UPTiM™
Unified Performance Tests using incremental Method
(Practical Tests for Practitioners)

By:
Dr. Haleh Azari, President
And
Ala Mohseni, Ph.D., P.E.
Pavement Systems LLC

OKDOT Webinar
January 25, 2016
Outline

• UPTiM Background

• Mixture Tests
  1. Rutting: AASHTO TP 116
  2. Fatigue
  3. Moisture Damage

• Binder Tests
  1. Low Temperature (iCCL)
  2. Intermediate Temperature
  3. High Temperature (iRLPD)

• Mixture Grading using Mastic Tests
  1. Low-Temperature Grade
  2. High-Temperature Grade

• Wrap up
What is UPTiM™?

• UPTiM is a **new and innovative** approach proposed by Pavement Systems to address the needs of asphalt industry:
  • practical characterization of new materials
  • that can also be incorporated into Pavement Design
  • Performance based QA/QC

• Determine the effects of new additives such as Polymer, Rubber, REOB, Rejuvenators, RAP/RAS on:
  1. Rutting
  2. Fatigue Cracking
  3. Thermal Cracking
  4. Moisture Damage
  5. Top-down Cracking
  6. Block Cracking
UPTiM™ Principles

- **Unified**
  - Same general methodology applied to all tests,
  - Same parameter (m*) used for all tests
  - m* = Permanent strain rate at steady state

- **Performance Test**
  - Low, intermediate (fatigue) and high temperature,
  - Asphalt binder, Emulsions, mastic and mixture,
  - Moisture damage

- **Incremental**
  - Test conducted in several stress / temperature increments (previously multiple tests on one sample was avoided)
Due to consolidation (field compaction) and visco-elastic effects not related to field performance

shear deformation, the best representation of field

Tertiary stage is failure primarily due to fatigue

UPTiM Parameter $m^*$

Primary

Secondary

Tertiary

Rapid change in strain rate

Minimum strain rate

Flow Number

no. of Cycles

Strain rate consistent

$m^*$
UPTiM Incremental Approach
UPTiM Advantages

• **Field Simulated**
  • No pre-assumption about stress-strain relationship
  • Test variables (load, temp.) are set similar to the field
  • Test parameter (m*) is directly related to damage in field

• **Practical Tests**
  • All tests are quick (conducted in less than half hour)
  • Easy to prepare samples, mount the specimen

• **Environmentally Friendly**
  • Uses less asphalt material, thus less fumes
  • No hazardous materials (alcohol, solvents, etc.)
  • Very easy to clean without the need for chemicals
UPTiM Extends Superpave Objectives

- Superpave:
  - Allows determination of a mixture’s ability to resist fracture and permanent deformation

- UPTiM’s additional objectives:
  - Predict the performance and distress
  - Include New Materials such as RAP, RAS, Rubber, REO, etc.
  - Include Near Surface distresses such as:
    - Top-down cracking
    - Block cracking
UPTiM™ 10-Year Development

- Developed by Pavement Systems
- 2005, idea was initiated by Dr. Mohseni during development of LTPPBind
- 2008, initial proposal prepared by Mohseni for FHWA
- 2010, iRLPD competed with 6 candidate methods at ETG for evaluating existing rutting protocols
- 2012, iRLPD moisture damage and fatigue tests final development
- 2013, iRLPD was chosen as the best test method to correlate with field rutting performance
- 2014, Low / intermediate Temp. Binder tests developed
- 2015, iRLPD Rutting test becomes AASHTO TP 116
- 2015, mastic test was verified by materials from states
UPTIM™ Test Modes

• Creep (iCCL™)
  • incremental Creep for Cracking at Low temperature
  • Low Temperature binder and mastic tests

• Repeated Load (iRLPD™)
  • Incremental Repeated Load Permanent Deformation
  • High Temperature Binder, Mastic, and Mixture
  • Intermediate Temperature Binder, Mastic, Mixture
  • Moisture damage
UPTiM Testing Equipment: Dynamic Shear Rheometer (DSR) and Asphalt Mixture Performance Tester (AMPT)
iRLPD™ Rutting
AASHTO TP 116

• Specimen Compacted to the size (NOT cut/Cored)
• No LVDT attached
• Loading
  • Repeated load, 0.1s/0.9s
  • Stress: 200, 400, 600, 800 kPa
  • 500 cycles/increment
• Test Temperature:
  • Eq. Based on Degree-Days
• Test parameter:
  • Minimum Strain Rate ($m^*$)
  • $m^*$ master curve $m^*_a TP^b$
  • Unit Rut due to Any $T$ and $P$
• ESAL Prediction from $m^*$
• Duration: 33 minutes
Ranking of ETG Mixtures
Estimating ESAL from m*

ESAL\textsubscript{A} = 10^{(1.7 - 0.07 \textit{m}^*)}

Where:
- ESAL\textsubscript{A} = Allowable ESAL, million ESAL
- \textit{m}^* = Minimum Strain Rate at 600 kPa and \textit{T}_{eff}
- \textit{T}_{eff} = 58 + 7.0 \times DD - 15 \log(z + 45) (Degree-Days from LTPPBind)

<table>
<thead>
<tr>
<th>Traffic Category</th>
<th>Traffic Level, MESALs</th>
<th>Critical MSR Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 to &lt;3</td>
<td>16 to &lt;24</td>
</tr>
<tr>
<td>2</td>
<td>3 to &lt;10</td>
<td>10 to &lt;16</td>
</tr>
<tr>
<td>3</td>
<td>10 to &lt;30</td>
<td>3 to &lt;10</td>
</tr>
<tr>
<td>4</td>
<td>≥30</td>
<td>&lt;3</td>
</tr>
</tbody>
</table>
Verification of ETG Mixtures

![Graph showing traffic level (MESALS) for different mixtures with design traffic and allowable traffic comparison.](image)
iRLPD Mixture Fatigue Test

Principles of ANY Fatigue Test:

1. Fatigue Cracking:
   • Fatigue: Repeated Load
   • Cracking: Test should be carried to failure
2. Loading rate should be similar to the field
3. Should include rest period
4. Damage should be similar to the field
5. Sample should be long-term aged
6. Test should be conducted at Critical Fatigue Temperature defined as the temperature at which material is neither ductile nor stiff
iRLPD Mixture Fatigue Test

- AMPT
  - 150-mm Dia. SCB
  - 50-mm Thick. compacted
  - Uses actuator (No LVDTs)
- Loading:
  - Repeated load:
    - 0.1 s Load, 0.9 s rest period
- Stress Sweep
- Test Temperature:
  - Temperature sweep
- Parameters:
  - Fatigue Index: m* at failure
  - Intermediate Temperature
- Duration: 25 min., max

![Graph and table showing test results]
iRLPD Fatigue Samples are Easy to Make and Long-Term Aged Using AASHTO R30
iRLPD™ Mixture Fatigue Index for ALF

![iRLPD Mixture Fatigue Index for FHWA ALF Study](chart.png)
Correlation between Mixture & Extracted Binder Fatigue Index

iRLPD Fatigue Index (MSR) - Mixture vs Binder

- Lab PG64-22
- Control
- 20% RAP
- 40% RAP
- 20% RAS

Binder Fatigue Index, Millistrain

Mixture Fatigue Index, Microstrain
iRLPD Moisture Damage Test

- AMPT, No LVDTs
- Sample size:
  - SCB 150-mm x 50-mm
- Loading:
  - Before conditioning
  - Part of conditioning
  - After conditioning
- Test Temperature: 25°C
- Parameter:
  - Moisture Damage = m* Ratio before and after conditioning
  - Criteria = Damage Ratio > 1.5
iRLPD-Moisture vs AASHTO T-283

• Efficiency
  • Provides better Moisture Damage Measure than TSR
  • Damage is caused by Pore pressure; directly related to the field condition
  • Significantly higher precision
  • Same specimens used before and after conditioning

• Cost-effectiveness
  • Reduces sample preparation and testing time by 80%
    • Total conditioning and testing time is 4 hr
  • Runs on AMPT. (No extra loading device or Jig)

• Sustainability
  • Requires significantly less material
Questions?
iRLPD™ Binder Tests

1. Low Temperature
2. High Temperature
3. Intermediate Temperature
4. Emulsions
5. Aging
iCCL™ (icicle)
Incremental Creep for Cracking at Low temperature
incremental Creep for Low-Temperature Cracking (iCCL) Binder Test

• DSR, 8-mm Plate, 0.5-mm Gap
• Loading (follows BBR):
  • Creep load
  • Test time: 60 seconds for each increment
• Temperature increments:
  • From 0 to LT PG+10, every 6°C
• Parameters:
  • Total Strain after 60 seconds
  • \( m^* = \text{Strain Rate at 60 seconds} \)
    \[ = \gamma_{t=60} - \gamma_{t=59} \text{ in } \mu\varepsilon \]
Creep Test at -12°C for PG 64-22
FHWA ALF Binders

m* at -12°C

Low-Temp. Grade

Chart 1: m* at -12°C

Chart 2: Low-Temp. Grade
MnDOT Binders (m* @ -12°C)
OKDOT Binders Low-Temperature Grade
$m^*$ at -12°C (183 Binders, 20 States)

Recent: SC, NC, OK, MD, CO, MS, MN, WA, VA, VW, OH, NE, ME, FL

Previously: AL, IN, NJ, TX, WI, WY

Suppliers: Nustar, Holly Fr., Ergon

AASHTO AMRL, FHWA ALF, NCAT
iCCL Provides $m^*$ Master Curve for Continuous Grading
Effect of Physical Hardening on Grade

\[ y = 2077.8x^{-2.821} \]
\[ R^2 = 0.998 \]
PAV Does not Represent Near Surface

- WRI Aging Study 2006-2008
- HMA pavements oxidize most rapidly at their top surfaces
- The binder at the surface has a much higher stiffness than bulk
- The depth of the RTFO/PAV viscosity corresponding to 48 months was estimated at 40 mm
- 65% Reduction of viscosity from the top to the next 13-mm
- Minor differences between the sections below the top section
Near Surface Ranking Different than PAV
Emulsion Recovery/Aging Method for iCCL
iCCL Can Test Asphalt at Near Surface

• Superpave binder tests on RTFO/PAV, designed for:
  1. Bottom up Fatigue Cracking
  2. Low-Temperature Thermal Cracking

• UPTiM includes aging asphalt to near surface level
  • Aging is conducted well beyond RTFO/PAV level

• iCCL is used to test near surface binder for:
  1. Top-down Fatigue Cracking
  2. Block Cracking

• iCCL extends the capabilities to:
  1. Physical Hardening
  2. Emulsions Durability
Advantages of iCCL Test

• Provides same grade as BBR
  • However, with much less effort and at much less time

• Can be used as a quick screening tool

• The test on DSR is significantly simpler
  • test takes about 30 minutes
  • No frequent calibration of the device
  • No dealing with hazardous material

• The specimen preparation is simpler
  • No molding and demolding
  • No limitations of storage and testing time
Questions?
iRLPD™ High Temperature Binder Test

- AASHTO M 320 HT Binder Grade is the core of asphalt Binder Testing
- iRLPD HT Binder Test is a PG Plus test designed to Extends M320 capabilities:
  - Provide Allowable Traffic
  - Binder Stress Sensitivity
  - Modification level (Polymer, Rubber)
  - Correlated with Mixture
iRLPD™ High Temperature Binder Test

- DSR 25 mm plate (M 320)
- Loading:
  - Repeated Load (0.1/0.9 s)
  - 30 Cycles/increment
  - Stress Increments: 1, 3, 5 kPa
- Temperatures:
  - 3 temperature increments:
    - PG, PG-6°C, PG-12°C
- Parameters:
  - \( m^* = a T^b S^c \) \( (R^2 \sim 1.0) \)
  - \( c = \text{Stress Non-linearity coefficient} \)
- Duration: 15 Minutes
High Temp. Mixture vs. Binder MSR (m*)

\[ y = 2.1047 \ln(x) - 0.5099 \]
\[ R^2 = 0.8948 \]
iRLPD™ Binder Fatigue Test

Basis: Incrementally increase Temperature until Failure

1. Loading is set similar to passing of heavy truck axle
   • Loading rate resembles high speed traffic
   • Includes rest period which significantly affect performance
   • Stress level is similar to field

2. Sample long-term aged

3. Test is carried to fatigue crack initiation

4. Parameter is taken at Critical Fatigue Temperature similar to SHRP Intermediate Temperature
iRLPD Binder Fatigue Test

- **DSR:**
  - RTFO/PAV
  - 8 mm plate, 0.5 mm Gap

- **Loading:**
  - 0.1 s load / 0.9 s rest
  - 60 cycles/increment

- **Temperature Sweep:**
  - Start at Midpoint PG,
  - Increase 1°C to reach Failure

- **Parameters:**
  - Fatigue Index= Permanent Strain at failure (m*)
  - Intermediate Temperature= Temperature at failure

- **Duration:** 20 Minutes
- **Correlated to Mixture**
ALF Extracted Binder Fatigue Index

iRLPD Binder Fatigue Index for FHWA ALF Study

Fatigue Index, Millistrain

<table>
<thead>
<tr>
<th></th>
<th>Fatigue Index</th>
<th>Int. Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG64-22 RTFO/PAV Extracted</td>
<td>16.0</td>
<td></td>
</tr>
<tr>
<td>Control Lane 1 Extracted</td>
<td>12.0</td>
<td>40.0</td>
</tr>
<tr>
<td>20% RAP Lane 6 Extracted</td>
<td>10.0</td>
<td>38.0</td>
</tr>
<tr>
<td>40% RAP Lane 5 Extracted</td>
<td>8.0</td>
<td>36.0</td>
</tr>
<tr>
<td>20% RAS Lane 3 Extracted</td>
<td>6.0</td>
<td>34.0</td>
</tr>
</tbody>
</table>
ALF Mixture vs. Extracted Binder Fatigue

iRLPD Fatigue Index (MSR) - Mixture vs Binder

- PG64-22
- 20% RAP
- 40% RAP
- 20% RAS
Fatigue Index for 65 Binders (9 PGs)
Questions?
Mixture Performance Grade using UPTiM Mastic Tests

Contents:
1. Quick Mastic Recovery from Mixture
2. iCCL Low Temperature Mastic Test
3. iRLPD High Temperature Mastic Test
4. Applications for Determining Effect of RAP/RAS/Rubber, REOB and Rejuvenators
Mastic Low Temperature (iCCL) Test

E) 64-22 20% +5
F) 64-22 30%
G) 64-22 30%
H) 64-22 +4% RAS
A) 58-28 20%+5 W
B) 64-22 25% +4
C) 64-22 30%
D) 58-28 40%
Minnesota DOT Mastic LT m* at -12°C
Oklahoma DOT LT Mastic Grade

<table>
<thead>
<tr>
<th>Temp</th>
<th>Aging</th>
<th>State</th>
<th>Outlier</th>
<th>Average of LPG2</th>
</tr>
</thead>
<tbody>
<tr>
<td>OK64-22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK64-22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK70-28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK64-22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK64-22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK64-22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK64-22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK64-22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK64-22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK64-22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK64-22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK64-22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK70-28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK70-28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OK76-28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

OK Low Temperature Mastic

-28
-22

Binder

LPG

52
Mastic LT m* at -12°C (118 mixtures)
High Temperature Mastic Test at 64°C

A) 58-28 20%+5 W
F) 64-22 30%
H) 64-22 +4% RAS
OK DOT Mixtures Mastic HT Grade
MnDOT Mixtures Mastic HT Grade
Mastic HT Grade for 58 Mixtures
LTPPBind® V3.1 = Mastic HT Requirement
# ALF Mastic Test for Effect of RAP/RAS

<table>
<thead>
<tr>
<th>ALF Lane #</th>
<th>% ABR RAP</th>
<th>Virgin PG Grade</th>
<th>Drum Discharge Temperature</th>
<th>WMA Process</th>
<th>Paving Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>64-22</td>
<td>300-320</td>
<td>--</td>
<td>8/27/2013</td>
</tr>
<tr>
<td>3</td>
<td>--</td>
<td>20</td>
<td>300-320</td>
<td>--</td>
<td>8/29/2013</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>64-22</td>
<td>300-320</td>
<td>--</td>
<td>8/19/2013</td>
</tr>
<tr>
<td>6</td>
<td>20</td>
<td>64-22</td>
<td>300-320</td>
<td>--</td>
<td>9/18/2013</td>
</tr>
</tbody>
</table>
ALF Mastic High Temperature Grade

ALF Lab and Field Mixture PG

<table>
<thead>
<tr>
<th></th>
<th>True PG</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG64-22</td>
<td>64</td>
</tr>
<tr>
<td>ALF Lane 1</td>
<td>64</td>
</tr>
<tr>
<td>40% RAP Lab</td>
<td>82</td>
</tr>
<tr>
<td>40% RAP Lane 5</td>
<td>94</td>
</tr>
<tr>
<td>20% RAS Lane 3</td>
<td>106</td>
</tr>
</tbody>
</table>
ALF Mastic Low-Temperature Grade

The graph shows the low-temperature grade comparison for different ALF mixtures:

- **ALF-Control** has the highest low-temperature grade among the samples.
- **ALF-Rap20** and **ALF-Rap40** show moderate low-temperature grades.
- **ALF-Ras20** has the lowest low-temperature grade.

Legend:
- Blue bars represent 58-28 grade.
- Red bars represent 64-22 grade.
ALF Mastic vs. Extracted + PAV Binder

\[ y = 0.3132x + 1.6443 \]
\[ R^2 = 0.9406 \]
Mastic vs. PAV Binder for Selected Binders

\[ y = 0.2965x - 7.1085 \]

\[ R^2 = 0.9556 \]
LTPPBind® V3.1 +i = Allowable Traffic
Questions?
UPTiM™ Capabilities

• Variety of Materials:
  • Binder
  • Mastic
  • Mixture
  • Emulsion
  • Near Surface aged materials

• Variety of Distresses:
  • Rutting
  • Block Cracking
  • Fatigue Cracking
  • Moisture Damage
  • Physical Hardening
  • Top-down Cracking

• Different Temperatures:
  • Low Temperature
  • High Temperature
  • Intermediate Temperature
UPTiM Tests Improve Current Standards

Prof. Andre Molenaar (Tu Delft): These tests are fast, accurate, and meaningful and would work well for QA/QC (ISAP 2014)

1. iRLPD-Rutting (AASHTO TP 116) imp. AASHTO TP 79
2. iRLPD-Mixture Cracking imp. AASHTO T 321
3. iRLPD-Moisture Damage imp. AASHTO T 283
4. iRLPD- Binder High Temperature imp. AASHTO T 315
5. iRLPD- Binder Fatigue imp. AASHTO T 315
6. iCCL- Binder Low-Temperature imp. AASHTO T 313 (BBR)
7. iRLPD- High Temperature Mastic Grade
8. iRLPD- Mastic Fatigue
9. iCCL – incremental Creep for Cracking at Low Temp.
UP TiM

- Safer
- Faster
- Simpler
- Practical
- Universal
- Innovative
- Field Related
- Very Accurate
- Highly Efficient
- Quality Control
- Technically sound
- Highly Repeatable
- Extend Capabilities
- Environmentally Friendly
- Determine Effect of RAP/RAS
Current Status of UPTiM™ Implementation

• **iCCL:** Being considered for European standards

• **Mixture Fatigue:**
  • ASTM Work item
  • North Carolina implementation

• **Rutting:** AASHTO TP 116
  • Looking for states to implement

• **Moisture Damage:**
  • 14 states showed interest in a survey

• **Binder, Mastic Tests:**
  • Perform testing for a state and a European country
Services Provided by Pavement Systems

• **Implementation, software and training:**
  - Rutting: AASHTO TP 116

• **Evaluation:**
  - Mixture Fatigue
  - Moisture Damage

• **Perform Screening Tests:**
  - iCCL for binders
  - iRLPD Fatigue for binder and mastic

• **Quality Control**
  - Mixture Performance Grading using high and low temperature mastic Tests
Where do we go from here?

• Pavement Systems has developed UPTiM in-house
  • With no external funding

• We are going to work with individual states and countries for implementation
  • Evaluation / implementation in the states
  • European Standards, etc.

• A large scale project would expedite implementation
  • National Effort
  • International level
Questions?

Contact:
Dr. Haleh Azari, President
Pavement Systems LLC
6105 Maiden lane
Bethesda, MD 20817
(202) 286-0148
azri@pavesys.net

www.pavesys.net