ACHIEVING 50% RAP

Properties of Plant Mixes Containing High Asphalt Binder Replacement

Gerry Huber
Heritage Research Group
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%
## Phase One Mixes

<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>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>12.5</td>
<td>50</td>
<td>3</td>
</tr>
</tbody>
</table>
Discharge Temperature

- 70%
- 60%
- 60%
- 50%
- 50%
- 50%
Aggregate Temperature

The graph shows the aggregate temperature in degrees Fahrenheit (F) for different percentages. The percentages are 70%, 60%, 60%, 50%, 50%, and 50%. The temperature values range from 300 to 900 degrees Fahrenheit, with the highest temperature reaching around 800 degrees Fahrenheit at 60%.
Drum Temperature

Drum Shell Temperature, °F

70%  60%  60%  50%  50%  50%
Baghouse Exhaust Temperature

![Bar graph showing Baghouse Exhaust Temperature at different percentages. The graph indicates temperature in Fahrenheit (F).]
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
½ inch Crushed Limestone
½ inch Pea Gravel
Natural Sand
Phase Two Recycled Materials

- Fine RAP
- Coarse RAP
- Post Consumer Shingles
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>Mix</th>
<th>Coarse</th>
<th>Fine</th>
<th>Shingles</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>64-22</td>
<td>52-28</td>
<td>52-28</td>
</tr>
<tr>
<td>10</td>
<td>52-28</td>
<td>52-28</td>
<td>52-28</td>
</tr>
<tr>
<td>11</td>
<td>52-28</td>
<td>52-28</td>
<td>52-28</td>
</tr>
<tr>
<td>12</td>
<td>52-28</td>
<td></td>
<td>52-28</td>
</tr>
<tr>
<td>13</td>
<td>64-22</td>
<td></td>
<td>52-28</td>
</tr>
</tbody>
</table>
Discharge Temperature

- Mix 9
- Mix 10
- Mix 11
- Mix 12
- Mix 13
Volumetric Properties

Mix 9: 64-22
Mix 10: 52-28
Mix 11: 52-28
Mix 12: 52-28
Mix 13: 64-22
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)

![Graph showing Cantabro Test results](image)

- **Asphalt Binder Replacement, %** vs. **Cantabro Loss, %**
- **Average High and Low Temperature Grade, °C** vs. **Cantabro Loss, %**
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
Laydown Operation
Uncompacted Mat
Compaction
## Quantity Placed

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