Recycled Asphalt Pavement

What’s Going On In There?

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RAP Use

Use Increasing
20.4% (2014)
AASHTO STANDARD

- M323 Superpave Volumetric Mix Design
- Changes
  - Dec 2014
M323 Terminology

- **Percent RAP**
  - Reclaimed Asphalt Pavement Binder Ratio (RAPBR)

\[ RAPBR = \frac{Pb_{RAP} \times PRAP}{Pb_{total}} \]
Indiana DOT

- Virgin Binder Graded Based on Asphalt Binder Replacement (RAP or Shingles)
  - 0 to 25%
  - 25 to 40%
- Based on properties of
  - RAP binder
  - New binder
Properties of RAP

- Sample RAP Stockpiles
- Recover Asphalt Binder
  - Measure Grade
- Sample New Asphalt Binder
  - Measure Grade
    - PG 64-22
    - PG 58-28
Location of RAP Stockpiles Sampled

33 RAP Stockpiles
RAP
High Temperature Properties

mean = 90
s2 = 5.0

Frequency
RAP

Low Temperature Properties

![Graph showing frequency distribution of low temperatures with mean = -11 and s2 = 3.1.](image)
PG64-22
Low Temperature Properties

![Bar Chart]
PG58-28
Low Temperature Properties

![Frequency Distribution Graph]

-28.7
Maximum RAP (PG64-22)

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

\[ = \frac{-22.0 - (-25.1)}{-11.1 - (-25.1)} = 23\% \]
Maximum RAP (PG58-28)

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

= \frac{-22.0 - (-28.7)}{-11.1 - (-28.7)}

= 38\%
INDOT Binder Grade Selection

- Virgin Binder Grade

<table>
<thead>
<tr>
<th>No Change in Grade</th>
<th>&lt; 25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Grade Softer</td>
<td>&gt;= 25%</td>
</tr>
</tbody>
</table>

Mixing???
Diffusion

Virgin asphalt acts as a ‘lubricant’

Pavel Kriz
Esso Canada
Diffusion

Happens with Time

\[ \eta^*, \text{ Pa.s} \]

Diffusion Time, s

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Esso Canada
Effect of Temperature on Diffusion

Lower Temperature Slower Blending

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Esso Canada

Time to equilibrium

2 hours  25 hours  6 hours
TU Delft Research

Looking at Blending Zone

RAP-binder

Virgin bitumen

12mm

130°C, 40 secs

RAP-binder

Virgin bitumen

Blended bitumen
Mixing

- Occurs by Diffusion
Diffusion In Practice

Blending

Time, days

100 days

mix

transport

silo

paving

service

10^{-4} 10^{-2} 10^{0} 10^{2} 10^{4}

0.5 0.6 0.7 0.8 0.9 1

HMA

WMA

Pavel Kriz
Esso Canada
Investigation of Low and High Temperature Properties of Plant-Produced RAP Mixtures

North Central Superpave Center
# Design and Produce Mix

<table>
<thead>
<tr>
<th>Binder Grade</th>
<th>0%</th>
<th>15%</th>
<th>25%</th>
<th>40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 64-22</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Mix A</td>
<td></td>
<td>Mix B</td>
<td>Mix C</td>
<td>Mix D</td>
</tr>
<tr>
<td>PG 58-28</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Mix E</td>
<td></td>
<td></td>
<td>Mix F</td>
<td></td>
</tr>
</tbody>
</table>
Hot Mix Plant
Mix Stiffness (PG 64-22)

![Graph showing Mix Stiffness for different mixes and reduced frequencies.](image)

- Mix4-A (0% RAP)
- Mix4-B (15% RAP)
- Mix4-C (25% RAP)
- Mix4-D (40% RAP)
Mix Stiffness (PG 64-22)
Same Mix (PG58-28)

Control versus PG58-28

Log $|E^*|$, MPa vs. Log Reduced Frequency, Hz

- MixA (0% RAP)
- MixE (25% RAP)
- MixF (40% RAP)
Same Mix (PG58-28)

Control versus PG58-28

Log $|E^*|$, MPa vs. Log Reduced Frequency, Hz

MixA (0% RAP)
MixE (25% RAP)
MixF (40% RAP)
Cracking Temperature

Example 1

![Graph showing cracking temperature and strength for different samples (PB-A to PB-F). The x-axis represents samples, while the y-axis represents temperature. The graph indicates the cracking temperature and strength for each sample.]
Cracking Temperature
Example 2

![Graph showing cracking temperature and strength for different mixes](image-url)
Where is the Limit?

- Hot recycling
  - How much can be put through a plant?

- Issues
  - Virgin Aggregate temperature
  - Drum temperature
  - Baghouse temperature
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%
Mix Experiment

- Counterflow drum mix plant
  - With mixing drum
- 19 mm NMPS
  - 25 mm crushed gravel
  - 12.5 mm crushed limestone
  - 12.5 mm pea gravel
  - Natural sand
Recycled Materials

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

![Bar chart showing recycled components for different mixes.

- Mix 9: 64-22 (Coarse 0, Fine 15, Shingles 22)
- Mix 10: 52-28 (Coarse 25, Fine 25, Shingles 0)
- Mix 11: 52-28 (Coarse 25, Fine 25, Shingles 0)
- Mix 12: 52-28 (Coarse 25, Fine 25, Shingles 0)
- Mix 13: 64-22 (Coarse 0, Fine 15, Shingles 22)
Asphalt Binder Replacement

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

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

<table>
<thead>
<tr>
<th>Temp F</th>
<th>60%</th>
<th>50%</th>
<th>50%</th>
<th>50%</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>840</td>
<td>705</td>
<td>710</td>
<td>712</td>
</tr>
</tbody>
</table>
Drum Temperature

Drum Shell Temperature, °C

- 60%
- 60%
- 50%
- 50%
- 50%
Drum Mix Plant Limits

- Maximum 50% RAP
- Drum Shell Temperature
  - max 800 F
- Aggregate Temperature
  - max 700 F
- Exhaust Temperature
  - min 220 F
  - max 400 F
Dutch Experience

Sustainability high on the political agenda

- Small but densely populated country
- We are a prosperous country
- Competition between nature, agriculture, housing, transport, recreation, industry, excavation, landfill et cetera for scarce area of land
- Recycling, sustainable development encouraged by society
- Recycling is being made economic feasible
Contractor Visits

Trials at 90%
ASFALTGRANULAAT 0/11

0/11
RAP Use in Indiana

- Percent limits based on
  - Laboratory research
  - Properties of Plant mix
  - Properties of new asphalt binder
  - Properties of reclaimed asphalt binder
  - Percent reclaimed asphalt binder
So That's What's Going On In There

RAP

Thank You