

A Fundamental Approach to Moisture Damage in Asphalt Mixtures

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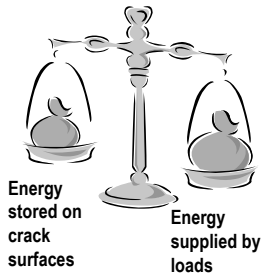
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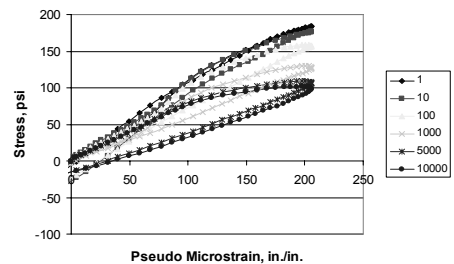
Using calculated adhesive bond energy to predict moisture damage through stripping

Start with Schapery's First Principles Fracture Theory

- Load-induced energy that causes fracture
- Balanced by energy stored on newly formed cracks



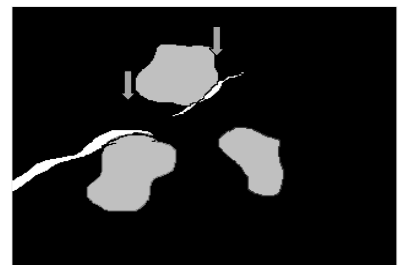
Dissipated Pseudo Strain Energy (Area within adjusted hysteresis loops)



Cohesive Fracture



Adhesive Fracture



Water Invades the Interface – Stripping



Calculation of Bonding Energy

- * Adhesion between asphalt and aggregate

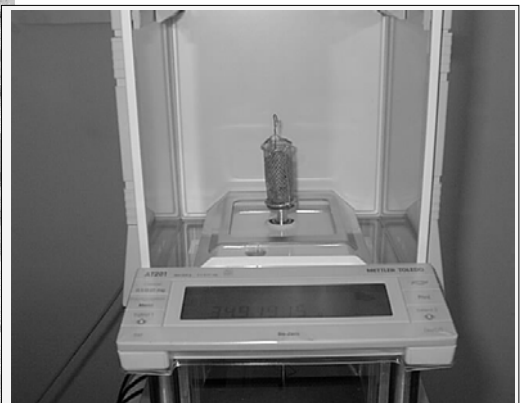
$$\Delta G_{ij}^a = \Gamma_i + \Gamma_j - \Gamma_{ij}$$

- * Cohesive bond within mastic (asphalt and mineral filler)

$$\Delta G_i^c = 2\Gamma_i$$

Measuring Surface Energy

- * Asphalt
 - Wilhelmy plate
 - Measures surface energy of wetting (healing) and surface energy of de-wetting, fracture
- * Aggregate
 - Universal Sorption Device (USD)
 - Measures surface energy by adsorption of solute gases



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Adhesive Bond (ergs/cm²)

Binder	GA	TX LS	CO LS
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Granite
AAD-1
AAM-1
HCR
HCR –
Aged
Water

Gibbs Free Energy Per Unit Amount (ergs/gm) x 10³

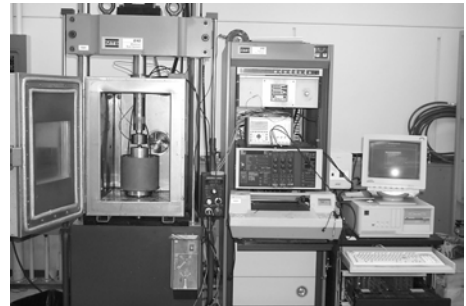
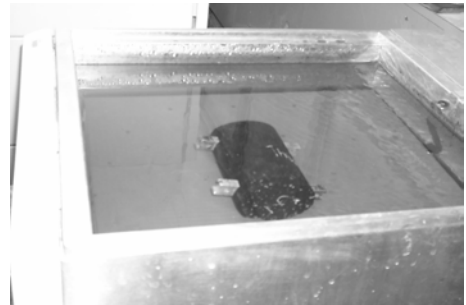
Binder	GA	TX LS	CO LS
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Granite
AAD-1
AAM-1
HCR
HCR
Aged

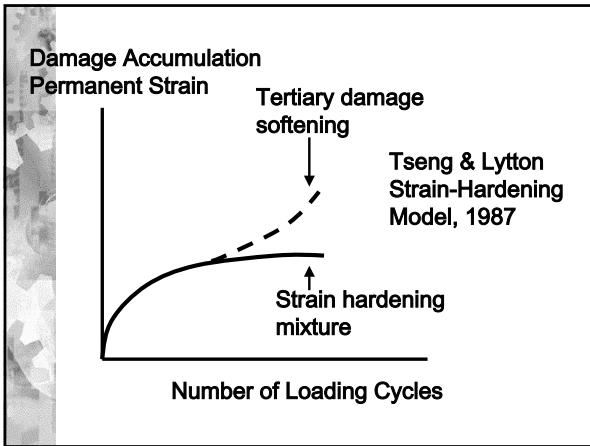
Adhesion - Dry and Wet (ergs/cm²)

Combination	Bond, dry	Bond, wet
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AAM-LS
AAD-LS
AAM-G
AAD-G



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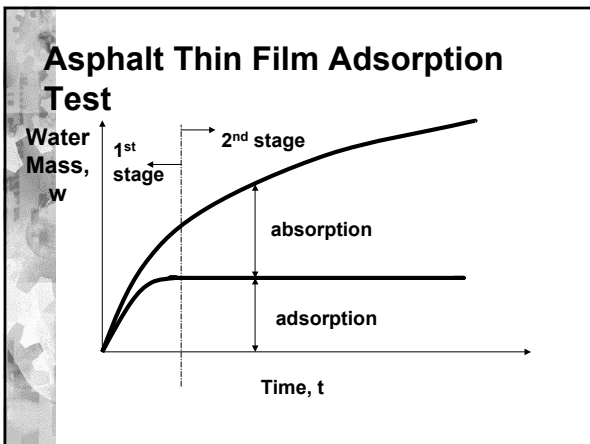
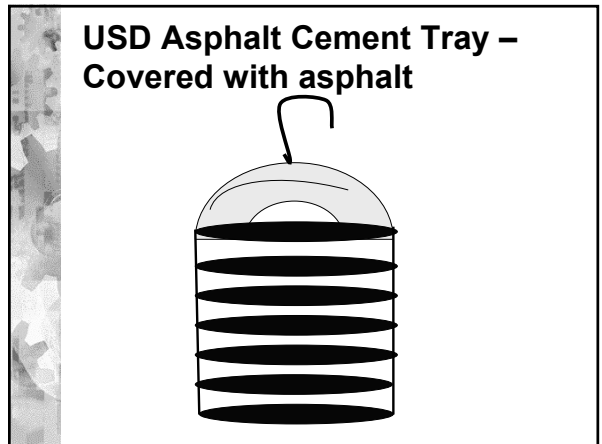


Comparison of Free Energy of Adhesion and Triaxial Testing (Saturated)

Mix	Cycles to accel. damage	Free energy (ergs/g)	Free energy of adhesion (wet)
DLS			
MLS			
DGG			
MGG			

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Use cohesive bond strength and effect of moisture intrusion to assess weakening of the mastic



Comparison of USD and MTS Results

	AAD	AAM
D	0.0008	0.0029
W ₁₀₀	0.00153	0.00114
W ₁₀₀ Ratio	AAD/AAM = <u>1.34</u>	
Cycles, Accel. Damage	550	425
Damage Ratio	AAD/AAM = <u>1.29</u> ¹	

¹Note: AAD also has a 15% higher free volume than AAM.

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Conclusions -1

- SFE is a fundamental property related to both cohesive and adhesive fracture
- SFEs of asphalt-aggregate systems were successfully measured by Wilhelmy plate and USD

Conclusions -2

- The SFEs of asphalt cement can be measured in both wetting (healing) and dewetting (fracture) modes
- Normally, the SFE of dewetting is higher than that of wetting based on contact angle results from the Wilhelmy plate method

Conclusions -3

- All adhesive bond calculations are positive – energy is required to break bonds
- Adhesive bond between water and aggregates are considerably higher than between bitumen and aggregate – stripping will likely occur

Conclusion 4

- SFE of adhesion can be calculated between bitumen and aggregate in presence of water
- Numbers are negative – breaking a unit area of bond releases energy
- More negative – more moisture sensitivity

Conclusions -5

- Both the SFE of the asphalt and the aggregate are important in adhesion
- It is important to calculate Gibbs Free Energy of Adhesion per unit mass in comparing different systems
 - Consider granite v. limestone
 - Results are consistent with experience

Conclusions -6

- Accelerated mechanical mixture permanent deformation testing validates the predictions by adhesion theory