ACHIEVING 50% RAP

Properties of Plant Mixes Containing High Asphalt Binder Replacement

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How Much RAP Can Be Used?
Considerations

- Can We
  - Produce Quality Product
  - Put Through Mixing Plant
  - Place The Mix
  - Compaction It
Scope

- Trials up to 70% RAP
- Produce and Place on Low Volume Road
  - Measure quality
  - Measure properties
Indiana DOT

Virgin Binder Grade Asphalt Binder Replacement
- 0 to 25% - no change
- 25 to 40% - down one grade, high and low

Maximum Replacement
- 25% shingle binder
- 40% RAP or Shingle plus RAP
Recycled Asphalt Binder Sources

- RAP: 4 – 5%
- Fine RAP: 5 – 7%
- Coarse RAP: 2 – 3%
- Manufacturer Scrap: 18 – 22%
- Post Consumer: 22 – 25%
Phase One

- Counter flow drum mix plant
- Embedded burner
  - RAP inlet capacity
  - Mixing chamber volume
- Water injection
  - Mixing aid

- RAP
  - 50%
  - 60%
  - 70%

- Post Consumer Shingles
  - 0%
  - 3%
<table>
<thead>
<tr>
<th>Mix</th>
<th>Size</th>
<th>RAP</th>
<th>RAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25.0</td>
<td>70</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>25.0</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>12.5</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>12.5</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>12.5</td>
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</tr>
<tr>
<td>6</td>
<td>12.5</td>
<td>50</td>
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</tbody>
</table>
Discharge Temperature
Aggregate Temperature

![Bar chart showing aggregate temperature in degrees Fahrenheit for different percentages.](chart.png)
Drum Temperature

Drum Shell Temperature, °F

70%  60%  60%  50%  50%  50%
Baghouse Exhaust Temperature
60% RAP
70% RAP
Decisions from Phase One

- Maximum 50% RAP
- Drum Shell Temperature
  - max 800°F
- Aggregate Temperature
  - max 700°F
- Exhaust Temperature
  - min 220°F
  - max 400°F
Phase Two Experiment

- Counterflow drum mix plant
  - With mixing drum
- 19 mm NMPS
  - 1 inch crushed gravel
  - ½ inch crushed limestone
  - ½ inch pea gravel
  - Natural sand
RAP Feeder
Mixer Drum
Counter Flow Drum
1 inch Crushed Gravel
½ inch Crushed Limestone
½ inch Pea Gravel
Phase Two Recycled Materials

- Fine RAP
- Coarse RAP
- Post Consumer Shingles
Post Consumer Shingles
Coarse RAP (1/2 to 1 inch)
Coarse RAP (1/2 to 1 inch)
Fine RAP (minus 1/2 inch)
Fine RAP (minus 1/2 inch)
Recycled Components

<table>
<thead>
<tr>
<th></th>
<th>Coarse</th>
<th>Fine</th>
<th>Shingles</th>
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</thead>
<tbody>
<tr>
<td>Mix 9</td>
<td>28</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Mix 10</td>
<td>28</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Mix 11</td>
<td>28</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Mix 12</td>
<td>28</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Mix 13</td>
<td>28</td>
<td>13</td>
<td>4</td>
</tr>
</tbody>
</table>
Asphalt Binder Replacement

Mix 9 64-22
Mix 10 52-28
Mix 11 52-28
Mix 12 52-28
Mix 13 64-22
Discharge Temperature

- Mix 9
- Mix 10
- Mix 11
- Mix 12
- Mix 13
Asphalt Binder Grade

Temperature

Mix 9 64-22
Mix 10 52-28
Mix 11 52-28
Mix 12 52-28
Mix 13 64-22
Cantabro Loss Test (Durability)

- LA Abrasion Test Machine
- Test without Steel Balls
Cantabro Test (Durability)

- Cantabro Test (Durability)
- Asphalt Binder Replacement, %
- Cantabro Loss, %
- Average High and Low Temperature Grade, °C
- Cantabro Loss, %

Graphs showing the relationship between asphalt binder replacement, cantabro loss, and average high and low temperature grade.
Blending Analysis

- M323 to calculate the limiting amount

\[
\% RAP = \frac{T_{\text{blend}} - T_{\text{virgin}}}{T_{\text{RAP}} - T_{\text{virgin}}}
\]

- Predicted Temperature of Blend

\[
T_{\text{blend}} = T_{\text{virgin}} + \% RAP (T_{\text{RAP}} - T_{\text{Virgin}})
\]
Calculated vs Measured

Calculated High Grade, C vs Measured High Grade, C

Calculated Low Grade, C vs Measured Low Grade, C
Placement

County Road resurfacing
- 2 inches base
- 19.0-mm mix
- 1.5 inches surface

Placed
- May 31, 2011
- June 1, 2011
Construction Conditions

Haul time
● 30 minutes approx

Weather
● 85 °F
● Sunny

Paver
● Roadtec RP150
  ● 50 to 60 ft/min

Compactor
● Bomag BW266
  ● 3 vibratory passes, 1 static
Uncompacted Mat
Compacted Mat
## Quantity Placed

<table>
<thead>
<tr>
<th>Mix Number</th>
<th>Tons</th>
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<tbody>
<tr>
<td>9</td>
<td>300</td>
</tr>
<tr>
<td>10</td>
<td>150</td>
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<tr>
<td>11</td>
<td>300</td>
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<tr>
<td>12</td>
<td>125</td>
</tr>
<tr>
<td>13</td>
<td>125</td>
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Paving Crew Observations

- Flows through paver
- Mat lays well
  - (little handwork in this application)
- Compacts well
  - No tenderness
Conclusions
Phase 1 Conclusions

- 50% RAP is reasonable maximum
  - With conventional counterflow drum

- With 60 and 70% RAP
  - Uncoated particles present
  - Aggregate temperature too high
    - Burns the asphalt binder
  - Drum temperature too high
    - Metal softens and wears
Phase 1 Conclusions (cont’d)

Criteria selected for

- Drum shell temperature
  - 800°F maximum
- Virgin aggregate temperature
  - 700°F maximum
- Bag house exhaust
  - 220°F minimum
  - 400°F maximum
Phase 2 Conclusions

Volumetric Properties Can Be Controlled
- With 50% RAP
- With 67% asphalt binder replacement

Durable Mixtures Can Be Produced
- With 67% asphalt binder replacement
  - 18% from RAS
  - 49% from RAP
Phase 2 Conclusions (cont’d)

- High Temperature Grade
  - Not well predicted with blending formula
  - Some under predicted
  - Some over predicted

- Low Temperature Grade
  - Consistently under predicted by blending formula
RAP and RAS
Green As The Wind
Thanks