Obtaining Mix Performance with High RAP and Modified Binders

Tanya Nash, P.E.
Asphalt Testing Solutions & Engineering, LLC
Objectives

- RAP
  - Defining High RAP
  - Management and Best Practices
- Modified Binders
  - Classification of modifiers
  - Effects of modification
- Evaluation of Performance
What is High RAP?

- NAPA 2019 Annual Survey - average percent RAP used in HMA / WMA is 21.1%
- Range of Usage
  - Ohio: Average 32%
  - Arizona: Average 9%
- NCHRP Report 927 defined high recycled binder ratios between 0.3 and 0.5
Recycled Asphalt Pavement

It’s as simple as putting it back in the mix
What Is Really Happening?
The 3 “Limits” to High RAP Mixes

- Heat Transfer Capability of the Plant
- Managing Dust in the Final Mix
- Binder Characteristics in the Final Mix
#1: Heat Transfer

- High RAP Plants are often now a two-step process
  - Drying and Heating
  - Mixing
#2: Managing Dust

- Maintain dust/binder ratio
- Dust in the RAP is “bound” and can’t be “liberated”
- Manage the dust removed from the virgin material (partial dust removal)

➤ Several ways to do this ...

- Variable Speed Rotary Valve
- Collection & Return Pod on Load Cells
- Variable Speed Air Lock at Transfer Screw
#3: Final Binder Characteristics

Know Your RAP
Binder Characteristics

Recovered Performance of RAP and Mix

• Binder Performance Testing
• Mixture Performance Testing
### What’s Really in Your Asphalt Mix?

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Rejuvenators</th>
<th>Recycled</th>
<th>Polymers</th>
<th>Mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Anti-Strips</td>
<td>• Crude Oil</td>
<td>• Vacuum Tower Asphalt Extender (VTAE)</td>
<td>• Elastomers (SBS)</td>
<td>• Fibers</td>
</tr>
<tr>
<td>• Warm Mix</td>
<td>• Flux</td>
<td>• Ground Tire Rubber (GTR)</td>
<td>• Plastimers (Elvaloy)</td>
<td>• Lime</td>
</tr>
<tr>
<td>• Stiffening / Softening Agents</td>
<td>• Bio Oils</td>
<td></td>
<td>• Latex</td>
<td>• GTR</td>
</tr>
<tr>
<td></td>
<td>• Corn Oils</td>
<td></td>
<td>• SBR</td>
<td>• Pelletized Polymers</td>
</tr>
<tr>
<td></td>
<td>• Tall Oil</td>
<td></td>
<td></td>
<td>• RAP</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• RAS</td>
</tr>
</tbody>
</table>

**Anti-Strips**

![Anti-Strips Image](image1)

**Rejuvenators**

![Rejuvenators Image](image2)

**Recycled**

![Recycled Image](image3)

**Polymers**

![Polymers Image](image4)

**Mixture**

![Mixture Image](image5)
Performance Beyond PG

- Delta Tc – method for measuring the loss of relaxation properties of asphalt binders
- Ductility – Ability of a material to be stretched without breaking
- Glover-Rowe – simplified equation for the ductility estimated from DSR data

\[ G - R = G^* \left( \cos \delta \right) \times \frac{2}{\sin \delta} \]

@ 15°C and 0.005 rad/sec
Performance Beyond PG

• Cross-Over Temperature ($T_{wc}$): binder transitions from a viscous material to an elastic material
  • lower the temperature the less prone the binder is to cracking

• Rheological Index (R-Value): log of the glassy modulus of the binder minus the log of the modulus where the phase angle is 45
  • Larger the R value, the more brittle and prone to cracking
  • NCHRP 9-59 uses BBR data to calculate

\[
R = \frac{\log\left(\frac{S}{3000}\right)}{\log(1-m)}
\]

Recommended: $1.5 > R > 2.5$

Important for the virgin binder and the blended binder
<table>
<thead>
<tr>
<th>Year</th>
<th>Company/Innovator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1890</td>
<td>Barber Asphalt Paving Company</td>
<td>Asphalt cement 12 to 15% / Sand 70 to 83% / Pulverized carbonite of lime 5 to 15%</td>
</tr>
<tr>
<td>1905</td>
<td>Clifford Richardson, New York Testing Company</td>
<td>Surface sand mix: 100% passing No. 10, 15% passing No. 200, 9 to 14% asphalt. Asphaltic concrete for lower layers, VMA terminology used, 2.2% more VMA than current day mixes or ~0.9% higher binder content</td>
</tr>
<tr>
<td>1920s</td>
<td>Hubbard Field Method (Charles Hubbard and Frederick Field)</td>
<td>Sand asphalt design. Stability with compression test (performance) asphaltic concrete design (Modified HF Method)</td>
</tr>
<tr>
<td>1927</td>
<td>Francis Hveem (Caltrans)</td>
<td>Surface area factors used to determine binder content; Hveem stabilometer and cohesionmeter used. Stability + Durability. Air voids not used initially, mixes generally drier relative to others, fatigue cracking an issue</td>
</tr>
<tr>
<td>1943</td>
<td>Bruce Marshall, Mississippi Highway Department</td>
<td>Refined Hubbard Field method, standard compaction energy with drop hammer. Stability + Durability. Initially only used air voids and VFA, VMA added in 1962; stability and flow utilized</td>
</tr>
<tr>
<td>1993</td>
<td>Superpave</td>
<td>Level 1 (volumetric). Levels 2 and 3 (performance based but never implemented). 25 Years Without the Promised Performance Test!</td>
</tr>
</tbody>
</table>

Rutting & Moisture

• Tensile Strength Ratio
  AASHTO T 283

• Hamburg Wheel Tracking
  AASHTO T 324

• Asphalt Pavement Analyzer
  AASHTO T 340
Fatigue (Cyclic Loading)

Low Temperature Cracking
Evaluate your mix

Rejuvenator Study
Evaluation Process

Phase I
Preliminary Testing of Contractor’s “Go-To” Superpave Design with 13 recycling agents, 3 warm mix products, 3 PG binders

Baseline Testing

Phase II
Development of Performance Curves for Hot and Warm Mixtures in the study

Performance Ranking

Analysis
Determination of Optimum Asphalt Content Range based on Performance

Understanding of Production Parameters
**Recycling Agent Performance Evaluation**

**CONTROL**

- 35% RAP (0.38 RBR)
- 12.5mm GA Granite | PG 67-22

13 Recycling Agents - Aromatic (1), Veggie Oil (3), Bio-Based Oil (6), Tall Oil (3)

3 – Warm Mixes produced at 275°C

3 – PG binder grades: PG 52-28, 52-34, 67-22
Recycling Agent Dosage per NCHRP 9-58

\[ \text{PGH}_{\text{Blend}} = (\text{RAP}_{\text{BR}} \times \text{PGH}_{\text{RAP}}) + (\text{BR} \times \text{PGH}_{\text{Base}}) \]

\[ \%\text{RA} = \frac{(\text{PGH}_{\text{Blend}} - \text{PGH}_{\text{Target}})}{1.82} \]

*For aromatic extracts (A), a lower slope rate of 1.38 is recommended

Where:
- \( \text{PGH}_{\text{Blend}} = \) Continuous PG high temp. (PGH) of recycled binder blend (°C)
- \( \text{RAP}_{\text{BR}} = \) RAP binder ratio
- \( \text{PGH}_{\text{RAP}} = \) Continuous PGH of the RAP binder (°C)
- \( \text{BR} = \) Base binder ratio = 1-RBR
- \( \text{PGH}_{\text{Base}} = \) Continuous PGH of the base binder (°C)
- \( \text{PGH}_{\text{Target}} = \) Continuous PGH of target climate (°C)

<table>
<thead>
<tr>
<th>Properties</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{RAP}_{\text{BR}} )</td>
<td>0.38</td>
</tr>
<tr>
<td>( \text{PGH}_{\text{RAP}}, ^\circ \text{C} )</td>
<td>91.0</td>
</tr>
<tr>
<td>( \text{BR} )</td>
<td>0.63</td>
</tr>
<tr>
<td>( \text{PGH}_{\text{Target}}, ^\circ \text{C} )</td>
<td>70.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Properties</th>
<th>PG 67-22</th>
<th>PG 52-28</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{PGH}_{\text{Base}}, ^\circ \text{C} )</td>
<td>68.5</td>
<td>54.5</td>
</tr>
<tr>
<td>( \text{PGH}_{\text{Blend}}, ^\circ \text{C} )</td>
<td>77.1</td>
<td>68.4</td>
</tr>
<tr>
<td>%\text{RA}</td>
<td>Non-Aromatic</td>
<td>3.87</td>
</tr>
<tr>
<td></td>
<td>Aromatic</td>
<td>5.11</td>
</tr>
</tbody>
</table>

What do these “negative” numbers tell a contractor?
Production Analysis

Performance Asphalt Content % \((C_{\text{Index}} = 30 \text{ min.})\)

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Control</th>
<th>G</th>
<th>I</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tall Oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veggie Oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PG 52-28</td>
<td>6.38</td>
<td>5.96</td>
<td>5.82</td>
<td>5.64</td>
<td>5.47</td>
<td>5.39</td>
<td>5.33</td>
</tr>
<tr>
<td>Warm Mix</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm Mix</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm Mix</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum ((C_{\text{Index}}))</td>
<td>6.38</td>
<td>5.96</td>
<td>5.82</td>
<td>5.64</td>
<td>5.47</td>
<td>5.39</td>
<td>5.33</td>
</tr>
<tr>
<td>Performance Opt.</td>
<td>6.9</td>
<td>6.5</td>
<td>6.4</td>
<td>6.2</td>
<td>6.0</td>
<td>5.9</td>
<td>5.9</td>
</tr>
<tr>
<td>Dosage Efficiency</td>
<td>---</td>
<td>4.08</td>
<td>2.52</td>
<td>1.84</td>
<td>6.45</td>
<td>2.17</td>
<td>3.00</td>
</tr>
</tbody>
</table>

Florida DOT Specification for Asphalt Content
- Design Target ± 0.55% before stopping production

Performance Optimum = Minimum AC + Specification
Control Performance Optimum = 6.38 + 0.55 = **6.88% AC**
Final Comments

• Identify what limits High RAP usage
  • Plant components
  • Binder properties
  • Mixture Properties

• What are the modifiers available to you
  • Approved by the agency
  • Cost
  • Knowledge

• Evaluate
  • What works for one, does not always work for another
Questions?

Tanya Nash, P.E.
tnash@ats.consulting
(904) 510-3072

Asphalt Testing Solutions & Engineering
7544 Philips Hwy
Jacksonville, Florida 32256