Transportation Consortium of South-Central States (Tran-SET)

Impacts of Moisture on Asphalt Properties

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Developing a test protocol to quantify moisture susceptibility for asphalt concrete

Stripping related moisture damage has been recognized as one of the major pavement distresses since the early 1990s, since it prematurely deteriorates the performance and durability of asphalt pavements. The objective of this study is to develop an effective test protocol to quantify moisture susceptibility of asphalt mixtures using Mechanistic-Empirical approaches (Texas Boiling test, Tensile Strength Ratio, Retained Stability, and Hamburg Wheel Tester), surface chemistries, and molecular level material properties. Based on a comprehensive literature review, a detailed project plan and a test matrix have been developed. Binder samples originating from two different crude sources have been collected. The moisture resistance related tests such as static contact angle measurements and Texas Boiling tests have been completed for this study. In addition, the evaluation of nano mechanical properties using an Atomic Force Microscopy (AFM) and measurement of surface chemistries using a static contact for asphalt binder samples are in progress. After conducting all necessary tests for this project, effective test method(s) for evaluating moisture resistance of asphalt pavements will be determined.

Problem Statement

Stripping in asphalt concrete (AC) is a complex mechanism, which is caused by the loss of adhesive bond between the asphalt binder and the aggregate (a failure of binder aggregate bonds) or by a softening of the cohesive bonds within the asphalt binder (a failure within binder itself). Numerous studies have been done to develop an accurate and effective tool for quantifying moisture sensitivity of asphalt concrete. Almost all agencies use the most popular forms of moisture resistance tests of asphalt mixtures such as the Texas Boiling, Indirect Tensile Strength, and Hamburg Wheel test methods. However, only the Arkansas Department of Transportation Department (ARDOT) uses the Marshall-based Retained Stability test, which is obsolete and abandoned by other states due to its poor correlation with the field performance. The outcomes of this project are expected to recommend an effective tool for the prediction of moisture damage in asphalt pavements.

Summary

To achieve the goals of this study, an extensive literature review on moisture damage in asphalt binders was conducted to prepare a detailed test plan. Next, the required asphalt binder samples were collected from two different crude sources (Source 1 - Canadian crude: Ergon Asphalt and Emulsions, Inc. Memphis, TN and Source 2 - Arabian crude: Marathon Petroleum Corporation, Catlettsburg, KY).

The moisture sensitivity tests such as static contact angle measurements and Texas Boiling tests were conducted for this study. Guidelines, provided by the Texas Transportation Institute (TTI), were followed to conduct the Texas Boiling test. In this test, the stripping of asphalt binders was measured through visual observation, and shown in Table 1.

Table 1. Summary of Texas Boiling Test.

Asphalt Binder Designation	Binder Sample Source	Percentage of Asphalt Retained (%)
PG 64-22	1	50
	2	55
PG 70-22 (PPA-modified)	1	60
	2	65
PG 70-22 (SBS-modified)	1	70
	2	70

On the other hand, an Optical Contact Analyzer (OCA) device was used in this study to measure the contact angles of asphalt binders and aggregates. In addition, the determination of nano-mechanical properties of asphalt binders using AFM has started for this study. The AFM tests were conducted on the dry and wet conditioned binder samples to capture the topography of surface of the asphalt binders as well as mechanical properties at molecular level. In AFM tests, the Peak-Force Quantitative Nanomechanical Mapping (PFQNM) techniques of AFM were used. After conducting AFM scan (Figure 1), surface morphology and mechanical properties of asphalt binder are quantified using Nano Scope Analyses 1.5.

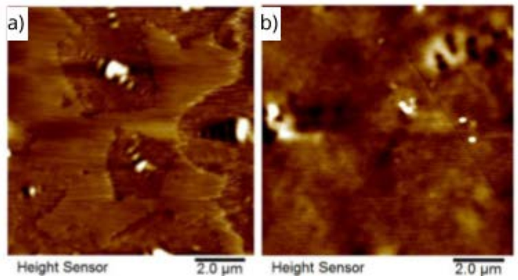

Figure 1. AFM-based map of asphalt binder, where the morphology of asphalt binder is observed at (a) Dry condition; (b) Wet condition.

Findings

Various tests for predicting moisture-induced damage of asphalt mixtures can be classified into three general categories: (i) components and compatibility test, (ii) tests on the loose mix, and (iii) tests on the compacted mix. As mentioned earlier, selected tests are being following to evaluate an effective and simple test method for predicting moisture resistance of asphalt mixes.

Based on the Texas boiling tests results, the percentage of asphalt retention for styrene-butadine polymer (SBS) modified binder was higher than the Polyphthalamide polymer (PPA) modified PG 70-22 binders. Moreover, the PPA-modified PG 70-22 binder performed significantly better than the base binder (PG 64-22). Compatibility analysis of asphalt binders shows higher adhesion energy in wet condition and lower adhesion energy in dry condition for (PPA) modified asphalt binders from Source 1. However, an opposite trend was noticed in case of Source 2 binders. The evaluation of moisture on the binder properties at the molecular level were investigated using AFM. The topographic image revealed that surface of the binder samples is significantly changed due to the effect of water In other words, it can be concluded that moisture changed the morphology of the asphalt binder surface, where moisture decreased the surface roughness. Furthermore, the effect of moisture also observed in all mechanistic data.

The effect of moisture changes the modulus and adhesion force values significantly in wet binder samples. Under the wet condition, modulus values reduced significantly from 536 MPa to 271 MPa, which is a 50% reduction from the dry samples. Further, the variation of adhesion values in the wet samples was considerably lower compared to the dry samples (from 85 nN to 20 nN). AFM test results showed that about 76% higher adhesion values were observed in the dry samples.

Impacts

This study will help ARDOT and other transportation agencies to follow a simple and effective tool to predict moisture-induced damage of asphalt. The findings of this study are expected to help to have a better understanding of the effects of water in asphalts at the molecular level, and thereby help pavement professionals and engineers to use a proper binder for roadway construction as well as to develop a suitable test to quantify moisture damage potentials.

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

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