High RAP Asphalt Mixes and Asphalt Mixes with Shingles

Pennsylvania Asphalt Pavement Association
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Penn State University
Outline

1. Introduction to RAP Usage in Asphalt
2. General Info. on RAP Characterization
3. Proposed Changes for Design of RAP Mixes
4. RAP Stockpiling and Management
5. Brief Review of Shingles in Asphalt Mixes
Outline

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5. Brief Review of Shingles in Asphalt Mixes
RAP USAGE

- Approximately 71.9 million tons of RAP placed in pavements in 2014.
  (Source: NAPA)

- #1 Recycling Product in USA
Environmental/Economical Benefits

- Landfill Saving: 50 Million Cubic Yards each Year

- Cost Savings: $2.8 Billion

Source of Information: NAPA
RAP Usage in HMA/WMA

Numbers are in Million Tons

Year

2009 2010 2011 2012 2013 2014

RAP Usage in HMA/WMA, Million Tons

56.1 62.1 66.7 68.3 67.8 71.9

Source of Information: NAPA
RAP Usage in HMA/WMA Pennsylvania Data

Data: Courtesy of PennDOT
HMA/WMA with RAP
Pennsylvania Data

Data: Courtesy of PennDOT
HMA/WMA with RAP
Pennsylvania Data

Data: Courtesy of PennDOT
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Questions

- Is there full binder blending?
- How to find RAP aggregate gradation?
- How to find RAP binder content?
- Do we need to grade RAP binder and how?
- What is the best way to stockpile RAP?
- Do we need to fractionate RAP into sizes?
- How is application temperature affected by RAP usage?
- What percent of RAP to use in the mix?
Aggregate Gradation vs. Black Rock Gradation

**Extracted Aggregate**

**Black Rock**
RAP Binder Content

% Binder Content from Extractions

Scalped (Finer Portion)

As received

% Binder Content

Extractions

Using Solvent Extraction

Extraction 1, RAP as Received
Extraction 2, RAP as Received
Extraction 3, RAP after Scalped
Extraction 4, RAP after Scalped
Extraction 5, RAP after Scalped
Extraction 6, RAP after Scalped
RAP Binder Content from Burn-off

% Binder Content from Burn-Offs (After Cf)

- **As received**
- **Scalped (Finer Portion)**

Burn-Offs:
- Burn-off 1, RAP as Received
- Burn-off 2, RAP as Received
- Burn-off 3, RAP after Scalped
- Burn-off 4, RAP after Scalped
- Burn-off 5, RAP after Scalped
- Burn-off 6, RAP after Scalped

Using Ignition Oven
Process for RAP Binder Characterization

- Common practice for determination of RAP binder properties?
  - Binder Extraction
  - Binder Recovery
  - Binder Aging
  - Rheological Testing to Grade
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Main Source of Information for Changes

NCHRP Report 752, 2013,
Transportation Research Board,
National Research Council, Business
Office, 500 Fifth Street N.W.,
Washington D.C.  20001.

This publication is also available on
the Internet at

Affected PennDOT Publications regarding Changes in RAP/RAS Usage

- Bulletin 27 (Mix Design)
- Section 409 of Spec 408 (Construction Spec.)
- Publication 2 (POM)
RAP Mix Design

- Design Covered in Bulletin 27
- Details in Chapter H of Bulletin 27
RAP Mixes in PA

Current Protocols

- Tier 1 (Low RAP): Less than 15% RAP in Mix
- Tier 2 (High RAP): More than 15% RAP in Mix

Notes:

- The above are based on RAP content in the mix.
- Move is taking place to consider RAP binder content rather than the RAP content in the mix.
New Definitions for RAP Usage

- **New Term:** Reclaimed Asphalt Binder Ratio: **RBR**

- **Definition:**
  - **RBR** is defined as the amount of RAP and RAS asphalt binder in the mixture divided by the total asphalt binder in the mixture.
### Example Calculation for RBR

<table>
<thead>
<tr>
<th>Component</th>
<th>Content in Total Mix</th>
<th>Binder Content in the Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAP</td>
<td>20%</td>
<td>0.2 X 4.8 = 0.96%</td>
</tr>
<tr>
<td>RAS</td>
<td>5%</td>
<td>0.05 X 21.5 = 1.08%</td>
</tr>
</tbody>
</table>

**Mix total binder content: 6.6%**

**Total binder contribution from RAP and RAS:**

\[
0.96\% + 1.08\% = 2.04\%
\]

**Determine RBR:**

\[
RBR = \frac{2.04}{6.6} = 0.31
\]
## Proposed Mix Design Tiers

<table>
<thead>
<tr>
<th>Mix Design Tier</th>
<th>Pavement Course(s)</th>
<th>RBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Wearing and Binder</td>
<td>≤ 0.20</td>
</tr>
<tr>
<td></td>
<td>Base</td>
<td>≤ 0.25</td>
</tr>
<tr>
<td>II</td>
<td>Wearing and Binder</td>
<td>&gt; 0.20 and &lt; 0.25</td>
</tr>
<tr>
<td></td>
<td>Base</td>
<td>&gt; 0.25 and &lt; 0.30</td>
</tr>
<tr>
<td>III</td>
<td>Wearing and Binder</td>
<td>≥ 0.25</td>
</tr>
<tr>
<td></td>
<td>Base</td>
<td>≥ 0.30</td>
</tr>
</tbody>
</table>
How Does the Change Impact Existing Mix Designs?

Total of 4423 Mixes

<table>
<thead>
<tr>
<th>Tier</th>
<th>Old System</th>
<th>New System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 1</td>
<td>3429</td>
<td>1930</td>
</tr>
<tr>
<td>Tier 2</td>
<td>994</td>
<td>1926</td>
</tr>
<tr>
<td>Tier 3</td>
<td></td>
<td>567</td>
</tr>
</tbody>
</table>

Note: Tier 1 and Tier 2 mixes are significantly reduced in the new system compared to the old system. Tier 3 mixes are also reduced, but to a lesser extent.
Concern about RAP Aggregate $G_{sb}$

- How Do We Find RAP Aggregate Sp. Gr. ($G_{sb}$)?

- Two Ways Are Proposed:
  - 1. Do solvent extraction and run AASHTO T84 and T 85
  - 2. Backcalculate $G_{sb}$ using RAP Aggregate Effective Sp. Gr. and Binder Absorption
Concern about RAP Aggregate Binder Absorption

- How Do We Find RAP Aggregate Binder Absorption?
- Two Ways Are Proposed:
  - Assume absorption based on historical data
  - Use Lab Work
    1. Find Gsb of ignition oven extracted aggregate using T84 and T85.
    2. Blend aggregate from ignition oven with binder and find Gse
    3. Use results from steps 1 and 2 to find Gsb.
Work under Proposed New Tiers

- **Tier 1**
  - Sampling
  - Gradation of RAP Aggregate
  - Asphalt Content
    - Ignition or Solvent Extraction
  - RAP Aggregate Sp. Gr.
    - Several Options Exist
      - Sp. Gr. on aggregate from solvent extraction
      - Using Gmm, Gse, and binder absorption
Work under Proposed New Tiers

- Tier 2
  - Sampling – Split Samples needed from Stockpile
  - Gradation of RAP Aggregate
  - Consensus Properties of RAP Aggregate
  - Asphalt Content
    - Only through Solvent Extraction
  - RAP Aggregate Sp. Gr.
Work under Proposed New Tiers

- **Tier 3**
  - **Sampling** – Three Split Samples needed
    - One Set for Testing in an Independent Laboratory.
    - One Set for Mix Design
    - One Set for LTS
  - **Gradation of RAP Aggregate**
  - **Continuous Binder Grade by Independent Lab**
  - **Consensus Properties of RAP Aggregate**
  - **Asphalt Content**
    - Only through Solvent Extraction
  - **RAP Aggregate Sp. Gr.**
Work under Proposed New Tiers

- **Tier 3**
  - Determine Required Binder Grade
  - Performance Testing (Hamburg Wheel Tracking)

<table>
<thead>
<tr>
<th>Design ESALs (million)</th>
<th>Maximum Hamburg Rut Depth, (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 3</td>
<td>---</td>
</tr>
<tr>
<td>3 to &lt;10</td>
<td>10</td>
</tr>
<tr>
<td>10 to &lt;30</td>
<td>8</td>
</tr>
<tr>
<td>≥ 30</td>
<td>6</td>
</tr>
</tbody>
</table>
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QUESTIONS?

- Do We Need to Categorize/Classify RAP Stockpiles

- Do We Need to Tie Field Usage and RAP Content to RAP Categories?

- Do We Need to Have Limits on the RAP Content Depending on the Pavement Layers/Traffic?
**Example of RAP Stockpile Classification (Iowa DOT)**

<table>
<thead>
<tr>
<th>Classified RAP</th>
<th>Certified RAP</th>
<th>Unclassified RAP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Requirements</strong></td>
<td><strong>Requirements</strong></td>
<td><strong>Requirements</strong></td>
</tr>
<tr>
<td>- Documented source</td>
<td>- Undocumented Source</td>
<td>- Undocumented Source</td>
</tr>
<tr>
<td>- Stockpiled Separately</td>
<td>- Poor Stockpiling</td>
<td>- Unknown/Poor Aggregate</td>
</tr>
<tr>
<td>- Meets Quality Control</td>
<td>- Meets Quality Control</td>
<td>- Poor Stockpiling</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Allowable Usage</th>
<th>Allowable Usage</th>
<th>Allowable Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 15% weight in surface</td>
<td>- 10% surface ≤ 300K ESAL</td>
<td>- 0% surface for all ESAL</td>
</tr>
<tr>
<td>- Min. 70% virgin AC</td>
<td>- 20% Interm. ≤ 1M ESAL</td>
<td>- 10% Interm. ≤ 1M ESAL</td>
</tr>
<tr>
<td>- No limit in other layers</td>
<td>- 20% Base for all ESAL</td>
<td>- 10% Base for all ESAL</td>
</tr>
</tbody>
</table>

**Source:** Section 2303. Hot Mix Asphalt Mixtures. Iowa DOT Standard Specifications
## Example of RAP Stockpile Classification (Illinois DOT)

<table>
<thead>
<tr>
<th>Fractionated RAP (FRAP)</th>
<th>Homogenous RAP</th>
<th>Conglomerate RAP</th>
<th>Non-Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Requirements</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- May represent more than one aggregate type or quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- At least C quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Min. two size fractions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 100% pass 1.5, 3/4, or 1/2 inches</td>
<td><strong>Requirements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Same aggregate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- At least C quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Similar gradation/AC</td>
<td><strong>Requirements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- May represent more than one aggregate type or quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Unknown/Poor Aggregate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Requirements</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- RAP stockpiles that do not meet the requirements of the stockpile categories</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# RAP/RAS Maximum Asphalt Binder Replacement (ABR) Percentage (Illinois DOT)

<table>
<thead>
<tr>
<th>HMA Mixtures</th>
<th>RAP/RAS Maximum ABR %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Binder/Leveling</td>
</tr>
<tr>
<td>Ndesign</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>70</td>
<td>15</td>
</tr>
<tr>
<td>90</td>
<td>10</td>
</tr>
</tbody>
</table>
FRAP/RAS Max. Asphalt Binder Replacement (ABR) Percentage (Illinois DOT)

<table>
<thead>
<tr>
<th>HMA Mixtures</th>
<th>Ndesign</th>
<th>Binder/Leveling Binder</th>
<th>Surface</th>
<th>Polymer Modified</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
<td>50</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>40</td>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>40</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>40</td>
<td>30</td>
<td>10</td>
</tr>
</tbody>
</table>
RAP in Construction

- Specs covered in Section 409

- Minimum QC requirements covered in the Project Office Manual (Pub 2)
Attention to RAP Quality

- Reference Publications:
  - Publication 2, Project Office Manual.

- Distinguish between
  - Clean RAP: Free of subbase, dirt, soil, …
  - Contaminated RAP: mixed with subbase, soil, …
Where to Use Clean RAP:

- Exclusively for paving roadways or shoulders
- Don’t use for shoulder back-up and fill activities

Where to Use Contaminated RAP:

- Shoulder back up and/or stabilization
Change from %RAP to %RBR

- **Current:** Special Consideration when 15% < RAP Usage < 35%
- **Proposed:** Special Consideration when RBR > 0.20 for Wearing/Binder or RBR > 0.25 for Base Mixes
- Follow **Minimum QC Requirements** for RAP Stockpiles:
  - Incoming RAP (Raw RAP)
  - Processed RAP
RAP Stockpile Preparation

- for Processed RAP
  - Level Pad (Follow Section 106.05 of Spec 408).
  - Max. Agg. Size of RAP ≤ NMAS
  - Sample every 1,000 tons during processing for asphalt content and gradation
  - Sample every 3,000 tons for Gmm, G_{se}, and G_{sb}
  - If RBR ≥ 0.25, then use PTM 702 for asphalt content
  - Ok. to use PTM 757 if correlation factor is established.
  - Determine average and std. dev. of 10 samples
  - Baseline std. dev. shall meet Spec 409 Table B-1
Could We Add Mat’l to Stockpile?

- Yes if
  - Take Samples every 1,000 tons
  - Determine A New Standard Deviation
  - Ensure the New Standard Deviation meets specification limits
What Size of Stockpile? And Should It Be Covered?

- Ensure proper drainage of stockpile.
- Place in shelter with open ends.
- Use conical stockpile to naturally drain water.
- Avoid heavy equipment on the top of RAP stockpile.
- Limit the height to 20 feet to reduce potential for self-consolidation.
Should We Fractionate RAP?

- Recommended for High RAP Mixes
  - Pros
    - Flexibility in meeting Mix Design requirements
    - Better control of gradation and less variability
    - Isolate the RAP with high fine content
  - Cons
    - Increases the cost
    - Requires more space
    - Increases the number of bins needed
Should We Combine RAP from Multiple Sources?

- If large quantity from one project available, better to use a designated stockpile, i.e. single source stockpile
  - Less crushing needed, and possibly less cost
  - Some projects only allow RAP from the same road

- If combining multiple sources
  - Ensure consistency and uniformity
How Much RAP Crushing is Ok?

- Crushing generates fines, and should be minimized.
- More crushing also generates more uncoated surface.
- Use screening to remove large particles from millings before crushing.
Variability in RAP Stockpiles and Establishing Acceptable Tolerances
Looking at RAP Variability

- Data from Several Studies Considered:
  1. PennDOT Data of Six Stockpiles (PennDOT)
  2. TTI Study of 2009 (Zhou et al., 2010)
  3. FHWA Report of 1984 (NCHRP 752)
  4. NCAT Study of Georgia Mixes (NCHRP 752)
  5. ICAR Study of Florida (NCHRP 752)
  6. Texas High RAP Study (Solaimanian et al., 1995)
  8. Mix Design Manual (NCHRP 673 by AAT)
Variability in Asphalt Content

Asphalt Content

<table>
<thead>
<tr>
<th>Study Number</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Min.
- Max.
Variability in Mat’l Passing #200

Pass #200 Sieve

Study Number

<table>
<thead>
<tr>
<th>Study Number</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>4</td>
<td>1.5</td>
<td>2.0</td>
</tr>
<tr>
<td>5</td>
<td>2.0</td>
<td>2.5</td>
</tr>
<tr>
<td>6</td>
<td>1.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Variability in Mat’l Passing #8

Pass #8 Sieve

<table>
<thead>
<tr>
<th>Study Number</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>6.0</td>
</tr>
<tr>
<td>4</td>
<td>5.0</td>
</tr>
<tr>
<td>5</td>
<td>5.0</td>
</tr>
<tr>
<td>6</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Min. and Max.
Figure 9-4. Maximum RAP content as a function of standard deviation for asphalt binder content. For $n = 5$ Samples from a single RAP stockpile.
Figure 9-3. Maximum RAP content as a function of standard deviation for aggregate percent passing. For n = 5 Samples from a single RAP stockpile.
Figure 9-6. Maximum RAP content as a function of average standard deviation for asphalt binder content. For \( n = 5 \) Samples from a blend of RAP stockpiles, and no stockpile making up more than 70% of the RAP blend.
Figure 9-5. Maximum RAP content as a function of average standard deviation for aggregate percent passing. For \( n = 5 \) Samples from a blend of RAP stockpiles, and no stockpile making up more than 70% of the RAP blend.
Data from Two More Sources

Asphalt Content

Data Source #7: Mix Design Tool
Data Source #8: Mix Design Tool

Std. Dev.

0.00 0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45

Fine Fractionated Stockpiles
Coarse

Multiple RAP Stockpile
Single RAP Stockpile

RBR = 0.30
Data from Two More Sources

Passing #200 Sieve

- Fractionated Stockpiles
- Single RAP Stockpile
- Multiple RAP Stockpile

Data Source #7: Mix Design Tool

RBR = 0.30
Data from Two More Sources

Passing #8 Sieve

<table>
<thead>
<tr>
<th>Fractionated Stockpiles</th>
<th>Single RAP Stockpile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine</td>
<td>Data Source #8: Mix Design Tool</td>
</tr>
<tr>
<td>Coarse</td>
<td>RBR = 0.30</td>
</tr>
</tbody>
</table>

Multiple RAP Stockpile

Std. Dev.

Data Source #7

58
## Proposed Table for Standard Deviation of RAP Asphalt Content and RAP Gradation

<table>
<thead>
<tr>
<th>Mixture NMAS</th>
<th>RBR</th>
<th>Max. Std. Dev. for Asphalt Content</th>
<th>Max. Std. Dev. for Percent Passing No. 200 Sieve</th>
<th>Max. Std. Dev. for Percent Passing All Other Sieves</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>≤ 19 mm</strong></td>
<td>RBR ≤ 0.20</td>
<td>0.6</td>
<td>2.5</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>RBR &gt; 0.20</td>
<td>0.5</td>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>and &lt; 0.25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RBR ≥ 0.25</td>
<td>0.4</td>
<td>1.5</td>
<td>3.0</td>
</tr>
<tr>
<td><strong>≥ 25 mm</strong></td>
<td>RBR ≤ 0.25</td>
<td>0.6</td>
<td>2.5</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>RBR &gt; 0.25</td>
<td>0.5</td>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>and &lt; 0.30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RBR ≥ 0.30</td>
<td>0.4</td>
<td>1.5</td>
<td>3.0</td>
</tr>
</tbody>
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Availability of Recycled Asphalt Shingles (RAS)

- Over 10 million tons of RAS annually
- Almost 90% Post-Consumer Tear Off (RAS-TO)
- Waste from Production (RAS-MW)
RAS Usage

- Approximately 2 million tons of RAS placed in Pavements in 2014.

(Source: NAPA)
RAS Usage in HMA/WMA

Numbers are in Million Tons

Source of Information: NAPA
Shingle Composition

Surface granules (ceramic)  
(UV, fire Protection, Color)

Base material  
(fiberglass reinforcing mat or organic felt)

Asphalt coating  
(with mineral stabilizers  
(lime dust, 70% passing #200 sieve))
Shingle Composition

Organic Based Shingles

- Asphalt: 30-36%
- Felt: 2-15%
- Mineral Filler: 8-40%
- Mineral Granules: 20-38%

- Heavier
- More Expensive
- Higher Wind Resistance

An Example of Composition
Shingle Composition
Fiberglass Based Shingles

- Asphalt: 18-22%
- Felt: 2-15%
- Mineral Filler: 8-40%
- Mineral Granules: 20-38%

- Lighter
- Cheaper
Stockpiling of Processed/Shredded RAS

- Remove all deleterious material including nails
- Process and grind shingles before use
  - AASHTO PP 078: grind to 3/8 inch
- Blend with fine virgin aggregate at 50-50 blend
  - Minimizes agglomeration
- Avoid direct sunlight and store under roof
  - Minimizes agglomeration
Ground Shingles

- Coarse
- Fine
How Much of the Mix is RAS?

EXAMPLE

- RAS binder content: 18%
- Target RBR from RAS: 0.17
- Target binder content of the mixture: 6.5%
- RAS binder needed to deliver target RBR from RAS: 0.17 \times 6.5 = 1.11\% of the mixture
- Amount of RAS needed as a percent of the mix: \frac{1.11}{18} \times 100 = 6.2\%
- So at 50:50 blend, the RAS-fine aggregate blend will be 12.4\% of the weight of the mixture (i.e. 2 \times 6.2 = 12.4).
Process for RAS Binder Characterization

- What is best practice for determination of RAS binder properties?
  - Binder Extraction
  - Binder Recovery
  - Rheological Testing to Grade
Binder Recovered from RAS
Too Stiff to Pour

375°F
Binder Recovered from RAS
Right after RTFO aging: binder not covering the entire bottle
Blend before Recovery of Binder

- Extract RAS Binder:
  - Alternative 1: Blend with virgin mix before extraction.
  - Alternative 2: Blend with virgin binder after extraction
    - Use a Soft Binder Such as PG 52 or 58
    - Blend at Different Proportions of RAS Binder

- Recover the blended Binder
Limits on RAS Content in the Mix

- RBR Contribution from RAS
  - $\leq 0.20$ for wearing/binder courses
  - $\leq 0.25$ for base course
Resources for RAS in Asphalt

- **AASHTO MP023-15:**
  Standard Specification for Reclaimed Asphalt Shingles for Use in Asphalt Mixtures

- **AASHTO PP078-14:**
  Standard Practice for Design Considerations When Using Reclaimed Asphalt Shingles (RAS) in Asphalt Mixtures
Resources for RAS in Asphalt

- NAPA IS-136
Guidelines for the Use of Reclaimed Asphalt Shingles in Asphalt Pavements (October 2009)
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Disclaimer

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Thank You!