RAP in SMA

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Background

• MSHA and MAA RAP Task Force
  – How Can Overall RAP Usage be Increased?

• Use Low Percentage of RAP in Mixtures Where RAP is Not Permitted
  – SMA
  – Mixtures Requiring PMA
Concerns

• Effect of RAP on PMA
• Effect of RAP on Mixture Performance
• Constructability
2007 Field Project

- SMA With 10 % RAP
- I-270 Near Washington Beltway
- RAP and Virgin Mixtures
- Testing and Analysis
  - Binder Blending Study
  - Mixture Performance Properties
  - Acceptance Properties
Binder Blending Study

• Recover RAP Binder
• Laboratory Blends
  – PG 76-22
  – 0, 15, 25, 50, 100 % RAP
• Binder Properties
  – PG Grade
  – Master Curves
  – Elastic Recovery
  – MSCR
Master Curves

Reduced Frequency at $T_r$ (25°C), rad/sec
Binder Blending Findings

• Performance Grade
  – High Temperature Improves
  – Low Temperature Worsens
  – Intermediate Temperature Critical

• Elastic Recovery
  – Decreases Rapidly With Increasing RAP

• MSCR
  – Rutting Resistance and Recovery Improves
Mixture Performance Properties

- **Dynamic Modulus**
  - Plant Aged
  - LTOA

- **Flow Number**
  - Plant Aged

- **Continuum Damage Fatigue**
  - LTOA
Plant Aged Dynamic Modulus

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LTOA Dynamic Modulus

LTOA Without RAP
LTOA With RAP

Reduced Frequency, Hz

Temperature, C

Log Shift Factor

E*, ksi
Continuum Damage Fatigue

Reduced Cycles vs. Damage $|E^*/E^*|_{Initial}$

- Blue line: Without RAP
- Red line: With RAP
Mixture Performance Findings

• Dynamic Modulus
  – RAP Increases Plant Aged Stiffness
  – LTOA Stiffness Similar

• Flow Number
  – RAP Improves Rutting Resistance

• Fatigue
  – Fatigue Resistance Similar
Acceptance Properties

• Project Averages
  – AC
  – Gradation
  – In-Place Density

• Estimated Performance
  – Permeability
  – Rutting Resistance
  – Fatigue Resistance
# Project Averages

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<tr>
<th>Property</th>
<th>Without RAP</th>
<th>With RAP</th>
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<tr>
<td></td>
<td>Average</td>
<td>Standard Deviation</td>
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<tr>
<td>Asphalt Content, %</td>
<td>6.6</td>
<td>0.23</td>
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<tr>
<td>Minus 200, %</td>
<td>8.7</td>
<td>1.24</td>
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<tr>
<td>In-Place Density, %</td>
<td>95.5</td>
<td>0.58</td>
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NCHRP Report 567

• Models relating engineering and performance properties to volumetric properties

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<th>V_a</th>
<th>V_{be}</th>
<th>V_{agg}</th>
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<td>VMA</td>
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<td>Aggregate</td>
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NCHRP Report 567 Relationships

- **Permeability**
  - Air Voids
  - Gradation

- **Rutting Resistance**
  - Binder Stiffness
  - Gradation
  - Design Compactive Effort
  - In-Place Density

- **Fatigue Resistance**
  - Effective Binder Content
  - Design Compactive Effort
  - In-Place Density
Permeability

- Very Low for Both Mixtures for All Lots
  - High In-Place Density
  - High Filler Content
Rutting Resistance

Estimated Rut Depth, mm/MESAL

Lot Number

Without RAP
With RAP

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Effect of In-Place Density

Relative Fatigue Life, % of Design

Pavement Density

Without RAP
With RAP

94.5 95.0 95.5 96.0 96.5 97.0 97.5

Pavement Density
Acceptance Findings

- Project Averages
  - Similar for Both Mixtures

- Permeability
  - Very Low for Both Mixtures
    - Excellent In-Place Density

- Rutting Resistance
  - Improved for RAP Mixture
    - Higher Binder Stiffness

- Fatigue Resistance
  - Similar for Both Mixtures
    - Increases with In-Place Density
Overall Conclusions

• RAP Binder Does Affect Properties of PMA
  – Formulate PMA for Use With RAP?

• Increased Plant Aged Stiffness
  – Improved Rutting Resistance

• Similar Long Term Aged Stiffness
  – Similar Fatigue Life

• Similar Acceptance Properties
Questions?

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