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Tack Coat Materials, Application and Best Practices

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Tack Coat Agency Perspective

- Focus temporarily switched to tracking
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- Tracking is still work in progress
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- Need to get back to basics
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Training

- ODOT Inspector Training
  - Reinforce Tack use
- ODOT/APAO Advance Pavers Workshop (2013)
- FHWA Tack Workshop (2015)
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Field Data Collection

- ASTM D2995 Standard Practice for Estimating Application Rate and Residual Application Rate of Bituminous Distributors
- Explore what other DOT’s have as standard of practice.
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- SPR 782 HMAC Layer Adhesion Through Tack Coat
  - Dr. Erdem Coleri, Oregon State University
    - Complete in 2016
Tack Coat Agency Perspective

- Working together, we can reach the goal
HMAC Layer Adhesion Through Tack Coat

Erdem Coleri
OSU

Larry Ilg
ODOT
Other contributors

• Grad students at OSU:
  • David Covey
  • Aiman Mahmoud

• TAC members:
  • Norris Shippen - ODOT
  • Keven Heitschmidt - Albina Asphalt
  • Troy Tindall - BlueLine
  • Anthony Boesen - FHWA

• Thanks to Ron Depue and David Davies for their help with field testing
Why do the tack coats fail?

Critical stress types at the interface (Raab and Partl 2004).

Which mechanism is more critical? Shear or tension?

Slippage cracking
How to improve tack coat performance?

**Research Objectives**

- Applying the optimum rate
- Develop a QC/QA device – Field tack coat tester
- Reduce tracking
  - Not allowing construction traffic before the set (How long do we need to wait?)
  - Using tack coats that track less
- Non-uniform and inaccurate spraying
- Using better tack coats (New emulsions, CO1 and CO2)
- Checking the bond strength for QC/QA
  - Coring and shear testing in the lab
  - Can we come up with a less destructive and an easier method?

**HOW IMPORTANT IS THE BOND STRENGTH?**

**CAN WE EXTEND PAVEMENT STRUCTURAL LIFE BY USING BETTER TACK COATS?**
Impact of bond strength on performance

• **King and May (2003):**
  - Fatigue life decreases by 50 % when the bonding is reduced by 10 %.

• **Roffe and Chaignon (2002):**
  - Pavement service life can reduce from 20 years to 7 years due to the lack of bond between two asphalt layers.

• **Akhtarhusein et al. (2004):**
  - Delamination problem can be reduced by increasing overlay thickness. Increased overlay thickness reduces critical interface shear stresses and minimizes the risk of bond failure.

• **Mohammad et al. (2012):**
  - Tack coat type and application rates are determined to be more important for structures with thin overlays.
Outline

• Research method
• Lab set time measurement and regression equations
• 3D viscoelastic finite element modeling
• Field testing and preliminary results
  • Field Tack Coat Tester (FTCT)
  • Wheel tracking device
  • Other tests
• Lab tack coat testing
• Coring and shear testing
• Summary
Research Method

1. Bond strength

Shear testing with field cores

Optimum application rate

Rheological tests

- Softening point
- Penetration
- Viscometer
- DSR

Field tack coat tester (FTCT)

Field bond tester

2. How important is the bond strength?

- 3D finite element modeling
- MEPDG simulations

3. Tracking

- Weight measurements
- Wheel tracking device
Lab set time measurements – Procedure

![Graph showing weight (g) over time (sec) with 'Raw Data' and 'Filtered Data' lines.](image-url)
# Tack coat types and test conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Experimental Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emulsion</td>
<td>CO1_CSS1H, CO1_New, CO2_NEW, CO2-SS1H</td>
</tr>
<tr>
<td>Temperature (°F)</td>
<td>Room: 59 °F, High: 95 °F</td>
</tr>
<tr>
<td>Application Rate (gal/yd$^2$)</td>
<td>0.045 (L), 0.105 (M), 0.164 (H)</td>
</tr>
<tr>
<td>Texture</td>
<td>Open grade (OG), dense grade (DG), steel plate (SP)</td>
</tr>
<tr>
<td>Replicates</td>
<td>2</td>
</tr>
</tbody>
</table>
Lab set time measurement – Results

Note: low temp (59 °F), medium rate (0.105 gal/yd²)
Regression equations – Developed models

\[ \text{Set Time} \sim \text{Temperature} + \text{Texture} + \text{Emulsion} + \text{Rate} \]

<table>
<thead>
<tr>
<th>Model Type</th>
<th>Model Specification</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eq.#1: AC Core</td>
<td>[ \text{SET} = 612.60 - 29.856 \times \text{TEMPF} + 10,877.52 \times \text{MTD} + 539.11 \times \text{CSS} + 1H + 5.784.47 \times \text{EBS.RBC-329.61} \times \text{EE} + 46,226.40 \times \text{ACTR} ]</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>(0.7475) (0.1304) (0.4622) (0.5850) (0.0000) (0.7376)</td>
<td></td>
</tr>
<tr>
<td>Eq.#2: AC Core w/ no MTD</td>
<td>[ \text{SET} = 1,063.70 - 28.076 \times \text{TEMPF} + 489.71 \times \text{CSS} + 1H + 5.729.40 \times \text{EBS.RBC-340.97} \times \text{EE} + 46,026.99 \times \text{ACTR} ]</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>(0.5533) (0.1488) (0.6169) (0.0000) (0.7274) (0.0000)</td>
<td></td>
</tr>
<tr>
<td>Eq.#3: AC Core + Steel</td>
<td>[ \text{SET} = 2,799.99 - 46.791 \times \text{TEMPF} + 9,185.86 \times \text{MTD} + 294.57 \times \text{CSS} + 1H + 5.336.73 \times \text{EBS.RBC-493.39} \times \text{EE} + 40,088.63 \times \text{ACTR} ]</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>(0.0342) (0.0011) (0.2618) (0.6732) (0.0000) (0.4802)</td>
<td></td>
</tr>
<tr>
<td>Eq.#4: AC Core + Steel w/ no MTD</td>
<td>[ \text{SET} = 3,054.59 - 45.79 \times \text{TEMPF} + 266.94 \times \text{CSS} + 1H + 5.305.85 \times \text{EBS.RBC-499.74} \times \text{EE} + 39,970.96 \times \text{ACTR} ]</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>(0.0196) (0.0014) (0.7027) (0.0000) (0.4755) (0.000)</td>
<td></td>
</tr>
</tbody>
</table>

Note: Numbers inside the parentheses are the p-values of the regression coefficient.
Set time regression equations

- Set time regression equations were developed to calculate in-situ set times during construction in order to minimize vehicle tracking.

- Various parameters were included:
  - Texture of AC surface not significant.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Df</th>
<th>F Value</th>
<th>Pr(F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (F)</td>
<td>1</td>
<td>1.79</td>
<td>0.1882</td>
</tr>
<tr>
<td>Texture (in)</td>
<td>1</td>
<td>0.00</td>
<td>0.9711</td>
</tr>
<tr>
<td>Emulsion</td>
<td>3</td>
<td>16.76</td>
<td>0.0000</td>
</tr>
<tr>
<td>Application Rate (gal/yd²)</td>
<td>1</td>
<td>43.68</td>
<td>0.0000</td>
</tr>
<tr>
<td>Residuals</td>
<td>41</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ANOVA analysis results for AC cores
A smart phone app for set time

- Enter “Temperature”, “Emulsion type”, “Rate”, and “Wind speed”
- App will calculate set time with a high reliability level
- App will start the countdown and send a notification when the tack coat is set.

Set Time ~ Temperature + Emulsion + Rate + Wind speed
3D viscoelastic finite element model to evaluate the effects of structural characteristics on tack coat performance

Dynamic truck wheel
3D viscoelastic finite element model to evaluate the effects structural characteristics on tack coat performance

NEXT STEP:
Developed models will be used to evaluate the impact of tack coat strength on structural performance

HOW IMPORTANT IS THE BOND STRENGTH?
CAN WE EXTEND PAVEMENT STRUCTURAL LIFE BY USING BETTER TACK COATS?
WHAT IS THE PERCENT INCREASE IN SERVICE LIFE THAT CAN BE CREATED BY USING BETTER TACK COATS?
Field testing and preliminary results

99W: Amity – Hoffman Road

<table>
<thead>
<tr>
<th>Day</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>Milled CO1_CSS-1H</td>
<td>0.08, 0.10, 0.12 gal/yd²</td>
</tr>
<tr>
<td>Day 2</td>
<td>Milled CO1-NEW</td>
<td>0.08, 0.12, 0.16 gal/yd²</td>
</tr>
<tr>
<td>Day 3</td>
<td>Milled CO2-NEW</td>
<td>0.08, 0.12, 0.16 gal/yd²</td>
</tr>
<tr>
<td>Day 4</td>
<td>Overlay CO1_CSS-1H</td>
<td>0.05, 0.07, 0.09 gal/yd²</td>
</tr>
<tr>
<td>Day 5</td>
<td>Overlay CO2_NEW</td>
<td>0.05, 0.07, 0.10 gal/yd²</td>
</tr>
<tr>
<td>Day 6</td>
<td>Overlay CO2_CSS-1H</td>
<td>0.05, 0.07, 0.10 gal/yd²</td>
</tr>
</tbody>
</table>
Field testing – Typical site layout

First lift on a milled surface – August  X  3 locations
Second lift on the new surface – September   X   3 locations

N

Regular rate

Stake 3

0.10gal/yd²

200feet

Stake 2

0.07gal/yd²

200feet

Stake 1

0.05gal/yd²
Field Tack Coat Tester (FTCT)

Earlier version: wired data acquisition

Latest version: wireless tack coat tester
FTCT test procedure

Several parking lot experiments were conducted at OSU to develop a test procedure for FTCT

• Attach a thick foam material on load platen
• Place 80 lb weight on the frame to be able to apply a compressive load on the surface with tack coat
• Heat the emulsion for 8 minutes using an infrared heating lamp to break the emulsion.
• Using the control software (laptop or tablet), apply a compressive load of 60 lb and wait for three minutes.
• Pull the load up at a constant displacement rate of 0.008 in/sec and record the maximum tensile stress (tensile strength) applied.
Field tack coat tester (FTCT) – Results

Note: Results from 0.08 gal/yd² rate

Load Curve with Varying Rates
- 0.05 gal/yd²
- 0.07 gal/yd²
- 0.10 gal/yd²

Note: Results from emulsion CO2_NEW on overlay surface
A new temperature control system is developed to reduce measurement variability.
Wheel tracking device

- Simulate rolling truck tire (match the actual truck tire pressure, 105 psi, by adjusting weight and tire area)
- Measure tracking of tack coat (weigh the tires or just visual inspection)
Wheel tracking device – Trends

Grinded Surface Wheel Tracking

- CO1_NEW
- CO1_CSS-1H
- CO2_NEW

Overlay Surface Wheel Tracking

- CO1_NEW
- CO1_CSS-1H
- CO2_CSS-1H
Field testing – Other tests

Field spraying rate measurement

Field texture measurements – Sand Patch
Field testing – Sand patch

![Bar chart showing mean texture depth for Loc 1, Loc 2, and Loc 3 on milled and overlay surfaces.](image-url)
Field testing – Spraying rate

![Field testing graph showing spraying rate comparison between milled and overlay surfaces. The target spraying rates are indicated on the x-axis, and the actual spraying rates are shown on the y-axis. The graph includes box plots for each surface type, illustrating the distribution of actual spraying rates at different target rates.](image-url)
Field testing – Tack coat sampling

Field tack coat sampling
Lab tack coat testing

ASTM D6997: Distillation

ASTM D36: Softening Point
Lab tack coat testing – Softening point

Softening Point (°F)

CO1_NEW
CO1_CSS-1H_a
CO1_CSS-1H_b
CO2_NEW
CO2_CSS-1H

CO1: Company 1
Lab tack coat testing

ASTM D5: Penetrometer

ASTM D4402: Rotational Viscometer (RV)
Lab tack coat testing – Penetration

Penetration @ 25 °C (10⁻¹ mm)

- CO1_NEW
- CO1_CSS-1H_a
- CO1_CSS-1H_b
- CO2_NEW
- CO2_CSS-1H
Lab tack coat testing – RV

Rotational Viscosity @ 135°C (Pa-s)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Viscosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO1_NEW</td>
<td></td>
</tr>
<tr>
<td>CO1_CSS-1H_a</td>
<td>2.5</td>
</tr>
<tr>
<td>CO1_CSS-1H_b</td>
<td></td>
</tr>
<tr>
<td>CO2_NEW</td>
<td>1.5</td>
</tr>
<tr>
<td>CO2_CSS-1H</td>
<td></td>
</tr>
</tbody>
</table>
Lab tack coat testing

ASTM D2196: Dynamic Shear Rheometer (DSR)

DSR tests will be conducted soon.
Coring and shear testing

Inter-layer shear strength testing device
Shear testing – Impact of rain on bond strength
Experiments with 90 cores from field test sections were completed last Friday. Results are currently being processed and analyzed. Some preliminary results:
Shear testing – Results for field cores

Experiments with 90 cores from field test sections were completed last Friday. Results are currently being processed and analyzed. Some preliminary results:

- Strength (psi)
  - 0.08 gal/yd

- Texture depth (in)
  - 0.06
  - 0.10
  - 0.14
  - 0.18
  - 0.22

- Bond strength (psi)
  - MILLED
Shear testing – Texture effect

![Shear testing graph]

The graph compares the strength (in psi) of different textures in Overlay and Milled conditions. The strengths are as follows:

- **Overlay**:
  - CO1_NEW_b: 60 psi
  - CO1_CSS-1H_b: 50 psi
  - CO2_CSS-1H: 40 psi
  - CO1_CSS-1H_a: 30 psi

- **Milled**:
  - CO1_NEW: 120 psi
  - CO2_NEW: 110 psi
A field shear tester for tack coat performance monitoring

- Less destructive than taking cores
- Faster and does not require coring or testing in the lab
Progress and remaining tasks

1. Bond strength

Shear testing with field cores

Rheological tests

Field tack coat tester (FTCT)

Field bond tester

Optimum application rate

2. How important is the bond strength?

- 3D finite element modeling
- MEPDG simulations

3. Tracking

- Weight measurements
- Wheel tracking device
Technologies that are being developed

Wireless field tack coat tester

Model to evaluate bond strength

In-situ shear strength tester

IOS and Android apps for set time notification

Wheel tracking device
Other contributions to the knowledge and practice

• Correlation functions to predict long-term bond strength from simple binder experiments
• Recommendations to reduce tracking
• Most effective spraying rates to maximize bond strength
• Models to predict the impact of bond strength on service life
• Recommendations to improve current QC/QA procedures
• Effectiveness of new tack coat products
Spray pavers and current method

Spray pavers

Current method

Taken from worldhighways.com
Q & A

Thank you!

This study is sponsored by Oregon Department of Transportation (ODOT). This funding is gratefully acknowledged.