Outline

• Experimental Design – Refresher
• ALF Loading Status
• Laboratory Test Results
  – S-VECD – *Loose Mix/Gyratory Unaged and Aged*
  – Texas Overlay Tester - *Cores*
• Comparison of Lab Cracking Tests vs. Field
• Future Steps
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### ALF Experimental Design

<table>
<thead>
<tr>
<th>Warm Mix Technology</th>
<th>HMA / WMA Production Temperature</th>
<th>Recycle Content</th>
<th>300°F - 320°F</th>
<th>240°F - 270°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foam Chem.</td>
<td>-</td>
<td>-</td>
<td>Foam</td>
<td>Chem.</td>
</tr>
<tr>
<td>0%</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>20% ABR RAP</td>
<td><a href="#">✓</a> PG64-22</td>
<td>-</td>
<td><a href="#">✓</a> PG64-22</td>
<td><a href="#">✓</a> PG64-22</td>
</tr>
<tr>
<td>≈ 23% by weight</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20% ABR RAS</td>
<td><a href="#">✓</a> PG64-22</td>
<td><a href="#">✓</a> PG58-28</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>≈ 6% Shingle by weight</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40% ABR RAP</td>
<td><a href="#">✓</a> PG64-22</td>
<td><a href="#">✓</a> PG58-28</td>
<td><a href="#">✓</a> PG58-28</td>
<td><a href="#">✓</a> PG58-28</td>
</tr>
<tr>
<td>≈ 44% by weight</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- [✓](#) indicates a suitable combination.
- PG58-28 and PG64-22 are binder grades.
ALF Loading Conditions

• Controlled 20ºC @ 20mm
• Loading only one direction
• Lateral Wander
• 425 Super Single Tire
• 100 psi inflation
• 14,200 lb load
• ~4-inch thick asphalt
• ~22-inch thick agg base
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<table>
<thead>
<tr>
<th>Lane</th>
<th>Description</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>WMA-Foam 20% ABR</td>
<td>Complete</td>
</tr>
<tr>
<td>11</td>
<td>WMA-Chem 40% ABR 58-28</td>
<td>Complete</td>
</tr>
<tr>
<td>5</td>
<td>HMA 40% ABR</td>
<td>Complete</td>
</tr>
<tr>
<td>1</td>
<td>HMA 0% Control</td>
<td>Complete</td>
</tr>
<tr>
<td>3</td>
<td>HMA 20% ABR RAS</td>
<td>Complete</td>
</tr>
<tr>
<td>4</td>
<td>WMA-Chem 20% ABR</td>
<td>Complete</td>
</tr>
<tr>
<td>7</td>
<td>HMA 20% ABR RAS 58-28</td>
<td>Loading Now...</td>
</tr>
<tr>
<td>2</td>
<td>WMA-Foam 40% ABR 58-28</td>
<td>Loading Now...</td>
</tr>
<tr>
<td>8</td>
<td>HMA 40% ABR 58-28</td>
<td>Next</td>
</tr>
<tr>
<td>6</td>
<td>HMA 20% ABR</td>
<td>Next</td>
</tr>
</tbody>
</table>
Cracking Performance Measured...

Crack lengths are individually traced with “map-measure”
# Cracking Performance Measured...

<table>
<thead>
<tr>
<th>Lane &amp; Mix</th>
<th>ALF Passes to First Crack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane 9 WMA-Foam 20% ABR</td>
<td>142,000</td>
</tr>
<tr>
<td>Lane 11 WMA-Chem 40% ABR 58-28</td>
<td>60,000</td>
</tr>
<tr>
<td>Lane 5 HMA 40% ABR</td>
<td>37,000</td>
</tr>
<tr>
<td>Lane 1 HMA 0% Control</td>
<td>368,000</td>
</tr>
<tr>
<td>Lane 3 HMA 20% ABR RAS</td>
<td>42,000</td>
</tr>
<tr>
<td>Lane 4 WMA-Chem 20% ABR</td>
<td>90,000</td>
</tr>
</tbody>
</table>
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Analysis of S-VECD Lab Data...

What’s this graph all about?
These two groups are the same 10 ALF mixes

Same data - analyzed two different ways
This is the “semi-RAW” lab data from AMPT fatigue

Before S-VECD Analysis
Case Example – Data from AMPT

Sample “A”

\[ N_{\text{FAIL}} = 22,510 \]

\[ \bar{\varepsilon}_{\text{AVG}} = 469 \]

Sample “B”

\[ N_{\text{FAIL}} = 920 \]

\[ \bar{\varepsilon}_{\text{AVG}} = 982 \]
This is the performance determined once the VECD properties have been obtained; e.g. $C(S)$
Unaged Full Size Gyratory

C(S)
Damage
Characteristic
Curves

$N_{FAIL}$

$\varepsilon$ Strain

$\Sigma$
This was necessary, but not the end-product.
This matters

Unaged Full Size Gyratory

This matters
The graph illustrates the relationship between the number of cycles to failure ($N_{FAIL}$) and the VECD simulated controlled strain. The data is categorized into different scenarios:

- **Perfect Construction - Thin**
- **As Built - Thin**
- **Perfect Construction - Thick**

The graph shows the trend lines and data points for each category, indicating how the number of cycles to failure decreases as the strain increases. The axes are labeled as follows:

- **Y-axis**: Number of cycles to failure ($N_{FAIL}$)
- **X-axis**: VECD simulated controlled strain

The data points are color-coded for easy differentiation between the different categories.
As-Built vs. Perfect Construction (thin)

Asphalt Thickness

Average = “Perfect”

Base Stiffness
Average Loose Mix Gyratory Specimens 7% +/- 0.5%
Average Loose Mix Gyratory Specimens 7% +/- 0.5%
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Texas Overlay Tester

- FHWA cored & trimmed the bottom surface
- Cores shipped to TTI
- TTI split cores into Top Lift & Bottom Lift
- 5 replicates
- Tested at: 20°C
  - 0.020 inch displacement
  - (0.5 mm)
Texas Overlay Test: 20C and 0.020 inch opening displacement
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Laboratory Cycles to Failure, S-VECD (fixed strain)
Loose Mix – Gyratory Compacted – 7% +/- 0.5%
Loose Mix – Gyratory Compacted – 7% +/- 0.5%

Laboratory Cycles to Failure, S-VECD (Fixed Strain)

Long-Term Oven Aged
Long-Term Oven Aged

Laboratory Cycles to Failure, S-VECD *(AS-BUILT)*
Loose Mix – Gyratory Compacted – 7% +/- 0.5%
Loose Mix – Gyratory Compacted – 7% +/- 0.5%

Long-Term Oven Aged

Laboratory Cycles to Failure, S-VECD (AS-BUILT)
Loose Mix – Gyratory Compacted – 7% +/- 0.5%
Laboratory Cycles to Failure, S-VECD *(PERFECT CONSTRUCTION)*

Loose Mix – Gyratory Compacted – 7% +/- 0.5%
Loose Mix – Gyratory Compacted – 7% +/- 0.5%

Long-Term Oven Aged

Laboratory Cycles to Failure, S-VECD (PERFECT CONSTRUCTION)
Loose Mix – Gyratory Compacted – 7% +/- 0.5%
Field Cores

Loose Mix – Gyratory Compacted – 7% +/- 0.5%

S-VECD (Fixed Strain)

Texas Overlay Tester - Field Cores - Cycles to Failure Field Cores
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Upcoming Efforts

• **Identify the Recycled Binder Ratio (aka ABR) which provides Equivalent Performance**
  – Equivalent to 0% RAP PG64-22 ??
    20% RAP PG64-22 ??
  – Lab-batched mixes
  – Add more virgin binder
  – Conduct this **only** on 40% RAP ABR PG58-28
    20% RAS ABR PG58-28

• Long Term Aging vs. Field Aging
• Extraction & Recovery – Large Quantities
• Variability in Lab Crack Test
• Collaborative Testing
  – Beam Fatigue @ AAT
  – SCB @ LaDOTD
  – IDT @ WSU
  – OT*, SCB, Cantaboro, IDT @ NCAT
The Pigeon Needs a Bath!

I do not.
The water is too hot.

Too cold.

Too lukewarm.

Too hot.

Too wet!

Too cold.

Not enough toys.

Too many toys.
Too deep!

Not deep enough.

Too cold.

Now it's too hot again!

Too reflective.

Well, I guess this is okay.

That is still too hot!
The Pavement Engineer Needs a Cracking Test!

Thank You.

Questions?
Comments?
Concerns?
Virgin Binder Sampling and Properties

- In-line sampling port just before entering the drum
- One gallon on each day of production
Virgin Binder Sampling and Properties

20C RTFO |G*|sin(δ) (kPa)

PG64-22
PG58-28

f = Foam

e = Evotherm


58%
Virgin Binder Sampling and Properties

PG64-22
PG58-28

$e = \text{Evotherm}$
$f = \text{Foam}$

RTFO - HTPG

RTFO - ITPG

RTFO - LTPG
Lane1, 0% Recycle HMA PG64-22

Gyr. Air Voids

Thickness

Gyr. VMA

Top Air Voids

Gyr. VFA

Bottom Air Voids

Binder Content

#200

4.75mm
Lane 2, 40% ABR RAP Foam PG58-28

Gyr. Air Voids

Thickness

Gyr. VMA

Top Air Voids

Gyr. VFA

Bottom Air Voids

Binder Content

#200

4.75mm
Lane 4, 20% ABR RAP WMA Evotherm PG64-22

Gyr. Air Voids

Thickness

Gyr. VMA

Top Air Voids

Gyr. VFA

Bottom Air Voids

Binder Content

#200

4.75mm
Lane 6, 20% ABR RAP HMA  PG64-22

Gyr. Air Voids

Thickness

Gyr. VMA

Top Air Voids

Gyr. VFA

Bottom Air Voids

Binder Content

#200

4.75mm

Gyr. Air Voids

4.4”

3.6”

4%
Lane 8, 40% ABR RAP HMA PG58-28

Gyr. Air Voids

- Thickness: 4.4”
- Top Air Voids: 6%
- Bottom Air Voids: +2%
- Gyr. VMA: 78%
- Gyr. VFA: +0.2%
- Binder Content: +7%
- #200: -7%
- 4.75mm: -2%
Lane9, 20% ABR RAP WMA Foam PG64-22

Gyr. Air Voids

Thickness

Gyr. VMA

Top Air Voids

Gyr. VFA

Bottom Air Voids

Binder Content

#200

4.75mm
Lane 10, 40% ABR RAP WMA Evotherm PG58-28

Gyr. Air Voids

Thicknes

Gyr. VMA

Top Air Voids

Gyr. VFA

Bottom Air Voids

Binder Content

#200

4.75mm

...but kept in place
Lane 11, 40% ABR RAP WMA Evotherm PG58-28 (#2)

Gyr. Air Voids

- Thickness
- Gyr. VMA
- Gyr. VFA
- Binder Content
- Top Air Voids
- Bottom Air Voids
- #200
- 4.75mm
Characteristics of Recycled Asphalt Materials

**RAP**
- 13 samples taken as stockpile was built
- 4.7% average AC content by solvent
  - 0.2% std. dev. AC
- TCE Recovered PG
  - PG89.4-21.7
  - ITPG 29.1C

**RAS**
- Tear-Offs
- 99.4% Passing ½” sieve
- 85.2% Passing #4 sieve
- 20.9% AC by solvent
- High Temp >>> PG140

*Dedicated RAP and RAS stockpiles for the Project*