PA Initiative on Asphalt Mix Performance Tests

Pennsylvania Asphalt Pavement Association

Regional Technical Meeting

March 17, 18, 19, 2020

Gary Hoffman, PAPA
and
Mansour Solaimanian, Penn State
# DISCUSSION TOPICS

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<tr>
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<th>Performance Based Testing &amp; Long-Life Asphalt Pavements</th>
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</thead>
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<td>PA Initiative on Performance Testing</td>
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<tr>
<td>3</td>
<td>Candidate Performance Tests</td>
</tr>
<tr>
<td>4</td>
<td>Results, Summary, Conclusions</td>
</tr>
</tbody>
</table>
# DISCUSSION TOPICS

1. Performance Based Testing & Long-Life Asphalt Pavements
2. PA Initiative on Performance Testing
3. Candidate Performance Tests
4. Results, Summary, Conclusions
LLAP Best Practices

- SMA Wearing
- WMA/Antistrip
- MTV Required
- Longitudinal Joint Density Specification
- **RIDE SPECIFICATION OPTIONAL**
- Tack Coat Every Layer (New Section 460)
- % **WITHIN TOLERANCE (PWT) ACCEPTANCE**
- **INCENTIVIZE CRITICAL ELEMENTS (i.e. MAT DENSITY)**
- **PERFORMANCE TESTS/BALANCED MIX DESIGN**
Examples of Performance Tests

- DCT
- IDEAL-CT
- crack
- Wheel Tracking
- rut
- SCB
Performance Test & LLAP

driven by:

- TQI
- STIC
Balanced Asphalt Mix Design

[Diagram showing a graph with axes labeled 'Asphalt Content' on the horizontal axis and 'Cracking Resistance' on the vertical axis. The graph includes a blue line representing cracking resistance and a red line representing rutting resistance. The area between the two lines is labeled 'Acceptable AC Range,' indicating the desired range for the asphalt mixture.]
HWT testing Pilot

Hamburg Wheel-Tracking Device
HWT Testing Advantages

• Well accepted nationally for rut testing

• Rutting Resistance Measure
  • Very well established track record detecting rut-prone asphalt mixtures.
  • Rules of thumb
    • 12.5mm at 20,000 cycles for polymer modified mixes
    • 12.5mm at 10,000 cycles for non-polymer modified mixes

• Moisture Susceptible Aggregate Measure
  • Can replace AASHTO T283 (TSR) eventually
HWT Standard Special Provision Status

- Standard Special previously circulated through APQIC Pro-team.
- CT 1 and CT 2 circulated
- Shooting for end of March for solicitation letter to Districts.
- Asking Districts to include the special provision on a minimum of 3 projects in the 2020 construction season with anticipated final inspection dates before October 31, 2021.
- Payment is a PDA. (about $700 per test)
HWT Standard Special Provision 2020

• HWT Testing results are for **information only** in 2020.

• HWT test results are not required until the **final project inspection**.

• No project construction delays because of testing availability or results in 2020.

• Payment to contractor for HWT testing in 2020.

• Incremental changes in future years.
  • Incidental to JMF, Testing requirement for JMF approval, Limits established…
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</tbody>
</table>
Performance Testing

- General agreement on the rutting test (HWT) and test protocols.

- The “school is still out” on the best cracking test and test protocols.
Industry SCB/IDEAL CRACK Testing: How Did It Start?

- Move to Crack Performance Testing
- Initiated by Asphalt Quality Improvement Committee and PAPA
- Industry Interested in Accelerating Move to Performance Testing
Purpose of the Effort

- Bridge the Gap to Crack Performance Testing
- Investigate Performance of PA Mixes in SCB/IDEAL crack performance tests
- Develop A Database of SCB/IDEAL Test Results
- Evaluate Sensitivity of the PA Mixes to the Tests
- Evaluate Correlation with Field Performance
SCB
Mix Criteria and Variables

- Air Void: 5.5% (Final SCB Specimen)
- Design Binder Content (and +0.5%)
- Mixes with 15% RAP at Design BC and at 0.5% Higher Binder Content
- Mixes at higher RAP Contents
- NMAS: 4.75, 9.5mm, 12.5mm, 19mm, 25mm
- Lab vs Plant Produced
- Short term vs Long Term Aging
Data Range: Flexibility Index (higher is better)

Average = 8.1

Average = 4.6
General Observations

1. Higher AC Content $\rightarrow$ higher F.I.
2. Higher RAP content lower F.I.
3. Longer aging $\rightarrow$ lower F.I.
4. Plant mix has higher F.I. than lab mix
5. Higher voids $\rightarrow$ higher F.I.
6. SMA mix delivers higher F.I.
7. Finer mix with high BC $\rightarrow$ higher F.I.
# DISCUSSION TOPICS

1. Performance Based Testing & Long-Life Asphalt Pavements
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4. Results, Summary, Conclusions
Performance Tests Under Consideration

- Hamburg Wheel Tracking
- IDEAL-CT Test
Hamburg Wheel Tracking (AASHTO T 324)

Moisture Conditioning with Hydrostatic Pore Pressure (ASMT D7870) + 20 Hr. Conditioning for Adhesion

MiST (Moisture Induced Stress Tester)
Traffic Effect on Moisture Damage

Pore Pressure Build-Up
Due to External Cyclic Stress

Compression/Tension Cycle
(Cyclic Pressure/Suction)
Wheel Tracking Test Data

Zone of Primary Creep

Zone of Secondary Creep

Wheel Passes

Tertiary Creep

Stripping Inflection Point
Binder Stiffness Effect

Number of Wheel Passes

Rut Depth, mm

Source: Dolomite/Limestone
Binder Stiffness Effect

HWT - Submerged

PG 64-22  PG 58-28

SP 12.5mm – Limestone Aggregate (Aggregate 1)
Binder Stiffness Effect

HWT - Submerged

PG 64-22  PG 58-22

SP 9.5mm – Limestone/Dolomite Aggregate
(Aggregate 2)
Mix/Aggregate Effect

Number of Wheel Passes

Rut Depth, mm

Mix 1
Mix 2

PG 58-22
Mix/Aggregate Effect

Number of Wheel Passes

Rut Depth, mm

Mix 1
Mix 2

PG 64-22
Rejuvenator Effect – 35% RAP Mix

Number of Wheel Passes

Rut, mm

-0% Rejuvenator
-2% Rejuvenator
-5% Rejuvenator
-8% Rejuvenator

0 4,000 8,000 12,000 16,000 20,000
Looking at Wheel Tracking Results for

- Submerged
- MiST Conditioned
- Dry
Aggregates Used in the Study

Limestone, Dolomite, and Siliceous Gravel

Dolostone shown here
HWTD - Submerged

PARAMETERS from WHT

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIP (# of passes)</td>
<td>11,262</td>
</tr>
<tr>
<td>Ratio of the slope (strip/creep)</td>
<td>4.99</td>
</tr>
<tr>
<td>Max Rut (mm)</td>
<td>-24.10</td>
</tr>
<tr>
<td>No. of Passes to 10 mm rut depth</td>
<td>14,294</td>
</tr>
<tr>
<td>Rut depth at 10,000 passes, mm</td>
<td>-5.36</td>
</tr>
<tr>
<td>Stripping Slope (mm/1000 passes)</td>
<td>1.52</td>
</tr>
</tbody>
</table>
HWTD – after MiST

**PARAMETERS**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIP (# of passes)</td>
<td>10,740</td>
</tr>
<tr>
<td>Ratio of the slope (strip/creep)</td>
<td>1.38</td>
</tr>
<tr>
<td>Max Rut (mm) at 22,000 passes</td>
<td>-8.91</td>
</tr>
<tr>
<td>No. of Passes to 10 mm rut depth</td>
<td>25,296</td>
</tr>
<tr>
<td>Rut depth at 10,000 passes, mm</td>
<td>-5.4</td>
</tr>
<tr>
<td>Stripping Slope (mm/1000 passes)</td>
<td>0.30</td>
</tr>
</tbody>
</table>
HWTD - Dry

### PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIP (# of passes)</td>
<td>&gt;22,000</td>
</tr>
<tr>
<td>Ratio of the slope (strip/creep)</td>
<td>0.92</td>
</tr>
<tr>
<td>Max Rut (mm) at 22,000 passes</td>
<td>-6.44</td>
</tr>
<tr>
<td>No. of Passes to 10 mm rut depth</td>
<td>51,470</td>
</tr>
<tr>
<td>Rut depth at 10,000 passes, mm</td>
<td>-5.17</td>
</tr>
<tr>
<td>Stripping Slope (mm/1000 passes)</td>
<td>0.12</td>
</tr>
</tbody>
</table>
PG 58-28
Wet

PG 58-28
Dry
Dry vs. MiST vs. Submerged

Mix 1 - Left Track
Performance Tests Under Consideration

- Hamburg Wheel Tracking
- IDEAL-CT Test
## Traffic Based Criteria (HWT) - Example

<table>
<thead>
<tr>
<th>Traffic Level, (Million ESALs)</th>
<th>Max. Rut Depth at 20,000 passes (mm)</th>
<th>SIP (Min.)</th>
<th>Strip/Creep Ratio (Max.)</th>
<th>Passes to 10mm Rut (Min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 10</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>16,000</td>
<td>2.0</td>
<td>15,000</td>
</tr>
<tr>
<td>≥ 3 and &lt;10</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>14,000</td>
<td>2.0</td>
<td>12,000</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>16,000</td>
<td>3.0</td>
<td>14,000</td>
</tr>
<tr>
<td>&lt;3</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>14,000</td>
<td>3.0</td>
<td>10,000</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>16,000</td>
<td>4.0</td>
<td>12,000</td>
</tr>
</tbody>
</table>
**IDEAL Cracking Test for Asphalt Concrete**

**Indirect Tensile Asphalt Cracking Test**

**IDEAL-CT**

Proposed by Research at Texas Transportation Institute (TTI)
Indirect Tensile Strength Test
(for AASHTO T 283, Tensile Strength Ratio (TSR))

\[ S_t = \frac{2P}{\pi tD} \]
Indirect Tensile Test at Low Temp.

IDT Test, -20°C, 12.5 mm/min

Stress, psi

Strain, %
Fracture Work = Area under the curve

Fracture Energy $G_f = \frac{\text{Fracture Work}}{\text{Area}}$

$G_f = \frac{\text{Fracture Work}}{tD}$

$t = \text{specimen thickness}$

$D = \text{specimen diameter}$
IDEAL – Test Results

Criteria established based on $CT_{Index}$

$$CT_{Index} = \frac{G_f}{P} \times \left( \frac{l_{75}}{D} \right)$$

$$\frac{P}{l} = |m_{75}| = \frac{P_{85} - P_{65}}{l_{85} - l_{65}}$$
Source of Mixes & Conditioning

Sources 1 and 2

Lab Prepared Mix → Long Term Aged (5 days @ 185°F) → LTOA

Source 3

Plant Prepared Mix → Short Term Aged → STOA
## Types of Mixes Tested (25 Mixes)

<table>
<thead>
<tr>
<th>Source</th>
<th># of Mixes</th>
<th># of Plugs</th>
<th>Mix Origin</th>
<th>Mix Condition</th>
<th>NMAS, mm</th>
<th>Binder Grade</th>
<th>Binder Content</th>
<th>RAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>9</td>
<td>27</td>
<td>Lab Prod.</td>
<td>LTOA</td>
<td>9.5</td>
<td>58-28</td>
<td>5.2 to 6.2</td>
<td>0, 15, 25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>64-22</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>76-22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>02</td>
<td>9</td>
<td>27</td>
<td>Lab Prod.</td>
<td>LTOA</td>
<td>9.5</td>
<td>58-28</td>
<td>5.1 to 6.1</td>
<td>0, 15, 25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>64-22</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>76-22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>03</td>
<td>7</td>
<td>35</td>
<td>Plant Prod.</td>
<td>STOA</td>
<td>6.3</td>
<td>64-22</td>
<td>6.3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>76-22</td>
<td>6.9</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9.5 (3)</td>
<td>64-22</td>
<td>5.9 &amp; 6.0</td>
<td>15.0, 20.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19 (2)</td>
<td>64-22</td>
<td>4.8 &amp; 5.1</td>
<td>25.0, 28.5</td>
</tr>
</tbody>
</table>

Types of Mixes Tested (25 Mixes)
Air Void Comparison

Reported Air Void, %

NECEPT Air Void, %
Breaking Specimens

Test Temperature: 25°C
Displacement Rate: 50 mm/min
Test Repeatability

Source 1

Specimens C4, C5, C6

NMAS: 9.5 mm, PG 64-22
Design Binder Content: 5.7%
Virgin Binder Content: 4.2
Average Air Void: 5.3%
RAP: 25%
Long term aged: 120 hrs at 85°C

Average IDEAL CT: 35.8
COV: 4.4%

Displacement Rate: 50 mm/min
Test Temperature: 25°C

COV on Fracture Energy: 4.4%
Test Repeatability

Specimens T1, T2, T3

Source 2

NMAS: 9.5 mm, PG 64-22
Design Binder Content: 5.6%
Virgin Binder Content: 5.6%
Average Air Void: 5.4%
RAP: 0%
Long term aged: 120 hrs at 85°C

Average IDEAL CT: 125.4
COV: 10.9%

Displacement Rate: 50 mm/min
Test Temperature: 25°C

COV on Fracture Energy: 1.0%
Specimens T16, T17, T18

Source 2

NMAS: 9.5 mm, PG 64-22
Design - 0.5% Binder Content: 5.1%
Virgin Binder Content: 5.1%
Average Air Void: 5.4%
RAP: 0%
Long term aged: 120 hrs at 85°C

Average IDEAL CT: 68
COV: 12.8%

Displacement Rate: 50 mm/min
Test Temperature: 25°C

COV on Fracture Energy: 1.0%
Displacement Rate: 50 mm/min
Test Temperature: 25°C
Specimens 6, 7, 8, 9, 10

Source 3

NMAS: 9.5 mm
Total Binder Content: 5.9%
Virgin Binder Content: 4.9%
PG 64-22
Average Air Void: 5.7%
RAP: 20%
Plant Produced Mix
Short Term Aged

Average IDEAL CT: 121
COV: 21.6%

COV on Fracture Energy: 4.4%
Test Repeatability

Source 3

Displacement Rate: 50 mm/min
Test Temperature: 25°C
Specimens 31, 32, 33, 34, 35

NMAS: 6.3 mm
Total Binder Content: 6.9%
Virgin Binder Content: 6.9%
PG 76-22
Average Air Void: 5.3%
RAP: 0%
Plant Produced Mix
Short Term Aged

Average IDEAL CT: 233
COV: 18.3%

COV on Fracture Energy: 2.8%
Test Repeatability

NMAS: 9.5 mm, PG 76-22
RAP: 15%

Average IDEAL CT: 38.9
COV: 44.4%

NOTE: COV too high
Test Repeatability

NMAS: 9.5 mm, PG 76-22
RAP: 0%

Average IDEAL CT: 44.4
COV: 37.9%

If only 2 specimens, COV=13%
Test Repeatability

NMAS: 9.5 mm
PG 64-22
RAP: 15%

Average IDEAL CT: 192
COV: 74.1%

NOTE: COV very high, results not acceptable
Test Repeatability

NMAS: 9.5 mm
PG 64-22
RAP: 15%

Average IDEAL CT: 210
COV: 43.5%

NOTE: COV too high
Test Repeatability

NMAS: 9.5 mm,
PG 64-22
RAP: 15%

Average IDEAL CT: 32.9
COV: 45.0% (2 specimens)
What COV should we use?

<table>
<thead>
<tr>
<th>Criterion on COV</th>
<th>Number of Mixes</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\geq 30%$</td>
<td>5</td>
</tr>
<tr>
<td>$\geq 25%$</td>
<td>6</td>
</tr>
<tr>
<td>$\geq 20%$</td>
<td>7</td>
</tr>
<tr>
<td>$\geq 15%$</td>
<td>15</td>
</tr>
<tr>
<td>$\geq 10%$</td>
<td>20</td>
</tr>
</tbody>
</table>

COV: Coefficient of Variation

Total Number of Mixes: 23
Effect of Binder Content
(Source 1)

<table>
<thead>
<tr>
<th>Binder Content, %</th>
<th>CT, index</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>5.7</td>
<td></td>
</tr>
<tr>
<td>6.2</td>
<td></td>
</tr>
</tbody>
</table>

PG 64-22
No RAP
NMAS 9.5 mm
Effect of Binder Content
(Source 2)

Binder Content, %

CT$\_\text{index}$

<table>
<thead>
<tr>
<th>Binder Content, %</th>
<th>CT$_\text{index}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>0</td>
</tr>
<tr>
<td>5.6</td>
<td>120</td>
</tr>
<tr>
<td>6.1</td>
<td>320</td>
</tr>
</tbody>
</table>

PG 64-22
No RAP
NMAS 9.5 mm
Effect of RAP Content
(Source 1)

<table>
<thead>
<tr>
<th>RAP Content, %</th>
<th>NMAS 9.5 mm</th>
<th>PG 64-22</th>
<th>PG 76-22</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td>LTOA</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Binder:
- NMAS 9.5 mm: 5.7%
- PG 64-22: 6.2%
- PG 76-22: 5.7%

CT index
Effect of RAP Content
(Source 2)

NMAS 9.5 mm Total Binder=6.1%
PG 64-22

Total Binder=5.6%
PG 64-22

Total Binder=5.6%
PG 76-22

CT

RAP Content, %
Specimens T13, T14, T15

NMAS: 9.5 mm, PG 64-22
Design + 0.5% Binder Content: 6.1%
Average Air Void: 5.5%
RAP: 25%
Long term aged: 120 hrs at 85°C

Average IDEAL CT: 466
COV: 15.8%

Displacement Rate: 50 mm/min
Test Temperature: 25°C
Effect of RAP Content
(Source 3)

% shown is binder content.

CT_index

NMAS=19 mm
PG 64-22
5.1%

NMAS=9.5 mm
PG 64-22
6.0%

NMAS=6.3 mm
PG 76-22
6.9%

NMAS=6.3 mm
PG 64-22
6.3%

RAP Content, %
Effect of Binder Grade & RAP (Source 1)

NMAS 9.5 mm
Binder Content: 5.7%

Binder Grade

58-22 | 64-22 | 64-22 | 64-22

CT Index

25% RAP

15% RAP

25% RAP
Effect of Binder Grade & RAP
(Source 2)

Binder Grade

25% RAP

No RAP

15% RAP

25% RAP

NMAS 9.5 mm
Binder Content: 5.6%
## DISCUSSION TOPICS

1. Performance Based Testing & Long-Life Asphalt Pavements
2. PA Initiative on Performance Testing
3. Candidate Performance Tests
4. Results, Summary, Conclusions
Summary & Recommendations (HWTD)

- HWTD effectively captures binder effect.

- HWTD effectively captures mix differences.

- Initial impact of water is **reduction** of rutting (improvement of performance).
Summary & Recommendations (HWTD)

- Damaging effect of water is manifested through increase of cycles and loading.

- Performance of mix under load significantly better than performance under water/load combination (Dry vs Wet)

- Best to establish HWTD criteria in connection with the traffic level (ESALs)
Summary & Conclusions (IDEAL-CT)

- Trend of Data very similar to SCB

- IDEAL-CT Range: 33 to 460

- In most cases, the test is very repeatable

- COV mostly under 25%
Summary & Conclusions (IDEAL-CT)

- Increasing binder increases flexibility

- Increasing RAP over 20% decreases flexibility

- Use of soft binder with high RAP: mixed results (RAP binder stiffness effect?)
Recommendations
(IDEAL-CT)

- Use four replicates

- Need a limit on COV
  - Round robin testing needed
  - Recommendation on COV: 25%
Long Life Asphalt Projects – DCT data

Mansour’s NOTE: This slide seems out of place. I suggest you remove or place somewhere else.
The Brazilian Test
(The Split Test or Indirect Tensile Test)

- Tensile Strength of Concrete (Carneiro, 1943)
- Tensile Strength of Stabilized Materials (Hudson, Kennedy, 1967)
- Tensile Strength of Asphalt (Kennedy et al., 1969)
- Tensile Strength of Rocks (ISRM, 1978)