Industry Use of the AMPT

Richard Steger, P.E.

InVia Pavement Technologies, LLC

2013 NCAUPG Technical Conference
Outline

1. Tests run on the Asphalt Mixture Performance Tester (AMPT) or similar devices/load frames
   - Dynamic Modulus (E*)
   - Flow Number (F_n) / Flow Time
   - Direct Tension Cyclic Fatigue
   - Overlay Test

2. How Industry can use the device
   - Specification/Supplier Guidelines Development
   - New Product Development
Outline

1. Tests run on the Asphalt Mixture Performance Tester (AMPT) or similar devices/load frames
   - Dynamic Modulus (E*)
   - Flow Number (F_n) / Flow Time
   - Direct Tension Cyclic Fatigue
   - Overlay Test (Draft ASTM)

2. How Industry can use the device
   - Specification/Supplier Guidelines Development
   - New Product Development
Apparatus
Outline

1. Tests run on the Asphalt Mixture Performance Tester (AMPT) or similar devices/load frames
   • Dynamic Modulus (E*)
   • Flow Number ($F_n$) / Flow Time
   • Direct Tension Cyclic Fatigue
   • Overlay Test (Draft ASTM)

2. How Industry can use the device
   • Specification/Supplier Guidelines Development
   • New Product Development
Mixture Characterizations using AMPT

Mixture Stiffness

- Dynamic Modulus (E*) - AASHTO TP 79-11 / T 342-11
- Determines the dynamic modulus and flow number for HMA/WMA
- Material input for pavement design

Resistance to Permanent Deformation

- Flow Number ($F_n$) / Flow Time (also AASHTO TP79-11)
AASHTO TP 79

Dynamic Modulus ($E^*$)
Flow Number ($F_n$) / Flow Time
Outline

1. Tests run on the Asphalt Mixture Performance Tester (AMPT) or similar devices/load frames
   - Dynamic Modulus (E*)
   - Flow Number ($F_n$) / Flow Time
   - Direct Tension Cyclic Fatigue
   - Overlay Test (Draft ASTM)

2. How Industry can use the device
   - Specification/Supplier Guidelines Development
   - New Product Development
Mixture Characterizations using AMPT

Durability

• Cyclic Fatigue - *Simplified Continuum Damage Uniaxial Fatigue*

• Proposed AASHTO Method
  ◦ *Standard Method of Test for Determining the Damage Characteristic Curve of Asphalt Concrete from Direct Tension Cyclic Fatigue Tests*
Cyclic Fatigue

Direct Tension Cyclic Fatigue
Outline

1. Tests run on the Asphalt Mixture Performance Tester (AMPT) or similar devices/load frames
   - Dynamic Modulus (E*)
   - Flow Number (F_n) / Flow Time
   - Direct Tension Cyclic Fatigue
   - Overlay Test (Draft ASTM)

2. How Industry can use the device
   - Specification/Supplier Guidelines Development
   - New Product Development
Mixture Characterizations using AMPT

Reflective Cracking

• Overlay Test

• Draft ASTM Standard Test Method
Reflective Cracking

Overlay Test
Outline

1. Tests run on the Asphalt Mixture Performance Tester (AMPT) or similar devices/load frames
   • Dynamic Modulus ($E^*$)
   • Flow Number ($F_n$) / Flow Time
   • Direct Tension Cyclic Fatigue
   • Overlay Test (Draft ASTM)

2. How Industry can use the device
   • Specification/Supplier Guidelines Development
   • New Product Development
WMA Chemical Manufacturer’s Guidelines/Specification Development

Modeled after existing work

• NCHRP 9-43, Report 691

• Build/expand on Appendix to AASHTO R 35: Special Mixture Design Considerations and Methods for Warm Mix Asphalt (WMA)

Address WMA lab sample prep to replicate field produced mix

WMA Mix Evaluations

• Coating, Compactability, Moisture Sensitivity, Rutting
WMA Chemical Manufacturer’s Guidelines/Specification Development

Expand on Compaction Ratio (Compactability)

• gyrations to 92 percent relative density, CDI/ Locking Point
• CFI / TFI / N@Norm $S_g\% (0.95)$
• $\sum W(N1 - N2) S_g$

Workability Test (Compactability)

• Dongré Workability Test (DWT)
  ◦ Currently run on Pine G2, other compactors should be able to run
  ◦ No special equipment
  ◦ ASTM Draft Test Method
WMA Chemical Manufacturer’s Guidelines/Specification Development

Determine effective dose rate for WMA additive
  • Compaction Metric (example)
  • DWT (example)

Evaluation of HMA & WMA using AMPT
  • Dynamic Modulus, $E^*$
  • Flow Number, $F_n$
  • Direct Tension Cyclic Fatigue
  • Overlay Test
Example HMA Mix Compaction Ratio

Gyration or "Compaction" Ratio

P109 no Evo Remakes

- 150C 1.060
- 120C 1.222
- 105C 1.270
- 90C 1.371
- 75C 2.365

18 January 2013
Example WMA Mix Compaction Ratio

Gyration or "Compaction" Ratio

- P109 W/Evo Remakes
Example HMA Mix - Norm Sg(N1-N2)

Normalized $S_g(N1-N2)$

P109 no Evo Remakes

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>150°C</td>
<td>149.14</td>
</tr>
<tr>
<td>120°C</td>
<td>123.74</td>
</tr>
<tr>
<td>105°C</td>
<td>105.42</td>
</tr>
<tr>
<td>90°C</td>
<td>93.10</td>
</tr>
<tr>
<td>75°C</td>
<td>58.83</td>
</tr>
</tbody>
</table>

INVIA

January 2013
Example WMA Mix - Norm Sg(N1-N2)

Normalized $S_g(N1-N2)$

P109 W/Evo Remakes

- 150C: 24.67
- 120C: 22.79
- 105C: 26.40
- 90C: 56.93
- 75C: 105.04

Legend:
- 150C
- 120C
- 105C
- 90C
- 75C
Example WMA Mix DWT workability

Temperature vs. DWT

\[ y = -0.0003x^3 + 0.1468x^2 - 21.846x + 1101.5 \]
\[ R^2 = 0.9764 \]

\[ y = 1.1413x - 78.756 \]
WMA Chemical Manufacturer’s Guidelines/Specification Development

Mixture aging

• As per RRD 370, *Guidelines for Project Selection and Materials Sampling, Conditioning, and Testing in WMA Research Studies*

PMFC -> DWT, Compaction Metrics

PMLC -> TSR, HWT, MiST, E*, F[sub n], OT, Direct Tension Cyclic Fatigue

• PMFC Aging conditions
  ◦ Compacted within 1 to 8 hours of production

• PMLC Aging conditions
  ◦ **TSR, HWT, MiST** - 2hrs @ WMA Compaction Temp + 16 Hr at 60C (140F) +2 Hr Compaction Temp
  ◦ **E*, F[sub n], OT, Cyclic Fatigue** - Long Term Aging (AASHTO R30) 5 days at 85C (185F) + 2 Hr at Compaction Temp
WMA Chemical Manufacturer’s Guidelines/Specification Development

Evaluate $E^*$, $F_n$, OT, Direct Tension Cyclic Fatigue

Current Status –

• Collected mix on 11 projects / 18 mixtures
• Running $E^*$, $F_n$, OT, Direct Tension Cyclic Fatigue
Outline

1. Tests run on the Asphalt Mixture Performance Tester (AMPT) or similar devices/load frames
   • Dynamic Modulus (E*)
   • Flow Number (Fn) / Flow Time
   • Direct Tension Cyclic Fatigue
   • Overlay Test (Draft ASTM)

2. How Industry can use the device
   • Specification/Supplier Guidelines Development
   • New Product Development
New Product Development

EvoFlex™ Recycling Additive

• Product Purpose
  ◦ Binder Grade Modification
  ◦ Improve RAP/RAS Blending
  ◦ Improved Workability
  ◦ Improved Coating

How is AMPT being used?

• Evaluate Binder, RAP, and RAS components during design to determine appropriate EvoFlex™ dose rate

Dynamic Modulus $E^*$

• Compare measured mix $E^*$ to Binder/Mix $E^*$ predicted via the Hirsch Model

Determine Blended Binder Grade

• Binder $G^*$ -> Run Hirsch Model -> Predict Mixture $E^*$
New Product Development

Comparisons - Allow product development to move forward

• How much to use?
• How to add material to mix in lab?

Commercialization activities

• How to use material in the mix design
• Demonstrate how materials perform
  • Mixture Stiffness and Rutting
  • Durability
  • Reflective Cracking
New Product Development

Testing Outline

• Dynamic Modulus Master Curve Testing on Plant Produced Mixture (AASHTO TP 79-11)

• Extraction and Recovery of Binders from Plant Produced Mixtures (AASHTO T 164 and ASTM D 5404)

• Partial Master Curve Testing of the As-Recovered Binder (AASHTO T 315)

• Compare Measured E* (from AMPT) with Predicted E* (Hirsch Model) \( F_n \) run for information only

• Grading of the Recovered Binders (AASHTO R29)
New Product Development

Testing Outline

• Dynamic Modulus Master Curve Testing on Plant Produced Mixture (AASHTO TP 79-11)

• Extraction and Recovery of Binders from Plant Produced Mixtures (AASHTO T 164 and ASTM D 5404)

• Partial Master Curve Testing of the As-Recovered Binder (AASHTO T 315)

• Compare Measured E* (from AMPT) with Predicted E* (Hirsch Model) Fn run for information only

• Grading of the Recovered Binders (AASHTO R29)
Mix E* Measured Master Curve
AASHTO TP 79-11

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Air Voids</th>
<th>VMA</th>
<th>VFA</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 58-28</td>
<td>5.1</td>
<td>14.5</td>
<td>64.8</td>
</tr>
</tbody>
</table>

Dynamic Modulus Master Curve

- Low Speed or High Temperature
- High Speed or Low Temperature

Reduced Frequency (Hz)

E* (ksi)
Hirsch Model

\[ E^* = f (VMA, VFA, \text{and } G^*_{\text{binder}}) \]

\[ E^* = P_c \left[ 4,200,000 \left(1 - \frac{VMA}{100}\right) + 3G^*_{\text{binder}} \left(\frac{VFA \times VMA}{10,000}\right) \right] + \left(1 - P_c\right) \left[ 1 - \frac{VMA}{100} + \frac{VMA}{4,200,000 + 3 \times VFA \times G^*_{\text{binder}}} \right]^{1.58} \]

\[ P_c = \left( \frac{20 + \frac{VFA \times 3G^*_{\text{binder}}}{VMA}}{650 + \left(\frac{VFA \times 3G^*_{\text{binder}}}{VMA}\right)^{0.58}} \right)^{-1.58} \]

Binder Extraction and Recovery
AASHTO T 164 & ASTM D 5404
New Product Development

Testing Outline

• Dynamic Modulus Master Curve Testing on Plant Produced Mixture (AASHTO TP 79-11)

• Extraction and Recovery of Binders from Plant Produced Mixtures (AASHTO T 164 and ASTM D 5404)

• Partial Master Curve Testing of the As-Recovered Binder (AASHTO T 315)

• Compare Measured E* (from AMPT) with Predicted E* (Hirsch Model) Fn run for information only

• Grading of the Recovered Binders (AASHTO R29)
Binder Testing AASHTO R29-08
New Product Development

Testing Outline

• Dynamic Modulus Master Curve Testing on Plant Produced Mixture (AASHTO TP 79-11)

• Extraction and Recovery of Binders from Plant Produced Mixtures (AASHTO T 164 and ASTM D 5404)

• Partial Master Curve Testing of the As-Recovered Binder (AASHTO T 315)

• Compare Measured E* (from AMPT) with Predicted E* (Hirsch Model) $F_n$ run for information only

• Grading of the Recovered Binders (AASHTO R29)
Compare Mix E* (Measured) to Binder E* (Predicted)
New Product Development

Testing Outline

• Dynamic Modulus Master Curve Testing on Plant Produced Mixture (AASHTO TP 79-11)

• Extraction and Recovery of Binders from Plant Produced Mixtures (AASHTO T 164 and ASTM D 5404)

• Partial Master Curve Testing of the As-Recovered Binder (AASHTO T 315)

• Compare Measured E* (from AMPT) with Predicted E* (Hirsch Model)

• Grading of the Recovered Binders (AASHTO R29)
## Binder Grading (AASHTO M320)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Test</th>
<th>Temperature °C</th>
<th>PG 58-28 E-3 19-mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>As Recovered</td>
<td>G*/sinδ, kPa AASHTO T 315</td>
<td>58</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>64</td>
<td>5.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>70</td>
<td>2.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>76</td>
<td>1.21</td>
</tr>
<tr>
<td>Pressure Aging Vessel Residue</td>
<td>G*/sinδ, kPa AASHTO T 315</td>
<td>16</td>
<td>6695</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19</td>
<td>4840</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22</td>
<td>3330</td>
</tr>
<tr>
<td></td>
<td>Creep Stiffness, MPa AASHTO T 313</td>
<td>-18</td>
<td>204</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-12</td>
<td>112</td>
</tr>
<tr>
<td></td>
<td>m-value</td>
<td>-18</td>
<td>0.306</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-12</td>
<td>0.343</td>
</tr>
<tr>
<td>Continuous Grade, °C</td>
<td>High</td>
<td>N/A</td>
<td>71.1</td>
</tr>
<tr>
<td></td>
<td>Intermediate</td>
<td>N/A</td>
<td>18.7</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>N/A</td>
<td>-29.0</td>
</tr>
<tr>
<td>Grade</td>
<td>AASHTO M 320</td>
<td>N/A</td>
<td>70-28</td>
</tr>
</tbody>
</table>
Summary

AMPT Mechanical Testing

• Specification/Supplier Guidelines Development
  ◦ Dynamic Modulus Data Can be Used to Evaluate Chemical WMA
  ◦ Allows Supplier to understand WMA effects on mixture mechanical tests
  ◦ Mixture mechanical tests used to develop Supplier point of view on how best to use WMA
  ◦ Mechanical mixture test data can be related to field performance
  ◦ Predicted field performance can make it easier to agencies to adopt new products for regular use in construction

• New Product Development – EvoFlex™
  ◦ Mix E* used to evaluate RAP & RAS mixtures with EvoFlex™
  ◦ Test is sensitive to binder stiffness
Acknowledgements

Jason Bausano, PhD, P.E. – Research Engineer
MeadWestvaco Specialty Chemicals Division

Todd Lynn, PhD, P.E. – Principal Engineer
Thunderhead Testing
Questions?