USE OF THE AMPT TO EVALUATE PAVEMENT PERFORMANCE
ASPHALT MIXTURE ETG MAY 9TH, 2018

Derek Nener-Plante, M.S., P.E.
Asphalt Pavement Engineer

Integrity – Competence - Service
MaineDOT has not yet gained expertise in the AMPT and the analysis methods... yet.

Thanks to the following for their assistance:

- Dr. Kim & NC State Students / Staff
- FHWA
- MaineDOT lab staff
Talking Points

**Purpose:** To give the motivation, methodology, early results, and lessons learned from Maine’s work with the AMPT

**How?**
- Maine’s overall plan for AMPT
- Proficiency Test Results
- Performance-Related Specification Shadow Project
- PEMD
Background - MaineDOT

- Responsible for over 8,400 centerline miles of the 24,000 total miles in Maine
- Average capital program of $269 million per year
- Superpave mix design – full QA system based upon on volumetrics
Motivation for Change

Why doesn’t the HMA of today perform as well as it did in the past?

Are all mixes at the same NMAS / gyration created equal?

Is our current way of assessing payfactors effective?

Is 4% voids the right target for all mix designs?

Is this design optimized for payfactor or performance?
Background – HMA Process

- HMA acceptance program based upon PWL Volumetric requirements (Voids, VMA, VFB, AC)
- Most mix designs blend different combinations of aggregates
  - Crushed ledge product (granite, sandstone, limestone, etc.)
  - Crushed gravel product
  - Natural sands
  - RAP (10% - 20%)
- Using un-calibrated PavementME for design
Maine’s AMPT Objectives

- To provide data to predict pavement performance in the State of Maine, for potential use in the following applications:
  - Pavement design (PavementME, FlexPave, etc.)
  - Performance-Related Specification (PRS) development
  - Performance-Engineered Mixture Design (PEMD)
Asphalt Mixture Performance Tester Series

Dynamic Modulus, Cyclic Fatigue, and Stress-Sweep Rutting
AMPT Performance Test Methods

- **Modulus**
  - Axial compression dynamic modulus test (AASHTO T 378)
  - Dynamic modulus mastercurve and time-temperature shift function

- **Cracking Resistance**
  - AMPT cyclic fatigue test (AASHTO TP 107)
  - C vs. S (damage characteristic curve)
  - Energy-based failure criterion
  - Sapp cracking index parameter

- **Rutting Resistance**
  - Stress Sweep Rutting (SSR) test (spec under review by Asphalt Mixture and Construction ETG)
  - Reduced load time and stress shift factors
  - Shift model coefficients
  - Permanent strain index parameter
Rutting Test Specimen

- 100 mm
- 150 mm
- 178 mm

4 gyratory specimens needed

E* and Fatigue Test Specimen

- 38 mm
- 100 mm
- 110 mm

2 gyratory specimens needed
AMPT 38 mm Specimens
AMPT 38 mm Specimens
How?

- Setting up “calibration” projects all over the state (4-5 per year)
  - Acquire samples of all materials in all lifts — some to be tested and some to be retained indefinitely
  - Test all HMA lifts in the AMPT series
    - DM, CF, & SSR @ 5.0% air voids
    - DM @ 7.0% air voids
  - Will monitor performance for years
  - Will also build a library of different mixes across the state
- Target other projects for PRS or PEMD testing — same mix design at different volumetrics
Proficiency Tests

- First step = ensure that MaineDOT labs can perform the testing
- One large sample of plant produced mix was obtained from one truck
  - MaineDOT fabricated specimens and shipped to NCSU
  - The same mixture were tested at MaineDOT and at NCSU
  - The test results were compared
Proficiency Test Results

- Dynamic Modulus Tests

![Graph showing dynamic modulus tests results with various data points and fitting curves for different samples.](image-url)
Proficiency Test Results

Cyclic Fatigue Tests - Damage Characteristic Curve

- MaineDOT_1
- MaineDOT_2
- MaineDOT_3
- Fit_MaineDOT
- NCSU_1
- NCSU_2
- NCSU_3
- NCSU_4
- Fit_NCSU
Proficiency Test Results

Cyclic Fatigue Tests - Failure Criteria

$R^2 = 0.9649$
Proficiency Test Results

- Cyclic Fatigue Tests - Failure Criteria

\[ R^2 = 0.9983 \]
Objective: Use AMPT predictive models to show the impact of volumetric changes

- 10 samples were acquired in the field from the same mix design on the same project
- Volumetric acceptance tests were performed on each
- Performance tests were conducted on 4 of the 10 samples at MaineDOT
- 3 samples were shipped to NCSU.
## Sample Volumetric Properties

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Air Voids</th>
<th>VMA</th>
<th>Gmb</th>
<th>Gmm</th>
<th>% Binder</th>
<th>In-place Density</th>
<th>Test AV</th>
<th>Status</th>
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<td>Maine DOT</td>
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<tr>
<td>352</td>
<td>4.7</td>
<td>15.5</td>
<td>2.426</td>
<td>2.546</td>
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<tr>
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<td>2.412</td>
<td>2.524</td>
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<td>3.9</td>
<td>16.8</td>
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<td>2.502</td>
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<td>92.5</td>
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<td>17.3</td>
<td>2.391</td>
<td>2.509</td>
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<td>92.9</td>
<td>7.5</td>
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<td>NCSU</td>
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<td>16.4</td>
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<td>2.507</td>
<td>5.8</td>
<td>94.3</td>
<td>5.7</td>
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</table>
Sample Volumetric Properties

[Graph showing data points and lines indicating different categories such as QA Samples @ AV Limits, As Constructed, MaineDOT Testing, and NCSU Verification.]
Testing Results

- **Dynamic Modulus**

  ![Graph of Dynamic Modulus](image1.png)
  ![Graph of Dynamic Modulus](image2.png)
Testing Results

- Cyclic Fatigue Tests

![Graph 1](image1)

![Graph 2](image2)

![Graph 3](image3)

![Graph 4](image4)
Pavement Performance Prediction

Asphalt 4 in.

Base 8 in.

Subgrade

FlexPAVE™ 1.0
Fatigue Damage Prediction

% Damage Area vs. ESALs

- 159352_AV 7.5%
- 159355_AV 2.5%
- 159360_AV 2.5%
- 159361_AV 7.5%
- 159362_AV 5.7%
Rutting Depth Prediction

- Rut Depth (mm)
- Time (month)

Lines for:
- 159352_AV 7.5%
- 159355_AV 2.5%
- 159360_AV 2.5%
- 159361_AV 7.5%
- 159362_AV 5.7%
The PVR was calibrated using the performance test results generated by MaineDOT.

PVR was used to predict performance for mixes with different volumetric properties that were tested at NCSU for verification.
Verification of Cracking PVR

- Fatigue damage in 4-inch asphalt pavement

![Graph showing predicted % damage area versus FlexPAVE % damage area with points for calibration sections and verification section marked.]
Verification of Rutting PVR

- Rut depth of the AC layer in the 4 inch pavement

![Graph showing predicted rut depth vs. FlexPAVE rut depth.]

- Calibration Sections
- Verification Sections
Fatigue Index Parameter

- $S_{app}$
  - Fatigue resistance index
  - Considers both modulus and ductility

<table>
<thead>
<tr>
<th>Traffic Level (million ESALs)</th>
<th>$S_{app}$</th>
<th>Tier</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;= 3</td>
<td>$S_{app} \leq 8$</td>
<td>Light</td>
<td>L</td>
</tr>
<tr>
<td>&gt;3 and &lt;= 10</td>
<td>$8 &lt; S_{app} \leq 18$</td>
<td>Standard</td>
<td>S</td>
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<tr>
<td>&gt;10 and &lt;= 30</td>
<td>$18 &lt; S_{app} \leq 25$</td>
<td>Heavy</td>
<td>H</td>
</tr>
<tr>
<td>&gt;30</td>
<td>$25 &lt; S_{app} \leq 30$</td>
<td>Very Heavy</td>
<td>V</td>
</tr>
<tr>
<td>&gt;30 and slow traffic</td>
<td>$S_{app} &gt; 30$</td>
<td>Extremely Heavy</td>
<td>E</td>
</tr>
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</table>
% Damage from FlexPAVE™ vs. Sapp

![Graph showing the relationship between % Damage Area and Sapp, with a regression line and R² = 0.9836.]

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Test AV</th>
<th>Sapp</th>
</tr>
</thead>
<tbody>
<tr>
<td>159352</td>
<td>7.5</td>
<td>16.8</td>
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<tr>
<td>159355</td>
<td>2.5</td>
<td>29.3</td>
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<tr>
<td>159360</td>
<td>2.5</td>
<td>31.3</td>
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<tr>
<td>159361</td>
<td>7.5</td>
<td>18.1</td>
</tr>
<tr>
<td>159362</td>
<td>5.7</td>
<td>26.5</td>
</tr>
</tbody>
</table>
PEMD Concept

Volumetric Design

AMPT Testing @ 4.0% voids

Check against criteria

Adjust asphalt content

AMPT Testing at new target

Check against criteria
Performance-Engineered Mix Design

- Cracking Resistance
- Rutting Resistance

Minimum Required

Final optimum

Candidate Performance Optimum

Minimum Required
Performance-Engineered Mix Design

Predictive Equations or Agency’s Experience

Candidate Performance Optimum
Methodology

- 12.5 mm NMAS – 75 gyration – 20% RAP
- PG 64-28 binder (PPA modified <1%)
- Four different asphalt contents
  - Target - 0.5% (5.1%)
  - Target (5.6%)
  - Target + 0.5% (6.1%)
  - Target + 1.0% (6.6%)
Rutting Performance

![Graph showing rutting performance over number of cycles for 5.1%, 5.6% (Target), 6.1%, and 6.6%Permanent Strain vs. Number of Cycles.](image-url)
Rutting Performance

Permanent Strain @ 12,000 Cycles

- 5.1%
- 5.6% (Target)
- 6.1%
- 6.6%
**D^R Failure Criterion and Modulus**

*Measure of Toughness*

*Measure of Stiffness*
Sapp as a Fatigue Cracking Index
Fatigue Cracking Performance of Maine Mix Compared to Other Mixtures

![Bar chart showing fatigue cracking performance comparison between different mixtures with Maine having the lowest Sapp value of 9C.](chart_image)
Rutting Performance of Maine Mix Compared to Other Mixtures
Current mix design aim (5.6% AC) appears to optimize performance (fatigue cracking / rutting)

Data acquired follows logical mix design trends

Testing time for the PEMD approach is rather long, although it can be reduced

Steep learning curve with AMPT testing – although it does enhance fundamental understanding of mixes
Cyclic fatigue – Use bearing with top spacer plate for higher success rate. I suspect some of our failed test are due to stresses during bolt-up due to slightly non-parallel ends.

Cyclic fatigue – Allow 1.5hrs once bolted in AMPT to fully climatize prior to running the dynamic modulus fingerprint test (helps prevent unacceptable errors in the Dynamic Modulus Ratio between the dynamic modulus and cyclic fatigue data).

Cyclic fatigue – Be conservative when selecting the on-specimen strain rate, we had to decrease the on-specimen strain levels in order to stop end failures (failures outside the gauge points).

Dynamic Modulus – It isn’t surprising if some of the quality indicators fall slightly outside of the acceptable range, especially at high temp.

Tuning – Take the time at the beginning to work with tuning to get appropriate PID values, defaults were significantly off.

Coring – If your small specimens are coming out slightly ribbed, try decreasing the water pressure feeding the drill.

Equipment – Suggestion to have 6 pairs of cyclic fatigue end plates and 72 Gauge Points (LVDT studs to be able to prepare specimens while climatizing and testing others to maximize efficiency).
AMPT Lessons Learned

- It's all in the details...
  - Sealing of samples after receipt
  - Proper storage of samples
  - Selection of air void content
  - Use of CoreLok for air void determination
  - Conditioning of samples
Observations to Date

- The proficiency test results showed MaineDOT was able to perform the AMPT tests and generate high-quality data.
- The test results from the shadow mixes showed the test methods are able to predict the different pavement performance due to changes of AQC parameters.
- The performance-volumetric relationship was used to predict the pavement performance based on AQC data.
- The preliminary mix design and test confirmed the capacity of the mechanistic models and verified the original volumetric design of the mix.
Thank you for the opportunity.

Any Questions?

Derek Nener-Plante, M.S., PE
Asphalt Pavement Engineer
Derek.Nener-Plante@maine.gov
207-215-0849