Update on the Super Air Meter

Hope Hall, Jake LeFlore,
Chad Staffileno, Mark Fennell
Tyler Ley, PE, PhD
Acknowledgements

• Oklahoma DOT
• FHWA
• Kansas DOT
• Nebraska DOT
• Iowa DOT
• Minnesota DOT
• Idaho DOT
• North Dakota DOT
• New York DOT
• Pennsylvania DOT
• Connecticut DOT
• Illinois DOT
• Indiana DOT
• Michigan DOT
• Wisconsin DOT
• New Jersey DOT
• RMC Foundation
• American Concrete Pumping Association
Overview

• Introduction
• Why are people using the SAM?
• What are people doing with the SAM?
• How is the SAM improving?
Why are people using the SAM?

Poor air void system
Large Bubbles

Good air void system
Small Bubbles
What Do You Want in an Air-Void System?

- Volume of air provided is the same for both.
- Case B has a better air void distribution.
What Do You Want in an Air-Void System?

- Volume of air provided is the same for both.
- Case B has a better air void distribution.
What Do You Want in an Air-Void System?

- Volume of air provided is the same for both.
- Case B has a better air void distribution.
<table>
<thead>
<tr>
<th>Method</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field performance</td>
<td>years</td>
</tr>
<tr>
<td>Rapid freeze thaw</td>
<td>months</td>
</tr>
<tr>
<td>Petrographic</td>
<td>days</td>
</tr>
<tr>
<td>Super Air Meter</td>
<td>minutes</td>
</tr>
</tbody>
</table>
The implementation circle

From Chavez, O’Hara, and Vaidya
The implementation circle

From Chavez, O’Hara, and Vaidya
Sam Field Study

21 State DOTs + 1 Canadian Province helped analyze **231 concrete mixtures from 110 different projects**

More than: 15 different SAMs and operators, 62 different aggregates, 19 cement sources, 20 different fly ashes, 39 different admixtures

60% pavements, 20% bridge decks, and 20% other self-consolidating, precast, ready mix, and central mix concrete

Thank you to all that helped!
What air content do you specify?

Air content between 3.75% and 7.75% for 0.008” spacing factor. 231 field mixes.
Air content between 3.75% and 7.75% for 0.008" spacing factor

These mixtures have good air contents and spacing factors that are not recommended.
These mixtures have good air contents and spacing factors that are not recommended.

Air content between 3.75% and 7.75% for 0.008” spacing factor
Air content between 3.75% and 7.75% for 0.008” spacing factor.

These mixtures have good air contents and spacing factors that are not recommended.
Summary

• We need to know the size of bubbles within the concrete

• The volume of air does not tell you about bubble size

• What if we could measure this in the fresh concrete???
Super Air Meter (SAM)

digital gauge

six clamps!
Over 227 lab mixtures from two different research groups

10 mins in fresh concrete

88% agreement

Ley et al., 2017
Vermont DOT 46 field mixtures

Figure 1: SAM Agreement of All Data

85% agreement
Vermont quote!

21 SCC field samples investigated
100% of samples had correct air content
20% of them had a spacing factor \( > 0.008'' \)
85% of the SAM testing accurately predicted the spacing factor
PennDOT 50 field mixtures

83% agreement
ODOT – 53 field mixtures

90% agreement
UNC Charlotte – 20 mixes

80% agreement
Lafarge Holcim - Innis NCC 2018

Whitehall Concrete Lab
Spacing Factor vs SAM Number
All Mixes

R² = 0.7486

40 out of 44 points in “agreement”

90% agreement
Other Data

Iowa DOT
FHWA Mobile Concrete Lab
NCHRP Project lead by Peter Taylor
German Research Team
Poland Research Team
Other Data

There have been two data sets that don’t look as good.

Differences in hardened air void preparation.
Need for training and better documentation.

If you have data to discuss then please let us know!
Discussion

Seven independent studies show that the SAM Number tells you about the bubble size distribution in fresh concrete.

This means the SAM can give you new insights into the quality of the air in the concrete before it has set.
What about freeze thaw?
What air content do you use?

3.5 Months

Recommended

Not Recommended

Air Content %

5 mins

Durability Factor %
What air content do you use?

Small bubbles

Large bubbles

3.5 Months

Recommended

Not Recommended

Air Content %

Durability Factor %

5 mins
Durability Factor %

SAM Number

- 0.40 WROS 20%FA
- 0.45 WROS 20%FA
- 0.35 WROS+PC1
- 0.40 WROS+PC1
- 0.40 WROS+PC2
- 0.40 WROS+PC3
- 0.40 WROS+PC4
- 0.40 WROS+PC5
- 0.40 WROS+WR
- 0.40 WROS
- 0.45 WROS
- 0.45 WROS+PC1
- 0.50 WROS
- 0.50 WROS+PC1

98 mixtures
91% agreement

3.5 Months

Recommended
Not Recommended

Cliff of Doom

10 mins
Discussion

The SAM gives you similar data as the rapid freeze thaw testing and can be completed before the concrete hardens.
The implementation circle

From Chavez, O’Hara, and Vaidya
Update from States

• New York
• Michigan
• Wisconsin
• Colorado
New York

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>3</td>
</tr>
<tr>
<td>Shadow Pavements</td>
<td>2</td>
</tr>
<tr>
<td>Shadow Bridges</td>
<td>2019</td>
</tr>
<tr>
<td>Full Spec Pavements</td>
<td>2020?</td>
</tr>
</tbody>
</table>

New York is using a systematic process to introduce the SAM as a shadow specification in a district and then move to full specification. They have 26 SAMs as a department.
Michigan Concrete Association has developed a SAM training course based on OSUs training and offered it three times. Michigan has a federal STIC grant to implement the SAM. They have 19 SAMs owned by the department.
<table>
<thead>
<tr>
<th>Training</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shadow Pavements</td>
<td>2019</td>
</tr>
<tr>
<td>Shadow Bridges</td>
<td>2020</td>
</tr>
<tr>
<td>Full Spec Pavements</td>
<td>2020</td>
</tr>
<tr>
<td>Full Spec Bridges</td>
<td>2021</td>
</tr>
</tbody>
</table>

Wisconsin has sponsored their own research project over the SAM.
All new submitted mixture designs must have a SAM < 0.20. Colorado has some very experienced SAM users (Rod McMahon, Mary McFadden, Kevin Klein and David Figurski,).
Discussion

A number of states are starting to get experiences with SAMs through shadow and full specifications on bridge and pavement projects.

Training has been an important step in all of these states.

Would your state like training in 2019?
The implementation circle

From Chavez, O’Hara, and Vaidya
Improvements to the SAM

• Shotgun/Cape
• Leak check
• Reliability
• Tools to help design mixtures
• Internal curing
• Impact of vibration on air
Controlled Air Pressure Extender aka CAPE

Step 1 (14.5 psi)
Step 2 (30 psi)
Step 3 (45 psi)
Leak Check Top Chamber

- Pressure the top chamber to 45 psi
- Record value
- Wait 5 min and compare values
- If pressure loss is > 0.10 psi then you have a leak that must be addressed
- Use soapy water to find and fix it
How do we know if the SAM test was completed correctly?

• Is it a bad test or is it bad concrete?

• How do we know?
SAM Reliability Factor

We collected all pressure steps from 600 SAM tests

300 completed “correctly” and 300 completed “incorrectly”

We used machine based learning algorithms to find trends

Built a Logistic model to create a reliability factor
What does it detect?

Leak from sand grain on rim

Leaky petcock

Not getting air out of bottom chamber when adding water

Slow leak in top chamber
How do you use it (for now)?

While running the test write down the equilibrium pressure steps

Put the values in a spreadsheet and it tells you if it is “likely correct” or “likely incorrect”

This will be changed to be done within the gauge.
I will send the spreadsheet out to anyone that wants it!!!

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Example</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Run</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.5 psi</td>
<td>9.93</td>
<td>9.27</td>
</tr>
<tr>
<td>30 psi</td>
<td>23.38</td>
<td>22.30</td>
</tr>
<tr>
<td>45 psi</td>
<td>37.65</td>
<td>36.37</td>
</tr>
<tr>
<td><strong>Second Run</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.5 psi</td>
<td>10.43</td>
<td>9.49</td>
</tr>
<tr>
<td>30 psi</td>
<td>24.02</td>
<td>22.55</td>
</tr>
<tr>
<td>45 psi</td>
<td>38.32</td>
<td>36.61</td>
</tr>
<tr>
<td><strong>Air Content (%)</strong></td>
<td>2.53</td>
<td>3.12</td>
</tr>
<tr>
<td><strong>SAM @ 14.5 psi</strong></td>
<td>0.5</td>
<td>0.22</td>
</tr>
<tr>
<td><strong>SAM @ 30 psi</strong></td>
<td>0.64</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>SAM @ 45 psi</strong></td>
<td>0.67</td>
<td>0.24</td>
</tr>
<tr>
<td><strong>Reliability Factor</strong></td>
<td>0.52</td>
<td>0.26</td>
</tr>
</tbody>
</table>

**Result:** Likely Correct

> 0.50 likely correct
< 0.50 likely incorrect
Yes! No!
Discussion

The Reliability Factor estimates if the SAM test was completed correctly. This will reduce the number of bad SAM tests and make people more confident in their results.

This is also a great training tool.
How do I improve my SAM Number?

• Increase the air content in a mixture.

• Carefully examine your construction process

• Use the SAM Curve to design your concrete mixture with special attention to your mixture ingredients.
Mixtures with Large Air Voids

Mixtures with Small Air Voids

SAM Curve!!!

Hall and Ley, 2017
Comparisons

• Comparing admixture combinations
• Comparing cements
Why is this useful?

You only need to do a single concrete mixture and you will know if that combination of materials has a large or small air void system.
Discussion

• By plotting your data on the SAM Curve you can immediately tell if your air void system is made of large or small bubbles.

• This immediate feedback can be used to rapidly iterate to a mix with a good air void system.
Internal curing with SAM

If you use < 30% replacement of light weight by volume and the material is properly saturated then you can use the SAM for the air content and SAM Number
How does vibration from a paver impact the air void system in concrete?
WisDOT Research Project

![Graph showing air content of road materials](image)
SAM Number > 0.30 did poorly

WisDOT Research Project
Discussion

• When the SAM Number was < 0.30 before the paver there was little change in SAM Number before and after the paver despite the concrete losing ~ 2% air

• When the SAM Number was > 0.30 there was a significant change in the SAM Number before and after the paver
Conclusion

The SAM is a valuable tool to determine the size distribution of the bubbles in fresh concrete.

People are buying into the SAM and changing their process.

The device continues to improve and is useful to evaluate the freeze thaw durability of concrete.
Why do you lose air volume when pumping air entrained concrete?

& Why does the air come back?
Would you like to measure w/cm in fresh concrete in < 10 min?

• Contact me if you would like to try our new field test method with 0.01 w/cm accuracy.
Contact me if you are interested in taking a ride on the Phoenix!!!
Questions?

www.tylerley.com
www.superairmeter.com

Instagram – Concrete.tyler
How variable is the SAM?

Based on 170 head to head lab mixes
4 round robin tests in Michigan, Illinois, Wisconsin, and Oklahoma

SAM Number standard deviation = 0.049
How does that compare to other tests?

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Parameter</th>
<th>COV</th>
<th>Time to complete the test</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAM</td>
<td>SAM Number$^1$</td>
<td>15.2%</td>
<td>10 min</td>
</tr>
<tr>
<td>ASTM C457</td>
<td>Spacing Factor$^2$</td>
<td>20.1%</td>
<td>7 days</td>
</tr>
<tr>
<td>ASTM C666</td>
<td>Durability Factor$^3$</td>
<td>22.7%</td>
<td>3.5 months</td>
</tr>
</tbody>
</table>
AASHTO PP84-19 Specification

Mixture Design
SAM < 0.20 and Air > 4%

Field
SAM < 0.30 and Air > 4%
AASHTO PP84-19 Specification

Mixture Design
SAM < 0.20 and Air > 4%

Field
SAM < 0.30 and Air > 4%

Why are they different??
Why are they different?

Number of tests

0.20 0.30
Mix Design
SAM Number
Acceptance Based on 666

Based on 666
Low quality air void system

High quality air void system

25% in the low quality quadrant!!!

70% agreement

231 field mixes

- Alaska
- Arizona
- Colorado
- Florida
- Idaho
- Illinois
- Iowa
- Kansas
- Manitoba
- Michigan
- Minnesota
- North Dakota
- Oklahoma
- Ohio
- Pennsylvania
- South Dakota
- Tennessee
- Utah
- Washington
- West Virginia
- Wisconsin
Mixtures with Large Air Voids

Mixtures with Small Air Voids

Mix 1 4.7%, SAM 0.33

Mix 2 4%, SAM 0.18

Hall and Ley, 2017
Mix 1 – large air voids
4.7% SAM 0.33

Mix 2 – small air voids
4.0% SAM 0.18