Work element M1a: Affinity of Asphalt to Aggregate

Work Done This Quarter

The research group continued using the Sessile Drop method to measure contact angles of different asphalt binders with three liquids: distilled water, ethylene glycol, and formamide. Preliminary comparison between contact angle measurements, which can be used as a quantitative estimation of wettability, and Bitumen Bond Strength (BBS) results was conducted. The experimental results showed that the BBS and contact angle measurements are in agreement. Binders with higher pull-off tensile strength correspond to binders with higher wettability capacity (i.e., lower contact angles). Note that the comparison was performed based on Sessile Drop results with distilled water as probe liquid. The materials used for BBS-Sessile Drop comparison are listed in Table M1a.1.

Table M1a.1. Materials used for Contact Angle and BBS testing.

Solution	Distilled Water, Ethylene Glycol, Formamide
Aggregate	Limestone and Granite
Asphalt Binders	FH 64-22 & CRM 58-28
Modified Asphalt Binders	FH 64-22 +1% Polyphosphoric Acid (PPA), FH 64-22+0.7% Elvaloy 4170+0.17% PPA FH 64-22+0.7% Elvaloy AM+0.17% PPA FH 64-22+0.5% Anti-Stripping FH 64-22+2% Plastomer (CBE) CRM 58-28 +1% PPA

Table M1a.2 show the ranking of the asphalt binders based on contact angle measurements with distilled water. Tables M1a.3 and M1a.4 show the ranking based on the pull-off strength results at dry and wet conditions (i.e., 96 hours) in granite substrate, respectively.

Table M1a.2. Sessile Drop results for asphalt binders.

Contact Angle in Water				
Sample	**Average (°)**	**Std**	**CV (%)**	**Rank**
FH 64-22 + 2% CBE	108.1	0.57	0.53	1
FH 64-22 + 1% PPA	108.7	0.74	0.68	2
FH 64-22+0.7% Elvaloy 4170+0.17% PPA	109.9	1.50	1.36	3
FH 64-22+0.7% Elvaloy AM+0.17% PPA	110.3	0.67	0.61	4
FH 64-22 + 0.5% Anti-Stripping	111.1	0.48	0.43	5
FH 64-22 Neat	111.1	0.61	0.55	6

It can be seen from Tables M1a2-M1a.4 that both tests rank the asphalt binders similarly. Lower contact angle with distilled water indicates higher wetting tendency. When wettability increases, the surface of aggregates to be wetted by the asphalt binder increases, thereby improving the adhesion between the asphalt and aggregate as observed in the BBS results.

Table M1a.3. BBS results at dry condition for asphalt binders.

BBS test – Dry condition				
	Pull-off Strength (MPa)	**Std (MPa)**	**CV (%)**	**Rank**
FH 64-22 + 2% CBE	2.206	0.02	1	1
FH 64-22 + 1% PPA	2.138	0.03	1.5	2
FH 64-22+0.7% Elvaloy 4170+0.17% PPA	2.019	0.08	3.8	3
FH 64-22 + 0.5% Anti-Stripping	2.01	0.07	3.3	4
FH 64-22+0.7% Elvaloy AM+0.17% PPA	1.869	0.11	5.8	5
FH 64-22 Neat	1.856	0.2	10.8	6

Table M1a.4. BBS results at wet condition for asphalt binders.

BBS test – Wet condition (96 hours)				
	Pull-off Strength (MPa)	**Std (MPa)**	**CV (%)**	**Rank**
FH 64-22 + 1% PPA	1.924	0.09	4.8	1
FH 64-22 + 0.5% Anti-Stripping	1.651	0.01	0.6	2
FH 64-22 + 2% CBE	1.24	0.02	1.9	3
FH 64-22+0.7% Elvaloy 4170+0.17% PPA	1.237	0.02	1.3	4
FH 64-22+0.7% Elvaloy AM+0.17% PPA	1.125	0.02	2	5
FH 64-22 Neat	1.004	0.03	2.9	6

It was also observed that contact angle decreases with asphalt binder modification. The increase in wettability is also evident from the increased hydrophilic characteristics of the asphalt binder with the addition of PPA. The different ranking observed for FH 64-22+0.5% Anti-stripping binder using contact angle and pull-off strength results can be explained by the fact that in the BBS test there is an interaction between the asphalt binder and the granite aggregate. A better adhesion can be achieved between an acidic binder and an acidic aggregate such as granite by using amines as anti-strip additives since amines, which are basic organics, alter the surface of an acidic aggregate to provide better adhesion (Tunnicliff and Root, 1984). The cohesive failure type observed for FH 64-22+0.5% Anti-Stripping binders (Figure M1a.1) supports this explanation.

Figure M1a.1. Photograph. Cohesive failure for asphalt binder FH 64-22+0.5% Anti-stripping with granite.

Significant Results

Figure M1a.2. shows contact angle results of asphalt binders measured with three probe liquids (i.e., distilled water, formamide, and ethylene glycol). These probe materials are pure and homogeneous liquids that do not react chemically or dissolve with asphalt binders.

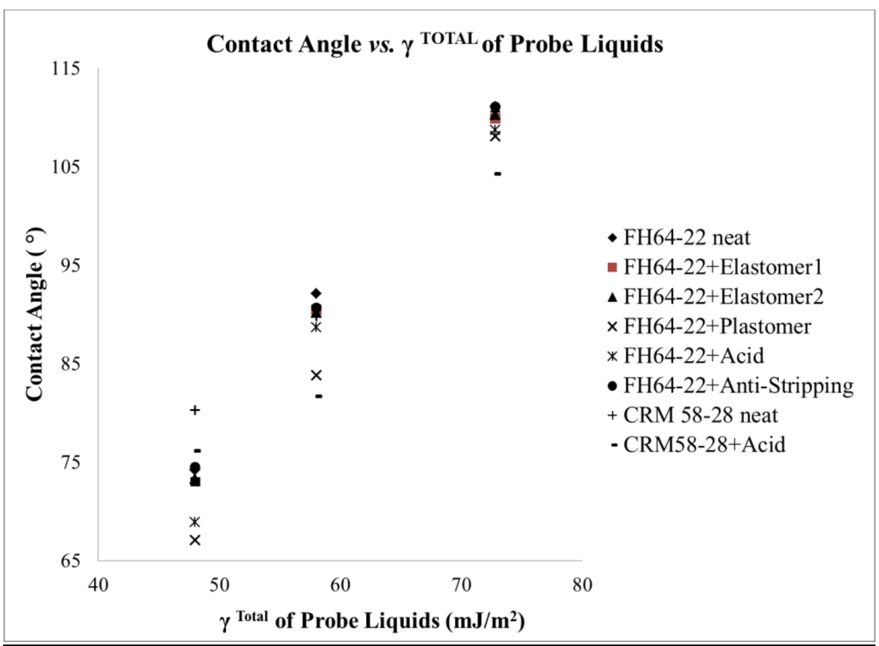

Figure M1a.2. Graph. Contact angles with water, formamide, and ethylene glycol.

The Young-Dupre equation which relates the contact angle, the surface energy components of the probe liquid, and the surface energy components of the substrate can be used to estimate the surface energy of the asphalt binders and aggregates. Then, by using the estimated surface free energy of both binder and aggregates, the adhesive bond in dry and wet conditions can be calculated using Gibbs free energy.

Significant Problems, Issues and Potential Impact on Progress

Aggregates for asphalt mixture preparation for Tensile Strength Ratio (TSR) testing were not available for the research team for the past quarter. The team contacted other partners for materials availability but the response was negative. The research team is expecting to obtained materials from a local pit once they are open after winter season. The research team will double efforts in completing the TSR testing and will not expect delay in the progress of this work element.

Work Planned Next Quarter

Efforts will focus on the estimation of surface energy for both binders and aggregates indirectly with the contact angle measurements. Also, the adhesive bond between asphalt and aggregate in the presence of water will be calculated using Gibbs free energy for all materials and a comparison to the BBS results will be performed. The research team will use TSR testing results available from other work elements to continue the validation effort of the BBS test procedure.

Papers and Poster **Accepted/Published** and Presentation Given 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, Poster presentation at the Transportation Research Board (TRB) Annual Meeting, January 2011.

References

Tunnicliff, D. G., and Root, R. E., “Use of Anti-Stripping Additives in Asphalt Concrete Mixtures,” National Cooperative Highway Research Program (NCHRP) Report 274, 1984.