Mobile Asphalt Testing Trailer Program (MATT): Recent Experience in Arizona

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Amir Golalipour, Ph.D.
David J. Mensching, Ph.D., P.E.
FHWA Pavement and Materials
Binder Activities
Asphalt Mixture Performance Tester (AMPT)
Arizona Project Results & Discussions
Questions
<table>
<thead>
<tr>
<th>Acronyms</th>
<th>Descriptions</th>
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<tbody>
<tr>
<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
</tr>
<tr>
<td>ABCD</td>
<td>Asphalt Binder Cracking Device</td>
</tr>
<tr>
<td>ABTL</td>
<td>Asphalt Binder Testing Laboratory</td>
</tr>
<tr>
<td>AIMS</td>
<td>Aggregate Imaging System</td>
</tr>
<tr>
<td>AMPT</td>
<td>Asphalt Mixture Performance Tester</td>
</tr>
<tr>
<td>BBR</td>
<td>Bending Beam Rheometer</td>
</tr>
<tr>
<td>CAA</td>
<td>Coarse Aggregate Angularity</td>
</tr>
<tr>
<td>CC</td>
<td>Concentric Cylinders</td>
</tr>
<tr>
<td>DSR</td>
<td>Dynamic Shear Rheometer</td>
</tr>
<tr>
<td>DTT</td>
<td>Direct Tension Tester</td>
</tr>
<tr>
<td>ETG</td>
<td>Expert Task Group</td>
</tr>
<tr>
<td>Gmb</td>
<td>Bulk Specific Gravity</td>
</tr>
<tr>
<td>GTR</td>
<td>Ground tire rubber</td>
</tr>
<tr>
<td>HMA</td>
<td>Hot mix asphalt</td>
</tr>
<tr>
<td>HQ</td>
<td>Headquarters</td>
</tr>
<tr>
<td>MATT</td>
<td>Mobile Asphalt Testing Trailer</td>
</tr>
<tr>
<td>MSCR</td>
<td>Multiple Stress Creep and Recovery</td>
</tr>
<tr>
<td>PAV</td>
<td>Pressure Aging Vessel</td>
</tr>
<tr>
<td>PEMD</td>
<td>Performance-Engineered Mixture Design</td>
</tr>
<tr>
<td>PG</td>
<td>Performance Grading</td>
</tr>
<tr>
<td>PRS</td>
<td>Performance Related Specification</td>
</tr>
<tr>
<td>QA</td>
<td>Quality Assurance</td>
</tr>
<tr>
<td>RAP/RAS</td>
<td>Reclaimed Asphalt Pavement/Reclaimed Asphalt Shingles</td>
</tr>
<tr>
<td>RTFO</td>
<td>Rolling Thin-film Oven</td>
</tr>
<tr>
<td>RV</td>
<td>Rotational Viscometer</td>
</tr>
<tr>
<td>SSR</td>
<td>Stress Sweep Rutting</td>
</tr>
<tr>
<td>TFHRC</td>
<td>Turner-Fairbank Highway Research Center</td>
</tr>
<tr>
<td>WMA</td>
<td>Warm Mix Asphalt</td>
</tr>
</tbody>
</table>

Note: FHWA does not endorse products or manufacturers. Trade or manufacturers’ names appear in this presentation solely for informational purposes.
Pavement & Materials Discipline

- **Program Office**
  - Office of Preconstruction, Construction, and Pavements (FHWA HQ, Washington, DC)
    - Mobile Asphalt Testing Trailer (MATT)
    - Asphalt Binder Testing Laboratory (ABTL)
- **Research and Development**
  - TFHRC (McLean, VA)
- **Technical Services**
  - Resource Center
- **Divisions**
Program Objective

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- **Provide Support to National Initiatives**
  - Performance-Engineered Mixture Design (PEMD)
  - Increased Pavement Density
  - Development of New QA Concepts for HMA
  - Understanding Asphalt Rubber Testing
  - Binder Performance Testing

- **Provide Assistance with State-specific Issues**
  - Technical Guidance
  - Forensics
MATT Program History

- Projects began in 1988
  - Demonstration Project 74: Field Management of Asphalt Mixes Using Volumetric Quality Control
- Transition to Superpave implementation
  - Early 1990s
  - Classroom and hands-on training
- Transition to performance-related specifications
  - Shadow testing
  - AMPT user since 2003
- Innovative materials and practices
  - WMA, SMA, GTR, RAP/RAS, increased density
MATT visits since 2007

Map showing visits to various states in the United States, categorized by type of visit:
- Yellow: Field Work
- Blue: Workshop/Hands-on Training/Presentation/Open House/Technical Assistance
- Brown: Both Field Work and Technical Assistance
Technical Workshops
Training for the Maryland State Highway Administration staff
Field visits
Other MATT Activities

- Conferences
- Expert task group support
- NCHRP panels and project participation
- Division Office rotational assignments
- Academic journal papers and presentations
Seven projects between 2013 to 2015
Collaboration with four State DOTs to evaluate their specifications based on project results
Working with FHWA ETG to develop AASHTO standard for asphalt rubber testing
Binder Activities
# Binder Characterization

## TEST PROCEDURES

- **Performance Grading**
  - AASHTO M 320
  - AASHTO M 332 (MSCR)
  - AASHTO R 49 (Low Temperature PG)
- **Solubility & Separation**
  - AASHTO T 44
  - ASTM D7173

## EQUIPMENT

- RV
- DSR
- RTFO
- PAV
- Vacuum Degassing Oven
- BBR
- DTT
- ABCD (AASHTO TP 92)
- Torsional bar testing
Boundaries for $J_{nr}$ values are established based upon traffic level.

As traffic level increases, lower $J_{nr}$ value is required -> basically stiffer binder.

<table>
<thead>
<tr>
<th>Traffic Loading</th>
<th>$J_{nr3.2}$ (1/kPa)</th>
<th>$J_{radiff}$ (Percent)</th>
<th>Recommended Traffic Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Traffic (S)</td>
<td>$\leq 4.5$</td>
<td>Maximum 75%</td>
<td>&lt; 10 million ESALs or Traffic Speed $&gt;70$ km/h</td>
</tr>
<tr>
<td>Heavy Traffic (H)</td>
<td>$\leq 2.0$</td>
<td>Maximum 75%</td>
<td>10 to 30 million ESALs or Traffic Speed 20 to 70 km/h</td>
</tr>
<tr>
<td>Very Heavy Traffic (V)</td>
<td>$\leq 1.0$</td>
<td>Maximum 75%</td>
<td>&gt; 30 million ESALs or Traffic Speed $&lt; 20$ km/h</td>
</tr>
<tr>
<td>Extremely Heavy Traffic (E)</td>
<td>$\leq 0.5$</td>
<td>Maximum 75%</td>
<td>&gt; 30 million ESALs and Standing Traffic (Toll plaza or Port)</td>
</tr>
</tbody>
</table>
% Recovery is plotted vs. $J_{nr}$.

Boundaries are established based upon measured $J_{nr}$ values at 3.2 kPa.

A simple above the line/below the line criteria provides the needed validation of polymer modification.

### Minimum % Recovery for Measured $J_{nr}$ values

<table>
<thead>
<tr>
<th>$J_{nr}$ @ 3.2 kPa</th>
<th>Minimum % Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0 - 1.01</td>
<td>30%</td>
</tr>
<tr>
<td>1.0 - 0.51</td>
<td>35%</td>
</tr>
<tr>
<td>0.50 - 0.251</td>
<td>45%</td>
</tr>
<tr>
<td>0.25 - 0.125</td>
<td>50%</td>
</tr>
</tbody>
</table>

Good agreement has been established between **elastomeric polymer modification** and rutting resistance.

Source: Asphalt Institute
MSCR Implementation

State Color Key

- Full Implementation
- Full Implementation Modified Grades Only
- Planned Full Implementation (12 months)
- Partial Implementation
- Planned Partial Implementation (12 months)
- Testing/Evaluation
- No Activity
- Considering Implementation (No Time Frame)
- To Be Posted Soon

Source: Asphalt Institute
DSR Testing Alternative: Asphalt Rubber Binder

- Can it fit within existing PG grading system?
- DSR Testing Geometry
  - Caltrans, University of California Pavement Research Center, Anton Paar, etc.
  - Concentric cylinder (CC) development testing evaluation looks promising.
  - CC test geometry may overcome specimen preparation limitations of PP geometry.
  - Draft AASHTO standard in development.
Advantages
- GTR modified asphalt can be measured with particle sizes up to 2 mm.
- No trimming problems and filling problems.
- No edge effects.
• $\Delta T_c$ has been identified as an important parameter related to asphalt binder durability.
  o $\Delta T_c = S \text{ critical temp} - m \text{ critical temp}$.
• As an asphalt binder ages, $\Delta T_c$ value becomes more negative.
  o Indicating a loss of relaxation properties.
• Threshold of -5 °C being evaluated as a cracking criteria.
Mixture Activities
Performance Testing

- AASHTO T 378 (former TP 79)
  - Dynamic Modulus
    - Mixture Stiffness
    - Rutting
    - Fatigue Cracking
  - Flow Number
    - Rutting
- AASHTO TP 107
  - Cyclic Fatigue
- AASHTO TP XX
  - Stress Sweep Rutting (SSR)
Proposed to enable field core testing
To improve the efficiency of laboratory specimen fabrication
Need less material to complete testing matrix

Image: North Carolina State University
Small Specimen Geometry

Imag: North Carolina State University
Types of Small Specimen Testing

Small Scale Dynamic Modulus

Small Scale Cyclic Fatigue
AMPT Small Specimen Advantages

- Field core testing
- Reduced sampling and material requirements for testing
- Same data output generated from small scale testing as full scale testing
Arizona Project
Arizona Project Description - 2015

- Open Graded Friction Course (OGFC) mixtures

- Three different Terminal blended Asphalt Rubbers

- Hybrid Binders:
  - PG70-22 TR+
    - (8 % GTR + 2 % SBS; solubility limit of 97%)
  - PG70-22 TR+ S92
    - (8 % GTR + 2 % SBS; solubility limit of 92%)
  - PG70-22 (contains only SBS)
Study Plans

- Topics investigated in this project
  - Solubility
  - Separation
  - DSR testing: gap size effect
  - Long term conditioning
Solubility – AASHTO T 44

- UW-Madison MARC have proposed changes to the standard
  - Use of toluene as the solvent
  - The addition of an analytical filter: To increase the filter area and reduce the potential for the fiberglass filter to become clogged during testing

- Analytical Filters used in this study
  - Celite
  - Diatomaceous Earth (DE)
- Use of toluene as the solvent
- The addition of an analytical filter
- Some differences in solubility
Solubility Results: 
Analysis of Variance

<table>
<thead>
<tr>
<th>Solubility Test Variation</th>
<th>PG 70-22 TR+</th>
<th>70-22 TR+ (S 92)</th>
<th>PG 70-22 (SBS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toluene</td>
<td>Not significant</td>
<td>Not significant</td>
<td>Not significant</td>
</tr>
<tr>
<td>Toluene + Celite 505</td>
<td>2.47 % lower</td>
<td>Not significant</td>
<td>0.52 % lower</td>
</tr>
<tr>
<td>Toluene + Diatomaceous Earth</td>
<td>1.16 % lower</td>
<td>Not significant</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

- Compared to Standard Method, AASHTO T 44.
- Not a statistically significant difference using toluene compared to trichloroethylene.
- The differences in solubility when using an analytical filter aid were 0.5 to 2.5 percent: significant considering solubility is normally specified to the nearest 0.1 percent!
Separation tests conducted following ASTM D7173: samples are stored in vertical tubes in an oven at 163 °C for 48 hours.

Test specimens taken from the top and bottom of the vertical storage tube are measured using AASHTO T 315.

GTR is separating and sinking to the bottom of the separation tube.

<table>
<thead>
<tr>
<th>Binder</th>
<th>Continuous High Temperature Grade for Top Specimen, (°C)</th>
<th>Continuous High Temperature Grade for Bottom Specimen, (°C)</th>
<th>Continuous High Temperature Grade Difference Top-Bottom, (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 70-22 TR+</td>
<td>80.7</td>
<td>81.0</td>
<td>-0.3</td>
</tr>
<tr>
<td>PG 70-22 TR+ (S 92)</td>
<td>78.2</td>
<td>96.6</td>
<td>-18.4</td>
</tr>
<tr>
<td>PG 70-22 (SBS)</td>
<td>76.7</td>
<td>78.3</td>
<td>-1.5</td>
</tr>
</tbody>
</table>
PG Results: PG 70-22 TR+ (S97)  
1 & 2 mm gap vs. Cup and Bob

- Same PG grade
- Cup & Bob (CC 17) slightly higher $G^*/\sin\delta$ value: perhaps due to trimming or shelf-aging of material
- Cup & Bob: smallest values of standard deviation
PP 1mm shows different material behavior

PP 1mm: possible particle interactions with plates → *higher stiffness & more elastic type behavior*

Similar results for PP 2mm and Cup & Bob
## DSR PG Results: 1 vs. 2 mm gap

*PG 70-22 TR+ (S 92) – Original binder at 76 °C*

<table>
<thead>
<tr>
<th>Item</th>
<th>1 mm gap Complex Modulus, (kPa)</th>
<th>1 mm gap Phase Angle, (°)</th>
<th>2 mm gap Complex Modulus, (kPa)</th>
<th>2 mm gap Phase Angle, (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replicate 1</td>
<td>1.52</td>
<td>58.6</td>
<td>1.34</td>
<td>63.3</td>
</tr>
<tr>
<td>Replicate 2</td>
<td>1.59</td>
<td>60.2</td>
<td>1.34</td>
<td>63.3</td>
</tr>
<tr>
<td>Replicate 3</td>
<td>NA</td>
<td>NA</td>
<td>1.32</td>
<td>63.8</td>
</tr>
<tr>
<td>Average</td>
<td>1.55</td>
<td>59.4</td>
<td>1.33</td>
<td>63.5</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.05</td>
<td>1.17</td>
<td>0.01</td>
<td>0.26</td>
</tr>
</tbody>
</table>

- For gap sizes of 1 to 2 mm: when there is an **interaction of the rubber particles with the testing plates** ->
  - ↑ gap : ↓ variability, ↓ the complex modulus, ↑ the phase angle.
- Lower G*/sinδ and phase angle for 1mm
PG Results: PG 70-22 TR+ (S92)
1 & 2 mm gap vs. Cup and Bob - RTFO

- Same PG grade
- PP 1mm: possible particle interactions with plates -> lower phase angle (more elastic type behavior)
- Differences decreased after RTFO conditioning
PG Results: PG 70-22 TR+ (S92)

- 2mm vs. Cup & Bob: most similar results
- Differences decreased after RTFO aging...
Only PG 70-22 TR+ (S 92) original binder show effects consistent with particle interaction.

When used to test binders modified with GTR, this gap may be too small to accommodate the rubber particles.

Concentric Cylinder (Cup & Bob) needed as testing geometry for these materials.

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### DSR PG Results: 1 vs. 2 mm gap

#### Statistical Analysis – Effect of 1mm increase in gap

<table>
<thead>
<tr>
<th>Binder</th>
<th>Original Complex Modulus</th>
<th>RTFOT Complex Modulus</th>
<th>Original Phase Angle</th>
<th>RTFOT Phase Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 70-22 TR+</td>
<td>Increases 0.04 kPa</td>
<td>Increases 0.07 kPa</td>
<td>Increases 0.63°</td>
<td>Zero difference</td>
</tr>
<tr>
<td></td>
<td>Not significant</td>
<td>Significant</td>
<td>Not significant</td>
<td>Not significant</td>
</tr>
<tr>
<td>PG 70-22 TR+ (S 92)</td>
<td>Decreases 0.22 kPa</td>
<td>Increases 0.22 kPa</td>
<td>Increases 4.05°</td>
<td>Increases 1.90°</td>
</tr>
<tr>
<td></td>
<td>Significant</td>
<td>Significant</td>
<td>Significant</td>
<td>Not significant</td>
</tr>
</tbody>
</table>
Summary of Findings

- **Solubility**: Toluene was found to be an acceptable alternative to Trichloroethylene as a solvent for solubility testing.

- **Separation**: GTR, due to its higher specific gravity than neat asphalt binder, is separating and sinking to the bottom of the separation tube. Separation of TR+ (S 92) binder during non-agitated long-term storage should be expected.

- **DSR testing**: Results indicate that particle interaction with the plates likely occurs when testing the PG 70-22 TR+ (S 92) using the parallel plate geometry.
Takeaway

- Separation: Needs to be considered for Asphalt Rubber Material. *(ASTM D7173)*

- DSR testing: All Asphalt Rubber Binders are **not** the same! Some may work with PP and some not. **Cup & Bob** is a scientific & practical solution.

- DSR testing:
  - **PP issues**: trimming, edge effect, particle interactions, rubber swelling, rubber mesh size and percentage, etc.
  - **Cup & Bob**: no trimming, exact volume filling, no edge effect
Technical Assistance

If you have upcoming projects for which you would like MATT technical assistance, contact:

- Amir Golalipour, amir.golalipour.ctr@dot.gov, 202.366.3982
- Dave Mensching, david.mensching@dot.gov, 202.493.3232

https://www fhwa dot gov/pavement/asphalt/trailer/
Thank You – Questions?

- Trailer is parked outside! Come in for a tour!
- We’re here to assist! Please stop by anytime for more discussion.