Industry/PennDOT Initiative
On Performance Testing

Annual Meeting of the
Northeast Asphalt User/Producer Group
NEAUPG
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P:\Shared\PowerPoint Presentations\2018 08 01 SCB Performance Testing for PAPA Bus Tour
Outline

• A Review of Semi-Circular Bend (SCB) Test
• PA Industry Initiative on SCB
• Results & Observations
• Next Steps
Outline

• A Review of Semi-Circular Bend (SCB) Test
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SCB Test Setup

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
Advantages of SCB Test

• Specimen Easily Prepared Using SGC or Field Cores
• Four Specimens from One Compacted Mix or Core
• Easy to Perform and Simple to Analyze
• Possible To Perform Test Using Marshall-Type Stability Tester
Test Loading Rate and Temperature

Current Protocols:
• 50 mm/min (too fast, not enough data points, higher COV)
• 0.5 mm/min (too slow, affected by creep)

Findings:
• Loading rate between 5 to 20 mm/min will minimize the effect of creep, and provide a reasonable range for FI for long term aged mix.

• Test at 20°C to simulate average PA climate
Specimen Preparation

- SGC Specimen or Field Cores
- Cut to Ensure Minimum AV Gradient
- Obtain Density
- Condition Specimens
- Conduct Test
Specimen Preparation and Testing

Specimen after Cutting and Ready for Testing

**Test Sensitivity**
- Strain Rate
- Temperature
- Sample Preparation (Voids)
- Sample Curing

Specimen before and after Testing
Typical Load vs Displacement Curves
3 Replicates, PG 58-28, 25°C

Lower strain Rate → lower peak & flatter post peak slope → same or higher F.I.
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How Did it Start?

• Move to Performance Testing for Mix Optimization

• Initiated by Asphalt Quality Improvement Committee and PAPA

• Industry Expressing Interest in Participating
Purpose of the Effort

- Impetus 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 Variables
- Evaluate Correlation with Field Performance
Mix Criteria and Variables

• Air Void: 5.5% (Final SCB Specimen)

• Design Binder Content (and +0.5%)

• Mixes with various RAP higher contents

• Short/Long term aging effects

• Laboratory mixes and plant produced mixes

• NMAS: 4.75, 9.5mm, 19mm, 25mm
## Summary of SGC Plugs Tested (total of 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>
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<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>
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<tr>
<td>02</td>
<td>Plant/Lab</td>
<td>Short/Long</td>
<td>9.5</td>
<td>64-22</td>
<td>6</td>
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<td>64-22</td>
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<td>9.5</td>
<td>64-22</td>
<td>1</td>
<td>0</td>
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<tr>
<td>05</td>
<td>Plant/Lab</td>
<td>Short</td>
<td>4.75, 9.5, 25</td>
<td>64-22 76-22</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></td>
<td></td>
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<td>0, 15</td>
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<tr>
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<td>Short</td>
<td>9.5, 19</td>
<td>64-22</td>
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<td>9.5</td>
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<td>2</td>
<td>15, 20</td>
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<tr>
<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>
Statistics

TOTAL NUMBER OF SGC PLUGS RECEIVED = 85

Number of Plugs in each Category

NMAS, mm

RAP Content, %
Outline

• A Review of Semi-Circular Bend (SCB) Test
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Air Voids

Reported vs. NECEPT Measured Air Void Comparison
(SGC plugs as received)
Asphalt Content

Number of Plugs in each BC Category

<table>
<thead>
<tr>
<th>Binder Content, %</th>
<th>Number of Plugs</th>
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</thead>
<tbody>
<tr>
<td>4.6</td>
<td>3</td>
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<tr>
<td>4.7</td>
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<td>4.8</td>
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<td>5.9</td>
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<td>6.1</td>
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<tr>
<td>6.6</td>
<td>2</td>
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<tr>
<td>6.8</td>
<td>2</td>
</tr>
<tr>
<td>6.9</td>
<td>2</td>
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</tbody>
</table>
Air Void Distribution

Overall Data Range and Distribution: Air Void *(After Cutting)*

**STOA**
- Target: 5 - 6%
- Average: 5.2%

**LTOA**
- Target: 5 - 6%
- Average: 5.4%
Peak Load Distribution

Overall Data Range and Distribution: Peak Load

STOA
Average: 3337 N

LTOA
Average: 4123.7 N
Flexibility Index Distribution

Overall Data Range and Distribution: Flexibility Index

**STOA**
- Median: 7
- Average: 8.1

**LTOA**
- Median: 5 or 6
- Average: 4.6
Post Peak Slope Distribution
General Observations (G.O.)

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 high F.I.
7. Finer mix with high BC $\rightarrow$ higher F.I.
General Observations (G.O.)

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 high F.I.
7. Finer mix with high BC → higher F.I.
Producer F: Plant Mix

G.O. #1

STOA: Short Term Oven Aging
LTOA: Long Term Oven Aging

JMF = 5.9%
Post Min $P_{be}$

JMF = 5.2%
Pre Min $P_{be}$
G.O. #1

Producer F: Lab Mix

**Flexibility Index**

Binder Content, %

Lab Mix

- **STOA**: Short Term Oven Aging
- **LTOA**: Long Term Oven Aging

**Plant**: Lab
1:0.5
G.O. #1

Producer H-1

STOA: Short Term Oven Aging
LTOA: Long Term Oven Aging
General Observations (G.O.)

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 high F.I.
7. Finer mix with high BC → higher F.I.
G.O. #2

Producer G-1

![Graph showing Flexibility Index vs RAP Content, %]

- **STOA**: Short Term Oven Aging
- **LTOA**: Long Term Oven Aging

- **PG64-22**: 1:0.67
- **PG76-22**: 1:0.67-0.76

15%:20%RAP
Producer G-2

G.O. #2

STOA: Short Term Oven Aging
LTOA: Long Term Oven Aging

PG64-22:
PG76-22:

1:0.15-0.25
STOA:LTOA

1:0.33-0.67
15%:20% RAP

Overlap with PG64-22
G.O. #2

Producer H-3

All Specimens were STOA

![Graph showing the relationship between RAP Content (%) and Flexibility Index for NMAS values of 9.5, 4.75, and 25. All specimens were STOA.](image-url)
G.O. #2

All Producers

Stiffness Index, Newtons/mm

Flexibility Index

STOA-With RAP  STOA-No RAP
G.O. #2

All Producers

Flexibility Index vs. Stiffness Index, Newtons/mm

- LTOA-With RAP
- LTOA-No RAP

Stiffness Index, Newtons/mm
G.O. #2

All Producers

Stiffness Index, Newtons/mm

Post Peak Slope

STOA-With RAP

STOA-No RAP
G.O. #2

All Producers

Stiffness Index, Newtons/mm

Post Peak Slope

LTOA- With RAP
LTOA- No RAP
General Observations (G.O.)

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 high F.I.
7. Finer mix with high BC → higher F.I.
G.O. #3

Producer L-1

Flexibility Index vs Binder Content, %

- STOA-0%RAP
- STOA-15%RAP
- LTOA-0%RAP
- LTOA-15%RAP

1:0.5
STOA:LTOA

1:0.55
0%:15%RAP
G.O. #3

Producer I

- STOA/LTOA
- 9.5mm
- PG64-22
- Multiple BC
- 0/15%RAP

\[ y = 0.2694x + 0.9484 \]

\[ R^2 = 0.6801 \]
G.O. #3

Producer F: Plant Produced

- STOA/LTOA
- 9.5mm
- PG64-22
- 4.8/5.4/5.5/5.9%BC
- 15%RAP

Flexibility Index

STOA vs LTOA
Binder Content

Binder Content

STOA
- AV: 5.5%
- BC: 4.8%
- BC: 5.5%
- BC: 5.4%

LTOA
- AV: 5.2%
- AV: 5.7%
- AV: 5.6%
- AV: 5.1%
- AV: 6.0%
G.O. #3

All Producers

![Graph showing Flexibility Index vs. Stiffness Index for All Producers with markers for STOA and LTOA.]
General Observations (G.O.)

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 high F.I.
7. Finer mix with high BC $\rightarrow$ higher F.I.
G.O. #4

Producer F

Plant Mix

Flexibility Index

Binder Content, %

STOA: Short Term Oven Aging
LTOA: Long Term Oven Aging

JMF = 5.9%
Post Min $P_{be}$

JMF = 5.2%
Pre Min $P_{be}$
Producer F (Continued)

Lab Mix

Flexibility Index

Binder Content, %

STOA: Short Term Oven Aging
LTOA: Long Term Oven Aging

Plant:Lab
1:0.5
G.O. #4

Producer E

- LTOA
- 9.5mm
- PG64-22

- 5.5%BC
- 0/15/25%RAP

![Graph showing Flexibility Index vs RAP Content (%) with Plant and Lab data points](image-url)
General Observations (G.O.)

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 high F.I.
7. Finer mix with high BC → higher F.I.
G.O. #5

All Producers

![Graph showing Specimen Air Void, % vs. Flexibility Index for All Producers with a target area highlighted.](image)
G.O. #5

All Producers

Specimen Air Void, %

Peak Load, Newtons
General Observations (G.O.)

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 high F.I.
7. Finer mix with high BC $\rightarrow$ higher F.I.
Producer H: Lab Produced

- STOA
- 9.5mm
- PG64-22/PG76-22

What effect do we see?
- Binder Content
- RAP
- Polymer

<table>
<thead>
<tr>
<th>Flexibility Index</th>
<th>Binder Content</th>
<th>RAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>AV: 4.7%</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>BC: 5.9%</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>AV: 4.5%</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>BC: 6.4%</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>AV: 4.7%</td>
<td></td>
</tr>
</tbody>
</table>

PG64-22 + 15%RAP
- BC: 5.9%
- AV: 4.7%

PG76-22 + 0%RAP
- BC: 6.9%
- AV: 5.3%

BC: 6.4%
Specimen 1

BC: 6.9%
Specimen 2
General Observations (G.O.)

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 high F.I.
7. Finer mix with high BC $\rightarrow$ higher F.I.
G.O. #7

Producer H: Lab Produced

- STOA
- 4.75mm
- PG64-22

- 6.8%BC
- 0/15%RAP

![Diagram showing Flexibility Index for Specimen 1, Specimen 2, and 15%RAP (6.1% Virgin Binder), with AV: 5.0% for Specimen 1 and Specimen 2, and AV: 4.7% for 15%RAP.]

AV: 5.0%
AV: 5.0%
AV: 4.7%
Outline

• A Review of Semi-Circular Bend (SCB) Test
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• Next Steps
Where could we go next?

1. Gather information from producers on details of aging protocol and specimen preparation.
2. More SCB testing to fill in some of the gaps.
3. Test mix(es) with proven good long term performance.
4. Test to determine long term effects of rejuvenators.
5. Track mix performance in the field to verify lab predictions.
Questions??  Thank you!!

To contact .............................................

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Safe, Smooth, Sustainable, Long Lasting Pavements!