Rejuvenators – Past, Present, & Future

2020 Transportation Short Course
October 13, 2020

Presentation Outline

• Introduction
• Rejuvenators: Past
• Rejuvenators: Present
• Rejuvenators: Future
Introduction

• Benefit of use of RAP/RAS
  • Economics/Reducing rutting/Environment
• Concerns: too stiff
  • Premature cracking

• One of solutions: Rejuvenators

<table>
<thead>
<tr>
<th>Temp. °C/°F</th>
<th>Product. Temp. (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>64/147</td>
<td>300</td>
</tr>
<tr>
<td>91/196</td>
<td>325</td>
</tr>
<tr>
<td>131/268</td>
<td>325</td>
</tr>
<tr>
<td>178/353</td>
<td>325</td>
</tr>
</tbody>
</table>

Introduction

• Function of rejuvenators
  • Rheological effect:
    • Soften aged binders and lower both high and low PG
    • Improve relaxation (BBR m-value)
  • Chemical effect: Re-balance the ratio of asphaltenes to maltenes

• Types of rejuvenators
  • Soft asphalt binders: AC10, AC5, AC2.5, ....
  • Aromatic extracts
    • Hydrolene, Reclamite
  • Re-refined waste materials
    • Re-refined engine oil bottoms (REOB)/ Re-refined waste fast food vegetable oil
  • Bio-based rejuvenators
    • Arizona Chemical, Ingevity, Cargil, Collaborative Aggregates, Roadscience
Rejuvenators: Past

- Many studies have been conducted in the past.
- TxDOT 5-6614-01: Rejuvenator Laboratory Characterization and Field Performance https://tti.tamu.edu/documents/5-6614-01-R1.pdf
  - Rejuvenators laboratory characterization
  - Four field projects
  - Rejuvenator classification specification
  - 4-step balanced mix design for RAP/RAS/Rejuvenators

Rejuvenators: Past

- Characterized three types of rejuvenators in the laboratory
  - Both chemical (GCMS) and rheological (DSR/BBR) properties
Rejuvenators: Past

• Constructed 4 field projects
  • Tyler District, SH31, included 5 test sections, 6/14/2014
  • Laredo District, FM468, included 5 test sections, 9/15/2015
  • Houston District, FM1463, included 4 test sections, 7/16/2016
  • San Angelo, US67, included 5 test sections, 4/12/2017

Rejuvenators: Past

• Recommended rejuvenator classification specification

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test method</th>
<th>Bio-R1</th>
<th>Bio-R2</th>
<th>Bio-R3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Fatty Acid Content (%)</td>
<td>GCMS</td>
<td>&gt;97</td>
<td>90-97</td>
<td>&lt;90</td>
</tr>
<tr>
<td>Saturated Fatty Acid Content (%)</td>
<td></td>
<td>Max. 50</td>
<td>Max. 50</td>
<td>Max. 50</td>
</tr>
<tr>
<td>Flash Point, COC, (°C)</td>
<td>AASHTO T48</td>
<td>219</td>
<td>219</td>
<td>219</td>
</tr>
<tr>
<td>Dynamic Viscosity of Original Sample</td>
<td>DSR</td>
<td>Report</td>
<td>Report</td>
<td>Report</td>
</tr>
<tr>
<td>Dynamic Viscosity Ratio of RTFO (or TTO) Residue to Original Sample</td>
<td>DSR</td>
<td>Max. 2</td>
<td>Max. 2</td>
<td>Max. 2</td>
</tr>
<tr>
<td>RTFO Mass Loss (%)</td>
<td>AASHTO T240</td>
<td>Max. 5</td>
<td>Max. 5</td>
<td>Max. 5</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>ASTM D1298</td>
<td>Report</td>
<td>Report</td>
<td>Report</td>
</tr>
</tbody>
</table>
Rejuvenators: Past

- 4-step balanced mix design for RAP/RAS/Rejuvenator mixtures
  - Select rejuvenator type
  - Select rejuvenator dose range (binder blending/testing)
    - Superpave PG requirements
    - ΔTc requirement
    - Aging characteristics: Glower-Rowe parameter
  - Obtain mixture properties from BMD (mixture testing)
  - Finalize rejuvenator dose based on engineering judgement

Rejuvenators: Present & Future

- Binder & Blend Characterization

- Mixture Evaluation
Rejuvenators: Present & Future

• Binder & Blend Characterization
  • Characterize Component Materials (PGH, PGL, $\Delta T_c$)
    \[ \Delta T_c @ PAV20 = T_S - T_m \]
  • Proportion Unique Materials Combination
    • Virgin Binder
    • RAP/RAS
    • Rejuvenator (if needed)
  • Evaluate with Aging (G-R)
    \[ G-R = \frac{G^*(\cos\delta)^2}{\sin\delta} \]

Binder & Blend Characterization: Virgin Binders

$\Delta T_c @ PAV20 > -3.5°C$
Binder & Blend Characterization: RAP Binders

ΔTc @ PAV20 > -7.5°C

 Binder & Blend Characterization: Blends

ΔTc @ PAV20 > -5.0°C
Binder & Blend Characterization: Materials Combination

\[ PGH_{Blend} = (V_{BR} \times PGH_{Virgin}) + (RAP_{BR} \times PGH_{RAP}) \]

\[ \%RA(estimate) = (PGH_{Blend} - PGH_{Target}) / \text{Slope Rate}^* \]

Binder & Blend Characterization: Aging

G-R 15°C, 0.005 rad/s

- **Block Cracking Zone**
- **Transition Zone**
- **More Aging**
- **Aging**
- **Recycling**
- **Rejuvenation**

Mix 1 - PG 76-22
Mix 2 - 90% PG 76-22 + 10% RAP
Mix 3 - 85% PG 70-22 + 15% RAP + 0% Rejuvenator
Mix 4 - 75% PG 70-22 + 25% RAP + 0.5 WMA @ 270°F
Rejuvenators: Present & Future

- Mixture Evaluation
  - Volumetrics
  - Rutting

**Table 11**

<table>
<thead>
<tr>
<th>High-Temperature Binder Grade</th>
<th>Test Method</th>
<th>Maximum # of Passes @ 12.5 mm</th>
<th>Rut Depth, Tested @ 55°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 64 or lower</td>
<td>Tensile</td>
<td>10,000法院</td>
<td>15,000法院</td>
</tr>
<tr>
<td>PG 70</td>
<td></td>
<td>20,000法院</td>
<td></td>
</tr>
<tr>
<td>PG 76 or higher</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Cracking w/Aging

**Table 11B**

<table>
<thead>
<tr>
<th>Critical Fracture Energy (CFE), in.-lb/in², Min</th>
<th>Test Method</th>
<th>Surface Mixtures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tensile</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**NRRI** = \( \frac{N \times (1 - RD)}{\text{Min RRI for PG}} \)

Mixture Evaluation

- Rutting

- Cracking w/Aging

**Performance Interaction Diagram**
THANK YOU!

Fujie Zhou
f-zhou@tti.tamu.edu

Amy Epps Martin
a-eppsmartin@tamu.edu