Work element M1a: Affinity of Asphalt to Aggregate

Work Done This Quarter

In this quarter, the research team compared bond strength measurements obtained with the Bitumen Bond Strength (BBS) test with fundamental thermodynamic parameters that quantify the bond strength of asphalt-aggregate systems such as work of cohesion and work of debonding. These parameters were calculated based on contact angle measurements using Sessile Drop Method with different liquids with known surface energy components.
The Young-Dupré equation described in previous quarterly reports was used to estimate the surface energy of the asphalt binders and aggregates. By using the estimated surface free energy of both binder and aggregates, the work of cohesion and work of debonding was calculated and compared to BBS results. The experimental results showed that the BBS and surface properties of different asphalt binders are generally in agreement. The selected probe liquids were distilled water, ethylene glycol, and formamide, which were chosen for their immiscibility with the asphalt binder and differing surface free energy components (Wei et al., 2010).

Significant Results

Figure M1a.1 shows a comparison between the pull-off strength results after wet conditioning for 24 hours and the work of cohesion (i.e., $2\gamma_{binder}$) of asphalt binders with limestone aggregate. It can be seen that higher work of cohesion results in higher pull-off strength. Note that the BBS results used for this comparison correspond to cohesive mode failure only.

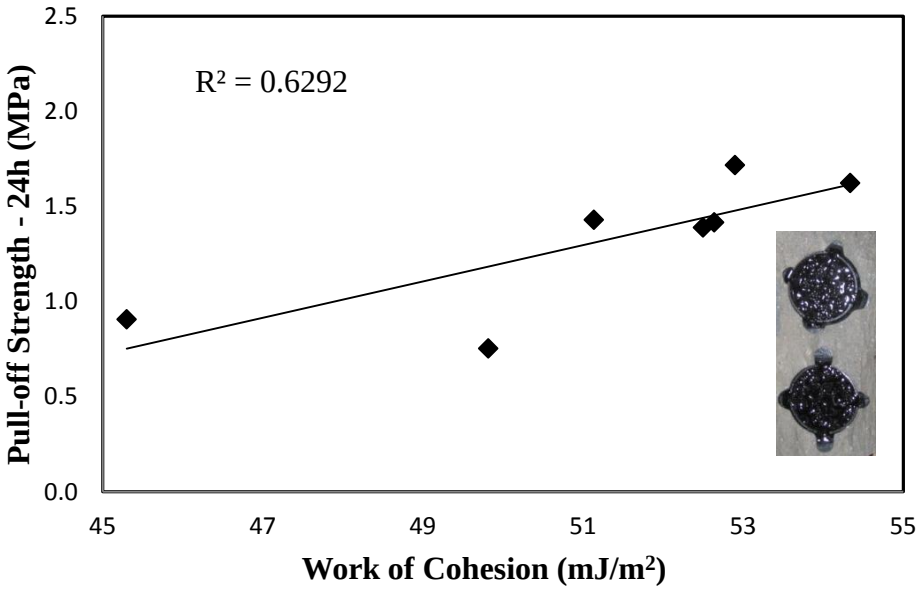


Figure M1a.1. Graph. Comparison between pull-off strength and work of cohesion of asphalt binders that showed cohesive failure with limestone aggregate after wet conditioning.

If the displacement of an asphalt binder from the aggregate surface is a thermodynamically favorable process then it must be associated with a reduction in the free energy of the system

(i.e., the total work done during the displacement process must be less than zero) (Bhasin, 2006). The energy associated with the displacement of asphalt by water from asphalt-aggregate interface (i.e., work of debonding) can be expressed in terms of the components of surface energy of water, aggregate, and asphalt binder.

The work of debonding calculated from surface energy measurements and the loss of pull-off strength in the BBS were compared for asphalt-aggregate systems with adhesive failure (Figure M1a.2). A fair correlation was observed between BBS adhesive failure results and the thermodynamic based parameter. As expected, higher loss of bond strength implies higher work of debonding. Furthermore, Figure M1a.3 indicates that higher work of debonding corresponds to lower bond strength of the asphalt-aggregate system after moisture conditioning.

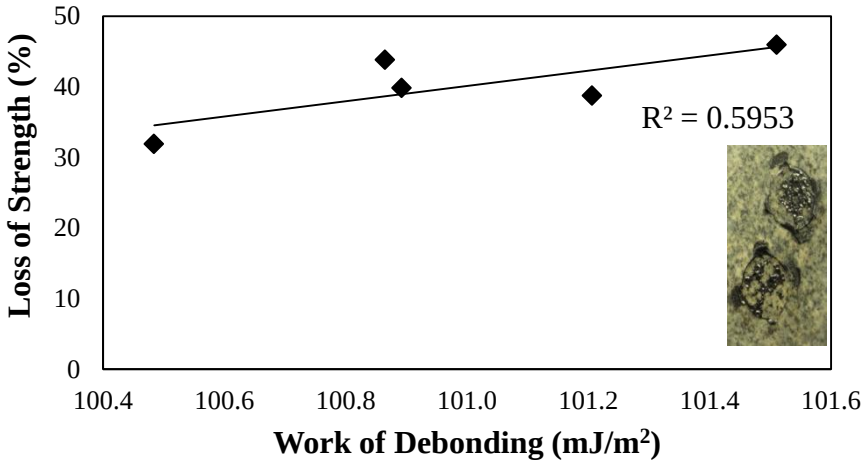
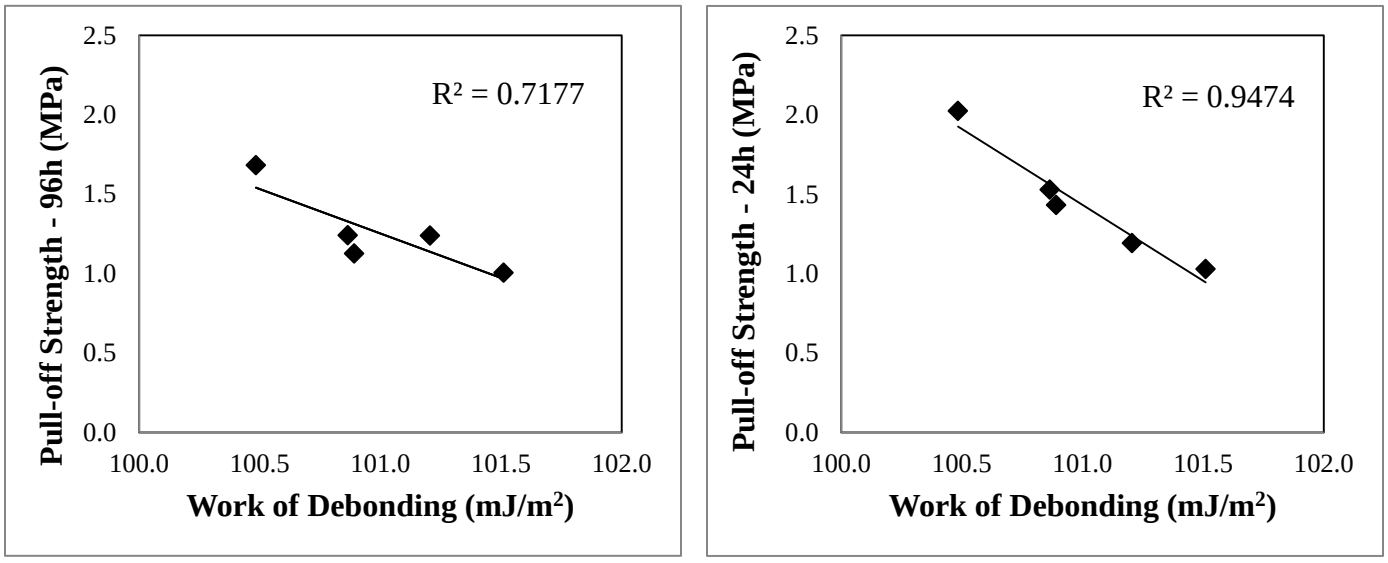


Figure M1a.2. Graph. Comparison between loss of strength and work of debonding of asphalt binders that showed adhesive failure with granite aggregate after wet conditioning.



a) b)

Figure M1a.3. Graph. Comparison between pull-off strength and work of debonding of binders with adhesive failure with granite after a) 96 hours and b) 24 hours of conditioning.

Work Planned Next Quarter

Efforts will focus on the validation of the BBS test procedure with mixture TSR testing results. Also, a detailed procedure to correct the bond strength obtained in the BBS due to binder stiffness will be developed. The research team will work in collaboration with Consortium partners to include information related to the development and implementation of the Bitumen Bond Strength (BBS) test as a chapter in a consolidated report for Moisture Damage work element.

Papers **Accepted** and Presentation Given in the Last Quarter

Bahia, H, Velasquez, R., Moraes, R., *Improving Moisture Resistance of Asphalt Mixes by Direct Measurement of Bond Strength between Aggregates and Asphalts*. Presentation at 1st Congreso de Infraestructura del Transporte **CITRANS,** San Jose, Costa Rica, June 15th to16th, 2011.

Moraes, R., Velasquez, R., Bahia, H., *Understanding Adhesion and Cohesion of Asphalt-Aggregate Systems Using the Bitumen Bond Test and the Sessile Drop Method*. Abstract accepted for 5th Eurasphalt and Eurobitume Congress, Istanbul, Turkey, 13th to 15th June, 2012.

Moraes, R., Velasquez, R., Bahia, H., *Selección de Materiales para Mezclas Asfálticas Resistentes al Daño por Humedad Utilizando el Método de La Gota Sésil*, XVI CILA – Congresso Ibero-Latino Americano do Asfalto, Rio de Janeiro, Brazil, 20th to 25th November, 2011.

Moraes, R., Velasquez, R., Bahia, H., *Selection of Moisture Damage Resistant Materials for Asphalt Mixtures Using the Bitumen Bond Strength Test and Sessile Drop Method*. Presentation for the 2011 Petersen Asphalt Research Conference, Laramie, Wyoming, 11th to 13th July, 2011.

References

Wei, Jianming; Huang, Xiaosheng; Zhang,Yuzhen (2010). *Influence of Commercial Wax on Performance of Asphalt*. Journal of Materials in Civil Engineering, pp. 760-766.

Bhasin, A.(2006). *Development of Methods to Quantify Bitumen-Aggregate Adhesion and Loss of Adhesion Due to Water*. Ph.D. Dissertation, Texas A&M University, College Station, Texas.