Evaluation of Moisture Susceptibility in a Warm Mix Asphalt Pavement: US 157, Hurdle Mills, NC

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Outline

- Project Description
- Objective
- Field Cores and Test Methods
- Discussion of Test Results
- Conclusions
Project Description

- Warm mix asphalt pavement constructed on US 157, Hurdle Mills, NC
- Zeolite-based technology
- RS9.5B Superpave surface mix
- TSR of the production mix – 50 to 60%
- Varying degrees of stripping observed from the specimens after moisture conditioning
Field Cores

- Twelve 6-inch diameter field cores obtained from each of the WMA pavement and the corresponding HMA pavement
- Thickness = 1.3 – 2 inches
- Trim down to 1 inch thickness
- Air voids measured via the Core-Lok method
Air Voids of Cores

Evaluated Separately

Air Voids (%)

Specimen ID

CON

WMA

5.6%

7.7%
Test Methods

- Indirect tension dynamic modulus test
- Indirect tension fatigue test
- Modified AASHTO T283 for moisture conditioning
Indirect Tensile Test
Dynamic Modulus Test

- SHRP Load Guide Device with two guide columns (NCHRP 1-28)
- Surface mounted LVDTs with 2 inch gauge length
- Eight frequencies: 25, 10, 5, 1, 0.5, 0.1, 0.05, 0.01 Hz
- Three temperatures: -10°, 10°, and 35°C for unconditioned and 5°, 20°, and 35°C for moisture conditioned specimens
- Target load level: Enough to cause 30 microstrains in the horizontal direction (60 to 100 microstrains in the vertical direction)
Dynamic Modulus

Unconditioned Conventional Mix

![Graph showing Dynamic Modulus for different Conventional Mixes. The x-axis represents Reduced Frequency (Hz) on a logarithmic scale, ranging from $10^{-7}$ to $10^5$, and the y-axis represents $|E^*|$ (MPa) on a logarithmic scale, ranging from $10^{-7}$ to $10^5$. Three curves are plotted for CON-1, CON-4, and CON-3.](image)
Phase Angle and Shift Factor

Unconditioned Conventional Mix

![Graph showing phase angle and shift factor](image)

- Horizontal Phase Angle (deg)
- Reduced Frequency (Hz)
- Vertical Phase Angle (deg)
- Log Shift Factor
- Temperature (°C)

**Graph Details:**
- **Horizontal Phase Angle (deg):**
  - CON-1
  - CON-4
  - CON-3

- **Reduced Frequency (Hz):**
  - 1E-07 to 1E+03

- **Vertical Phase Angle (deg):**
  - CON-1
  - CON-4
  - CON-3

- **Log Shift Factor:**
  - Temperature (°C)

- **Graph Range:**
  - Reduced Frequency (Hz): 1E-07 to 1E+03
  - Temperature (°C): -20 to 40
Dynamic Modulus

Unconditioned WMA Mix
Phase Angle and Shift Factor

Unconditioned WMA Mix

Horizontal Phase Angle (deg)

Reduced Frequency (Hz)

Vertical Phase Angle (deg)

Log Shift Factor

Temperature (°C)
Dynamic Modulus

Moisture-Conditioned WMA Mix

![Graph showing the relationship between Reduced Frequency (Hz) and |E'| (MPa) for WMA-12-Moist, WMA-11-Moist, and WMA-6-Moist.]
Phase Angle and Shift Factor

*Moisture-Conditioned WMA Mix*

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**Horizontal Phase Angle (deg)**

- WMA-12-Moist
- WMA-11-Moist
- WMA-6-Moist

**Vertical Phase Angle (deg)**

- WMA-12-Moist
- WMA-11-Moist
- WMA-6-Moist

**Reduced Frequency (Hz)**

- 1E-06 to 1E+00

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**Log Shift Factor**

- WMA-12-Moist
- WMA-11-Moist
- WMA-6-Moist

**Temperature (°C)**

- 0 to 40
Averaged Dynamic Modulus

![Graph showing averaged dynamic modulus plotted against reduced frequency (Hz). The modulus values for CON-Avg, WMA-Avg, and WMA-Moist-Avg are compared with percentage differences indicated at 5.6% and 7.7%.]
Averaged Phase Angle and Shift Factor

- Horizontal Phase Angle (deg)
- Reduced Frequency (Hz)
- Vertical Phase Angle (deg)
- Log Shift Factor
- Temperature (°C)

Graphs showing the relationship between various parameters with different data sets labeled as CON-Avg, WMA-Avg, and WMA-Moist-Avg.
Air Void-Dynamic Modulus Model

\[
\log(|E^*|) = a + \frac{b}{1 + \frac{1}{\exp^{d+e(\log(f_R))}}}
\]

\[a, b, d, e = \rho \times (\%AV) + \kappa\]

<table>
<thead>
<tr>
<th>Coefficients of Sigmoidal Function</th>
<th>Mix Types</th>
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</thead>
<tbody>
<tr>
<td>S9.5C</td>
<td>I19.0C</td>
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<tr>
<td>(\rho)</td>
<td>(\kappa)</td>
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<td>(a)</td>
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<td>(b)</td>
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<td>(e)</td>
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</table>
Effect of WMA on $|E^*|$

![Graph showing the effect of WMA on $|E^*|$](image-url)
Effect of Moisture Conditioning on Fingerprint $|E^*|$ @19°C & 10 Hz
Fatigue Test

- Controlled stress mode at 19°C
- Continuous haversine loading of a 0.1 sec loading without a rest period
- Three load magnitudes
- Fatigue life determined by the Bisection method applied to the relationship between horizontal strain and number of loading cycles
Bisection Method

Horizontal Strain

Number of Loading Cycles

$N_f$
Moisture Effect on Fatigue

**Strain-Based**

![Graph showing the effect of moisture on fatigue](image)

- **Strain Amplitude (microstrains)**
  - WMA (7.7%)
  - HMA (5.6%)
  - HMA (8.8%)

- **N_f (Cycle)**
  - N_f (WMA)
  - N_f (HMA)
  - N_f (M-WMA)
  - N_f (M-HMA)

- **Symbols**
  - ● CON
  - ○ CON-Moist
  - ▲ CON-High %AV
  - △ CON-Moist-High %AV
  - ■ WMA
  - □ WMA-Moist
  - ◇ WMA-High %AV
  - ◆ WMA-Moist-High %AV
Conclusions

- Better air void control and higher air voids from the WMA pavement than the HMA pavement
- Successful application of the indirect tension dynamic modulus and fatigue tests to field cores
- Lower dynamic moduli from the WMA than from the HMA
- Effects of moisture conditioning on dynamic modulus and fatigue life seem to be greater in the WMA than in the HMA.
Thank You!