Resource Responsible Use of High RAP (up to 50%) Asphalt Mixtures

Tim Aschenbrener
Federal Highway Administration

Northeast Asphalt User Producer Group
Albany, NY
November 3, 2022
Disclaimer

• This material is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange under cooperative agreement No. 693JJ31850010. The U.S. Government assumes no liability for the use of the information.

• The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers’ names appear in this material only because they are considered essential to the objective of the material. They are included for informational purposes only and are not intended to reflect a preference, approval, or endorsement of any one product or entity.

• All AASHTO and ASTM standards mentioned in this presentation content are non-governmental, voluntary standards and are not required under Federal law.
Acronyms

• AASHTO = American Association of Highway and Transportation Officials
• BMD = balanced mix design
• COAC = corrected optimum asphalt content
• CO$_2$e = carbon dioxide equivalents
• DGFC = dense-graded friction course
• FDR = full-depth reclaimation
• $G_{sa}$ = apparent specific gravity of the aggregate
• $G_{sb}$ = bulk specific gravity of the aggregate
• GTR = ground tire rubber
• GHG = green house gas
• HP = high polymer
• IS = information series
• MSCR = multiple stress creep compliance

• NAPA = National Asphalt Pavement Association
• NCHRP = National Cooperative Highway Research Program
• OGFC = open-graded friction course
• PMS = pavement management system
• PWL = percent within limits
• QA = quality assurance
• QC = quality control
• RAM = reclaimed asphalt materials
• RAP = reclaimed asphalt pavement
• RAS = recycled asphalt shingles
• RBR = reclaimed binder ratio
• VMA = voids in the mineral aggregate
• WHRP = Wisconsin Highway Research Program
• WMA = warm mix asphalt
“Development and Deployment of Innovative Asphalt Pavement Technologies”
## DDIAPT Innovation Area:
*Resource Responsible use of Materials for Flexible Pavement Systems*

<table>
<thead>
<tr>
<th>Innovation Area</th>
<th>Task</th>
<th>Topic</th>
<th>Tech Brief or Report</th>
<th>FHWA Document</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource Responsible use of Materials for Flexible Pavement Systems</td>
<td>B.1</td>
<td>High Reclaimed Asphalt Pavement (RAP) Mixtures</td>
<td>Resource Responsible Use of Reclaimed Asphalt Pavement in Asphalt Mixtures</td>
<td>FHWA-HIF-22-003</td>
</tr>
<tr>
<td></td>
<td>B.1.2</td>
<td>Cold &amp; Hot In-place Recycling</td>
<td>Cold Asphalt Recycling &amp; Hot In-place Recycling Best Practices</td>
<td>FHWA-HIF-22-XXX</td>
</tr>
<tr>
<td></td>
<td>B.2</td>
<td>Reclaimed Asphalt Shingles (RAS) Modified Binders and Mixtures</td>
<td>Practices and Lessons Learned when Using Reclaimed Asphalt Shingles in Asphalt Mixtures</td>
<td>FHWA-HIF-22-001</td>
</tr>
<tr>
<td></td>
<td>B.3</td>
<td>Asphalt Rubber-Modified Binders</td>
<td>Effective Use of GTR Modified Asphalt Binder in Asphalt Mixtures</td>
<td>FHWA-HIF-22-011</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Resource Responsible Use of Recycled Tire Rubber in Asphalt Pavements</td>
<td>FHWA-HIF-20-043</td>
</tr>
</tbody>
</table>

[https://www.fhwa.dot.gov/pavement/recycling/](https://www.fhwa.dot.gov/pavement/recycling/)
Introduction and Background

Benefits and Communication

Design Considerations

Construction and QA

Summary

https://www.fhwa.dot.gov/pavement/recycling/rap.cfm
Introduction

Past:
• Long history of RAP.
  • All State DOTs allow.
• 2008 asphalt binder price peak.
  • Desire to increase RAP.
• Reports.
  • 2011 FHWA.
  • 2013 NCHRP.
  • 2016 NCHRP Synthesis.
  • 2015-2016 NAPA.
• 2014 some challenges.
  • High stiffness and long-term durability.

Moving Forward:
• Some State DOT success at higher dosages.
• Task Objective:
  • Visit high dose States (up to 50% RAP) for positive practices & lessons learned.
Why Responsibly Use High RAP?

- **Optimize:**
  - Cost.
    - Initial and life cycle.
  - Environmental Considerations.
    - Conservation of natural resources.
    - Reduction of CO$_2$e.
  - Pavement Performance.
    - Equal pavement performance.

Images: Pixabay
History of RAP Use:
2020 NAPA IS-138 Annual Survey: RAP, WMA, ...

Source: 2020 NAPA IS-138 Annual Survey
Trends:
• Most recycled material.
• ≈93% of RAP put back in new asphalt mixture.
• Annual savings:
  • 4.4M tons of asphalt binder (24M barrels).
  • 82M tons of aggregate.
  • $2.9 billion.
State DOTs Average Percent RAP Used

Trends:
- 0-9% ↓
- 10-14% ↓
- 15-19% ↑
- 20-29% ↑
- ≥ 30% ↑
- Steady @≈20%

Figure 8: Number of States at Different Average Percentage of RAP Used in HMA/WMA Mixtures, 2009–2020

Source: 2020 NAPA IS-138 Annual Survey
Cumulative GHG Emissions Reduction from use of RAP in New Asphalt Mixtures

Trends:
• Steady reduction of GHG emissions (tons CO$_2$e).
  • 2020: 2.3 MMT.
  • 2009: 1.5 MMT.
  • 2009 to 2020: 23.5 MMT.

Figure 19: GHG Emissions Reduction from Use of RAP in New Asphalt Mixtures, 2009–2020

Source: 2020 NAPA IS-138 Annual Survey
Virtual Site Visits

• **Florida DOT (FDOT):**
  - Unlimited RAP use for some mixture types.
  - Several producers use 40% RAP, One uses 50% in unlimited RAP mixture type.

• **Nebraska DOT (NDOT):**
  - Averaged 39% RAP use for the past 6 years.
  - Typical RAP range 35 to 50%.

• **New Jersey (NJDOT):**
  - High RAP specification: Min 20% RAP surface mixtures; 30% intermediate and base mixtures using BMD approach.

• **South Carolina DOT (SCDOT):**
  - Some mixtures with 25 to 35% RAP.
  - Alternative RAP uses, e.g. full-depth reclamation (FDR).

• **Washington DOT (WSDOT):**
  - Up to 40% RBR (≤20% from RAS).
  - Uses BMD approach.

• **Wisconsin DOT (WisDOT):**
  - >95% of 2.8 million tons of asphalt contains RAP.
  - 40% RAP in some mixtures.
Properties of Plant Mixes Containing High Asphalt Binder Replacement

- 2 different counterflow drum mix plants.
- 3 different RAP contents (50, 60, 70%).
  - Maximum 50% RAP.
- Mixing / coating.
- Drum shell temperature.
  - Max 800° F.
- Aggregate temperature.
  - Max 700° F.
- Exhaust temperature.
  - Min 220° F.
  - Max 390° F.
Outline

1. Introduction and Background
2. Benefits and Communication
3. Design Considerations
4. Construction and QA
5. Summary

https://www.fhwa.dot.gov/pavement/recycling/rap.cfm
Benefits: Quantifying and Communicating

- Nebraska DOT
    - [https://dot.nebraska.gov/media/3493/annual-report.pdf](https://dot.nebraska.gov/media/3493/annual-report.pdf)
  - Saving 2008 to 2020:
    - \(\approx 9.2\)M tons aggregate recycled.
    - \(\approx 498,000\) tons asphalt binder recycled.
    - \(\approx\) Cost saving of \$408M.
  - Post-Consumer Labeling Plan Sets Since 2014.

Source: Nebraska DOT
Benefits: Quantifying and Communicating

Illinois DOT: 2020
• Value: $65,356,915
  o 18% increase from 2019
• Total: 1,439,041 tons
  o 17% increase from 2019
• RAP: 1,113,695 tons
  o 36% increase from 2019
• RAS: 37,655 tons
  o 24% decrease from 2019

Nebraska DOT Pavement Performance Observations

- Nebraska Serviceability Index (NSI):
  - Range = 0 to 100.
  - “Good” ≥ 70%.

- Goal 80 to 85% of Highway System “Good:”
  - 92% of Interstate System “Good.”
  - 83% of Total Highway System “Good.”

- NSI has Increased since High RAP Implementation in 2013.

Source: Nebraska DOT
Pavement Performance with RAP

• RAP in Asphalt Mixtures: State of the Practice.
  • FHWA Publication: FHWA-NRT-11-021.

• NCHRP Report 752.
• NCAT Test Track.
• LTPP Studies.
Design Considerations

Criteria Commonly Used:
• Project selection:
  • Lift, traffic, mix type.
• Acceptable RAP limits.
• Softer binder.
• Additional asphalt binder.

Criteria Sometimes Used:
• Recycling agents.
• Mixture performance test.
**Rationale and Location for Using RAP**

**FDOT %RAP =f(mix type, location, binder type, and geographic location).**

- **Unlimited RAP:**
  - Intermediate and base mixes with neat binders.

- **20% RAP:**
  - Dense-graded friction course (DGFC) with granite aggregate.
  - All intermediate mixes with PG 76-22.

- **0% RAP:**
  - Dense-graded friction course (DGFC) mixes with South Florida limestone.
  - OGFC or High Polymer (HP).
<table>
<thead>
<tr>
<th>Type of Mix</th>
<th>Allowable Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RAS</td>
</tr>
<tr>
<td>Surface A</td>
<td>-</td>
</tr>
<tr>
<td>Surface B</td>
<td>-</td>
</tr>
<tr>
<td>Surface C</td>
<td>5</td>
</tr>
<tr>
<td>Surface D</td>
<td>5</td>
</tr>
<tr>
<td>Surface E</td>
<td>5</td>
</tr>
<tr>
<td>PMTLSC</td>
<td>5</td>
</tr>
<tr>
<td>Intermediate A</td>
<td>-</td>
</tr>
<tr>
<td>Intermediate B</td>
<td>-</td>
</tr>
<tr>
<td>Intermediate C</td>
<td>5</td>
</tr>
<tr>
<td>Base A</td>
<td>5</td>
</tr>
<tr>
<td>Base B</td>
<td>5</td>
</tr>
<tr>
<td>Base C</td>
<td>5</td>
</tr>
<tr>
<td>Base D</td>
<td>5</td>
</tr>
<tr>
<td>Shoulder Widening</td>
<td>5</td>
</tr>
</tbody>
</table>

1 Fractionated Fine RAP only.

Source: South Carolina DOT
## Criteria for Use of Softer Binder

<table>
<thead>
<tr>
<th>State</th>
<th>Softer Binder</th>
<th>Blending Chart</th>
<th>PG of Blended Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDOT</td>
<td>One to two PG bumps down based on RAP dose.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDOT</td>
<td>Low PG bumped down one grade. Only MSCR grades are specified.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NJDOT</td>
<td>Contractor selects. Must meet mixture performance test.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCDOT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WisDOT</td>
<td>Only to demonstrate that at higher RBR, blended binder meets the specified PG for the project per AASHTO M 332.</td>
<td></td>
<td>Only to demonstrate that at higher RBR, blended binder meets the specified (PG) for the project per AASHTO M 332</td>
</tr>
<tr>
<td>WSDOT</td>
<td>For all mixes containing RAS or &gt; 20% RAP.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Softer Binder

• Florida DOT
  • 0-15% RAP  – PG 67-22.
  • 16-30% RAP – PG 58-22.
  • >30% RAP  – PG 52-28.
  • Plus safeguards.

• Nebraska DOT
  • Low temperature bumped from -28 to -34.
  • MSCR grading with percent recovery for polymer modified binders.
Softer Binder

- Wisconsin DOT (WHRP 11-13)

<table>
<thead>
<tr>
<th>Recycled Asphaltic Material</th>
<th>Location in Pavement Structure and Allowable RBR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower Layers (RBR %)</td>
</tr>
<tr>
<td>RAS if used alone</td>
<td>25</td>
</tr>
<tr>
<td>RAP and FRAP in any combination</td>
<td>40</td>
</tr>
<tr>
<td>RAS, RAP, and FRAP in combination&lt;sup&gt;[1]&lt;/sup&gt;</td>
<td><strong>35</strong></td>
</tr>
</tbody>
</table>

Maximum Allowable Percent Binder Replacement.

<sup>[1]</sup> When used in combination the RAS component cannot exceed 5 percent of the total weight of the aggregate blend.

<sup>[2]</sup> The maximum allowable percent binder replacement, from RAS, RAP, and FRAP in combination, in an SMA mixture is 15 percent.
## Additional Asphalt Content

<table>
<thead>
<tr>
<th>State</th>
<th>FDOT</th>
<th>NDOT</th>
<th>NJDOT</th>
<th>SCDOT</th>
<th>WisDOT</th>
<th>WSDOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regressed Design %AV</td>
<td>1.5-4%</td>
<td></td>
<td>3.0-4.0%</td>
<td>≥3.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum %AC</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum %VMA &gt; AASHTO M323</td>
<td></td>
<td>+1.0%</td>
<td>+0.5%*</td>
<td>+0.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphalt Binder Separate Pay Item</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance Tests</td>
<td>Rutting, Cracking</td>
<td>Rutting</td>
<td></td>
<td>Rutting, Cracking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>Max %Gsa</td>
<td>COAC</td>
<td>Gsb of RAM aggs</td>
<td>Gsb of RAM aggs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Uses \( G_{se} \) but have low absorptive aggregates
Use of Additives

• Recycling Agents.
  • NJDOT and WSDOT allow recycling agents at Contractor’s option:
    • NJDOT to meet high RAP mixture performance test requirements.
    • WSDOT to meet blended binder (virgin, RAP, and recycling agent) PG requirements.
  • NDOT researching recycling agents for high recycled mixtures to “-40” PG binder.

• WMA
  • NDOT requires the use of an approved WMA additive.
# Mixture Performance Tests

<table>
<thead>
<tr>
<th>State</th>
<th>FDOT</th>
<th>NDOT</th>
<th>NJDOT</th>
<th>SCDOT</th>
<th>WisDOT</th>
<th>WSDOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rutting Test</td>
<td></td>
<td>APA</td>
<td>APA</td>
<td>APA</td>
<td>HWT</td>
<td>HWT</td>
</tr>
<tr>
<td>Cracking Test</td>
<td></td>
<td>TxOL</td>
<td>APA</td>
<td>APA</td>
<td>IDT</td>
<td>IDT</td>
</tr>
<tr>
<td>Mixture Design</td>
<td></td>
<td>APA</td>
<td>APA and TxOL</td>
<td>APA</td>
<td>HWT and IDT</td>
<td>HWT and IDT</td>
</tr>
<tr>
<td>Test Strip</td>
<td></td>
<td>APA</td>
<td>APA and TxOL</td>
<td>APA</td>
<td>IDT</td>
<td>1/10,000 tons</td>
</tr>
<tr>
<td>Production or Acceptance</td>
<td></td>
<td>APA</td>
<td>APA and TxOL</td>
<td>APA</td>
<td>HWT, IDEAL-CT</td>
<td>HWT, IDEAL-CT</td>
</tr>
<tr>
<td>Test(s) of Interest</td>
<td>IDEAL-CT</td>
<td>HWT, SCB</td>
<td>HWT, IDEAL-CT</td>
<td>HWT, IDEAL-CT</td>
<td>HWT, IDEAL-CT</td>
<td></td>
</tr>
</tbody>
</table>
Introduction and Background

Benefits and Communication

Design Considerations

Construction and QA

Summary

https://www.fhwa.dot.gov/pavement/recycling/rap.cfm
Contractor Input on Successful RAP Use

- Contractors Focused On:

<table>
<thead>
<tr>
<th>State</th>
<th>FDOT</th>
<th>NDOT</th>
<th>NJDOT</th>
<th>SCDOT</th>
<th>WisDOT</th>
<th>WSDOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Transfer</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture Control</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Dust Control</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>RAM Feed Bins</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantity Management</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Verifying %RAP</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Millings in Mix Design</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

31
Contractor Input on Successful RAP Use

- **Heat transfer.**
  - Plant equipment.
  - RAP stockpile moisture.
    - Minimizing and monitoring especially in wet climates.

- **Dust control.**
  - Plant equipment.
    - Metering back or wasting baghouse fines accurately.
    - Controlling fines (material passing the #200 sieve) when producing aggregates.
      - Washing crusher fines.

- Quantity management (availability of RAP).
Quality Assurance: QC

• Required QC Plan (FDOT, NDOT, NJDOT, SCDOT).
  • Submitted with mix design.
  • Where is RAP coming from?
  • How is it processed?
  • How is the quality measured?

• Contractor process control and QC.
  • Each asphalt plant has an on-site QC lab.
  • Consistency: blending, screening, crushing over-size materials, and stockpiling.

• Allowing fractionation of RAP (FDOT, SCDOT, WisDOT).
Quality Assurance: Acceptance

• Dedicated RAP stockpiles (FDOT, SCDOT, WSDOT).
• PWL acceptance specifications (FDOT, WisDOT, WSDOT).
• Mixture performance tests during test strips and acceptance (NJDOT, WSDOT).
Introduction and Background
Benefits and Communication
Design Considerations
Construction and QA
Summary

https://www.fhwa.dot.gov/pavement/recycling/rap.cfm
Summary

• NAPA reports about 20% RAP typical, participating State DOTs reported success with 30-50% RAP.

• Sustainable benefits: Cost, Environmental & Societal.

• Good pavement performance accomplished through:
  • Monitoring pavement performance.
  • Reviewing regularly DOT specifications, mixture design procedures, & performance test methods.
  • Working with asphalt producers for improvement.
  • Performing research as a basis for changes.
Summary

• Benefits and Communication.
  • Track and report.
  • Monitor pavement performance.

• Design Considerations.
  • Common criteria.
    • Project selection.
    • RAM limits, softer binder, additional asphalt.
  • Criteria sometimes used.
    • Recycling agents, mixture performance test.

• Construction and Quality Assurance.
  • Quality Assurance: QC plans and acceptance.

• Research and Training Needs.
Resources

Use of RAP & RAS in High Binder Replacement Asphalt Mixtures: A Synthesis

Best Practices for RAP and RAS Management

https://member.asphaltpavement.org/Shop/Product-Catalog

Resources


http://www.trb.org/Publications/Blurbs/174969.aspx

Thank You

Q & A

Tech Brief
FHWA-HIF-22-003
https://www.fhwa.dot.gov/pavement/recycling/rap.cfm

Summary Report
WRSC-TR-21-10
https://scholarworks.unr.edu/handle/11714/8000

Tim Aschenbrener
Federal Highway Administration
Timothy.aschenbrener@dot.gov