Characterization of RAP in Indiana: Changing INDOT Specification for RAP

Matthew Beeson, PE
Asphalt Engineer, INDOT
Objective

- Determine how much RAP can be used while maintaining specified low temperature grade
  - Determine an average value for PG grade of RAP Binder
  - Determine average PG grade of virgin binders
  - Calculate maximum allowable blend percentage of recycled binder and virgin binder
Background

- Indiana is a non-PG Plus state
- Base grade is PG 64-22 statewide
- PG 70-22 and PG 76-22 based on traffic
- PG 58-28, 64-28, and 70-28 used with higher levels of RAP

Prior to 2010

- Up to 15% RAP with no grade bump
- Up to 25% RAP with one grade bump
Indiana RAP PG Grading

- Characterize RAP binders statewide

- RAP samples obtained in 2007 from 33 HMA Plants
  - Indiana has about 100 Certified HMA Plants
  - Producers are not required to separate RAP by source
RAP Binder Recovery

- RAP Binder extracted by AASHTO T 164 Method A
  - Centrifuge
  - Trichloroethylene solvent

- RAP Binder recovered by AASHTO T 170 (Now AASHTO R 59)
RAP Binder Testing

- Recovered Binder Testing
  - AASHTO T 315 – DSR
    - Material tested at 70°C and every 6°C thereafter until $G^*/\sin \delta$ less than or equal to 2.20
  - AASHTO T 313 – BBR
    - Material tested at -12°C, -6°C, and 0°C
RAP Binder Testing

- High Temperature PG grade
  - Plot $\log \frac{G^*}{\sin \delta}$ vs. temperature

- Low Temperature PG grade
  - Plot $\log m$-value vs. temperature
RAP Binder Testing

- High Temperature PG grade
  - Using Equation of linear trend line
  - Pass/Fail temperature when G*/sin δ equals 2.20 (log value 0.342)

\[ y = -0.0566x + 5.4029 \]
\[ R^2 = 0.9998 \]
RAP Binder Testing

- Process repeated for Low Temperature Grade
  - Pass/Fail temperature when m-value equals 0.300 (log value -0.523)

![Graph showing the relationship between log m-value and temperature. The equation is given as $y = 0.0129x - 0.5009$ with $R^2 = 0.9965$.](image)
### Average RAP Binder Properties

<table>
<thead>
<tr>
<th></th>
<th>High Temperature</th>
<th>Low Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>90.2</td>
<td>-11.1</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>5.02</td>
<td>3.11</td>
</tr>
<tr>
<td>Minimum</td>
<td>83.0</td>
<td>-21.3</td>
</tr>
<tr>
<td>Maximum</td>
<td>104.0</td>
<td>-0.8</td>
</tr>
</tbody>
</table>

- **PG 90-11**
- No statistical difference found between different regions of Indiana
Virgin Asphalt Binder Data

- Determine average True Grade of virgin binders
- QA Acceptance PG Binder test results
  - Collected from 2008 testing at INDOT’s Central Lab
  - Represents all major PG Suppliers in state

RTFO DSR
- $G^*/\sin \delta$

RTFO/PAV BBR
- m-value
Virgin Asphalt Binder Data

- Acceptance testing only performed at expected PG temperature

- We borrowed the average slope from RAP Grading analysis
  - Line plotted through the acceptance point
  - Assumed the slope of this line (temperature susceptibility) remains unchanged from virgin to RAP binders
Example log (G*/sin δ) vs. Temperature
Example log (m-value) vs. Temperature

![Graph showing the relationship between log (m-value) and temperature. The graph displays a linear trend with temperature in °C on the x-axis and log (m-value) on the y-axis. The data points range from -30°C to -15°C. The slope of the line indicates a decreasing log (m-value) with increasing temperature.]
**Virgin Asphalt Binder Data**

- Average high and low temperature PG Grades

<table>
<thead>
<tr>
<th>Specified Binder Grade</th>
<th>PG -28 Grades</th>
<th></th>
<th></th>
<th></th>
<th>Specified Binder Grade</th>
<th>PG -22 Grades</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High Temp</td>
<td>Low Temp</td>
<td></td>
<td></td>
<td></td>
<td>High Temp</td>
<td>Low Temp</td>
<td></td>
</tr>
<tr>
<td>PG 58-28</td>
<td>63.6</td>
<td>-28.8</td>
<td></td>
<td></td>
<td>PG 64-22</td>
<td>67.6</td>
<td>-24.6</td>
<td></td>
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<tr>
<td>PG 64-28</td>
<td>68.9</td>
<td>-29.6</td>
<td></td>
<td></td>
<td>PG 70-22</td>
<td>72.5</td>
<td>-25.1</td>
<td></td>
</tr>
<tr>
<td>PG 70-28</td>
<td>70.4</td>
<td>-29.3</td>
<td></td>
<td></td>
<td>PG 76-22</td>
<td>77.8</td>
<td>-25.8</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>n/a</td>
<td>-28.7</td>
<td></td>
<td></td>
<td>Average</td>
<td>n/a</td>
<td>-25.1</td>
<td></td>
</tr>
</tbody>
</table>
Allowable Blend Percentage

- AASHTO M 323 appendix

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

- \% RAP – Percent binder replacement
- \(T_{\text{RAP}}\) – binder grade of RAP asphalt binder
- \(T_{\text{virgin}}\) – binder grade of virgin asphalt binder
- \(T_{\text{blend}}\) – binder grade of blended asphalt binder
Allowable Blend Percentage

- High Temperature Grade
  - High temperature PG grade of the RAP
    - Greater than target
  - High temperature PG grade of virgin binder
    - Greater than target

- Blend is always going to be greater than specified PG grade
Allowable Blend Percentage

- Low Temperature Grade
  - All blends targeting -22°C
- Using -22°C virgin binder
  \[
  \%
  \]

\[
%RAP = \frac{T_{blend} - T_{virgin}}{T_{RAP} - T_{virgin}} = \frac{-22.0 - (-25.1)}{-11.1 - (-25.1)} = 22.7% 
\]

- Using -28°C virgin binder
  \[
  \%
  \]

\[
%RAP = \frac{T_{blend} - T_{virgin}}{T_{RAP} - T_{virgin}} = \frac{-22.0 - (-28.7)}{-11.1 - (-28.7)} = 38.1% 
\]


Specification Change

- Based on our findings and the NCSC study
  - Up to 25% Binder Replacement allowed without a virgin PG grade change
  - 25% - 40% Binder Replacement allowed with high and low temperature PG grades reduced by one grade
  - Open Graded mixtures and high volume surface mixtures still limited to 25%
Specification Change

- A similar study can be completed in any state
- RAP Samples
- Virgin PG Binder samples
- Determine allowable blend percentage
Acknowledgements

- Michael Prather
  - INDOT
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Questions?

Matthew Beeson, P.E.
INDOT
Email: mbeeson@indot.in.gov
Phone: (317)610 – 7251 x 216