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PUTTING RESEARCH TO WORK
BRIEF

Toward a Simpler, Quicker Test for Asphalt Moisture Susceptibility

Moisture damage such as raveling, rutting and fatigue cracking contributes significantly to failure in hot-mix asphalt pavements. WisDOT currently uses the Tensile Strength Ratio test as specified by the ASTM D4867 standard to predict the susceptibility of asphalt mixtures to moisture damage.

What's the Problem?

The TSR test is expensive and time-consuming. In addition, two previous Wisconsin Highway Research Program studies (projects 0092-45-94 and 0092-01-03) found that TSR values do not correlate well with pavement performance and that TSR is ineffective at determining when the use of anti-stripping additives will provide enough benefit to be cost-effective.

When the TSR specification was first implemented, many mixes that had historically performed well were unable to achieve the required TSR value without the addition of anti-stripping agents, which raised concerns about the validity and repeatability of the test. HMA contractors and WisDOT have had to budget for anti-stripping additives in all construction projects, even when stripping is unlikely to be a serious problem. Furthermore, the TSR test requires a significant commitment of time and money during mix design development and department verification processes. WisDOT wanted to investigate less time-consuming, less expensive testing methods for predicting moisture susceptibility.

Research Objectives

This project sought to identify a nonmechanical screening test that would allow mixes that display resistance to moisture damage to forgo mechanical (TSR) testing. Investigators' objectives included:

- Evaluating the ability of the stripping test to accurately identify moisture-susceptible mixtures.
- Evaluating the ability of the fracture energy parameter to replace tensile strength as the mechanical test parameter used to quantify the effect of moisture on asphalt mixtures.
- Assessing the effects of specific binder and mixture properties on mechanical testing results.

Methodology

Asphaltic mixtures ranging from moisture resistant to moisture susceptible were used to evaluate the TSR, fracture energy and stripping test methods. These mixes included granite, gravel and limestone aggregates, with various mixture design components. The test methods were evaluated to determine their ability to reliably identify moisture damage due to sample conditioning and to identify the presence of an anti-stripping agent.

- A version of the Evaluation of Stripping in Loose Mixtures test developed by Quebec DOT, which measures the mass lost due to moisture conditioning of a loose mixture, was selected as a potential screening test. The test involves conditioning aggregate mix samples with water, agitating them in a gyratory shaker bath for 24 hours, washing and drying them, and then computing the percentage of mass lost to quantify stripping and loss of aggregate adhesion.
- Researchers used a fracture mechanics framework developed by Birgisson et al. in Florida, which evaluates fracture energy (the work required to fracture a mix specimen of a certain volume), to replace tensile strength as the mechanical test parameter used to quantify the effect of moisture on asphalt mixtures. This involved modifying the indirect tensile test to allow one test to measure both tensile strength and fracture energy.
- Results from the nonmechanical stripping test results were then compared with results of the mechanical TSR and fracture energy tests. The variability in TSR results was compared to ranges of TSR values published in WisDOT project 0092-45-94.

Investigator

"The fracture energy test shows promise in its ability to quantify moisture damage, but it needs further refinement."

–Andrew Hanz
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Researchers developed stress/strain curves using measurements from the Indirect Tensile Test machine (above, Fig. 3.3 of the final report) to compare ranges of TSR values from previous WisDOT studies.

Variations on these tests were performed to determine the effects on test results of a change in binder and mixture properties, as well as the effects of changes in aggregate type or gradation.

Results

Researchers concluded that neither the stripping test nor the fracture energy test were viable alternatives to the mechanical TSR test. Detailed results included:

- **Stripping test analysis.** The stripping test was able to distinguish moisture-susceptible mixes from less susceptible mixes and to identify the presence of an anti-stripping additive in moisture-susceptible mixes. However, high variability in test results prevented investigators from defining a threshold value that could be used in a mixture screening test.
- **Fracture energy test analysis.** Fracture energy analysis and the TSR test were both able to identify moisture-susceptible mixes and the contribution of liquid anti-stripping additives. However, the high variability of fracture energy testing results as reflected in the analysis of variance prevented investigators from recommending that this test be used to replace the TSR test.

Investigators also gained valuable insight into how aggregate properties and asphalt/aggregate adhesion affect mixture tensile strength. They found that binder properties, fine aggregate proportion and composition in the mixture, and percent of air voids did not significantly affect tensile strength.

Implementation and Benefits

Adding a simple screening test to current asphalt/aggregate moisture susceptibility testing requirements would save WisDOT money and time; investigators estimate engineers would spend 30 to 50 percent less time on mixture evaluation. This study represents substantial progress toward developing such a test; however, no alternative to current practice can be recommended at this time.

Over the long term, increasing understanding of the fundamental processes by which moisture damage occurs will aid in the mechanistic-empirical design of asphalt mixes and improve engineers' ability to predict pavement life. Fracture energy analysis, which provides data about changes in stresses and strains due to moisture conditioning, offers more information than tensile strength tests alone.

Further Research

Investigators recommend further refinement of the fracture energy test to reduce its variability, and further investigation into the physical causes of moisture damage. Specifically, the physiochemical interaction between the asphalt binder and aggregate should be investigated further, including the effect of surface tension on adhesive strength. The role of adhesion and the effect of the mastic (fine aggregate and binder) should also be studied further.

Flexible Pavements TOC Representative

"With this study, we have re-educated ourselves regarding the mechanisms of adhesion and cohesion when it comes to the mix performing as a unit."

–Judie Ryan
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This brief summarizes Project 0092-05-12, "Test Method to Determine Aggregate/Asphalt Adhesion Properties and Potential Moisture Damage," produced through the Wisconsin Highway Research Program for the Wisconsin Department of Transportation Research Program, 4802 Sheboygan Ave., Madison, WI 53707.

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