NCHRP 9-58
The Effects of Recycling Agents on Asphalt Mixtures with High RAS and RAP Binder Ratios

Project Update

Asphalt Mixture & Construction Expert Task Group
September 20, 2017
Research Team

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Outline

- NCHRP 9-58 Objectives & Research Plan

- Revised Phase II
  - Field Projects, Materials, & Laboratory Tests
  - Practical Evaluation Tools for High RBR Binder Blends & Mixtures
  - Engineering Binder Blends

- Moving Forward

- Phase III Work Plan
NCHRP 9-58 Objectives

- High RBR = 0.3 – 0.5
- Assess effectiveness of RAs to
  - partially restore binder rheology
  - improve mixture cracking performance at optimum dosage rates
- Evaluate the evolution of RA effectiveness with aging
- Recommend evaluation tools
NCHRP 9-58 Research Plan

**PHASE I**
Identification of Gaps in Knowledge on RA Use with High RBRs

- **Task 1.** Gather Information
- **Task 2.** Design Laboratory Experiment
- **Task 3.** Document Results in First Interim Report

**PHASE II**
Investigation of Effectiveness of RAs in Restoring Binder Rheology, Development of Blending Protocol, and Associated Mixture Performance

- **Task 4.** Conduct Laboratory Experiment
- **Task 5.** Design Field Experiment and Document Results in Second Interim Report

**PHASE III**
Validation of RA Use in Mixtures with High RBRs

- **Task 6.** Conduct Field Experiment
- **Task 7.** Propose Revisions to AASHTO Specifications and Test Methods
- **Task 8.** Develop Training Materials and Best Practices and Deliver Workshop
- **Task 9.** Document Results in Final Report

Bozeman, MT September 20, 2017
Field Projects

NV 9/15
0.15, 0.3 RAPBR
RAs: T2 + A2

TX 6/14
0.3 RBR
RA: T1

WI 9/16
0.2, 0.3 RAPBR
RA: V2

IN 9/15
0.3, 0.4 RBR
RA: T2

DE 12/16
0.3, 0.4 RBR
RA: T2
Revised Phase II Materials Combinations

- **RAP**
  - TX
  - NH
  - NV
  - IN

- **RAS**
  - TX MWAS, TOAS
  - CA TOAS
  - IN MWAS

- **Base Binder**
  - T1, T2
  - A1, A2
  - V1, V2
  - B

- **Recycling Agents**
  - TX PG 64-22 (-4.6), PG 70-22P (-4.9)
  - NH PG 64-28 (+1.4)
  - NV PG 64-28P (-3.6)
  - IN PG 64-22 (-1.2), PG 58-28 (-8)
  - MN PG 58-28 (0)

- **Virgin Aggregates**
  - TX
  - NV
  - IN

- **Rejuvenated Blend**
  - Rejuvenated Mixture

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September 20, 2017
Revised Phase II Lab Tests – BINDER & MORTAR

- BOTH: PGH, PGL
  \[ \Delta T_c = (T_S - T_m) \]

- Glover-Rowe
  \[ G-R = \frac{G^*(\cos\delta)^2}{\sin\delta} \] @ 15 °C, 0.005 rad/sec

- \( T_{\delta=45} @ 10 \text{ rad/sec} \)

- Carbonyl Area Growth by FT-IR

- \( T_g \) End & \( T_g \) Inflection by DSC

- SAR-AD
Revised Phase II Lab Tests - MIXTURE

- **Stiffness**
  - $M_R \ @ \ 25 \ ^\circ \mathrm{C}$
  - $E^*, \ \phi \ + \ \text{Mixture G-R}$

- **Cracking Resistance**
  - FI, CRI by I-FIT (SCB)
  - DCC by S-VECD
  - CRI by UTSST
  - $S, \ m$-value by BBR Sliver

- **Rutting Resistance**
  - RD by HWTT, APA Jr
Practical Evaluation Tools

- RA Dosage Selection (w/Aging)
  - Restore PGL (and Verify PGH)
  - Achieve $\Delta T_c = -5.0$
  - Restore *Continuous* PGH
- Balanced Binder Blends
  - Estimate PGH & RA Dosage
- Mixture Validation
RA Dosage Selection

1) Dosage to restore PG
   (Restore PGL - verify PGH)

2) Dosage to reduce $\Delta T_c$ to -5.0

3) Dosage to restore PGH to target PGH
RA Dosage Selection: Restore *continuous* PGH

Rutting

- 0.5 RBR
- 0.25 RAP
- 0.25 TOAS
RA Dosage Selection: Restore *continuous* PGH

- DOT Control (0.28 RBR) TX 64-22 - NO RA
- Recycled Blend (0.5 RBR) NH 64-28 + 14% V2

No rutting

**BALANCED**

0.5 RBR

0.4 RAP

0.1 TOAS

Phase III
Balanced Binder Blends - Blending Chart

\[
P_{GH_{Blend}} = (RAPBR \times P_{GH_{RAP}}) + (VBR \times P_{GH_{V.binder}})
\]
**Balanced Binder Blends - Estimate PGH**

\[
P_{GH_{Blend}} = (R_{APBR} \times P_{GH_{RAP}}) + (R_{ASBR} \times P_{GH_{RAS}}) + (V_{BR} \times P_{GH_{V.binder}})
\]

All recycled binder blends without RA
Estimate RA dosage to restore *continuous* PGH

\[
y = 1.663x + 70.859 \\
R^2 = 0.9151
\]

Dosage to restore PGH to **70**

\[
\%RA = \left( PGH_{Blend} - PGH_{Target} \right) / 1.7
\]

Dosage to restore PGH to **64**
Mixture Validation

**Resilient Modulus (kPa)**

- **DOT Control**
  - 0.3 RBR (0.1RAP-0.2MWAS) + 2.7% T1 (64-22)
- **Recycled**
  - 0.3 RBR (0.1RAP-0.2MWAS) + 4.5% T1 (64-22)
  - 0.5 RBR (0.25RAP-0.25TOAS) + 12.5% T1 (64-28)
  - 0.5 RBR (0.4RAP-0.1TOAS) + 14% T1 (64-28)

**Flexibility Index (EI)**

- **DOT Control**
  - 0.3 RBR (0.1RAP-0.2MWAS) + 2.7% T1 (64-22)
- **Recycled**
  - 0.3 RBR (0.1RAP-0.2MWAS) + 4.5% T1 (64-22)
  - 0.5 RBR (0.25RAP-0.25TOAS) + 12.5% T1 (64-28)
  - 0.5 RBR (0.4RAP-0.1TOAS) + 14% T1 (64-28)
**Mixture Validation**

**Phase III**

**Resilient Modulus (kPa)**

<table>
<thead>
<tr>
<th>Control</th>
<th>PGL</th>
<th>PGH</th>
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<tbody>
<tr>
<td>DOT control 0.32 RBR (0.25RAP+0.07MWAS) (S8-28)</td>
<td>Recycled 0.42 RBR (0.14RAP+0.28MWAS) + 3.5% T2 (S8-28)</td>
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**Flexibility Index**

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- **IN** Resources
Engineering Binder Blends

- Chemical Compatibility
- Representative Binder Blending
- Binder Blend Aging Prediction
- Rheological Balance
### RHEOLOGICAL BALANCE

<table>
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<tr>
<th>Highlights</th>
<th>Tools/Partner</th>
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<td><strong>Rejuvenation</strong></td>
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<tr>
<td>Restore PG, reduce G-R, reduce $T_{\delta=45^\circ}$</td>
<td>DSR/TTI</td>
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| Aging | | |
|-------|---------------------|
| Increase in G-R and $T_{\delta=45^\circ}$, with some at faster rate than control blends | DSR & FT-IR/TTI |
| RA can experience chemical changes with aging that affect rheology | DSR & FT-IR/TTI |

Phase III
Rheological Balance: Crossover Temperature ($T_{\delta=45^\circ}$)

Determination by T Sweep

Note: $T_{\delta=45^\circ}$ in this study was obtained from mastercurves and time-temperature superposition.

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Rheological Balance: Crossover Temperature ($T_\delta=45^\circ$)

Base Binders and DOT Control Blends

- Important to select high quality base binder with better $\Delta T_c$ and $T_\delta=45^\circ$
- Binders of same PG can have different $T_\delta=45^\circ$
- Challenging TX materials combo
Rheological Balance and Long-Term Aging

High RBR Rejuvenated Blends

- Balanced – rutting and cracking resistance.
- Balanced – RAP and RAS
- It is possible to recycle and rejuvenate high RBR blends.

Bozeman, MT
Asphalt Mixture & Construction Expert Task Group
September 20, 2017
Moving Forward

Phase III

- Mixture Cracking Resistance
- Binder Availability
- RA Type Selection
- Climate Effects
Mixture Cracking Resistance
BBR Sliver

Phase III for WI & DE
0.3 RBR

TX & NH RAP binder contents = 4.7%, 4.0% respectively

Mixture Total binder content: 4.5%

Phase III for IN, NV, WI, & DE + Unheated
RA Type Selection

Chemistry – FT-IR

- RA with smallest $\Delta$ FT-IR registered minimal $\Delta$ in rheology
- T1 w/ greatest $\Delta$ in rheology & among highest $\Delta$ FT-IR.

Phase III w/ 0.5 RBR blends w/WI matls + $\Delta$G-R & $\Delta$T$_{\delta=45}$ w/aging + FI
Climate Effects

9-58 Cumulative Degree Days (CDD)

- Texas
- Indiana
- Nevada
- Wisconsin
- Delaware

9-52 Ratio vs CDD

- Predicted
- Texas I
- New Mexico
- Wyoming
- South Dakota
- Iowa
- Indiana
- Florida
- 2h@135C + 5d@85C

- R² = 0.831

- 9-52: STOA 2hrs @ 135C + LTOA 5d @ 85C
- = 16,000 CDD = 11 mos warmer, 22 mos colder climates

Phase III w/Mₚ, Cracking Resistance + Limited Extracted Binders w/G-R
Phase III Work Plan

**Utilize**
WI & DE Materials

**Verify**
Practical Tools

**Provide**
Materials Selection Guidance

**Propose**
RBR, RA Dosage Limits
Binder & Mix Thresholds

**Evaluate**
Lab vs Field Aging

**Revise**
AASHTO Standards
NCHRP 9-58 Products

- High RBR = 0.3 – 0.5
- Material Selection Guidelines
- RA Dosage Selection Method
- Evaluation Tools w/aging protocols, RA blending methods, binder blend & mixture tests & thresholds
  - AASHTO recommended practice
- Better Understanding of
  - Recycled Binder Availability (Degree of Blending)
  - Chemical Compatibility
- Future Research
THANK YOU!

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