Tack Coat Materials and Methods for Optimizing for Thin HMA Applications

May 2011
Objectives

- The presentation will describe the purpose of tack coats, how they can affect mixture performance, and methods of measuring their effects.
  - This presentation will challenge traditional thinking on tack coats!

- A good bond is important for all mixes, and especially for thin mixes
Traditional definition and purpose

• **What is tack coat?**
  Tack coat is a light application of asphalt emulsion between hot mix asphalt layers designed to create a strong adhesive bond without slippage. Heavier applications may be used under porous layers or around patches where it also functions as a seal coat.

• **Why use tack coat?**
  Without tack coat the asphalt layers in a roadway may separate which reduces the structural integrity of the road and may also allow water to penetrate the structure.

• Source: [www.aema.org](http://www.aema.org)
Tack Coat - Constructability vs Performance

• Construction favors
  ▫ Low application rate
    • Curing
    • Traction
  ▫ Non-tacky hard binders
    • Tracking
• Performance may favor
  ▫ Higher, uniform application rates
  ▫ Polymer modified asphalt emulsions
• Construction needs and performance needs compete
What is an enhanced bonded pavement?

- An enhanced bonded pavement has a uniform application of a tack coat beneath an overlay and has a high bond energy and other enhanced mix properties.
- The tack may be conventional but is usually polymer-modified asphalt emulsion (PMAE).
- It may include multiple bonded layers.
- The asphalt mixture includes multiple types:
  - Dense-graded
  - Gap and open-graded mixes
  - Hot, warm, and cold mix
Enhanced Bonded Pavement Properties

- Higher tack application rates create a composite
- Composite mixture = HMA mixture + tack
- Composite mixture with an asphalt content gradient
  - Higher asphalt content at the bottom of the new mixture
- Can a tack coat actually improve the mixture?
Enhanced Bonded Pavement Effects

- Lift thickness
- Bonding to asphalt or PCC
- Cracking resistance
- Rutting resistance
Reduced Lift Thickness from Better Bond

- By increasing bonding (25% to 75%) lift thickness can be decreased by 0.5” and still result in increased pavement life by 21%
- Thickness reduction by 0.75” is possible when using a system that creates bonding 85% or more compared to 5” HMA with conventional tack and bonding of 25% or less
- The bond does not have to be completely gone to lose benefit from layer

Impact of Bonding Between HMA Lifts

![Graph showing the impact of bonding between HMA lifts](image)
Bond Strength of Composite Specimen

- Direct Tension Bond Energy Test (DTBE)
  - 0.5 mm/min rate of travel
  - 25°C test temperature
- Composite specimens - lab produced or field cores
- Commercially available tensile/compression equipment
Direct Tensile Bond Energy

- Plot load vs displacement
- Calculate stress (kPa)
- Calculate energy (area under load-displacement curve (J))
- Divide energy by cross sectional area (J/m²)
- Energy tells a different story than just peak load or stress
  - Blue line drops load rapidly after peak load (loses bond after very little movement)
  - Yellow line carries the load after the peak load (capable of maintaining bond during micro-strain movement of pavement)

Bond Testing
Load vs. Displacement

Blue line energy = 251 J/m²
Yellow line energy = 332 J/m²
Commercially Available Tension/Compression Equipment
Direct Tensile Bond Energy (DTBE) Testing

MoDOT Route T Bond Energy
HMA on HMA

<table>
<thead>
<tr>
<th>Tack Coat Rate and Type</th>
<th>Bond Energy, J/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.08 gsy Dilute CSS-1H, distributor</td>
<td>116</td>
</tr>
<tr>
<td>0.1 gsy Dilute CSS-1H, spray paver</td>
<td>137</td>
</tr>
<tr>
<td>0.1 gsy PMAE</td>
<td>248</td>
</tr>
<tr>
<td>0.14 gsy PMAE</td>
<td>278</td>
</tr>
<tr>
<td>0.21 gsy PMAE</td>
<td>293</td>
</tr>
</tbody>
</table>

Interface fracture
Mixture fracture
Dense-Graded HMA over Smooth PCC

Bond Energy vs Tack Rate and Type

Bond Energy, J/m²

Tack Coat Rate and Type, gal/yd²

No tack
0.05 CSS
0.12 PMAE
0.18 PMAE
0.24 PMAE

Bond Energy vs Freeze-thaw

0 Freeze-thaw
1 Freeze-thaw
Dense-Graded HMA over Milled AC Surface

Bond Energy vs. Tack Rate and Type

- No tack: 74 J/m²
- 0.05 CSS-1: 88 J/m²

Tack Rate and Type, gal/yd²
Dense-Graded HMA over Milled AC Surface

Bond Energy vs. Tack Rate and Type

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<tr>
<th>Tack Rate and Type, gal/yd²</th>
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<tr>
<td>No tack</td>
<td>74</td>
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<tr>
<td>0.05 CSS-1</td>
<td>88</td>
</tr>
<tr>
<td>0.18 PMAE</td>
<td>133</td>
</tr>
<tr>
<td>0.24 PMAE</td>
<td>153</td>
</tr>
<tr>
<td>0.3 PMAE</td>
<td>133</td>
</tr>
</tbody>
</table>
Tack Study for OAPA AQITFR

<table>
<thead>
<tr>
<th></th>
<th>SS-1</th>
<th>SS-1HP</th>
<th>PMCRS-1s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residue, %</td>
<td>62.0</td>
<td>61.1</td>
<td>67.7</td>
</tr>
<tr>
<td>Penetration, 25°C</td>
<td>87</td>
<td>92</td>
<td>117</td>
</tr>
<tr>
<td>ER, 10°C, 20 cm, 5 min, %</td>
<td>7</td>
<td>44</td>
<td>80</td>
</tr>
</tbody>
</table>

**Bond Energy Comparison**

Homogeneous, SS-1 & SS-1HP Emulsion, PMCRS-1S

Relative comparisons only. Test results here are not comparable to test results from other projects due to the base mixture having a different preparation method.
Bond Testing - Tensile or Shear?

Shear

• Pro’s
  ▫ Measures effects of interface sliding

• Con’s
  ▫ Can’t separate friction from bond
  ▫ Usually results in recommended low application rates contrary to field experience
  ▫ High stiffness tack coats increases shear stress values

Tensile

• Pro’s
  ▫ Commonly used in other industries to measure laminate bonding
  ▫ Greatly reduces friction between surfaces effect

• Con’s
  ▫ Need fixture to minimize eccentricity
  ▫ Fast travel rates creates break at the fixture attachment point
  ▫ Fractures through the weakest plane (not necessarily the interface)
Cracking Resistance – Compact Tension Test*
Method for measuring effect of tack on crack resistance

\[ S_f = \int P \cdot du \quad G_f = \frac{S_f}{W \cdot t} \]

**Test Procedure – ASTM 7313 (b)**
- CMOD Control
- Rate 1 mm/min

*Developed by the University of Illinois
Cracking Resistance - C(T) Data from Field Samples*

The higher the fracture energy, the more crack resistant the mixture is.

*Ahmed et al, AAPT 2010
**Cranking Resistance – Field Project**  
*Route T, Franklin Co., Missouri*

- Improved reflective cracking resistance

<table>
<thead>
<tr>
<th>Reflective Cracking after 9 months</th>
<th>Shot Rate (gal/sy) @ ~65% AC</th>
<th>Reflected cracks per 1000 meters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.03 CSS-1h</td>
<td>24.8</td>
</tr>
<tr>
<td></td>
<td>0.14 PMAE</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>0.21 PMAE</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>0.03 gal/sy conventional tack</td>
<td></td>
</tr>
</tbody>
</table>
Cracking Resistance – Field Project
US 36, Washington Co., Kansas

- Improved cracking resistance
  - Longitudinal and reflective

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**Transverse (reflective) and Longitudinal Cracking, ft per linear ft of paving @ 1.6 yrs**

**Longitudinal Cracking @ 1.6 yrs, %**
Cracking Resistance – Field Project

PFC Surface Cracks (Tack Method)

• 2006 crack susceptible dense Superpave mix
  – Surface cracks after 1.9M ESALs (Rehab at 5.6M)

• 2009 PFC surface placed with conventional tack
  – Surface cracks after 2.2M (cracking/pumping at 6.5M)

• 2009 bonded PFC surface placed with spray paver
  – Surface cracks after 4.1M (very good at 6.5M)

Source: NCAT Pavement Test Track Update, Buzz Powell
Rutting Resistance – Hamburg Wheel Tracking

- AASHTO T 324
  - Homogeneous mixture
  - Composite specimen
- Mix shown designed with rut resistance criteria
- 4X normal tack coat rate does not create rutting
Why are properties improved?

• Potential for reduced thickness
  ▫ Better bonding means less deflection -> better fatigue resistance -> longer life
• Better bonding important, especially for thin lifts -> less delamination, less potholes
• Reduced cracking
  ▫ Increased asphalt content at interface (unaged)
  ▫ Polymer-modified asphalt
• Rutting
  ▫ Gripping effect at interface results in less movement when stresses are applied.
Technical Challenges

- No universally accepted lab protocols developed for composite systems
  - Method developed by Road Science
  - Unique concept for asphalt laboratories
  - The tack has enough of an effect that it needs to be part of the lab specimens
  - Interaction effects of underlying layer, bonding layer, and new surface mix
Projects

• Arkansas – State highway 24
• California – City projects
• Kansas – Several state routes and interstate sections (i.e. US 36, I-70)
• Minnesota – I-94
• Missouri – State highways (i.e. Route T)
• Oklahoma – Interstate and state highways (i.e. I-40, SR 51)
• Texas – Interstate and state highways (i.e. I-20, US 75)
How is a high quantity of polymer modified tack applied to the road?

- Paver with integrated spray bar is a method that allows greatly expanded material selection and rates
- Spray paver application
  - Paver + distributor in one piece of equipment
    - Single pass paving/bonding system
    - **Sprays** emulsion tack
    - **Places** hot mix asphalt overlay
    - **Smoother** the mat
How is a high quantity of polymer modified tack applied to the road?

- Paver with integrated spray bar is a method that allows greatly expanded material selection and rates
  - No tracking
- Other methods?
Other Points

Will the increased shot rate be a problem with bleeding or rutting?
No. Field test sections with as much as 0.3 gal/yd$^2$ PMAE tack at 65% AC under a 1” dense graded HMA have not shown any signs of bleeding.

What about the moisture from the emulsion? Is stripping an issue?
No. Moisture from the emulsion that’s not driven off immediately resides in the mixture voids, which is different than in the binder film or aggregates. There’s been no reported problems on any field project.

Are there other benefits?
The increased shot rate may offer the benefits of sealing the underlying mixture.
Conclusions and Summary

• Bonding of traditional mixes with higher shot rates, polymer-modified asphalt emulsion, and improved methods:
  ▫ Potential for thickness reduction
  ▫ Potential for reduced delamination
  ▫ Improved cracking resistance - reflective and longitudinal crack resistance
  ▫ Improved rutting resistance from better bond

• Tack coat materials have the potential for improving the mixture
Questions?