Effects of RAP in HMA: Lab Study

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Asst. Professor
Purpose of Research

- Determine effect on asphalt concrete from substitution of RAP for virgin aggregate and binder
- Achieve through evaluation of changes in volumetric and mechanistic properties of mixtures as RAP percentages are increased
Using RAP in New Mixtures

- Replacement for some of virgin aggregate and binder
  - Gradation and % ac in RAP must be considered
- “Black rock” condition when RAP is used at low percentages
- Blending of ac is more influential to properties at higher RAP percentages
Test Specimens

- Mixes tested at following conditions:
  - 0% RAP (Control)
  - 15% RAP
  - 25% RAP
  - 40% RAP
- Two RAP sources
  - Processed RAP
  - Grindings
Mix Design

- Existing NHDOT 15% RAP mix design

- Target same gradation while keeping relative proportions of virgin blast rock and natural sand the same

- Designs follow Superpave procedure
Processed RAP Gradations
Grindings RAP Gradations

![Graph showing gradations of RAP with sieve sizes and percent passing.]

- Control Mix
- 15% Grindings
- 25% Grindings
- 40% Grindings
- Control Points
- Restricted Zone
RAP Binder Properties

- Processed RAP: PG 94-14
- RAP Grindings: PG 82-22
- High temp. grades much higher than PG 58-28 virgin binder
  - Based on research by Daniel & Kim, expect RAP mixtures to be stiffer
Laboratory Aged Mixtures

(From Daniel and Kim, TRB 1998)
Processed RAP Mixtures
### Mixture Volumetrics

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>15% RAP</th>
<th>25% RAP</th>
<th>40% RAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>% ac</td>
<td>4.8</td>
<td>5.1</td>
<td>5.4</td>
<td>4.9</td>
</tr>
<tr>
<td>VMA</td>
<td>13.1</td>
<td>13.3</td>
<td>16.3</td>
<td>15.2</td>
</tr>
<tr>
<td>VFA</td>
<td>69.4</td>
<td>69.9</td>
<td>75.4</td>
<td>73.6</td>
</tr>
</tbody>
</table>
Specimen Fabrication

- Mixing
- Compaction
  4% air voids

SUPERPAVE GYRATORY COMPACTOR

COMPACTION MOLD
Specimen Fabrication

- Coring
- Cutting
Test Setup Overview
Test Specimen (Compression)

FRICTIONLESS MEMBRANES
Test Specimen (Tension)
Material Property Tests

- Complex Modulus
  - Tension
  - Compression
- Creep Compliance in Compression
- Static Creep in Compression (flow time)
- Why These Tests?
  - Mechanistic-Empirical Design Guide
  - Simple Performance Test
15% Processed RAP

Graph showing the relationship between Reduced Frequency (Hz) and Dynamic Modulus (kPa). The x-axis represents Reduced Frequency (Hz), ranging from $10^{-3}$ to $10^7$, and the y-axis represents Dynamic Modulus (kPa), ranging from 0 to 800,000.
Dynamic Modulus (Compression)

Dynamic Modulus in Compression (kPa)

- Control
- 15% Proc

Reduced Frequency (Hz)
Dynamic Modulus (Compression)

Dynamic Modulus in Compression (kPa)

Control
15% Proc RAP
25% Proc RAP
40% Proc RAP

Reduced Frequency (Hz)
Dynamic Modulus (Tension)

Dynamic Modulus in Tension (kPa)

- Control
- 15% Proc RAP
- 25% Proc RAP
- 40% Proc RAP

Reduced Frequency (Hz)
Creep Compliance (Compression)

- Reduced Time (s)
- Creep Compliance (1/MPa)

- Control Fit
- 15% RAP Fit
- 25% RAP Fit
- 40% RAP Fit
# Static Creep (Flow Time)

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Creep Flow Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>553</td>
</tr>
<tr>
<td>15% RAP</td>
<td>1445</td>
</tr>
<tr>
<td>25% RAP</td>
<td>350</td>
</tr>
<tr>
<td>40% RAP</td>
<td>3050</td>
</tr>
</tbody>
</table>
Differences

- Higher asphalt content for 25% RAP
- Finer gradation for 25% and 40% RAP
- Angularity of RAP aggregate
- Higher VMA and VFA for 25% and 40% RAP
## Fine Aggregate Angularity

### Comparison Between Aggregates*

<table>
<thead>
<tr>
<th></th>
<th>Bank Run Sand</th>
<th>Washed Machine Sand</th>
<th>Unwashed Sand</th>
<th>Baghouse Fines</th>
<th>Processed RAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncompacted Void Content</td>
<td>41.8%</td>
<td>48.1%</td>
<td>48.7%</td>
<td>48.7%</td>
<td>46.2%</td>
</tr>
</tbody>
</table>

*All void testing was performed in accordance with ASTM 1252-98, Method A (Standard Graded Sample Method)*
## Fine Aggregate Angularity

### Total Values for Each Blended Mixture*

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<thead>
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<th>40% RAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncompacted Void Content</td>
<td>47.1%</td>
<td>46.4%</td>
<td>46.1%</td>
<td>45.9%</td>
</tr>
<tr>
<td>Superpave Requirement</td>
<td>0.3 to &lt;3 ESALs:</td>
<td>Minimum 40%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*All void testing was performed in accordance with ASTM 1252-98, Method A (Standard Graded Sample Method)*
RAP Heating Vs. Volumetrics

Examine 40% Processed RAP Mixture using same compaction effort

<table>
<thead>
<tr>
<th></th>
<th>Duration of Preheating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 Hr.</td>
</tr>
<tr>
<td>Air Voids</td>
<td>4.0%</td>
</tr>
<tr>
<td>VMA</td>
<td>15.1%</td>
</tr>
<tr>
<td>VFA</td>
<td>73.6%</td>
</tr>
</tbody>
</table>
# Mixture Volumetrics

<table>
<thead>
<tr>
<th></th>
<th>Processed</th>
<th>Grindings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>15% RAP</td>
</tr>
<tr>
<td>% ac</td>
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Future Work

- Complex modulus testing on grindings mixtures
- Testing of other RAP sources
- Simulate plant mixtures – RMRC project
I STILL BELIEVE...