Asphalt Rubber

Understanding Modified Asphalt Binder Technology Workshop

Julie Kliwer, PhD, PE
Objectives

- Understand what differentiates the different types of asphalt rubber materials
- Know ADOT specification philosophy as applied to asphalt rubber
- Know what affects the final properties of asphalt rubber
- Know asphalt rubber specification tests and their purpose
What is Crumb Rubber Modified Asphalt

- No easy answer
  - diverse recycled rubber sources
  - diverse processes and technologies
  - diverse opinions and perceptions
  - a moving target

- Sort of like “what is polymer modified asphalt”
Overview of CRM Technology

<table>
<thead>
<tr>
<th>Material</th>
<th>Process</th>
<th>Technology</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crumb</td>
<td>Wet</td>
<td>On-site blend</td>
<td>Modified</td>
</tr>
<tr>
<td>Rubber</td>
<td></td>
<td>Terminal blend</td>
<td>Binder</td>
</tr>
<tr>
<td></td>
<td>Wet</td>
<td>Other</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dry</td>
<td>Plus Ride</td>
<td>Rubber</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Generic</td>
<td>Aggregate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Others</td>
<td></td>
</tr>
</tbody>
</table>
Let’s focus on binders modified with rubber...
Asphalt Rubber Binder

- ASTM D6114 – blend of paving grade asphalt cements, ground recycled tire (vulcanized) rubber and other additives for use as a binder in pavement construction; rubber is blended/interacted in hot asphalt cement sufficiently to cause swelling of the rubber particles prior to use...this is “asphalt rubber”
  - traditional wet process AR such as used by ADOT, COP, MAG, BIA, etc.
  - historically blended on-site, occasionally in a terminal
- Terminal blended rubberized asphalt
  - aka “TR” products
Rubber in Asphalt Systems

- Rubber as an asphalt binder modifier
- Particulate systems (non-homogeneous)
  - ADOT Section 1009 (COP, MAG, etc.) for HMA or chip seals
    - ~20% rubber in paving asphalt
  - Polymer Modified Asphalt Rubber (PMAR) for chip seals
    - 15% ADOT Ty B rubber + 2-3% SBS in PG 64-16
  - Rubber Asphalt Binder (RAB) for chip seals or HMA
    - 10% #30 rubber + 2-3% SBS in PG 64-16
- Non-Particulate systems (homogeneous)
  - ADOT PG 76-22TR+ for HMA
    - 8-10% rubber + 1-3% SBS
  - AC-15-5TR (ADOT PG 64-28 TR+) for chip seals
    - 5% rubber + 1-3% SBS
Additives

- Used in conjunction with crumb rubber to facilitate manufacture or performance
  - Polymers – high temperature performance
  - Anti-stripping agents/coating enhancers – mitigate moisture damage, ravelling
  - Extender Oils – facilitates rubber/asphalt reaction; aromatic oils help compatibilize rubber and asphalt
  - High Natural Rubber – fatigue performance, high temperature performance
ADOT Asphalt Rubber (Section 1009)

- Use PG asphalt cement
  - CRA Ty 1: PG 64-16 desert
  - CRA Ty 2: PG 58-22 mid-zone
  - CRA Ty 3: PG 52-28 alpine

- Crumb rubber
  - Ty A: chip seal (deleted from ADOT specs)
  - Ty B: hot mix
<table>
<thead>
<tr>
<th>Property</th>
<th>CRA 1</th>
<th>CRA 2</th>
<th>CRA 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade of AC</td>
<td>PG 64-16</td>
<td>PG 58-22</td>
<td>PG 52-28</td>
</tr>
<tr>
<td>Rotational Vis, 350 F, Pa-S</td>
<td>1.5 – 4.0</td>
<td>1.5 – 4.0</td>
<td>1.5 – 4.0</td>
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<tr>
<td>Pen @ 39.2 F, dmm, min</td>
<td>10</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Softening Point, C</td>
<td>57</td>
<td>54</td>
<td>52</td>
</tr>
<tr>
<td>Resilience @ 77 F, % min</td>
<td>25</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Sieve Size</td>
<td>Type A</td>
<td>Type B</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>---------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>No. 8</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 10</td>
<td>95 - 100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>No. 16</td>
<td>0 - 10</td>
<td>75 - 95</td>
<td></td>
</tr>
<tr>
<td>No. 30</td>
<td></td>
<td>30 - 60</td>
<td></td>
</tr>
<tr>
<td>No. 50</td>
<td></td>
<td>5 - 30</td>
<td></td>
</tr>
<tr>
<td>No. 200</td>
<td></td>
<td>0 - 5</td>
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</table>
Rubber Grinding Methods

“cryo” grind

“ambient” grind
ADOT Proportions

- Minimum 20% rubber by weight asphalt cement

\[
\% \text{ rubber} = \left( \frac{20}{100} \right) \times 100\% = 20\%
\]

or

\[
\% \text{ rubber} = \left( \frac{20}{20+100} \right) \times 100\% = 16.7\%
\]
Rubber Blending Systems
Rubber Blending Systems
Manufacturing Parameters

- **Mixing**
  - 350° – 400° F binder when rubber added
  - react 325° – 375° F for 1 hour
  - test rotational vis

- **Handling**
  - thorough agitation
  - 325° – 375° during mix production
  - Max hold time 10 hrs above 325° F
  - only 1 cool/reheat cycle allowed
  - max 4 days above 250° F allowed
The Reaction Process

(*Theory of AR Manufacture*)

- During the reaction period
  - light fractions migrate from asphalt to rubber
  - rubber particles swell (4x original size)
  - viscosity of asphalt increases

Step 1

Step 2
Binder Design (aka “Blend Profile”)

- Confirm the reaction process
  - blend time
  - blend temperature
  - compatibility of components
- Determine specification compliance
- Final binder properties depend on
  - Asphalt source and grade
  - Rubber source
  - Amount of rubber
  - Gradation of rubber
  - Interaction time and temperature
Temperature Effects

Effect of Temperature on Reaction Viscosity

- Viscosity, cP
- Time, minutes

Graph showing the effect of temperature on reaction viscosity over time. The graph includes lines for different temperatures and a line indicating the minimum specification.
## Blend Profile 17% rubber

<table>
<thead>
<tr>
<th>Test Performed</th>
<th>Minutes of Reaction</th>
<th>Specified Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Viscosity, Haake at 177°C, Pa-s</td>
<td>2.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Resilience at 25°C, % Rebound (ASTM D3407)</td>
<td>30</td>
<td>34</td>
</tr>
<tr>
<td>Ring &amp; Ball Softening Point, °F (ASTM D36)</td>
<td>149.0</td>
<td>141.0</td>
</tr>
<tr>
<td>Needle Penetration at 4°C, 200g, 60 sec., 1/10mm (ASTM D5)</td>
<td>21</td>
<td>22</td>
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</table>
# Blend Profile 18% rubber

<table>
<thead>
<tr>
<th>Test Performed</th>
<th>Minutes of Reaction</th>
<th>Specified Limits</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Viscosity, Haake at 177°C, Pa-s</td>
<td>2.7</td>
<td>2.8</td>
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<tr>
<td>Resilience at 25°C, % Rebound (ASTM D3407)</td>
<td>34</td>
<td>36</td>
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<tr>
<td>Ring &amp; Ball Softening Point, °F (ASTM D36)</td>
<td>150.0</td>
<td>150.5</td>
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<tr>
<td>Needle Penetration at 4°C, 200g, 60 sec., 1/10mm (ASTM D5)</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Test Performed</td>
<td>Minutes of Reaction</td>
<td>Specified Limits</td>
</tr>
<tr>
<td>----------------------------------------------------</td>
<td>---------------------</td>
<td>------------------</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Viscosity, Haake at 177°C, Pa-s</td>
<td>3.6</td>
<td>3.5</td>
</tr>
<tr>
<td>Resilience at 25°C, % Rebound (ASTM D3407)</td>
<td>39</td>
<td>38</td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Ring &amp; Ball Softening Point, °F (ASTM D36)</td>
<td>158.0</td>
<td>157.0</td>
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<tr>
<td>Needle Penetration at 4°C, 200g, 60 sec., 1/10mm (ASTM D5)</td>
<td>22</td>
<td>24</td>
</tr>
</tbody>
</table>

Blend Profile 19% rubber
Viscosity

- **Purpose**
  - evaluate extent binder/rubber reaction
  - high temp handling characteristics
Resilience

- Purpose
  - measures elastic properties of binder
Softening Point

- **Purpose**
  - evaluate high pavement temp stiffness
Terminal Blended

Asphalt Rubber

- Polar opposite of traditional asphalt rubber ala ASTM D6114
  - smooth and homogeneous
- Developed in Texas by Wright Asphalt Products
  - TRMAC® product platform
- Terminal blended means not on-site blended
- Non-particulate system
  - almost completely soluble in TCE
  - 5 to 10% rubber (ADOT min. 8%)
  - typically 1-3% SBS (ADOT min. 2%)
- Low viscosity relative to traditional AR
- Looks and behaves like polymer modified asphalt
- Applications
  - just about every type of HMA
  - hot applied chip seals

Rubberized Asphalt
Terminal Blended Rubberized Asphalt

- Specified in ADOT Section 1005
  - Meet requirements of AASHTO M320 PG 76-22
  - Plus
    - Solubility ≥ 97.5%
    - Elastic Recovery (10º C) ≥ 55%
    - Softening Point ≥ 60º C
    - Phase Angle @ 76º C ≤ 75º
For more information


- http://www.wrightasphalt.com/