IMPACTS OF MIX REJUVENATORS ON PERFORMANCE

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Ohio Asphalt Paving 42nd Annual Conference
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The Problem is...

- **Cracking**
  - Although there are many causes... traffic conditions, pavement structure, poor drainage, climate
  - Focus is on how recycled materials are used
    - Reclaimed asphalt pavement (RAP)
    - Recycled asphalt shingles (RAS)
RAP and RAS

- **Benefits**
  - Economics
  - Reduced rutting
  - Environment
  - Source of aggregate

- **Disadvantages**
  - Stiffens mix
  - Dry mixtures
  - Mixes may be more prone to cracking
RAP and RAS PG Grade Determination

- Virgin Average PG=70
- RAP Average PG=91
- MWAS Average PG=131
- TOAS Average PG=178

Courtesy of Fujie Zhou, TTI
What is the latest on recycled materials in surface mixtures?

- No recycle
  - 6 districts
- No RAS
  - 16 districts
    - Additional 2 districts without RAS producers, 1 only 1 contractor uses
- Allow RAP
  - 19 districts
- Allow RAP and RAS
  - 9 districts

Notes:
- LBB does not allow RAP in SMA which is their primary surface mix
- YKM most producers don’t use RAS
- ELP no RAS producers
- ODA no RAS producers
Methods to Address Cracking

- Limit the quantity of RAP/RAS
  - Maximum recycled binder ratio
- Discount the effective asphalt content of RAP/RAS
  - TxDOT currently uses 100% effective for designing with RAP and RAS
- Use Superpave mix design procedure to allow more asphalt
  - TxDOT shift is towards using Superpave gyratory compactor
- Use softer virgin binders
  - PG 58-28
  - Consider lower temperature grade binders (e.g. PG XX-28, PG XX-34)
- Use a balanced mix design approach
  - Overlay test (cracking)
  - Hamburg wheel tracking test (rutting)
- Add rejuvenators to the mix
Rejuvenator Types

- **Bio-based (vegetation based)**
  - Arizona Chemical, Green Asphalt Technologies, Ingevity, Cargil, Collaborative Aggregates, Sonneborn, Roadscience

- **Aromatic extracts**
  - HollyFrontier, Reclamite

- **Re-refined waste materials**
  - Re-refined engine oil bottoms (REOB)
  - Re-refined waste fast food vegetable oil
Bio-Based and Aromatic Extract Vs. REOB

Bio-rejuvenators

Aromatic extract

REOB

ΔTc(C)

Rejuvenator Dosage Replacement of Asphalt

0%

2%

4%

6%

8%

10%

12%
Rejuvenator Function

- Asphalt composition
  - Asphaltenes (insoluble, brittle, not affected by oxidation)
  - Maltenes (oily, flexible, affected by oxidation)

- Role of rejuvenators
  - Re-balance maltene fraction of asphalt

- Dynamic Shear Rheometer (DSR)
  - Lowers high temperature PG grade

- Bending Beam Rheometer (BBR)
  - Softens aged binders (creep stiffness, S)
  - Improves relaxation (m-value)
Rejuvenator Effectiveness

- Virgin Binder PG 64-22
Rejuvenator Effectiveness

- Virgin Binder PG 64-22

![Graph showing rejuvenator effectiveness with lines for REOB, Aromatic extract, and Bio-rejuvenators against PG Low and Rejuvenator Dosage Replacement of Asphalt.](image)
Four Step Design Process

- **Step 1** – Select rejuvenator
- **Step 2** – Select rejuvenator dosage range (binder testing)
- **Step 3** – Obtain balanced mix design data (mix testing)
- **Step 4** – Select dosage based on engineering judgement
Step 1 – Select Rejuvenator

- Arizona Chemical/Kraton
- Green Asphalt Technologies
- Ingevity
- Cargil
- Collaborative Aggregates
- Sonneborn
- Roadscience
- Texas Road Recyclers
- HollyFrontier
Step 2 – Select Rejuvenator Dosage Range

- Example: Original Binder Specified = PG 70-22
- Proposed: 10% RAP, 5% RAS, PG 64-22
  - Extract and combine asphalt from RAP and RAS with virgin binder at proposed binder ratios according to the mix design (e.g. PG 82-16)
- Add rejuvenator until DSR high temperature grade and BBR low temperature grade match original specified binder (PG 70-22)
  - Dosage range = 2% – 5%

![Graph showing high temperature grade vs. Hydrogreen and low temperature grade vs. Hydrogreen]
Step 2 – Select Rejuvenator Dosage Range

- Check aging characteristics
  - Glover-Rowe parameter
  - Goal is to match aging characteristics of virgin binder

Aging Characteristics: PG70-22 Vs. Hydrogreen Rejuvenated Binder
Step 3 – Obtain Data from Balanced Mix Design

- Perform Hamburg wheel tracking tests and Overlay tests on mix produced in the laboratory
  - Overlay requirements are determined by Overlay program (TxACOL)
  - Number of cycles are project specific (traffic, climate, pavement structure, etc.)
Step 4 – Select Rejuvenator Dosage

- Use data gathered from Steps 1-3 to select rejuvenator dosage
  - Use engineering judgement to decide actual dosage
    - Higher rejuvenator dosage in areas more prone to cracking
    - Lower rejuvenator dosage in areas less prone to cracking
  - Factors include:
    - Traffic conditions
      - Interstate/high traffic levels
        - May consider lower rejuvenator dosage
      - FM roads with less traffic levels
        - May consider higher rejuvenator dosage
    - Pavement structure
    - Climate
Test Sections

- 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 (coming soon)
Tyler District – SH31

- Dense Grade Type C Mix Designs:
  - Virgin mix, PG 70-22, AC = 4.5%
  - 10% RAP, 5% RAS, PG 64-22, AC = 4.6%
  - 10% RAP, 5% RAS, PG 64-22, 2.6% Hydrogreen, AC = 4.5%
  - 10% RAP, 5% RAS, PG 64-22, 3.7% Evoflex, AC = 4.7%
  - 10% RAP, 5% RAS, PG 64-22, 2.0% ERA-1, AC = 4.9%
- Reflective cracking was observed on all sections
- After 2.5 years, cracking was similar with all sections
Tyler District – SH31

- Lessons learned
  - Dosage of rejuvenators may have been too conservative
  - Two lift overlay was constructed over jointed concrete pavement
    - Crack attenuating mix (CAM) was placed before winter and had previously cracked prior to placing test sections
    - Solution – Construct both sections at the same time
Superpave Type C Mix Designs

- Virgin mix, PG 70-22, AC = 6.1%
- 30% RAP, PG 64-22, AC = 6.3%
- 30% RAP, PG 64-22, 2.2% Road Science, AC = 6.3%
- 30% RAP, PG 64-22, 3.0% Arizona Chemical, AC = 6.3%
- 30% RAP, PG 64-22, 3.2% Hydrogreen, AC = 6.3%

April 8, 2016

November 16, 2016
Laredo District – FM468

- After 15 months, all sections performed well
- Laboratory molded densities did approach 98.0%
  - No rutting observed to date (~15 months)
  - FM468 is in the energy sector
  - High truck traffic due to the Eagle Ford Shale oil production
Dense Grade Type D Mix Designs

- 17% RAP, 3% RAS, PG 64-22, AC = 5.2%
- 17% RAP, 3% RAS, PG 64-22, 3.5% Arizona Chemical, AC = 5.2%
- 17% RAP, 3% RAS, PG 64-22, 4.0% Sonneborn, AC = 5.2%
- 17% RAP, 3% RAS, PG 64-22, 7.5% Evoflex, AC = 5.2%
Houston District – FM1463

- Too early to tell, but laboratory results look promising...

**Hamburg Rut Depth (mm)**

<table>
<thead>
<tr>
<th></th>
<th>Control (17%RAP/3%RAS)</th>
<th>Rejuvenator-1</th>
<th>Rejuvenator-2</th>
<th>Rejuvenator-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamburg Rut Depth (mm)</td>
<td>4</td>
<td>12</td>
<td>8</td>
<td>12</td>
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**OT Cycles**

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<tr>
<td>OT Cycles</td>
<td>10</td>
<td>80</td>
<td>90</td>
<td>40</td>
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Conclusions

- Rejuvenators have been shown to improve cracking resistance of RAP/RAS mixes in the laboratory.
- Use of rejuvenators may impact lab molded density and compaction effort in the field:
  - Consider changing lab molded density requirements/decrease number of gyrations.
  - Roller patterns will need to be adjusted (less compaction effort).
- Too early to determine their effectiveness in the field:
  - No problems were encountered with meeting air void requirements.
  - Difficult to know cost savings:
    - Performance based (more service life).
    - Will allow use of more recycled materials.
- Continuation of monitoring field test sections is needed.
Acknowledges

- Special thanks to the Texas Transportation Institute (TTI) and Dr. Fujie Zhou for the information presented in this presentation.
Questions