FHWA ALF Update & Performance Testing

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SES/TFHRC-FHWA
Outline

- ALF Density Study
  - Laboratory performance testing
  - ALF field testing

- ALF RAP/RAS Study
  - 20% & 40% RBR + additional virgin binder
  - Performance testing

- Stress Sweep Rutting Testing with Small Specimen
AC Field Density and CAB Geosynthetic Reinforcement

- Objectives
  - Investigation of Asphalt Concrete Compaction and Its Impact on Performance of Pavements Built with and without Geosynthetic Base Reinforcement
The Experiment

- One AC mixture
- Four Lanes (4 different AC compaction levels)
  - High (>92% compaction)
  - Medium (90-92%)
  - Low (<90%)
- Two structures per lane
  - Unreinforced
  - Reinforced with a Standard BS-1200
- Performance measures
  - Cracking
  - Rutting
Air voids of field cores (cont’d)

![Bar chart showing air void contents for different lanes and conditions.](chart.png)
# Air Voids of Field Cores

<table>
<thead>
<tr>
<th>Lane</th>
<th>SSD Whole</th>
<th>SSD Bottom Trimmed</th>
<th>CoreLok Whole</th>
<th>CoreLok Bottom Trimmed</th>
</tr>
</thead>
<tbody>
<tr>
<td>L9 (Low)</td>
<td>10.6</td>
<td>0.8</td>
<td>10.2</td>
<td>0.8</td>
</tr>
<tr>
<td>L10 (Mid)</td>
<td>8.6</td>
<td>1.2</td>
<td>8.3</td>
<td>1.1</td>
</tr>
<tr>
<td>L11 (High)</td>
<td>7.9</td>
<td>0.7</td>
<td>7.7</td>
<td>0.7</td>
</tr>
<tr>
<td>L12 (High)</td>
<td>7.1</td>
<td>0.9</td>
<td>6.8</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Loading Specs

- **Rutting**
  - Terminal state: 1.5 to 2 inches of total permanent deformation
  - Loading temperature:
    - Variable temperature:
      - 10K passes at 40°C
      - 10K passes at 50°C
      - Cycle until terminal state is reached
Loading Specs (Cont’d)

- Cracking
  - Loading temperature: 20°C
  - Terminal state: total cracking length > 1,000 inches
    - Early stages of cracking in which preventive maintenance would be optimum intervention in real pavements
Layout and Current Status

- $F_i$ – Fatigue test at aged conditions

- Completed Rutting
  - All but L12S2

- Completed Cracking
  - L9S2
  - L11S4
  - L12S3

- Next (until end of loading season):
  - L10S1
  - L12S2
Density Impact on AC Rutting

**L09S1 - AC**

**L10S2 - AC**

**L11S1 - AC**

**L12S4 - AC**

**L11S3 - AC**

* Needs validation (post-mortem)
Total Crack Length

- L09S2, AV=11.1%
- L12S3, AV=7.3%
- L11S4, AV=8.6%
Field Core Sampling + Testing

2016
0 day

2018
1.5 year
Loose Mix Laboratory Testing

- HWTD testing
  - Dry 50°C + wet 50°C
- Flow number
- Dynamic modulus
- Axial cyclic fatigue test
- Stress sweep rutting test
  - 4 air voids (7%, 8%, 9%, 11%)
  - 2-hour aging
  - 2 LTOA (5-day 85°C, 7-day 95°C)
HWDT

Loose mix + 50C dry

Impression, mm

Loose mix + 50C wet

Impression, mm

Field core + 50C dry

Impression, mm

Field core + 50C wet

Impression, mm
Flow Number

<table>
<thead>
<tr>
<th>Lane and Va</th>
<th>Flow Number (cycles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L12 (7%Va)</td>
<td>232</td>
</tr>
<tr>
<td>L11 (8%Va)</td>
<td>93</td>
</tr>
<tr>
<td>L10 (9%Va)</td>
<td>109</td>
</tr>
<tr>
<td>L9 (11%Va)</td>
<td>73</td>
</tr>
</tbody>
</table>
Effect of Air Voids on $|E^*|$
Aging Effect on $|E^*|$
Aging Effect on $|E^*|$
Aging Effect on $|E^*|$
Stress Sweep Rutting Testing

20°C

54°C
Fatigue Testing Results

- Axial cyclic fatigue (AASHTO TP107)
  - fatigue characteristics

<table>
<thead>
<tr>
<th>Parameters</th>
<th>L9 (11% Va)</th>
<th>L11 (8% Va)</th>
<th>L12 (7% Va)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C11</td>
<td>0.002</td>
<td>0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>C12</td>
<td>0.530</td>
<td>0.533</td>
<td>0.540</td>
</tr>
<tr>
<td>DR</td>
<td>0.496</td>
<td>0.477</td>
<td>0.493</td>
</tr>
</tbody>
</table>

\[
C = 1 - C_{11} \cdot S^{C_{12}}
\]

\[
D^R = \frac{\int_0^{N_f} (1 - C) dN}{N_f}
\]
RAP Mix + More Virgin Binder
ALF RBR Study
Objectives

- Examine the effect of asphalt binder replacement in the asphalt mixtures containing RAP
- Determine how much virgin binder needs to be added for the mixes to exhibit equivalent performance
- Improve RAP mix design to ensure satisfactory performance
Materials and Testing

- **Materials**
  - L1 (0% RBR, control mix, PG 64-22)
  - L6 (20% RBR, PG 64-22)
  - L5 (40% RBR, PG 64-22)
  - L8 (40% RBR, PG 58-28)

- **Additional Binder**
  - +0.25%, +0.5%, +0.75%

- **Testing**
  - Dynamic modulus
  - Direct tension fatigue (AASHTO TP 107)
  - Stress sweep rutting (SSR)
# Volumetrics

<table>
<thead>
<tr>
<th>Dimension (mm)</th>
<th>Sieve Size</th>
<th>Lane 1 (0% RBR)</th>
<th>Lane 6 (20% RBR)</th>
<th>Lane 5 (40% RBR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>3/4 inch</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>12.5</td>
<td>1/2 inch</td>
<td>98.3</td>
<td>98.0</td>
<td>97.1</td>
</tr>
<tr>
<td>9.5</td>
<td>3/8 inch</td>
<td>86.2</td>
<td>85.8</td>
<td>80.6</td>
</tr>
<tr>
<td>4.75</td>
<td># 4</td>
<td>47.6</td>
<td>44.6</td>
<td>37.9</td>
</tr>
<tr>
<td>2.36</td>
<td># 8</td>
<td>28.8</td>
<td>28.1</td>
<td>24.0</td>
</tr>
<tr>
<td>1.18</td>
<td># 16</td>
<td>20.1</td>
<td>20.6</td>
<td>18.6</td>
</tr>
<tr>
<td>0.6</td>
<td># 30</td>
<td>15.0</td>
<td>15.7</td>
<td>14.9</td>
</tr>
<tr>
<td>0.3</td>
<td># 50</td>
<td>11.0</td>
<td>11.7</td>
<td>11.6</td>
</tr>
<tr>
<td>0.15</td>
<td># 100</td>
<td>7.8</td>
<td>8.5</td>
<td>8.9</td>
</tr>
<tr>
<td>0.075</td>
<td># 200</td>
<td>5.3</td>
<td>5.8</td>
<td>6.3</td>
</tr>
</tbody>
</table>

### Diagram

![Graph showing percent passing for different sieve sizes and lanes](image)

### Table

<table>
<thead>
<tr>
<th></th>
<th>L1 (0% RBR)</th>
<th>L6 (20% RBR)</th>
<th>L5 (40% RBR)</th>
<th>L8 (40% RBR PG58-28)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ AC</td>
<td>+0</td>
<td>+0.25%</td>
<td>+0.5%</td>
<td>+0.75%</td>
</tr>
<tr>
<td>G&lt;sub&gt;mm&lt;/sub&gt;</td>
<td>2.747</td>
<td>2.735</td>
<td>2.723</td>
<td>2.718</td>
</tr>
<tr>
<td>Air Voids</td>
<td>4.93</td>
<td>4.14</td>
<td>3.13</td>
<td>1.89</td>
</tr>
<tr>
<td>G&lt;sub&gt;mb&lt;/sub&gt;</td>
<td>2.612</td>
<td>2.622</td>
<td>2.638</td>
<td>2.66</td>
</tr>
<tr>
<td>P&lt;sub&gt;b&lt;/sub&gt;</td>
<td>5.14</td>
<td>5.39</td>
<td>5.64</td>
<td>5.89</td>
</tr>
<tr>
<td>P&lt;sub&gt;be&lt;/sub&gt;</td>
<td>4.63</td>
<td>4.89</td>
<td>5.14</td>
<td>5.39</td>
</tr>
<tr>
<td>VMA</td>
<td>16.8</td>
<td>16.7</td>
<td>16.4</td>
<td>15.9</td>
</tr>
<tr>
<td>VFA</td>
<td>70.6</td>
<td>75.1</td>
<td>80.9</td>
<td>88.1</td>
</tr>
<tr>
<td>% dust</td>
<td>5.3</td>
<td>5.3</td>
<td>5.3</td>
<td>5.3</td>
</tr>
<tr>
<td>DB Ratio</td>
<td>1.14</td>
<td>1.08</td>
<td>1.03</td>
<td>0.98</td>
</tr>
</tbody>
</table>
**Volumetrics**

### Requirements

<table>
<thead>
<tr>
<th></th>
<th>3%–5%</th>
<th>&gt; 14%</th>
<th>65%–78%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air Voids</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>VMA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>VFA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Mixture Analysis

- **L1 (0% RBR)**
  - Air Voids %
  - VMA %
  - VFA %

- **L6 (20% RBR)**
  - Air Voids %
  - VMA %
  - VFA %

- **L5 (40% RBR)**
  - Air Voids %
  - VMA %
  - VFA %

- **L8 (40% RBR PG 58-28)**
  - Air Voids %
  - VMA %
  - VFA %
Dynamic Modulus

Dynamic Modulus, MPa vs. Reduced Frequency (Hz) for different levels:
- L1+0%
- L1+0.25%
- L1+0.5%
- L1+0.75%
- L6+0%
- L6+0.25%
- L6+0.5%
- L6+0.75%
Stress Sweep Rutting Results
Fatigue Testing Results

Under Analysis
Stress Sweep Rutting Testing

with

Small Geometry Specimen
AMPT Performance Tests

- TFHRC using AMPT/SPT for 14 years
- Dynamic modulus test
  - full size + small size specimens
- Axial direction tension cyclic fatigue test
  - full size + small size specimens
- Direct tension monotonic test
  - Small size specimens
- Stress sweep rutting test
  - full size + small size specimens
- Flow number test
Stress Sweep Rutting Test

- One loose mix (PG 64E-34)
- Three air voids
  - 5%, 7% and 9%
- Three temperatures
  - 20°C, 51°C, 45°C
- Two geometry
  - 38mm x 110mm
  - 100mm x 150mm
SSR Testing Results

- **Repeatability**
  - 38mm + 5% Va

![Graph of Deformation vs. Cycles]

**Deformation, (με)**

- 20C - 1
- 20C - 2
- 20C - 3
- 20C - 4

- 45C - 1
- 45C - 2
- 45C - 3
- 45C - 4

- 51C - 1
- 51C - 2
- 51C - 3
- 51C - 4
SSR Testing Results

- **Repeatability**
  - 38mm + 9% Va
SSR Testing Results

- Repeatability
  - 100mm + 5% Va

Graphs showing deformation over cycles for 20C-1, 20C-2, 45C-1, 45C-2, 51C-1, and 51C-2.
SSR Testing Results

- Effect of air voids
  - 38mm vs. 100mm

**Graphs**

- Small specimen
- Full size specimen
SSR Testing Results

- **Effect of geometry**
  - 38mm vs. 100mm

![Graph showing deformation vs. cycles for 20C+5%Va and 51C+5%Va](image)

- 38mm+20C+5%AV
- 100mm+20C+5%AV

![Graph showing deformation vs. cycles for 51C+5%Va](image)

- 38mm + 51C+5%AV
- 100mm + 51C+5%AV
SSR Testing Results

- Effect of geometry
  - 38mm vs. 100mm

![Graphs showing deformation vs. cycles for 38mm and 100mm geometries at 20C+9%Va and 45C+9%Va.]
Thank You!

+ Questions?