EVALUATING CHANGES IN RHEOLOGICAL PROPERTIES OF BLENDED BINDERS

Conventional Binder with Aged-Hardened Rubberized Binder
Rubberized Binder with Aged-Hardened Conventional Binder

SHAWN HUNG
PHD STUDENT
UCPRC
UC DAVIS

ZIA ALAVI
POST-DOCTORAL SCHOLAR
UCPRC
UC DAVIS

DAVID JONES
ASSOCIATE DIRECTOR
UCPRC
UC DAVIS
Outline

• Introduction
• Objectives
• Experimental Design
• Testing Results
• Conclusions
Introduction

• Rubberized hot-mix asphalt (RHMA) pavement has been increasingly used in California over the last 10 to 20 years
  • Reach the end of their design lives, will be milled off and added to RAP stockpile

• Currently, the amount of RAP used in new HMA varies between 15 and 25 percent
Why Use Rubberized Asphalt Concrete (RAC) in California?

- **Law-Assembly Bill 338**
  
  “Requires Caltrans (DOT) to use 35% RAC on its highway construction and repair projects”

- **Cost**
  
  Half the thickness of RAC will typically provide the same fatigue & reflective cracking life as full thickness dense-graded hot-mix asphalt (HMA) for overlays.

<table>
<thead>
<tr>
<th>Type</th>
<th>Hot Mix ($/ton)</th>
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</thead>
<tbody>
<tr>
<td>Conventional-DG</td>
<td>79 - 99</td>
</tr>
<tr>
<td>RAC-GG</td>
<td>91-99</td>
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Why Use Rubberized Asphalt Concrete (RAC) in California?

- **Other benefits**
  1. Not Contributing to Tire Stockpiles
  2. Use less virgin materials compared to HMA
  3. Less GHG emissions on both material production and construction phases
  4. Quiet


Current Challenges

- Currently, Caltrans does not permit the use of any reclaimed asphalt pavement (RAP) in any kind of RAC.

- Also, since RAC has been used in CA for about 30 years, more and more rubberized RAP has been generated.

  - What are the effects of using rubberized RAP in new HMA mixes?
  - What are the implications of using RAP in new RHMA mixes?
Research Objectives

Investigate the effects of incorporating
1. Rubberized RAP into asphalt concrete
2. RAP into rubberized asphalt concrete

Methodology
- Asphalt binders’ rheological properties
Experimental Design

- Aged rubberized binder cannot be satisfactorily extracted from RRAP
  - Artificially aged binders were used to simulate the extraction binders

- The properties of field-blend rubberized binder used in California cannot be accurately measured with a traditional parallel plate system
  - Relatively large crumb rubber particles (passing mesh #8)
  - Extremely high viscosity
  - Concentric cylinder was used to measure the rheological properties of binders
Parallel Plate

Concentric Cylinder

2 mm

6 mm
Parallel Plate

Concentric Cylinder

2 mm
Material Collection & Preparation

- One conventional binder (PG64-16)
- One rubberized binder (laboratory blended)

Rubberized binder preparation
- Base binder: PG 64-16 (same conventional binder)
- Rubber content: 18 percent by weight of total binder
- Grinding type: ambient
- Extender oil: four percent by weight of base binder

Blend in a mixer for 60 minutes at approximately 190°C
Artificial RAP/RRAP Binders

- The artificial RAP and R-RAP binders were prepared in a Pressure Aging Vessel (PAV) for 40 hours at 100°C.
RESULTS & CONCLUSIONS
\[
y = 1.7564e^{0.0283x} \\
R^2 = 0.99855
\]

\[
y = 1.6866e^{0.0291x} \\
R^2 = 0.99801
\]

\[
y = 11.176e^{0.01x} \\
R^2 = 0.99255
\]
G* @ 64°C (RTFO)

\[ y = 18.062 e^{0.0099x} \]
\[ R^2 = 0.96882 \]

\[ y = 4.2593 e^{0.027x} \]
\[ R^2 = 0.9981 \]

\[ y = 4.3988 e^{0.0251x} \]
\[ R^2 = 0.99776 \]

\( \delta @ 64°C (RTFO) \)

\( R^2 = 0.99776 \)
Viscosity @ 135°C (Unaged)

- Conv. + RAP
- Conv. + RRAP
- AR + RAP

- $y = 11.617e^{-0.018x}$
  - $R^2 = 0.9979$

- $y = 0.4023e^{0.0373x}$
  - $R^2 = 0.9942$

- $y = 0.4592e^{0.014x}$
  - $R^2 = 0.99762$
MSCR (RTFO)

- Conv. + RAP
- Conv. + RRAP
- AR + RAP

APR_3.2 kPa (%) vs. Jnr_3.2 kPa (1/kPa)
Frequency Sweep @ 64°C (Unaged)

- Conv.
- Conv.85-RAP15
- Conv.75-RAP25
- Conv.60-RAP40
- RAP
Frequency Sweep @ 64°C (Unaged)

- Conv.
- Conv.85-RRAP15
- Conv.75-RRAP25
- Conv.60-RRAP40
- RRAP

G* (Pa)

Phase Angle (degree)
Frequency Sweep @ 64°C (Unaged)

- **G* (Pa)**
- **Phase Angle (degree)**

- **Legend:**
  - **AR**
  - **AR85-RAP15**
  - **AR75-RAP25**
  - **AR60-RAP40**
  - **RAP**
**Frequency Sweep @ 64°C (RTFO)**

- **G* (Pa)**
- **Phase Angle (degree)**

Legend:
- **AR18**
- **AR85-RAP15**
- **AR75-RAP25**
- **AR60-RAP40**
Creep Stiffness @ -6°C, 60s

- 0% RAP
- 20% RAP
- 40% RAP
- 60% RAP

m-value @ -6°C, 60s

- 0% RAP
- 20% RAP
- 40% RAP
- 60% RAP
Conclusions

- Using concentric cylinder geometry on DSR accurately captures the changes between different blended binders.

- Rubberized binders are more elastic compared to conventional binders.

- Rubberized binders are less temperature susceptible than conventional binders.

- MSCR provides a better indication of rutting resistance than high temperature PG for rubberized binders.
Conclusions

- RRAP provides better rutting and low temperature cracking resistance compared to RAP on conventional binders containing RAP.

- RAP has little effect on rutting resistance but negative effects on low temperature cracking resistance.
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Thank you