USE OF REJUVENATORS
(RECYCLING AGENTS)
WITH RECYCLED MATERIALS

Transportation Short Course
October 10, 2017
MOTIVATION

- Reclaimed Asphalt Pavement (RAP)
- Recycled Asphalt Shingles (RAS)

- Workability
- Compaction
- Performance (cracking, raveling)
Wide, what is the typical RAP content used in asphalt mixtures?

- Less than 20%
- 20% - 30%
- More than 30%

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Provide, what is the typical RAS content used in asphalt mixtures?

- None
- Up to 3%
- More than 3%

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Provide, what are the most common barriers to using RAP and RAS in surface asphalt mixtures?

- Specification Limits
- Recycled Material Availability
- Recycled Material Quality

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HOW DO WE EXPRESS RAP AND RAS CONTENT?

• Traditionally, by % of total mix (10% RAP & 5% RAS)

• Recently, Recycled Binder Ratio or RBR (decimal)

\[ RBR = RAPBR + RASBR = \frac{Pb_{RAP} \times P_{RAP}}{Pb_{total}} + \frac{Pb_{RAS} \times P_{RAS}}{Pb_{total}} \]

## TxDOT ITEMS 340, 341, 344

### Table 5
**Allowable Substitute PG Binders and Maximum Recycled Binder Ratios**

<table>
<thead>
<tr>
<th>Originally Specified PG Binder</th>
<th>Allowable Substitute PG Binder</th>
<th>Maximum Ratio of Recycled Binder to Total Binder (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Surface</td>
</tr>
<tr>
<td>HMA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>76-22²</td>
<td>70-22 or 64-22</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>70-28 or 64-28</td>
<td>30.0</td>
</tr>
<tr>
<td>70-22²</td>
<td>64-22</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>64-28 or 58-28</td>
<td>30.0</td>
</tr>
<tr>
<td>64-22²</td>
<td>58-28</td>
<td>30.0</td>
</tr>
<tr>
<td>76-28²</td>
<td>70-28 or 64-28</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>64-34</td>
<td>30.0</td>
</tr>
<tr>
<td>70-28²</td>
<td>64-28 or 58-28</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>64-34 or 58-34</td>
<td>30.0</td>
</tr>
<tr>
<td>64-28²</td>
<td>58-28</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>58-34</td>
<td>30.0</td>
</tr>
<tr>
<td>WMA³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>76-22²</td>
<td>70-22 or 64-22</td>
<td>30.0</td>
</tr>
<tr>
<td>70-22²</td>
<td>64-22 or 58-28</td>
<td>30.0</td>
</tr>
<tr>
<td>64-22⁴</td>
<td>58-28</td>
<td>30.0</td>
</tr>
<tr>
<td>76-28²</td>
<td>70-28 or 64-28</td>
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<td>30.0</td>
</tr>
<tr>
<td>64-28⁴</td>
<td>58-28</td>
<td>30.0</td>
</tr>
</tbody>
</table>

1. Combined recycled binder from RAP and RAS.
2. Use no more than 20.0% recycled binder when using this originally specified PG binder.
3. WMA as defined in Section 344.2.6.2., “Warm Mix Asphalt (WMA).”
4. When used with WMA, this originally specified PG binder is allowed for use at the maximum recycled binder ratios shown in this table.
RECYCLED BINDER RATIO (RBR)

• Advantages:
  – RAPB & RASBR
  – Weighted average of multiple components

• Disadvantages:
  – Assumes 100% blending

Proposed shorthand notation:

A/B|D/E
  – A = RAP % of total mix
  – B = RAS % of total mix
  – C = RAPBR (decimal)
  – D = RASBR (decimal)
HOW CAN MORE RAP AND RAS BE USED IN SURFACE MIXTURES?

RAP + Virgin Binder + Recycling Agents → Rejuvenated Mixture

RAS + Virgin Aggregates

Rejuvenated Blend
WHAT ARE RECYCLING AGENTS?

Chemical products added to recycled asphalt mixtures

- To reduce mixture stiffness (asphaltene to maltene ratio)
- To improve the low-temperature and high-temperature PG

BETTER CRACKING RESISTANCE

- Other benefits: better workability, better compaction, etc.
WHAT TYPES OF RECYCLING AGENTS ARE AVAILABLE?

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>EXAMPLES</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraffinic Oils</td>
<td>Wast Engine Oil (WEO)</td>
<td>Refined used lubricating oils</td>
</tr>
<tr>
<td></td>
<td>Waste Engine Oil Bottoms (WEOB)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Valero VP 165©</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Storbit®</td>
<td></td>
</tr>
<tr>
<td>Aromatic Extracts</td>
<td>Hydrole®</td>
<td>Refined crude oil products with polar aromatic oil</td>
</tr>
<tr>
<td></td>
<td>Reclamite®</td>
<td>components</td>
</tr>
<tr>
<td></td>
<td>Cyclogen L©</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ValArro 130A©</td>
<td></td>
</tr>
<tr>
<td>Nathanic Oils</td>
<td>SonneWarmix RJ™</td>
<td>Engineered hydrocarbons for asphalt modification</td>
</tr>
<tr>
<td></td>
<td>Ergon HyPrene®</td>
<td></td>
</tr>
<tr>
<td>Triglycerides &amp; Fatty Acids</td>
<td>Waste Vegetable Oil</td>
<td>Derived from vegetable oils</td>
</tr>
<tr>
<td></td>
<td>Waste Vegetable Grease</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Brown Grease</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Delta S*</td>
<td></td>
</tr>
<tr>
<td>Tall Oils</td>
<td>Sylvaroad™ RP1000</td>
<td>Paper Industry byproducts</td>
</tr>
<tr>
<td></td>
<td>Hydrogreen®</td>
<td>Same chemical family as liquid antistrip agents and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>emulsifiers</td>
</tr>
</tbody>
</table>

Currently... Bio-oils (including reacted/stabilized products)
HOW TO SELECT A RECYCLING AGENT?

Chemistry (FT-IR)

Rheology (DSR)

RA with smallest Δ FT-IR registered minimal Δ in rheology
T1 w/ greatest Δ in rheology & among highest Δ FT-IR
HOW TO SELECT A RECYCLING AGENT?
HOW MUCH RECYCLING AGENT SHOULD I ADD TO THE MIXTURE?

- High-Temp PG (DSR)
  - Unaged
  - RTFO aged

- Low-Temp PG (BBR)
  20-hour PAV aged

\[
\Delta T_c = (T_S - T_m)
\]
RECYCLING AGENT DOSAGE SELECTION

**DETAILED METHOD**

**RECYCLED BLENDS:**

- Virgin binder +
- Recycled binder (extracted & recovered) +
  a) No recycling agent
  b) Low dosage (2% or 5%)
  c) Higher dosage (~10%)

---

**0.28 RBR (Tx PG 64-22 | 0.1 TxRAP | 0.18 TxMWAS | T)**

- Original G*/sin(d)
- RTFO G*/sin(d)
- PAV m-controlled
- PAV S-controlled

**Target Grade:** 70-22
**Blend Grade:** 70-23

**DTc = -9.0°C**

**Selected Dosage:** 6.0%
RECYCLING AGENT DOSAGE SELECTION
QUICK METHOD

- **RECYCLED MATERIALS:**
  - Virgin binder
  - Recycled binder (extracted & recovered)
- No recycled blends
- High-Temp PG only
- Unaged only

![Graph showing WI PG 58-28 + 0.31 WI RAP and WI PG 58-28 + 0.5 WI RAP with measured continuous PGH 0.31 RBR and 0.5 RBR.](image-url)
RECYCLING AGENT DOSAGE SELECTION

QUICK METHOD

- Estimate the High-Temp PG of the blend

\[ PGH_{Blend} = (RAP_{BR} \times PGH_{RAP}) + (RAS_{BR} \times PGH_{RAS}) + (B_{BR} \times PGH_{Base}) \]

- Estimate the recycling agent dosage

\[ Recycling \ Agent \ (\%) = \frac{PGH_{Blend} - PGH_{Target}}{slope \ rate} \]

OR

\[ Recycling \ Agent \ (\%) = \frac{PGH_{Blend} - PGH_{Target}}{1.72} \]
WHAT ABOUT BLENDING?

• Most DOTs assume 100% RAP/RAS binder blending
• In reality...

100% Blending
Perfect Blending

PARTIAL BLENDING

0% Blending
Black Rock
WHAT FACTORS AFFECT BLENDING?

**Artificial RAP**

- **0% Blending**
  - RAP 1: 4.27%
  - RAP 2: 4.50%
  - RAP 3: 5.11%
  - RAP 4: 6.01%
- **100% Blending**
  - RAP 1: 2%
  - RAP 2: 3%
  - RAP 3: 4%
  - RAP 4: 5%

**Blending**

- RAP content after mixing with virgin binder:
  - RAP 1: 93.0%
  - RAP 2: 86.1%
  - RAP 3: 67.5%
  - RAP 4: 40.1%

**Binder Blending**

- TX RAP: 40.8%
- NH RAP: 53.0%
- High Temp PG 107.6: 86.9%

Stiffer RAP yielded lower binder blending.

**RAP aging**
WHAT FACTORS AFFECT BLENDING?

**Artificial RAP**

<table>
<thead>
<tr>
<th>RAP</th>
<th>0% Blending</th>
<th>100% Blending</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAP 1</td>
<td>4.27%</td>
<td>93.0%</td>
</tr>
<tr>
<td>RAP 2</td>
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<tr>
<td>RAP 4</td>
<td>6.01%</td>
<td>40.1%</td>
</tr>
</tbody>
</table>

**Blending**

- **RAP aging**
- **Marginal increase when the recycling agent was added to the binder**

**High Temp PG**

- TX RAP: 107.6
- NH RAP: 90.0

**College Station, TX**

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*October 10, 2017*
WHAT FACTORS AFFECT BLENDING?

Artificial RAP

RA Binder content after mixing with virgin binder

- RAP 1
- RAP 2
- RAP 3
- RAP 4

- 0% Blending: 4.27%, 4.50%, 5.11%, 6.01%
- 100% Blending: RAP 1, RAP 2, RAP 3, RAP 4

Binder content after mixing with virgin binder

- RAP 1: 93.0%
- RAP 2: 86.1%
- RAP 3: 67.5%
- RAP 4: 40.1%

Blending

- High Temp PG 107.6
- TX RAP
- NH RAP 90.0

Higher blending when recycling agent was added to the RAP

RAP aging

107.6
90.0

40.8
43.7
53.0
86.9

73.4
75.6
# RAP Characteristics

<table>
<thead>
<tr>
<th>Source</th>
<th>PG</th>
<th>Continuous High-Temp PG (°C)</th>
<th>Continuous Low-Temp PG (°C)</th>
<th>$\Delta T_c$ (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texas</td>
<td>—</td>
<td>106.6</td>
<td>-2.4</td>
<td>-9.8</td>
</tr>
<tr>
<td>Indiana</td>
<td>88-10</td>
<td>90.4</td>
<td>-13.7</td>
<td>-6.2</td>
</tr>
<tr>
<td>Nevada</td>
<td>82-16</td>
<td>84.4</td>
<td>-20.4</td>
<td>-3.4</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>88-16</td>
<td>90.2</td>
<td>-20.6</td>
<td>-2.1</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>82-10</td>
<td>83.5</td>
<td>-10.9</td>
<td>-7.3</td>
</tr>
<tr>
<td>Delaware</td>
<td>82-10</td>
<td>86.2</td>
<td>-13.8</td>
<td>-4.4</td>
</tr>
</tbody>
</table>
TAKEAWAYS

• There is a push to increase the amount of recycled materials in asphalt mixtures.
• But, construction and performance issues still exist.
• It is possible to increase the amount of recycled materials by incorporating recycling agents.
• There are many recycling agents currently available and not a standard way of selecting the “right one”.

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TAKEAWAYS

• There are ways of estimating the recycling agent dosage with minimal testing.

• Partial blending occurs between the recycled materials binder and the virgin binder in the mixture.

• Degree of blending depends on the characteristics of the recycled materials (aging) and how the recycling agent is added to the mixture.
It is YOUR main takeaway from this presentation.

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THANK YOU!

Amy Epps Martin  
(979) 862.1750  
a-eppsmartin@tamu.edu

Edith Arámbula Mercado  
(979) 458-0209  
e-arambula@tti.tamu.edu