Assessment of Compatibility of Mineral Aggregates and Binders Used in Highway Construction and Maintenance Projects

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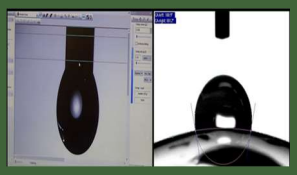

Highlight | Sept. 2020

Project No. 19BASU02

PI: Dr. Zahid Hossain (ASU)

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Stripping and delamination have been deemed as some of the major premature pavement distresses to most state Departments of Transportations (DOTs) and highway agencies. It is believed that the poor compatibility between asphalt binders and aggregates is one of the major reasons behind this. This study aims to analyze the compatibility of selected asphalt binders and aggregates used in Arkansas. Asphalt binders used in this study include PG 64-22, PG 70-22, and PG 76-22, and four different types of aggregates (sandstone, limestone, gravel, and dolomite) were evaluated in the laboratory. Selected physical and mechanical properties of the aggregates, rheological properties of the asphalt binders, surface free energy (SFE) measurements of the binders and aggregates, atomic force microscopy (AFM) analyses of binders, and limited laboratory and field performance of asphalt mixture samples were evaluated to determine the compatibility between the asphalt binders and aggregates.

Background

The performance of the asphalt-aggregate system depends on the cohesion within the asphalt binder, adhesion between the aggregates and asphalt, and degradation of the aggregates. The cohesive strength of the asphalt binder and the adhesive strength between the asphalt-aggregate systems can be determined by using the surface free energy (SFE) technique at both dry and wet conditions. Good-van Oss-Chaudhury theory or acid-base theory is used to calculate the free energies of the asphalt binder and the aggregates. The Sessile Drop (SD) method is the easiest and the most effective method to determine the contact angle and an OCA device is used to estimate the angles. Finally, the compatibility ratio is calculated which is an important parameter to identify proper asphalt binder-aggregate combination.

Project Summary

The primary objective of this proposed research project is to assess the durability of selected aggregates throughout Arkansas and their compatibility with asphalt binders from two different crude sources. Specific objectives of this study are given as follows: (a) evaluate physical and mechanical properties (e. g., absorption and durability) of aggregates; (b) determine surface free energies and adhesion properties of binders and aggregates; (c) recommend suitable test method(s) to screen incompatible aggregates; (d) develop a database of compatible aggregate-binder systems; and (e) rank the aggregate-binder systems based on physical, chemical, and mechanical properties.

To accomplish the objectives of this study, a series of laboratory tests have been conducted on selected binders and aggregates samples collected throughout Arkansas. Also, samples from two recently constructed chip seal projects have been collected and investigated in the laboratory.

Status Update

Physical, Mechanical, and chemical properties of aggregates (Sandstone, Dolomite, Limestone, and Gravel) have been determined as well as rheological properties of asphalt binders. Surface free energy approach was used to calculate the adhesion, cohesion, and compatibility ratio. All tested binder and aggregate combinations have been ranked based on their compatibility and other test results. For instance, based on the LA abrasion test results showed that gravel ranks no 1 while sandstone ranks no. 4 based on the percentage of loss.

It appears that Limestone and dolomite are showing higher compatibility with modified binders PG 76-22 and PG 70-22. At the same time, Sandstone is showing the lowest compatibility among these four aggregates.

The Atomic Force Microscope is found to be an effective tool to predict the moisture damage of the asphalt binders both qualitatively and quantitatively at the atomic scale. AFM test results concluded that the SBS-modified binder had

better resistance to moisture damage than all other binders.

Among all tests performed under the scope of this project, the Texas boiling test is simple, quick, and easy to perform for measuring the moisture susceptibility of the asphalt binder qualitatively. The Texas boiling test results revealed that the higher percentage of asphalt retained for PPA plus SBS-modified binders of both sources, indicating the higher moisture resistance with limestone and dolomite. While sandstone with unmodified asphalt binders had very little retention of asphalt binders. Field evaluation data suggest that chip seal samples show poor compatibility, which is also observed in the field conditions.

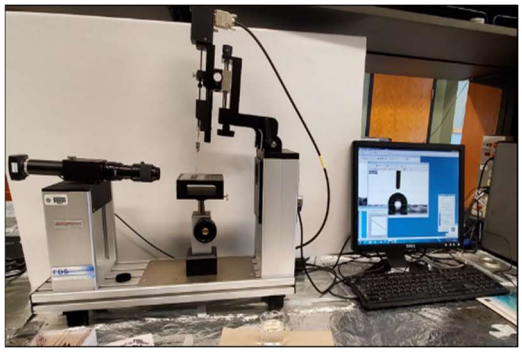

Figure 1. Experimental Setup for Sessile Drop Method.

Figure 2. OCA device (left) and Texas boiling test procedure (right).

Impacts

The outcome of this study is expected to be significant cost savings for agencies and contractors by choosing the suitable asphalt binders and aggregates, which are expected to have less premature pavement and last longer. The outcomes are also expected to help ArDOT and other industries in the region to use knowledge learned on compatible aggregate-binder systems. The main deliverables of this project are: (1) a technical report containing a database of compatible aggregate-binder systems and (2) dissemination of research findings at multiple conferences and symposia such as the 2020 Create@State Symposium, the 2020 Tran-SET Conference, and the 2020 Oklahoma Transportation Research Day. Graduate and undergraduate students have been trained and they are expected to enter the transportation workforce in the future.

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".

Learn More

For more information about Tran-SET, please visit our website, LinkedIn, Twitter, Facebook, and YouTube pages. Also, please feel free to contact Dr. Momen Mousa (Tran-SET Program Manager) directly at transet@lsu.edu.