New Approach for the Design of High RAP HMA

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Results From Recent Laboratory Efforts

• Evaluate Plant Produced Mixtures
  – RAP Contents of 25 % or More
  – 5% Recycled Asphalt Shingles
Acknowledgements

• Agencies
  – Maryland State Highway Administration
  – Pennsylvania Department of Transportation

• Producers
  – Aggregate Industries
  – F.O. Day Company, Inc.
  – Independence Construction Materials
  – Reliable Contracting Company, Inc.
Trends

- Increasing RAP Stockpiles
- Improved HMA Plants
  - Feeding
  - Mixing
- Improved Processing
  - Stockpiling
  - Sizing
- Recycled Asphalt Shingles
- PG Binders
AASHTO M323 Design Guidance

• Combined New and RAP Aggregates
  – Gradation
  – Angularity
  – Flat and Elongated

• Binder Grade Changes
  – < 15 % RAP, no grade change
  – 15 -25 % RAP, use one grade softer
  – > 25 % RAP, use blending chart
Issues

• AASHTO M323 Binder Recommendations Assume Complete Mixing of New and Recycled Binder

• AASHTO M323 Does Not Address RAS Binders
  – Much Different Rheology than Paving Binders
Our Approach

• Use Tests on Plant Produced Mixture
  – Degree of Mixing of New and Recycled Binder
  – Effective Grade of the Combined Binder

• Tests
  – Modulus (AASHTO TP62)
  – Strength (AASHTO T322)
  – Fatigue Resistance (Continuum Damage)
  – Creep Compliance (AASHTO T322)
Finding

• Dynamic Modulus Data Can Be Used to Evaluate RAP and RAS Mixtures
  – Test Is Highly Sensitive to Binder Stiffness
    • Assess Degree of Mixing of New and Recycled Binders
  – Interpreted to Estimate the Effective Grade of the Combined Binder
  – Relatively Easy to Perform with the Simple Performance Test System
Simple Performance Test System

• Product of NCHRP Projects 9-19 and 9-29

• Three Performance Related Tests
  – Dynamic Modulus
  – Repeated Load
  – Creep

• Temperature Control
  – 4 to 60 °C

• With and Without Confinement
Simple Performance Test System

• Rugged
  – 3 Years in FHWA Mobile Asphalt Lab

• Technician Friendly
  – Automated Testing Cell
  – Easy to Install Instrumentation
  – Standard Software
    • Testing and Analysis
    • Data Quality

• Reasonable Cost
  – $55,000
How?

• Perform Dynamic Modulus Master Curve Testing on Plant Produced Mixture
  – Standard Test in Simple Performance Test System

• Use Mixture Modulus Data to Estimate Effective Binder Modulus
  – Hirsch Model
    • Mixture Modulus = f(Binder modulus, VMA, and VFA)

• Compare Estimated Binder Modulus to PG Requirements
Examples

• Compare Estimated Binder Modulus With Recovered Binder Modulus
  – Example 1. 9.5 mm Mixture With PG 64-22 Produced in a Batch Plant
  – Example 2. 9.5 mm Mixture with PG 64-22 & 5% RAS Produced in a Batch Plant
  – Example 3. 9.5 mm Mixture with PG 64-22 & 35 % Fractionated RAP Produced in a Double Barrel
  – Example 4. 19.0 mm Mixture with PG 64-22 & 45 % Fractionated RAP Produced in a Double Barrel
9.5 mm With PG 64-22, Batch Plant

Reduced Frequency, rad/sec

Binder G*, kPa

From Mix

Recovered Binder
9.5 mm With PG 64-22 + 5% RAS, Batch Plant

Reduced Frequency, rad/sec

Binder $G^*$, kPa

From Mix
Recovered Binder

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9.5 mm With PG 64-22 + 35 %
Fractionated RAP, Double Barrel

<table>
<thead>
<tr>
<th>Reduced Frequency, rad/sec</th>
<th>Binder G*, kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0E-04</td>
<td>1.0E+00</td>
</tr>
<tr>
<td>1.0E-02</td>
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<tr>
<td>1.0E+08</td>
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</tbody>
</table>

- Blue squares: PG 64-22 With 35 % RAP From Mix Modulus
- Red circles: PG 64-22 With 35% RAP From Recovered Binder
19.0 mm With PG 64-22 + 45 %
Fractionated RAP, Double Barrel

Reduced Frequency, rad/sec

Binder $G^*$, kPa

- PG 64-22 With 45 % RAP From Mix Modulus
- PG 64-22 With 45% RAP From Recovered Binder

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Conclusions

• Can Estimate the Effective Stiffness of the Combined Binder in RAP and RAS Mixtures

• Binder Stiffness is an Indicator of the Degree of Mixing of RAP and RAS Binders
Mix Design / Evaluation

- Perform Dynamic Modulus Tests on Plant Produced Mixture
- Estimate Effective Combined Binder Modulus
- Compare to Allowable Binder Modulus
  - Lower Limits to Guard Against Poor Mixing
  - Upper Limits to Guard Against Excessive Stiffening
Graphically

Reduced Frequency at 20°C, rad/sec

Binder G*, kPa

Low Temperature
Intermediate Temperature
High Temperature

PG 64-22
PG 70-22

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High Temperature

- 70-22
- PG 64 + 45% RAP
- PG 64 + 5% RAS
- 64-22

G*, kPa

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Intermediate Temperature

- 70-22
- PG 64 + 45% RAP
- PG 64 + 5% RAS
- 64-22

G*, kPa

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Summary

• High Interest in Using Greater Amounts of RAP and RAS in Mixtures

• Current Design Guidance Assumes Complete Mixing of New and Recycled Binders

• Mixture Dynamic Modulus Tests Can Be Used to Evaluate Plant Produced Mix
  – Degree of Mixing of New and Recycled Binder
  – Effective Grade of the Combined Binder
Summary

• Mixture Testing Provides Advantages to Agencies and Producers
  – More Confidence in Acceptance of New Materials and Processes
  – More Flexibility in Use of Material
Questions?

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