Evaluation of binder blending on warm mix recycling

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Introduction

• Hot/Warm mix asphalt recycling
  - RAP binder is heated and re-activated
  - Fresh binder consumption is reduced
  - Economic and environmental benefits
  - Demand for higher RAP contents
Introduction

• Main challenges:
  - High variability of RAP properties
  - Workability issues
  - Performance uncertainties

• Blending between virgin binder and RAP binder
  - Mechanisms are not yet well understood
  - Affected by plant type, mixing temperature, mixing time, RAP properties, ...
- Degree of Blending (DoB)

- 100% DoB is often assumed during mix design
- Partial blending occurs in practice
- Wrong assumption can compromise performance
  Thinner binder film, stiffer binder coating RAP aggregates
• **Degree of Blending (DoB)**

**How can we measure DoB?**

- Staged extraction and recovery
Evaluation of recovered layers

- Conventional parameters (Penetration, R&B, ...)
- Rheological properties
- Chemical properties (FTIR, GPC, Microscopy, ...)

\[ \uparrow \text{Binder homogeneity} = \uparrow \text{DoB} \]
Introduction

Staged extraction in the literature
- Potential tool for evaluating binder homogeneity
- Variety of laboratory procedures, equipment, soaking times and analysis methods
- Method and concept can be further explored

Objective
Develop a staged extraction method using available equipment and apply it in the evaluation of plant-produced recycled mixtures
Plant-produced warm asphalt mixtures

- 30/45 pen binder + WM additive
- Basalt virgin aggregates
- Dense-graded mixtures
- 1.5% Hydrated lime filler
- 4.7% binder content

↓ 24.2% Cost
Plant-produced warm asphalt mixtures

<table>
<thead>
<tr>
<th></th>
<th>0% RAP</th>
<th>25% RAP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RAP binder content</strong></td>
<td>5.0 %</td>
<td>5.0 %</td>
</tr>
<tr>
<td><strong>Mixture binder content</strong></td>
<td>4.7 %</td>
<td>4.7 %</td>
</tr>
<tr>
<td>Virgin binder</td>
<td>4.7 %</td>
<td>3.5 %</td>
</tr>
<tr>
<td>RAP binder</td>
<td>0 %</td>
<td>1.2 %</td>
</tr>
<tr>
<td>Replaced virgin binder</td>
<td>0 %</td>
<td>26.6 %</td>
</tr>
<tr>
<td>Mixing temperature</td>
<td>140°C</td>
<td>140°C</td>
</tr>
<tr>
<td>Virgin aggregates temp.</td>
<td>140°C</td>
<td>180°C</td>
</tr>
</tbody>
</table>

Increased mixing time (60 s)
Reflux extraction apparatus (ASTM D2171-11 Method B)

- 3 reflux extraction sets
- 500 g of mixture in each cone
- 3 steps of extraction
- Aimed to obtain approximately the same amount of binder in each step
  - Time adjustments for each mixture
  - Starts when the solvent begins to drip from the condenser
- Binders recovered using the Abson method (ASTM D 1856-09)
Methodology

Evaluation of recovered binders

• DSR
  - $|G^*|$ master curves
  - MSCR tests
  - LAS fatigue tests

• FTIR Spectroscopy (ATR)
Results

- % of binder recovered in each step

<table>
<thead>
<tr>
<th>0% RAP</th>
<th>25% RAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>38%</td>
</tr>
<tr>
<td>Step 2</td>
<td>39%</td>
</tr>
<tr>
<td>Step 3</td>
<td>24%</td>
</tr>
</tbody>
</table>

5 min | 10 min | Until complete extraction | 20 min | 30 min | Until complete extraction
- $|G^*|$ master curves ($T_{ref} = 15°C$)
Results

- Black space diagram

\[ |G^*| (\text{Pa}) \]

\[ \text{Phase angle (°)} \]

\[ 0\% \text{ RAP} \]

\[ 25\% \text{ RAP} \]

\[ \begin{array}{ll}
\text{Virgin binder} & \text{RAP binder} \\
\text{Step 1} & \text{Step 1} \\
\text{Step 2} & \text{Step 2} \\
\text{Step 3} & \text{Step 3}
\end{array} \]
Results

- MSCR (70°C)

![Graph showing MSCR results for 0% and 25% RAP at 0.1 kPa and 3.2 kPa loads.](image-url)
Results

- LAS (20°C)

**Graphs:**
- **0% RAP**
  - Virgin binder
  - RAP binder
  - Step 1
  - Step 2
  - Step 3

- **25% RAP**
Results

- FTIR-ATR

Conclusions

- Rheological and chemical differences were also observed in the mixture without RAP
  - Increased aging in the contact between asphalt binder and aggregates

- Similar results for both mixtures indicate a high level of blending in the 25% RAP mixture
Conclusions

Ongoing studies:

• Analysis of heterogeneity for laboratory mixtures produced under different conditions (RAP conditioning, mixing times and temperatures)

• Plant produced mixture with higher RAP content (60%)

• Analysis of RAP alone
Thank you!
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