PA Initiative on IDEAL AND SCB CRACK TESTS

Pennsylvania Asphalt Paving Association
60th Annual Meeting

January 22, 2020

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

1. Performance Based Testing & Long Life Asphalt Pavements
2. Initiative on SCB/IDEAL-CT Testing in PA
3. Background on IDEAL-CT Tests
4. Discussion of Results, Summary & Conclusions
DISCUSSION TOPICS

1. Performance Based Testing & Long Life Asphalt Pavements
2. Initiative on SCB/IDEAL-CT Testing in PA
3. Background on IDEAL-CT Tests
4. Discussion of 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**
Examples of Performance Tests

DCT

IDEAL-CT

Wheel Tracking

SCB
Performance Test & LLAP driven by:

- TQI
- STIC
Long Life Asphalt Projects – DCT data
DISCUSSION TOPICS

1. Performance Based Testing & Long Life Asphalt Pavements
2. Initiative on SCB/IDEAL-CT Testing in PA
3. Background on IDEAL-CT Tests
4. Discussion of Results, Summary & Conclusions
Industry SCB/IDEAL CRACK Testing: How Did It Start?

- Move to 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 Performance Testing
- Investigate Performance of PA Mixes in IDEAL as a follow-up to previous study
- Develop A Database of SCB/IDEAL Test Results
- Evaluate Sensitivity of the PA Mixes to the Test
- 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

**STOA**
Average = 8.1

**LTOA**
Average = 4.6
General Observations

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

1. Performance Based Testing & Long Life Asphalt Pavements
2. Initiative on SCB/IDEAL-CT Testing in PA
3. Background on IDEAL-CT Tests
4. Discussion of Results, Summary & Conclusions
Research Team

Dr. Xuan Chen

Mr. Scott Milander
NECEPT Lab Coordinator
IDEAL Cracking Test for Asphalt Concrete

**Indirect Tensile Asphalt Cracking Test**

IDEAL-CT

Proposed by Research at Texas Transportation Institute (TTI)
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)
Resilient Modulus, ASTM D7369
Repeated Haversine Loading

\[
\mu = \frac{3.588 + 0.2699 \frac{\Delta V}{\Delta H}}{0.0627 - \frac{\Delta V}{\Delta H}}
\]

\(\Delta V\) = recoverable vertical deformation
\(\Delta H\) = recoverable horizontal deformation

\(\mu\) = Poisson’s ratio

\(P\) = load
\(t\) = thickness
\(M_r\) = Resilient Modulus

\[
M_r = \frac{P}{(\Delta H) xt} (0.2699 + \mu)
\]
Asphalt Concrete
Creep & Strength Test at Low Temperature
(for example, as input for Pavement ME)

Indirect Tensile Test

\[ P \text{ (Load)} \]

\[ t \]

\[ D \]
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, %
IDEAL – Test Results

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 $CT_{Index}$

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

$$\overline{\frac{P}{l}} = |m_{75}| = \frac{P_{85} - P_{65}}{l_{85} - l_{65}}$$
Index based on 0.65 and 0.75 Peak Load
DISCUSSION TOPICS

1. Performance Based Testing & Long Life Asphalt Pavements
2. Initiative on SCB/IDEAL-CT Testing in PA
3. Background on IDEAL-CT Tests
4. Discussion of Results, Summary & Conclusions
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>
Breaking Specimens

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

Load, Newtons

Displacement, mm

Specimens C4, C5, C6

Source 1

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

Load, Newtons

Displacement, mm

Load, Newtons

Displacement, mm

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%
Test Repeatability

**Source 2**

Specimens T16, T17, T18

- 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%
Test Repeatability

Source 3

Displacement Rate: 50 mm/min
Test Temperature: 25°C
Specimens 6, 7, 8, 9, 10

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%

Displacement, mm
Load, Newtons

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>≥ 30%</td>
<td>5</td>
</tr>
<tr>
<td>≥ 25%</td>
<td>6</td>
</tr>
<tr>
<td>≥ 20%</td>
<td>7</td>
</tr>
<tr>
<td>≥ 15%</td>
<td>15</td>
</tr>
<tr>
<td>≥ 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\textsubscript{index}</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2</td>
<td>40</td>
</tr>
<tr>
<td>5.7</td>
<td>80</td>
</tr>
<tr>
<td>6.2</td>
<td>100</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Binder Content, %</th>
<th>CT_{index}</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1</td>
<td>40</td>
</tr>
<tr>
<td>5.6</td>
<td>80</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)

- NMAS 9.5 mm
  - Total Binder=5.7%
  - PG 64-22

- LTOA
  - Total Binder=5.7%
  - PG 76-22

RAP Content, %

CT index

0 15 25 0 25 0 15
Effect of RAP Content (Source 2)

- NMAS 9.5 mm
  - Total Binder = 5.6% (PG 64-22)
  - Total Binder = 6.1% (PG 64-22)

- Total Binder = 5.6% (PG 76-22)

CT\text{index} vs. RAP Content, %

LTOA
Specimens T13, T14, T15

Load, Newtons

Displacement, mm

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$_{\text{index}}$

- NMAS=19 mm
  - PG 64-22
    - 4.8%
- NMAS=9.5 mm
  - PG 64-22
    - 6.0%
    - 6.0%
- NMAS=6.3 mm
  - PG 64-22
    - 5.9%
  - PG 76-22
    - 6.3%
  - PG 64-22
    - 6.9%

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

NMAS 9.5 mm
Binder Content: 5.7%

Binder Grade

CT_index

25% RAP
25% RAP
25% RAP
25% RAP

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

No RAP
15% RAP

100
80
60
40
20
0
Effect of Binder Grade & RAP
(Source 2)

NMAS 9.5 mm
Binder Content: 5.6%

CT\textsubscript{index}

Binder Grade

25% RAP

No RAP

15% RAP

25% RAP

58-28

64-22

64-22

64-22
Summary & Conclusions

- 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

- Increasing binder increases flexibility

- Increasing RAP over 20% decreases flexibility

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

- Use four replicates
- Need a limit on COV
  - Round robin testing needed
  - Recommendation: 20% to 25%
Thank You!