Work element M1a: Affinity of Asphalt to Aggregate

Work Done This Quarter

In this quarter, the research group focused its efforts in validating the effectiveness of the Bitumen Bond Strength (BBS) test for moisture damage evaluation. A comparison between the BBS test results and the modified Dynamic Shear Rheometer (DSR) strain sweep test was conducted. The comparison shows that the BBS test can rank materials similarly to a more sophisticated and time consuming test. The materials used are listed in Table M1a.1.

Table M1a.1. Materials used to compare BBS with DSR strain sweep tests.

Solution	Tap Water
Mineral Surface	Granite
Asphalt Binders	FH 64-22 & CRM 58-28
Modified Asphalt Binders	FH 64-22 + 0.7%Elvaloy (ELV) + 0.17% Polyphosphoric Acid (PPA) & CRM 58-28 + Styrene-Butadiene-Styrene (SBS)

The strain sweep tests in the DSR are performed using a cored rock disk of 25 mm in diameter and 5 mm thick as the bottom plate (i.e. substrate). The rock disk and the asphalt binder simulate the asphalt-aggregate interface in the asphalt mixture. In this test, a water cup, specially manufactured for the DSR is used for water conditioning. In order to monitor moisture damage in the aggregate-asphalt interface, rheological responses were measured using oscillatory loads with shear strains varying from 1 to 100% at a frequency of 1.6 Hz frequency (i.e., 10 rad/s) and 40°C, for both dry and wet (using tap water) conditioning. Two replicates were tested for each condition and test type.

Figure M1a.1 shows a typical result obtained from the DSR strain sweep procedure. It can be seen that water conditioning significantly affects the rheological properties of asphalt-aggregate systems.

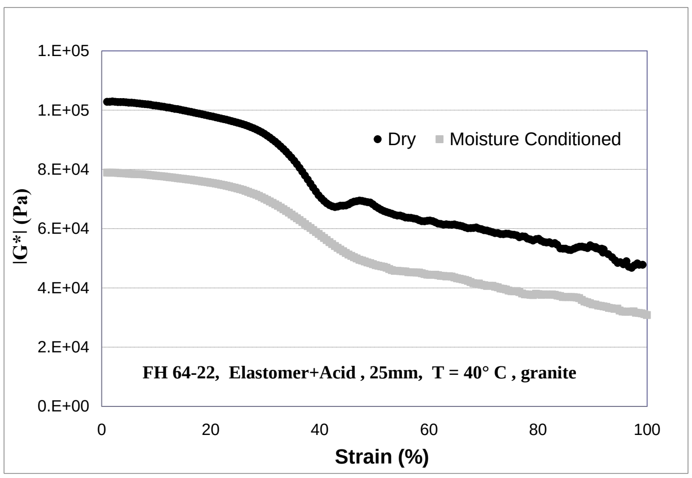

Figure M1a.1. Graph. Strain sweep test in DSR for FH 64-22+ELV+PPA and granite in dry and wet conditions.

Comparison of the BBS and DSR procedures involved the calculation of the percent loss of a specific property after water conditioning for 6 hours. In the case of the BBS test the pull of tensile strength (POTS) was used to calculate moisture susceptibility. On the other hand, for the DSR strain sweep test, the complex modulus |G*| at a strain of 1% was selected as the parameter. Note that similar results were obtained when selecting the complex modulus at higher strain levels (i.e., γ=100%). The following equation was used to compute moisture damage in the BBS test:

$$\%Loss\_After\_Moisture\_BBS = 1 - \frac{POTS_{WET}}{POTS_{DRY}} \tag{M1a.1}$$

where, $POTS_{DRY}$ and $POTS_{WET}$ are the pull-off tensile strength from BBS test in dry and moisture conditioning after 6 hours, respectively. To calculate the moisture damage in the strain sweep test, the following equation was used:

$$\%Loss\_After\_Moisture\_DSR = 1 - \frac{\left|G^*\right|_{\gamma=1\%,\_WET}}{\left|G^*\right|_{\gamma=1\%,\_DRY}} \tag{M1a.2}$$

where, $\left|G^*\right|_{\gamma=1\%,\_WET}$ and $\left|G^*\right|_{\gamma=1\%,\_DRY}$ are the complex modulus at a shear strain of 1% from DSR testing in dry and moisture conditioning after 6 hours, respectively.

Table M1a.2 shows the results for the three asphalt-aggregate systems tested in the BBS and DSR. It can be seen that the moisture susceptibility ranking from the BBS test and the DSR strain sweep test are the same.

Table M1a.2. Ranking moisture susceptibility of three different asphalt-aggregate systems with BBS and DSR testing

Asphalt-Aggregate System Description	***%Loss_DSR***	***%Loss_BBS***	**Ranking DSR**	**Ranking BBS**
CRM 58-28 neat Granite	10%	24%	2	2
CRM 58-28+SBS Granite	8%	22%	1	1
FH 64-22+ELV+PPA Granite	23%	26%	3	3

<u>Significant Results</u>

The research team obtained promising results regarding the feasibility of the BBS test for the characterization of the asphalt-aggregate interface. Limited results on the validation/verification of the BBS test procedure with the modified Dynamic Shear Rheometer (DSR) strain sweep test indicates that the BBS test can rank the asphalt-aggregate systems with respect to moisture damage similarly to more sophisticated and time consuming tests. Note that results are preliminary and a more extensive test matrix needs to be performed for such comparison. It is clear that the BBS test is a simpler and more practical test. The comparison is needed only for validation of the results in terms of ranking of aggregate-binder systems. A draft AASHTO standard for the BBS test procedure was submitted in this quarter for final approval.

Work Planned Next Quarter

The research team will continue testing the experimental matrix in Year 4 work plan. Emphasis will be paid in continuing the validation/verification of the BBS test procedure by performing Tensile Strength Ratio (TSR) tests of asphalt mixtures and by extending the experimental matrix which compares BBS with the modified dynamic shear rheometer (DSR) strain sweep test. Also, efforts will focus on understanding the mechanisms of adhesion between asphalt and aggregate based on surface energy measurements with the Atomic Force Microscope (AFM). The team is expecting to show that the BBS test can be used to determine the moisture susceptibility of asphalt-aggregate system and as a surrogate test for surface energy measurements.

Papers and Posters **Submitted** in the Last Quarter

Moraes, R., Velasquez, R., and Bahia, H., Measuring Effect of Moisture on Asphalt-Aggregate Bond with the Bitumen Bond Strength Test, submitted to the Transportation Research Board (TRB) 2011 Annual Meeting.