Asphalt Mix Performance Testing for PA
An Update

2019 PAPA REGIONAL TECHNICAL MEETINGS
March 19, 20 and 21, 2019

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DISCUSSION TOPICS

1. Performance Based Testing/SCB Initiative
2. A Summary of SCB Test Results
3. Long Life Asphalt Pavements (SMA)
4. RAP/RAS With Rejuvenators
5. IDEAL Test Initiative
DISCUSSION TOPICS

1 Performance Based Testing/SCB Initiative
BALANCED ASPHALT MIX DESIGN

GOAL: DESIGN/PLACE AN ASPHALT MIX THAT DOES NOT

- RUT
- CRACK
BALANCED ASPHALT MIX DESIGN

- Acceptable Rutting
- Acceptable Cracking
- Acceptable Cracking & Rutting

Diagram shows the relationship between asphalt content and Cracking Resistance, Rutting Resistance, and Acceptable AC Range.
Need Proper Performance Test for Balanced Mix Design

• Important Considerations:
  • Need Right Test
  • Appropriate Test Protocols
  • Right Acceptance Thresholds
Examples of Performance Tests

Wheel Tracking
Industry SCB 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 SCB

• Develop A Database of SCB Test Results

• Evaluate Sensitivity of the PA Mixes to the Test

• Evaluate Correlation with Field Performance
SCB Test Setup

Applied Load

Support Support

Notch

Specimen Thickness: 50 mm
Notch Depth: 15 mm
Notch Width: 1.5 mm
Parameters Used For Evaluation

Fracture Energy

\[ G_f = \frac{W_f}{B \cdot L} \]

**B:** Specimen Thickness  
**L:** Ligament Length

Flexibility Index

\[ FI = A \times \frac{G_f}{\text{abs}(m)} \]

**A:** Constant

Stiffness Index

Slope @ 50% Peak Load in Pre-Peak Curve
DISCUSSION TOPICS

A Summary of SCB Test Results
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
Plant vs Lab, and Aging Effect

Lab Prepared Mix
- Short Term Aged (2hr @ 275F)
- Long Term Aged (5 days @ 185F)

Plant Prepared Mix
- Short Term Aged
- Long Term Aged
## Summary of SGC Plugs Tested (85)

<table>
<thead>
<tr>
<th>Source</th>
<th>Mix Origin</th>
<th>Mix Condition</th>
<th>NMAS, mm</th>
<th>Binder Grade</th>
<th># of Binder Contents</th>
<th>RAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Plant</td>
<td>Long</td>
<td>9.5</td>
<td>64-22</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>02</td>
<td>Plant/Lab</td>
<td>Short/Long</td>
<td>9.5</td>
<td>64-22</td>
<td>6</td>
<td>0</td>
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<tr>
<td>03</td>
<td>Plant</td>
<td>Short/Long</td>
<td>9.5</td>
<td>64-22</td>
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<td>0</td>
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<td>04</td>
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<td>9.5</td>
<td>64-22</td>
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<td>0</td>
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<tr>
<td>05</td>
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<td>Short</td>
<td>4.75, 9.5, 25</td>
<td>64-22</td>
<td>4</td>
<td>0, 15, 30</td>
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<td>06</td>
<td>Plant/Lab</td>
<td>Short/Long</td>
<td>9.5</td>
<td>64-22</td>
<td>6</td>
<td>15</td>
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<tr>
<td>07</td>
<td>Lab</td>
<td>Long</td>
<td>9.5, 19</td>
<td>64-22</td>
<td>2</td>
<td>0, 15</td>
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<tr>
<td>08</td>
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<td>Short</td>
<td>9.5</td>
<td>64-22</td>
<td>4</td>
<td>10, 15</td>
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<td>1</td>
<td>15, 20</td>
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<td>Short/Long</td>
<td>9.5</td>
<td>64-22</td>
<td>2</td>
<td>15, 20</td>
</tr>
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<td>11</td>
<td>Lab</td>
<td>Long</td>
<td>9.5</td>
<td>64-22</td>
<td>1</td>
<td>0, 15</td>
</tr>
</tbody>
</table>
Air Void Comparison

![Air Void Comparison Graph](image-url)

- **NECEPT Measured AV, %**
- **Reported AV, %**
Specimen Preparation

- **SGC Specimen or Field Cores**
- **Cut to Ensure Minimum AV Gradient**
- **Obtain Density**
- **Condition Specimens at Test Temperature**
- **Conduct Test**
340 TEST SCB Specimens

Specimens After Cutting Ready for Testing

Specimens Before (L) / After (R) Testing
A Typical High Quality Test Result

4 Specimens – Same Plug
Data Range: Peak Load

**STOA**
Average = 3,337 N

**LTOA**
Average = 4,124 N
Data Range: Flexibility Index

STOA
Average = 8.1

LTOA
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.
Binder Content Effect

Plant Mix

Flexibility Index vs. Binder Content, %

- STOA
- LTOA
RAP Content Effect

All Specimens were STOA
Aging Effect

\[ y = 0.2694x + 0.9484 \]

\[ R^2 = 0.6801 \]
SMA vs Conventional Mix

Flexibility Index

<table>
<thead>
<tr>
<th>Specimen</th>
<th>BC (%)</th>
<th>AV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen 1</td>
<td>6.9%</td>
<td>4.7%</td>
</tr>
<tr>
<td>Specimen 2</td>
<td>6.9%</td>
<td>5.3%</td>
</tr>
</tbody>
</table>

PG64-22 + 15%RAP

PG76-22 + 0%RAP
Where should we go next?

1. Test mix(es) with proven good long term performance.

2. Track mix performance in the field to verify lab predictions.
DISCUSSION TOPICS

3 Long Life Asphalt Pavements (SMA)
Performance Test & LLAP driven by:

- TQI
- STIC
LLAP Best Practices

• MTV Required

• Longitudinal Joint Density Specification

• **RIDE SPECIFICATION OPTIONAL**

• Tack Coat Every Layer (New Section 460)

• % IMPORTANT WITHIN TOLERANCE (PWT) ACCEPTANCE

• **INCENTIVIZE CRITICAL ELEMENTS (I.E. MAT DENSITY)**

• PERFORMANCE TESTS
Rutting Test

• Hamburg Wheel Tacking Test. (AASHTO T 324)
  • Measures rutting potential and gives an indication of moisture sensitivity.
  • Gyratory samples %7.0 (+/- %1.0) air voids
  • Test run at 131° F (55° C)
  • 12.5mm (0.5 inch) rut at 20,000 cycles general rule of thumb for limit on superpave.
Cracking Test

- **Disk-Shaped Compact Tension (DCT) testing.** (ASTM D7313)
  - Measures fracture energy
  - Gyratory samples %7.0 (+/- %1.0) air voids.
  - Test run at 10°C above the low PG mix designation. (-12°C (10.4°F) for PG64-22)
  - Fracture energy requirements vary depending on mix type (SMA) and layer (wearing, binder)
**Cracking Test**

- **Illinois Flexibility Index** Test (IFIT) (AASHTO TP 124) (SCB TEST)
  - Measures fracture energy and post peek slope.
  - Uses fracture energy and load/displacement slope to compute Flexibility Index.
  - Gyratory samples %7.0 +/- %1.0 air voids
  - Test run at 250°C +/- 0.5°C (770°F).
  - Flexibility Index requirements vary depending on mix type (SMA) and layer (wearing, binder)

\[ FI = \frac{G_f}{m} \times A \]
Cracking Test

- **Overlay Test (OT). (TEX-248-F)**
  - Measures fatigue or reflective cracking potential.
  - Gyratory samples 7.0 ± 1.0 air voids.
  - Test run at 25°C (77°F).
  - Applies load to induce 0.025 (3/128ths) inches displacement.
  - Number of cycles to failure is reported along with percent decline in load.
Long Life Asphalt Projects – DCT data
Long Life Asphalt Projects – IFIT Data
Long Life Asphalt Projects – Overlay Test Data
Long Life Asphalt Paving Project - IFIT

IFIT Performance Diagram

- Lab Samples
- Core Samples
Implementation Challenges

- **Implementation will not be quick or simple**
  - Pick performance test(s)
  - Decide on test protocols.
  - Specification pilot(s).
  - Who will be doing testing and how large of an investment is the equipment?
    - Contractors / Producers
    - Special Testing Labs
  - Enough lead time between project bid and paving?
  - Trained technicians to run testing?
  - After the initial rush to get testing done will there be enough tests run to sustain an industry?
DISCUSSION TOPICS

4 RAP/RAS With Rejuvenators
Objectives of the Study

➢ Evaluate performance-based BMD for mixes with recycled materials and rejuvenators via binder tests and mixture mechanical tests.

Focus on intermediate and high temperature performance
Test Program – SCB Fracture Test

- Followed IFIT with two modifications

- Displacement Rate: 5 mm/min

- Test Temperature: 20°C [Using Effective Temperature (El-Basyouny and Jeong 2009)]
Test Program – Hamburg Test

- Evaluate Resistance to Permanent Deformation
- Following AASHTO T 324
- Test Temperature 50°C
- Two Replicates

Hamburg Wheel Tracking Device Used in the Study
Test Program – Binder Tests

**Intermediate Temp Performance**
- Glower Rowe (G-R) Damage Parameter
  - Temp/Frequency Sweep Test
  - Extrapolated \([G^* \cdot \cos(\delta)^2 \sin \delta]\) at 15°C and 0.005 rad/s
- \(G^*\) at 20°C and 10 rad/s
  - Direct Measurement

**High Temp Performance**
- High Temperature Continuous Grade
- Multiple Stress Creep Recovery (MSCR)
  - Non-recoverable creep compliance \(J_{nr}\)
  - 100 Pa and 3,200 Pa Stress levels
Benchmark Work – Materials

Six Benchmark Mixes

- Dolomite/limestone aggregate
- 9.5 mm Superpave gradation
- PG58-28 and PG76-22
- RAP (6.4% residual binder) – two Levels
- RAS (21% residual binder)

Gradation of All Benchmark Mixes
SCB Test Results – Flexibility Index (FI)

- Higher Aging → Lower FI
- Higher RAP/RAS → Lower FI
SCB Test Results – Peak Load (PL)

- Higher Aging ➔ Higher Strength
- Higher RAP/RAS ➔ Higher Strength
## Rejuvenator Effect – Materials

- Dolomite/limestone aggregate
- 9.5 mm Superpave gradation
- **PG58-28**

- **35%** RAP (6.4% residual binder, **45% RBR**)

- Rejuvenator **A** (*Modified vegetable oil*, multiple dosages)
Effect of Rejuvenator Content & Blending Methods

- Higher Rej Content → Higher FI
- Higher Rej Content → Lower Strength
Effect of Rejuvenator Dosage

- resembles typical balanced mix design plot
- Threshold Values on FI and Load?
Hamburg Test Results – Rut Depth

Rut Depth (RD) Under Different Rejuvenator Dosages
Cross Comparison – Rut Depth vs. Peak Load

(All mixes with 35% RAP)
Cross Comparison – Binder to Mix

(All mixes with 35% RAP)
Cross Comparison – Binder to Mix

(All mixes with 35% RAP)
Cross Comparison – Binder to Mix
Expanded Study – Materials

- PG58-28/PG64-22/PG76-22
- RAP (6.4% residual binder, 25%&35%)
- RAS (21% residual binder, 5%)
- All Blended with PG58-28

- Virgin Binder & Mix

- Rejuvenator A (Modified vegetable oil, up to 8% to binder)
- **Rejuvenator B (bio-based agent, 8% to binder)**
- **Rejuvenator C (hydrolene product, 8% to binder)**
- All Blended with PG58-28 and 35%RAP (45%RBR)

- RAP/RAS Binder & Mix

- Rejuvenator Binder & Mix
Cross Comparison with More Mixes

- LTOA/RAP/RAS reduces FI
- Rejuvenator increases FI
- Mixes with/without RAP/RAS form two distinct patterns
Conclusions

- Blending methods **do not** affect effectiveness of rejuvenators
- Optimizing Rejuvenator
  - Increases FI, Decreases PL (mix strength), and; Increases Rutting
- Rejuvenator decreases high temp continuous grade and raises Jnr.
- Adding rejuvenator decreases G* and G-R at intermediate temp.
DISCUSSION TOPICS

5 IDEAL Test Initiative
IDEAL Cracking Test for Asphalt Concrete

Indirect Tensile Test

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

\[M_r = \frac{P}{(\Delta H)xt}(0.2699 + \mu)\]

\(P\) = load
\(t\) = thickness
\(M_r\) = Resilient Modulus
Asphalt Concrete Creep & Strength Test

Indirect Tensile Test

\[ S_t = \frac{2P}{\pi t D} \]
Indirect Tensile Test (for TSR)
Indirect Tensile Test (for TSR)

IDT Test at -20°C, 12.5mm/min

Stress, psi

Strain, %
IDEAL – Test Results (Similar to SCB)

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 $CT_{Index}$

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

$$\frac{P_\bar{l}}{l} = |m_{75}| = \frac{P_{85} - P_{65}}{l_{85} - l_{65}}$$
IDEAL – Test Results – An Example

Source of Graph: Final Report, NCHRP IDEA Project 195
Fujie Zhou, Texas A &M Transportation Institute,
January 2019
Should We Look at IDEAL-CT for PA mixes?

- Need a crack test and this looks good.
- Test has potential for both design and QC
- Easy to do
- Correlates well with SCB
- Use with both cores and lab specimens
- Could use to catalog PA mixes
Thank You!