TRB Webinar: Design and Production of High-Reclaimed Asphalt Pavement Mixes

May 7, 2009, 2:00 PM EDT
Speaker information

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State-of-the-Practice for High Reclaimed Asphalt Pavement Mixes

TRB Webinar
May 7, 2009

Audrey Copeland, Ph.D.
Asphalt Pavement Engineer
Presentation Outline

• Defining High RAP
• State-of-the-Practice across the US and Issues to Consider for Increasing RAP Use
• Resources & Guidance
• Best Practices for Processing and Production
Defining High RAP

- Reclaimed Asphalt Pavement
- Removed and/or reprocessed pavement materials containing:
  - binder (5%)
  - aggregates (95%)

High RAP is defined as more than 25% RAP by weight of mix.
Reclaimed Asphalt Pavement (RAP)

Sources of RAP
- Milling
- Pavement removal
- Plant waste

Most Common Uses
- Addition to HMA
- Aggregate in cold-mix
- Granular base
- Fill or embankment material
State-of-the-Practice
Current Specification for RAP Mix Design

- AASHTO M 323 Standard Specification for Superpave™ Volumetric Mix Design

<table>
<thead>
<tr>
<th>Recommended Virgin Asphalt Binder Grade</th>
<th>Percent (%) RAP</th>
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<tbody>
<tr>
<td>No change in binder selection</td>
<td>&lt; 15</td>
</tr>
<tr>
<td>Select virgin binder grade one grade softer than normal</td>
<td>15 – 25</td>
</tr>
<tr>
<td>Follow recommendations from blending charts</td>
<td>&gt; 25</td>
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- Mixture with RAP must meet same requirements as virgin mixture.
States that **Permit** More than 25% RAP in HMA Layers

- Permit >25% in base layer only
- Permit >25% in multiple layers
- Do not permit >25% RAP
States that **Use** More than 25% RAP in HMA Layers

- **Use >25% in base layer only**
  - AK, WA, MT, ND, SD, WI, IL, IN, OH, MI, WI, IA, MO, AR, KY, WV, VA, NC, SC, GA, AL, MS, LA
  - CA, NV, UT, CO, WY, ID, OR, AZ, NM, OK, AR, TX, OK, LA, FL, HI

- **Use >25% in multiple layers**
  - CA, AZ, CO, NM, TX, OK, AR, LA, MO, KY, AL, GA, FL, VA, OH, MI, VT, ME, MA, RI, VT, NY, NJ, DE, MD, DC, MA, NH, PR

- **Do not use >25% RAP**
  - AK, WA, MT, ND, SD, WI, IL, IN, OH, MI, WI, IA, MO, AR, KY, WV, VA, NC, SC, GA, AL, MS, LA
Common Roadblocks

- Specifications
- Lack of processing
- Past experiences
- Lack of RAP availability

State Survey Results 2007-08
Why allow high RAP?

- Reduced costs

- For example…
  - **Upfront cost impact** - If specification allows high RAP, contractors may submit different bid prices on plant mix items or frequency of price adjustments and delays.
  - **Future cost impact** – higher RAP pavement may have different life-cycle properties

- The cost effectiveness of higher-RAP mixes depends on:
  - Unit cost of mixtures
  - Performance during and after placement
Issues to Consider when Increasing RAP

• Additional Processing & Quality Control (QC)
• Characterizing RAP
• Changing Binder Grade
• Mix Design
• Blending/Co-mingling of Virgin and RAP Binder
• Performance
Resources & Guidance
• Recycled Materials Resource Center (RMRC)

• Reclaimed Asphalt Pavement

• Roofing Shingle Scrap

Guidance Documents for using RAP

www.fhwa.dot.gov/pavement/recycling/rap
Advance the use of RAP in asphalt paving applications by providing highway agencies with critical information regarding the use of RAP, technical guidance on high-RAP projects, and direction on research activities.

The members consist of representatives from highway agencies, industry, and academia.

Website: www.moreRAP.us
• Asphalt and Aggregate Supply
• Value of RAP
• Agency Perspective and Contractor Experience
• Strategies to Maximize RAP Use
  – Plant Energy Efficiency
  – Emissions Reduction
• Mix Design for HMA Recycling
• Use of Polymers
• Reducing Transportation Fuel Costs
• Shingles in HMA
Best Practices for Processing and Production of High RAP Mixtures
Increasing RAP Use

The question we’re posing…

• *How much RAP can we allow in the mix and meet specification and constructability requirements?*

• Biggest impact can be made in processing and production.
Getting the RAP ready...

- Unprocessed RAP
  - Not subject to QC
  - Visual Inspection

- Processing RAP
  - Uniform size
  - Promotes final blend consistency
Fractionated RAP (FRAP)

- Fractionation is processing and separating RAP into at least two sizes, typically a coarse fraction and a fine fraction.
Considerations for Fractionating

- The market supplied by this plant allows RAP contents above twenty percent.
- Difficulty meeting mix design requirements, such as minimum VMA and dust proportion, for mixes with over twenty percent RAP.
- Difficulty keeping RAP mixes within quality control and acceptance limits.
- Sufficient space available in the stockpile area for RAP fractionation equipment & stockpiles.
Maintaining RAP Quality

- Stockpiling
  - Conical
  - Well-maintained
  - Sample frequently

- Comprehensive QC testing
  - Absorption
  - Moisture content
  - Asphalt content
  - Gradation
Efficient Operations

- Loader operator
- RAP feed system
  - Scalping screen
  - Sizing device
In the Plant

- Superheating of aggregate
- Air flow
- Baghouse
- Warm mix
Insuring Quality

- Final mixture
  - Volumetric properties
  - Extraction & recovery
  - Gradation
  - Asphalt content
  - High-RAP
    - PG grade of blended binder
    - Quality of Aggregate

- Performance Testing
Primary Performance Concerns

• Fatigue Cracking
  – Aging characteristics – virgin vs. RAP binder

• Low Temperature Cracking

• Durability (Raveling)
  – Moisture content
# Performance Testing Options

<table>
<thead>
<tr>
<th>Distress</th>
<th>Test</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Permanent Deformation</td>
<td>Asphalt Pavement Analyzer (APA)</td>
<td>AASHTO TP 63</td>
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<tr>
<td></td>
<td>Hamburg Wheel Tracking Device</td>
<td>AASHTO T 324</td>
</tr>
<tr>
<td></td>
<td>Flow Number (AMPT)</td>
<td>NCHRP 9-29 Proposed Standard Practice</td>
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<tr>
<td>Moisture Sensitivity</td>
<td>Tensile Strength Ratio (TSR)</td>
<td>AASHTO T 283</td>
</tr>
<tr>
<td></td>
<td>Hamburg Wheel Tracking Device (wet)</td>
<td>AASHTO T 324</td>
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<tr>
<td>Fatigue</td>
<td>4-point Bending Beam</td>
<td>AASHTO TP8</td>
</tr>
<tr>
<td></td>
<td>Continuum Fatigue Damage (AMPT)</td>
<td>NCHRP 9-29</td>
</tr>
<tr>
<td>Thermal Cracking</td>
<td>Temperature Stress Restrained Specimen Test (TSRST)</td>
<td>AASHTO TP10</td>
</tr>
<tr>
<td></td>
<td>Indirect Tensile Test (IDT)</td>
<td>AASHTO TP9</td>
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Laydown and Compaction

- No special requirement/techniques
  - May require more attention than conventional mixes

- Mix Workability - Stiffer
  - Density

- Cooler temperatures
  - Reduced compaction times
Performance of RAP Pavements

- High percentages of RAP have successfully been used for more than 30 years.

- Long-term performance of recycled asphalt pavements not well documented.

- Recycled asphalt mixtures designed using established mix design procedures and produced with appropriate QC/QA measures perform comparably to conventional mixtures.
Final Thoughts...

- Probably the greatest single upfront cost saving measure available to US highway agencies today is increasing the use of RAP in the construction and rehabilitation of asphalt pavements.

- The majority of State DOTs use between 10 and 20% RAP, but have potential to use up to 30%.

- Contractors can effectively use RAP often and in high amounts with processing and production best practices.
Design of High RAP Mixes

Andrea Kvasnak, PhD

Some photos taken from across the asphalt community
Superpave RAP Guidelines

- Tier 1: Up to 15% RAP
  - use specified grade
  - use $G_{sb}$ of virgin material
- Tier 2: 15%-25% RAP
  - use one full grade lower, e.g., a PG 64-28 instead of a PG 70-22
  - estimate $G_{sb}$ from $G_{se}$
- Tier 3: Over 25% RAP
  - use blending charts to determine required grade
  - estimate $G_{sb}$ from $G_{se}$
Additional Considerations

1. Sample
2. Characterize RAP
3. Select blended binder properties
4. Evaluate blended aggregate properties
5. Estimate initial asphalt content
6. Make volumetric specimens
7. AASHTO T 283
Consideration 1: Sample

- Sampling
  - Sample often

- Testing of RAP Sample
  - Asphalt content
  - Asphalt grade
  - Aggregate properties
  - Aggregate gradation
Consideration 2: Characterize RAP

• Why do you need to characterize?
  – Know how much asphalt is contributed
  – Know RAP binder stiffness
  – Know aggregate gradation

• Methods
  – Ignition
  – Solvent Extraction
Consideration 2: Characterize RAP, cont.

- **Ignition Oven**
  - Aggregate breakdown
  - Higher asphalt content
  - May affect aggregate properties
    - Gsb $\rightarrow$ changes in VMA

- **Solvent Extraction**
  - Residual asphalt
  - Lower asphalt content
    - May affect aggregate properties
Consideration 3: Select Blended Binder Properties

• Need to know target blended binder property
  – Blended binder critical temperature, $T_{\text{blend}}$

• Need to know either:
  – RAP Percentage
  – Virgin binder
How Do You Select the Virgin Binder for a RAP Percentage

- Extract and recover RAP binder
- Determine recovered RAP binder properties
- Calculate required virgin binder grade

\[ T_{crit} = \frac{T_{blend} - (RAP\% \times T_{RAP})}{(1 - RAP\%)} \]
How Do You Select the RAP Percentage for a Virgin Binder

- Extract and recover RAP binder
- Determine recovered RAP binder properties
- Determine virgin binder properties
- Calculate required virgin binder grade

$RAP\% = \frac{T_{blend} - T_{virgin}}{T_{RAP} - T_{virgin}}$
Consideration 4: Aggregate Properties

• Why do we need to know RAP aggregate properties?
  – RAP aggregate properties are as important as virgin aggregate properties
  – Combined properties of aggregates should meet consensus aggregate properties

• Develop aggregate blends using both virgin and RAP aggregate gradations
Consideration 5: Estimate Initial Asphalt Content

- Trial asphalt content needed for evaluating blends
- Account for both virgin and RAP asphalt contributions
How to Determine the Virgin Asphalt Content

- Determine the asphalt content of the RAP
- Select a RAP percentage
- Determining contribution of asphalt from RAP
  \[(\text{RAP }\%) \times (\text{RAP asphalt content})\]
- Select initial asphalt content for mix
- Subtract RAP asphalt contribution from optimum asphalt content
Consideration 6: Volumetric Specimens

- Fractionate RAP as you would virgin aggregate
- Preheat virgin aggregate and RAP
- RAP heating should be long enough to reach desired mixing temperature
RAP Heating Guidelines

• Heat RAP in cans
  NOT pans
  – Reduces surface exposure
• Determine appropriate heating time
  – Ovens vary
  – Container size affects heating time

![Graph showing the relationship between time and temperature](image.png)
Ability to Meet Volumetrics

- Treat RAP as mix component

- Challenges: VMA and dust/asphalt ratio
  - Good processing practices can be used to overcome this issue
    - Minimize generating dust in RAP stockpiles
    - Fractionate RAP for mix design flexibility and gradation control
Consideration 7: AASHTO T 283

- AASHTO T 283 conducted the same
- Same indirect tensile strength and tensile strength ratio criteria
- Often the RAP stiffens the mix thus resulting in higher indirect tensile strengths
Troubleshooting

- **What if mix is too stiff?**
  - Re-evaluate RAP
  - Use softer binder
  - Use WMA

- **What if mix is too soft?**
  - Binder may not be blending as well as anticipated
  - Stiffer virgin binder
  - Check plant

- **What if too many fines?**
  - Re-evaluate RAP
On-Going Research
Asphalt Research Consortium (ARC)
   – FHWA Cooperative Agreement

Two primary goals:

1. Properties of RAP binder without extraction and recovery

2. Accurately characterizing RAP aggregate
   - Collaborating with NCAT
Investigation of Properties of Plant Produced RAP Mixtures

- Assess current guidelines for RAP usage by determining low and high temperature properties of plant-produced HMA with varying RAP contents and virgin binder grades
- Investigate virgin and RAP binder blending during plant production
High RAP Mix Design

• NCHRP 9-46 Mix Design and Evaluation Procedure for High Reclaimed Asphalt Pavement Content in Hot Mix Asphalt

• **Objective**: Develop mix design method and specification for HMA containing up to 50% RAP.
NCAT Test Track High RAP Study

• Evaluate 0, 20, and 45% RAP using different binder grades
• Binder evaluated were soft, standard, polymer modified, and polymer modified with a compaction aid
Minnesota Road Research Facility Study

- Cold Climate Performance of RAP under Controlled Testing Conditions
Final Thoughts…

• Treat RAP like virgin aggregate

• Characterize RAP

• High RAP content mixes are feasible and economical

• Numerous resources available for
  – NAPA Best Practices
  – Other Contractors and State Agencies
  – RAP Expert Task Group
  – NCAT and other Researchers
www.fhwa.dot.gov/pavement/recycling/rap
www.MoreRAP.us
www.ncat.us

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Thank you! Questions?