Moisture Susceptibility Testing of New England Mixtures

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Project Background

• Moisture susceptibility: Extent to which an asphalt mixture is prone to experiencing moisture induced damage

• Moisture Damage results in significant reduction of pavement performance and service life

• Testing methods need to be able to effectively and reliably capture the extent of moisture damage susceptibility
  • Some New England DOTs have struggled with this recently
Project Objectives

• Evaluate good and poor performing asphalt mixtures in New England
  • Assess mechanisms responsible for poor performing mixtures

• Measure impacts of moisture induced-damage on pavement performance and service life

• Recommend a framework of testing and analysis procedures that is reliable and suitable for moisture susceptibility testing in New England
Test Plan Development
Mixture Selection

• Mixtures chosen on the basis of feedback from agency survey
• Goal was to incorporate a wide variety of properties
  • Mix designs
  • Volumetric properties
  • Aggregate Minerology
  • Binder Properties
  • Liquid Anti-Strip Additives (type and dosage)
  • Location/Climate
  • Historical Performance
Mixture Selection

- 10 mixtures sampled
  - 3 good performers, 7 poor performers
  - 5 from Maine
  - 3 from Vermont
  - 1 from Connecticut and New Hampshire
# Mixture Selection Table

<table>
<thead>
<tr>
<th>Mix</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>MEP1</strong></td>
<td>12.5mm Poor, No additive, 64-28</td>
</tr>
<tr>
<td><strong>MEP2</strong></td>
<td>12.5mm Poor/Moderate, Amine-based anti-strip additive, 64-28</td>
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<tr>
<td>MEP3</td>
<td>12.5mm Poor, No additive, 64-28</td>
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<td>MEP4</td>
<td>12.5mm Poor, No Additive, 64-28</td>
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<td>CTP1</td>
<td>12.5mm Moderate, Amine-based anti-strip additive, 64-22</td>
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<tr>
<td>MEG1</td>
<td>12.5mm Good, No Additive, 64-28</td>
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<tr>
<td>VTG1</td>
<td>12.5mm Good, WMA Additive, 70-28</td>
</tr>
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<td>NHG1</td>
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Testing Plan Approach

**Preparation**
- Sample materials
- Specimen fabrication and volumetric testing
- Divide specimens into testing sub sets

**Conditioning**
- Modified Lottman procedure (AASHTO T283)
- MIST (ASTM D7870)
- Multi-cycle freeze-thaw

**Laboratory Testing**
- AASHTO T283: Indirect Tensile Strength
- AASHTO T324: Hamburg Wheel Track
- AASHTO T342: Dynamic Modulus
- Fracture Test: DCT and SCB
Laboratory Testing and Results
Testing Protocols

- All specimens produced by reheating loose mixture
  - Buckets only used once (no re-heating to minimize aging and variability)
- All specimens produced at 7 +/- 0.5% air voids
AASHTO T283 and ITS

- Most popular moisture susceptibility test
- Main outcome is the Tensile Strength Ratio (TSR)
  \[ TSR = \frac{\text{Average Strength of Conditioned Specimens}}{\text{Average Strength of Unconditioned Specimens}} \]
- Widely used
- Gives indication of cohesion and adhesion of mixes
- Relatively simple
MIST Conditioning

- Moisture induced Stress Tester (ASTM D7870)
- Simulates effect of water under repeated traffic loading at different pressures and temperatures
  - Test temperature
    - 60° C for PG 64-28
    - 50° C for PG 58-28
  - Cycles – 3,500
  - Pressure – 40 psi
  - Adhesion phase – 20 hours (moisture conditioning)
  - Cohesion phase – 3.5 hours (pressure cycles)
AASHTO T283 Results

Ratio results do not show distinction between good and poor mixtures.
AASHTO T283 with MiST

Ratio results do not show distinction between good and poor mixtures.
• Semi Circular Bend Test (AASHTO TP105)
  • Focused on fatigue cracking evaluation
  • Several alternative analysis methods
  • Typically tested at intermediate temperatures (25C)
  • Illinois method (IFIT) used with MiST conditioning
  • Fracture Energy and Flexibility Index
Whiskers on plot represent standard deviation.
AASHTO TP105 - SCB

Whiskers on plot represent standard deviation

Flexibility Index

Pre-MIST  Post-MIST
AASHTO T342 – Dynamic Modulus

- Measures the stiffness of mixtures at various temperatures and loading frequencies
- Specimen loaded in compression sinusoidally
- Carried out on the Asphalt Mixture Performance Tester (AMPT)
- Dynamic modulus is a fundamental material property (can related to changes in structural capacity of pavement)
# Materials

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AASHTO T342 – Dynamic Modulus

![Graph showing dynamic modulus vs. reduced frequency for different conditions: Good Performer Unconditioned, Good Performer MIST, Poor w/ Additive Unconditioned, Poor w/ Additive MIST, Poor w/out Additive Unconditioned, Poor w/out Additive MIST.](image_url)
AASHTO T342 – Dynamic Modulus

Pavement Life Implications?
AASHTO Pavement ME

- Mechanistic-Empirical analysis procedure
  - Mechanistic structural response (stress, strains)
  - Empirical distress prediction (transfer functions)
- Dynamic modulus – primary asphalt material input
  - Simulated as worst case scenario
  - Only dynamic modulus change—everything else remained constant
PavementME Results - Rutting

Significant Loss of Life

0.5 Inch Rut Depth Failure Threshold

Total Rut Depth (inch) vs. Months in Service

- VTG1 Unconditioned
- VTG1 Conditioned
- VTP1 Unconditioned
- VTP1 Conditioned
- VTP2 Unconditioned
- VTP2 Conditioned
PavementME Results - Fatigue

25% Cracked Lane Area Failure Threshold
PavementME Results - Roughness

172 in/mile Failure Threshold
AASHTO T324 - Hamburg

- Simulative test that applies repeated traffic loads through steel wheels (tests conducted on dry and submerged specimens)
- Measure rut depth and number of wheel passes (typically go to 20,000 passes)
- Some agencies already use this for moisture testing, several agencies are already equipped to conduct this test
AASHTO T324 - Hamburg

• Hamburg testing done by Maine DOT
• All mixtures tested at 45C
• Conventional Results-Taken from sheets provided by Maine DOT

![Rut Depth vs. Number of Wheel Passes](image)

- **Consolidation**: Even after compaction, the sample continues to consolidate for the first few wheel passes.
- **Stripping Point**: The sample begins stripping, which contributes to an increasing rate of rutting.
- **Inverse stripping slope**: The slope is the inverse of creep.
AASHTO T324 - Hamburg

- 7 Mixtures shown here

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AASHTO T324 - Hamburg

MEP3 < MEP1 < VTP2 < VTP1 < MEP2 < VTG1 < NHG
Yellow < Light Blue < Dark Blue < Red < Orange < Green < Purple
AASHTO T324 - Hamburg

MEP3 < MEP1 < VTP2 < VTP1 < MEP2 < VTG1 < NHG

Wheel Passes

- MEP3
- MEP1
- VTP2
- VTP1
- MEP2
- VTG1
- NHG1

Stripping Inflection Point
Passes to Failure (12.5mm)
Hamburg Results-Traditional

Much clearer distinction between good and poor performers
Hamburg–TAMU Method

- Proposed by Yin et al. (2015)
- Uses Stripping Number (SN) and Stripping Life Threshold (ST)
- Higher SN and ST → Better Moisture Resistance
Hamburg–TAMU Method

- Stripping Life Threshold (ST)

\[ \varepsilon^{st} = \varepsilon_0^{st} [e^{\theta(LC - LC_{SN})} - 1] \]

Remaining Life \((LC_{ST})\)

- Additional load cycles to create 12.5mm rut depth after \(LC_{SN}\)

Higher \(LC_{ST}\) = better resistance to stripping
Hamburg– TAMU Method

MEP3 < MEP1 < VTP2 < VTP1 < MEP2 < VTG1 < NHG

Wheel Passes

MEP3 < MEP1 < VTP2 < VTP1 < MEP2 < VTG1 < NHG

Stripping Number

Stripping Threshold
Hamburg Results-TTI Me

Clear distinction between good and poor performers
Results – Overall Conclusions

• All mixes (good and poor) pass TSR requirements showing lack of distinction in current AASHTO T-283 approach

• Substantial drop in asphalt mix dynamic modulus after MiST conditioning
  • Loss of serviceability and reduced pavement life

• SCB fracture tests did not show promising results with moisture conditioning

• Hamburg wheel tracking test shows most promise at differentiating moisture susceptible mixes
  • Analysis conducted using standard method and new approach
Results – Recommendations

• As a mix design/screening test to ensure adequate field performance, the Hamburg wheel tracker is recommended
  • Both traditional and Texas method work well

• For performance-based design/specifications and life cycle cost-based design, dynamic modulus paired with pavement analysis is recommended.
Questions and Comments?

Thank you for your attention!