Project Summary

Texas Department of Transportation

0-4524: Application of Surface Energy Measurements to Evaluate Moisture Susceptibility of Asphalt and Aggregates

Background

Moisture damage in asphalt mixtures can occur within the asphalt mastic (cohesive fracture) or at the aggregate-mastic interface (adhesive fracture or failure). Whether or not a cohesive or adhesive failure occurs depends on the nature of the mastic and the relative thickness of the mastic. The majority of previous studies on this subject focused on the development of mixture tests and empirical parameters to quantify moisture sensitivity of asphalt mixtures. This project was conducted to attain fundamental understanding of the moisture damage process by carefully considering the mechanisms that influence durability of the adhesive interface between aggregate and asphalt and the cohesive strength and durability of the mastic.

What the Researchers Did

The first phase of the project focused on validation of the surface energy measurements and the dynamic mechanical analysis (DMA) through the evaluation of moisture susceptibility of materials and mixtures with known field performance. The second phase of the project evaluated the surface energy and moisture susceptibility of aggregate and asphalt combinations.

The following are the main tasks conducted in this project:

- Develop test protocols to determine surface energy of binders and aggregates.
- Catalog surface energy properties of commonly used asphalt binders and aggregates in Texas.
- Evaluate the impact of liquid anti-strips, modifications made by the manufacturers of asphalt binders, and aging on the surface energy of asphalt binder and its consequence on mixture performance.
- Evaluate the impact of water pH on its surface free energy and consequently on mixture resistance to moisture damage.
- Develop a test protocol to conduct dynamic mechanical analysis of the fine aggregate matrix (mixture of asphalt binder and fine aggregates).
- Develop a framework with a tentative protocol to evaluate moisture sensitivity of asphalt mixtures based on surface energy measurements and dynamic mechanical analysis of the fine aggregate matrix.
- Provide specifications for the equipment that can be used for measuring the surface energy of asphalt binder and aggregates.

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What They Found

The researchers developed a system of three steps to evaluate the influence of fundamental material properties, mixture modification, and mixture design on moisture susceptibility.

- In the first step, an energy-based parameter termed the energy ratio (ER) is calculated using the surface energy measurements and is used as a screening tool to select binders and aggregates that have good resistance to moisture damage.
- In the second step, the dynamic mechanical analysis of fine aggregate matrix specimens consisting of asphalt binder and fine portion of aggregates is used to evaluate moisture susceptibility.
- The moisture susceptibility of the full mixture is evaluated in the third step.

The testing in the second and third steps yields a crack growth index that is a function of fundamental material properties. The DMA testing is useful to evaluate moisture susceptibility of the materials without being influenced by mixture design and internal structure distribution. The evaluation of the full mixture is necessary, however, in order to verify that the mixture design and internal structure distribution are optimized to improve resistance to moisture damage. The preliminary recommendations for the parameters obtained in this system are summarized in the table below.

Parameter	Resistance to Moisture Damage			Notes
	Good	Fair	Poor	
Step 1: Energy Ratio*	? 0.8	? 0.8 < 0.5	? 0.5	The energy ratio is calculated from the binder cohesive energy, wet adhesive bond energy and dry adhesive bond energy.
Step 2: Ratio of Crack Growth Index at 10,000 Cycles (DMA Testing of Asphalt and Fine Portion of the Mixture)	≤ 1.5	> 1.5 ≤ 2.0	> 2.0 Or Failure Under Wet Condition	Ratio of crack growth index under wet conditions to crack growth index under dry conditions.
Step 3: Ratio of Crack Growth Index at 1,000 Cycles (Dynamic Testing of Full Mixture	≤ 1.2	> 1.2 ≤ 1.5	> 1.5 Or Failure Under Wet Condition	Ratio of crack growth index under wet conditions to crack growth index under dry conditions.

**** additional consideration must be made for aggregates with very low*** specific surface area.

What This Means

The framework and tentative protocols developed in this project can be used to select materials and design mixtures that have good resistance to moisture damage. In contrast to traditional methods that rely solely on testing of whole mixtures, this framework is based on a bottom-up approach to quantify moisture sensitivity of asphalt mixtures. In other words, in this framework materials are screened first, followed by tests on fine aggregate matrix and whole mixtures. Using this approach, the results of this project will contribute to the reduction of asphalt pavements failures due to moisture damage. This will translate to longer pavement life and less maintenance and construction cost.

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