using a visual test (boiling test) or a retained strength test (for example, indirect tensile, compression, Marshall stability, and so forth). The boiling test is strictly an empirical test of limited value since the results may be influenced by asphalt viscosity, degree of boiling, and time of exposure. Furthermore, it is not rational to boil the coated aggregate since exposure conditions in pavements are not even remotely similar.

The use of retained indirect tensile strength using either the Lottman procedure or modifications of his procedure appears to be the most widely accepted method for evaluation of potential water or freezing damage or both to asphalt paving mixtures. The Lottman saturation, freezing, and thawing conditioning procedure has been considered too severe for some researchers and state highway agencies. The Tunnicliff method requires saturation of 55 to 80% without any freezing cycles and is conditioned the same as Lottman's procedure in a 60°C (140°F) water bath for 24 h. However, Lottman provides 2 h at room temperature for partial drying before testing whereas Tunnicliff maintains moisture in the test specimen using a 25°C (77°F) water bath and performs the indirect tension test using wet specimens and a 50.8 mm/min (2-in./min) rate of loading.

Gilmore et al considered the Lottman procedure insufficiently severe and increased the thawing time and number of freeze cycles to achieve greater reductions in tensile strength ratio. Increased soaking at 60°C (140°F) had little effect beyond 48 h but an increase in repeated freeze cycles with warm water soak produced continual reduction in the tensile strength ratio.

Test specimens for determination of the tensile strength ratio are usually prepared at a compactive effort to produce air-void contents in the range of 6 to 8% as an attempt to simulate field conditions. However, most investigators reporting on pavement studies indicate numerous cases where in-service air-void contents are substantially greater than 8%. Water damage and severe stripping often occur when more open graded, high air void surface mixtures are placed over dense, well compacted, asphalt concrete. Takallou et al and Kennedy point out the importance of providing both good mix design and field compaction to achieve relatively low air-void contents and a well sealed pavement. Laboratory tests indicate that when higher asphalt contents or other improvements reduce the air-void content, the susceptibility to moisture damage is greatly reduced and the effect of antistripping agents is not as pronounced.

There are a variety of other test methods that have been used to evaluate water and freezing damage. Kennedy used the Texas freeze-thaw pedestal test (an adaptation of the test developed at the Western Research Institute) to evaluate the effectiveness of different antistripping additives on fine river gravel and fine sand. This is a relatively simple test to perform, but the viscoelastic properties of the asphalt and their influence on test results have been neglected. If the same asphalt is used in all comparisons, the test results will at least be comparative. However, different asphalts may have widely varying shear moduli and viscosity at the recommended test temperatures. Therefore, it is entirely possible to achieve poor test results even though the aggregate is not susceptible to stripping.

Dynamic diametral fatigue tests were conducted by Kim et al to evaluate mix moisture content effects on compacted and Lattman conditioned specimens. Parameters derived from the diametral tests include resilient modulus, repetitions to failure, and permanent vertical compressive strain. Tests of this type are time consuming and perhaps suitable for research studies, but not desirable as a conventional test method to evaluate stripping potential and antistripping additives. The lack of density control (air-void content), particularly on the North Oakland-Sutherlin evaluation, makes interpretation of the test parameters difficult with respect to the deteriorative effects of moisture and conditioning.

The evaluation of cold-recycled mixtures by Tia and Wood using water immersion conditioning of gyratory compacted mixtures indicated that Hveem R-value tests were not sensitive to the effects of water on mixtures containing emulsion or foamed asphalt. However, significant reductions in Hveem S-value, Hveem cohesiometer value, Marshall stability, and diametral resilient modulus were observed between as compacted and conditioned test specimens. It was observed that increased curing time and compaction effort improved the water resistance of these mixtures. This investigation did not address mix durability resulting from freeze-thaw cycles. However, Castedo et al evaluated moisture and freeze-thaw damage to assess the effectiveness of admixtures in various foamed asphalt mixtures. The modified Marshall stability tests appeared to yield results sensitive to the effects of conditioning and antistripping additives. Pulse velocity measurements attained at a different number of freeze-thaw conditions seem to be related to the modified Marshall stability. These results provide some general guidelines for laboratory evaluation, but no information is given on the degree or severity of water and freezing damage to pavement constructed with cold mix.

The evaluation of lime and different liquid antistripping agents by Kennedy, Butlon, Castedo et al, Gilmore et al, and Kim et al generally indicate anywhere from marginal to substantial improvement in the mixture's resistance to water and freezing damage. Lime appears consistently beneficial provided the method of treatment at the plant is performed properly. The use of lime does require that it be considered in the mix design procedure since it acts as a mineral filler in addition to the effect of providing antistrip properties.

The advantage of using liquid antistripping agents over lime is the simplicity of adding them directly to the asphalt. Obviously, cost may be a factor, but in many instances this is relatively cheap insurance to minimize the potential for water damage.

The approach of requiring an antistripping agent to achieve a retained tensile strength not less than 70 to 75% (or minimum wet-dry Marshall stability of 85% and so forth) may be realistic depending upon the reliability of the test method, but it tends to negate the potential for improving a mix that marginally meets the minimum requirement. The problem of sometimes specifying or not specifying the use of antistripping agents in supplier furnished asphalts can lead to confusion and irate suppliers. One of seven aggregate sources in the Miami, FL, area was found to have stripping tendencies. In the evaluation of these materials the approved antistripping agents corrected this problem as well as increased the retained tensile strengths from about 80 to over 100% for friction course mixtures using these aggregates. Since there was a substantial improvement in test properties and a relatively low cost for antistripping agents (approximately \$0.01/sq. yd.), it was specified for all friction course mixtures.

Durability of asphalt paving materials can be influenced by moisture in the mix. Aggregates and RAP with high moisture content may result in mixtures having excess moisture at the time of placement. If severe, this can produce a flushing (or bleeding) condition resulting in a low skid resistance surface. Laboratory tests demonstrate that residual moisture in the compacted specimen increases stripping potential. Recommendations generally require moisture contents less than 1.0% or the use of a suitable antistripping agent in cases where reduction in mix moisture content is not feasible.

The papers presented in this STP have been organized according to three major topics. It should be recognized that considerable overlap exists in the information provided by the authors. Although test technique and objectives are varied, there are numerous substantiating statements regarding the causes of water damage, the methods for evaluation, and recommendations for corrective action. Interpretation of the information for application to site specific problems or development of specifications is relegated to the reader of this publication.

Byron E. Ruth
University of Florida, College of Engineering, Department of Civil Engineering, Gainesville, FL 32611; symposium chairman and editor.