HIGH RAP MIXTURES

Properties of Plant Mixes Containing High Asphalt Binder Replacement

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Objective

How much RAP can be used?

Considerations
- Quality product
- Mixing plant
- Placement
- Compaction
Is RAP Available?
Scope

- How much RAP can go through a plant?
  - Trials up to 70%

- Produce and Place on Low Volume Road
  - Measure quality
  - Measure properties
Asphalt Binder Replacement

\[
\% \text{Asphalt binder replacement} = \frac{\% \text{recycled binder}}{\% \text{total binder}}
\]

- RAP
- Coarse RAP
- Fine RAP
- Shingles
Typical Asphalt Binder Content

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

- Field Experiment
- Focus on High Binder Replacement
  - RAP
  - Post Consumer Asphalt Shingles
Phase One

- RAP
  - 50%
  - 60%
  - 70%
- Post Consumer Shingles
  - 0%
  - 3%
- Counter flow drum mix plant
- Embedded burner
  - RAP inlet capacity
  - Mixing chamber volume
- Water injection
  - Mixing aid
## Phase One Mixes

<table>
<thead>
<tr>
<th>Mix</th>
<th>Size</th>
<th>RAP</th>
<th>RAS</th>
<th>AC</th>
<th>BR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25.0</td>
<td>70</td>
<td>0</td>
<td>6.0</td>
<td>33</td>
</tr>
<tr>
<td>2</td>
<td>25.0</td>
<td>60</td>
<td>0</td>
<td>4.1</td>
<td>41</td>
</tr>
<tr>
<td>3</td>
<td>12.5</td>
<td>60</td>
<td>0</td>
<td>5.6</td>
<td>(47)</td>
</tr>
<tr>
<td>4</td>
<td>12.5</td>
<td>50</td>
<td>3</td>
<td>5.6</td>
<td>29</td>
</tr>
<tr>
<td>5</td>
<td>12.5</td>
<td>50</td>
<td>3</td>
<td>7.1</td>
<td>31</td>
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<tr>
<td>6</td>
<td>12.5</td>
<td>50</td>
<td>3</td>
<td>6.6</td>
<td>33</td>
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</tbody>
</table>
Discharge Temperature

![Bar chart showing discharge temperature at different percentages: 70%, 60%, 60%, 50%, 50%, 50%. The y-axis represents discharge temperature in °F, with values ranging from 0 to 350. Each bar represents a percentage level, with the discharge temperature increasing as the percentage decreases.](image-url)
Aggregate Temperature

![Bar chart showing aggregate temperature in degrees Fahrenheit (F) with corresponding percentages. The chart indicates a significant increase in temperature at 60% with values at 700°F, while other percentages show a steady temperature of around 500°F.]
Drum Temperature

Drum Shell Temperature, F

<table>
<thead>
<tr>
<th>Drum Shell Temperature, F</th>
<th>70%</th>
<th>60%</th>
<th>60%</th>
<th>50%</th>
<th>50%</th>
<th>50%</th>
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<tbody>
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<td>800</td>
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<td>850</td>
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<td>900</td>
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<td>950</td>
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<td>1000</td>
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</tbody>
</table>
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 390 F
Phase Two Experiment

- Counterflow drum mix plant
  - With mixing drum
- 19 mm NMPS
  - 1.0 in crushed gravel
  - $\frac{1}{2}$ in crushed limestone
  - $\frac{1}{2}$ in pea gravel
  - Natural sand
1.0 inch Crushed Gravel
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 (½ to 1 inch)
Coarse RAP (½ to 1 inch)
Fine RAP (minus ½ inch)
Fine RAP (minus $\frac{1}{2}$ inch)
Recycled Components

Mix 9
- Coarse RAP: 64%
- Fine RAP: 22%
- Shingles: 0%

Mix 10
- Coarse RAP: 52%
- Fine RAP: 28%
- Shingles: 0%

Mix 11
- Coarse RAP: 52%
- Fine RAP: 28%
- Shingles: 0%

Mix 12
- Coarse RAP: 52%
- Fine RAP: 28%
- Shingles: 0%

Mix 13
- Coarse RAP: 64%
- Fine RAP: 22%
- Shingles: 0%
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
Volumetric Properties

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

Asphalt Content
Air Voids
Asphalt Binder Grade

Performance Grade

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

\[
T_{\text{blend}} = T_{\text{virgin}} + \% RAP (T_{\text{RAP}} - T_{\text{Virgin}})
\]
Blending Analysis

For multiple recycled materials

\[ T_{blend} = \frac{\%RAP_F \times T_{RAP_F} + \%RAP_C \times T_{RAP_C} + \%RAS \times T_{RAS} + \%Virgin \times T_{Virgin}}{\sum(\%RAP_F + \%RAP_C + \%RAS + \%Virgin)} \]
Calculated vs Measured

Calculated High Grade, C vs Measured High Grade, C

Calculated Low Grade, C vs Measured Low Grade, C
Cantabro Loss Test (Durability)

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

Asphalt Binder Replacement, %

Cantabro Loss, %

Average Temperature Grade, °C

Cantabro Loss, %
Placement

- County Road resurfacing
  - 50 mm base
    - 19.0-mm mix
  - 38 mm surface
- Placed
  - May 31, 2011
  - June 1, 2011
Construction Conditions

- **Haul time**
  - 30 minutes approx

- **Weather**
  - 85F sunny

- **Paver**
  - Roadtec RP150
    - 50 to 60 ft/min

- **Compactor**
  - Bomag BW266
    - 3 vibratory passes, 1 static
Laydown Operation
Compaction
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
- Criteria selected for
  - Drum shell temperature
    - 800°F maximum
  - Virgin aggregate temperature
    - 700°F maximum
  - Bag house exhaust
    - 220°F minimum
    - 390°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
RAP and RAS
Green Asphalt

Thanks
RAP in HMA

- Black Rock?
  - Limestone
    - 3 million – 12 million psi
  - Aged Asphalt Binder
    - 150,000 psi glassy stiffness
    - 1,500 psi (50F)

- Homogenous Blending?
  - No

- Partial Blending??
Partial Blending

Composite Material
- Virgin Binder
- Reclaimed Binder