Update on the Super Air Meter

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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?

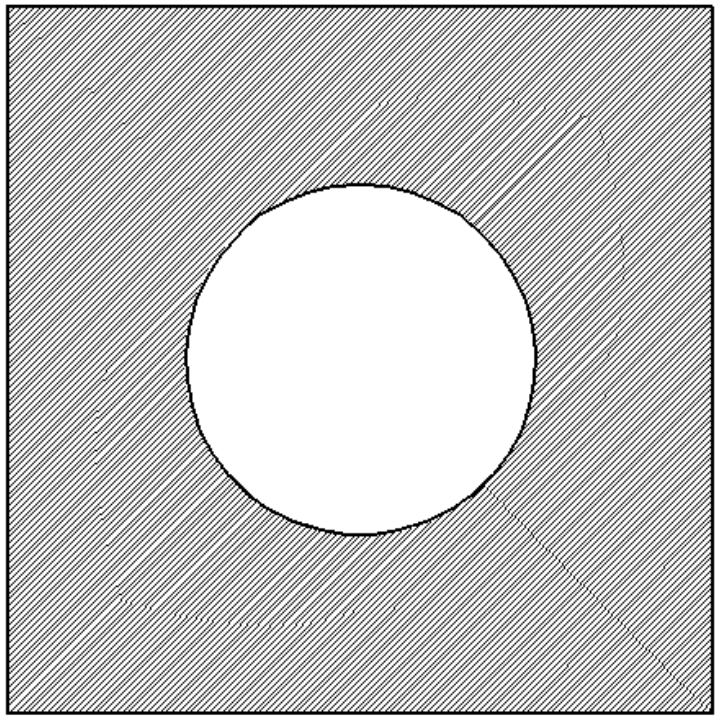
Why are people using the SAM?

Poor air void system
Large Bubbles

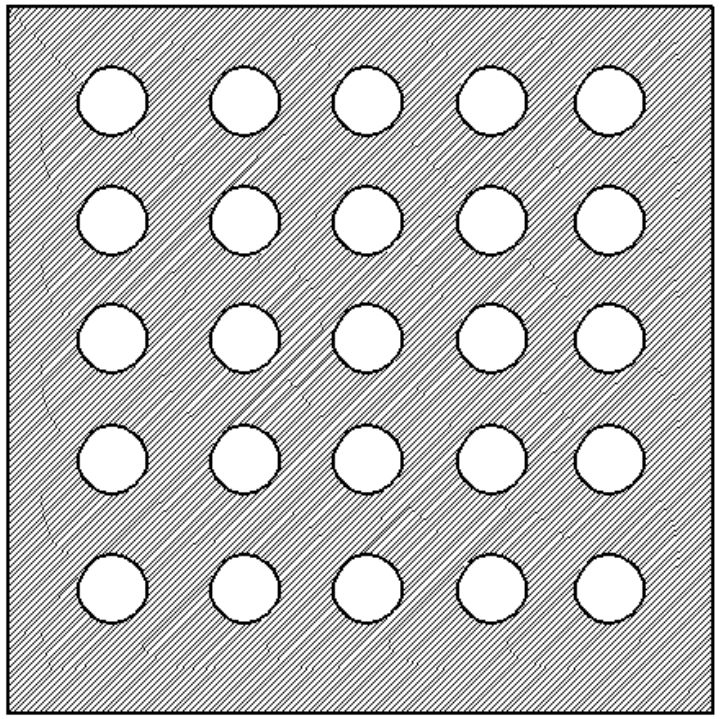
Good air void system
Small Bubbles

What Do You Want in an Air-Void System?

A



B



- 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?

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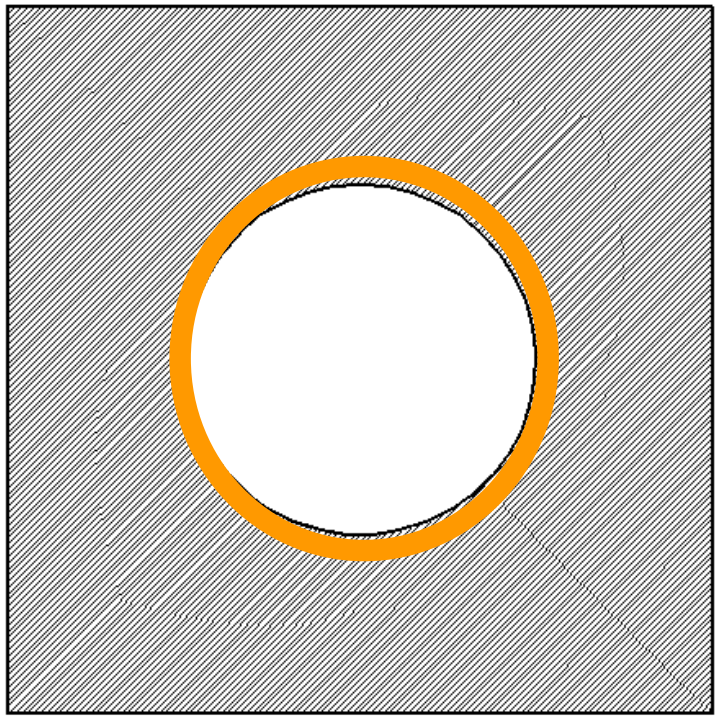
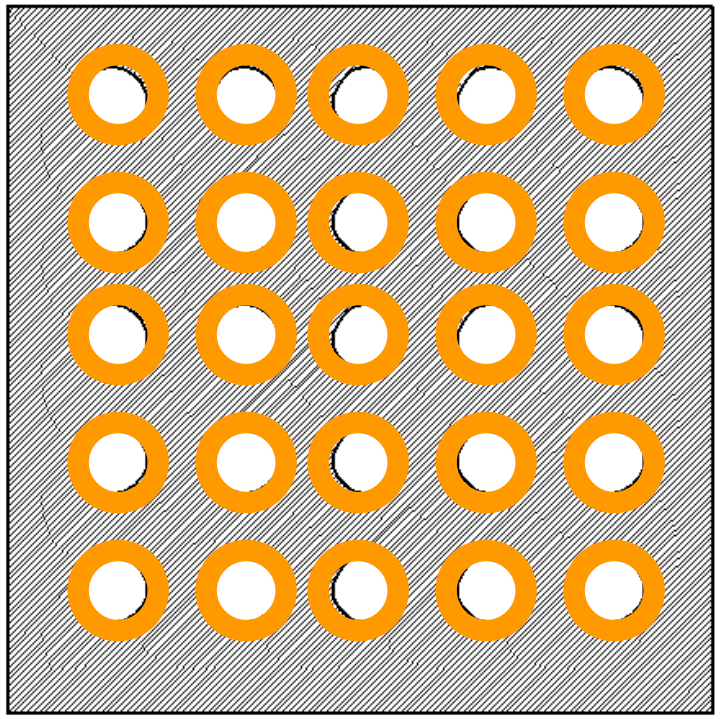


B



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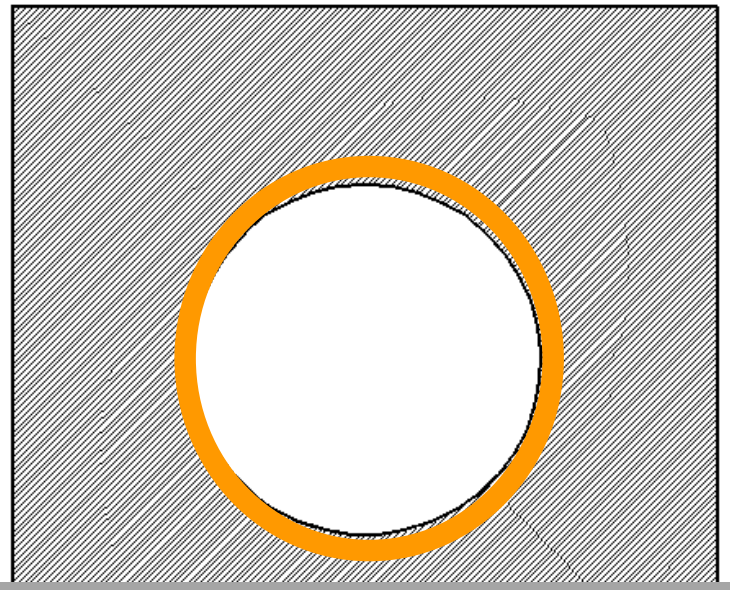
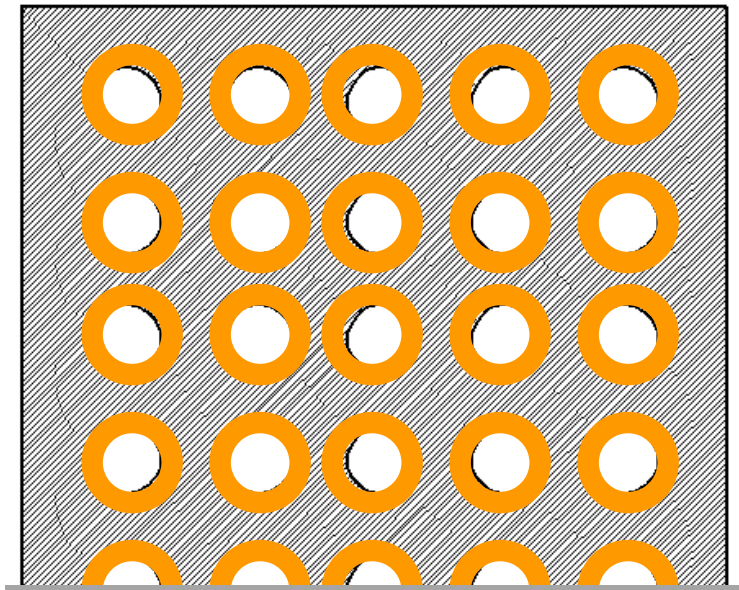
What Do You Want in an Air-Void System?

A



Large Bubbles

B



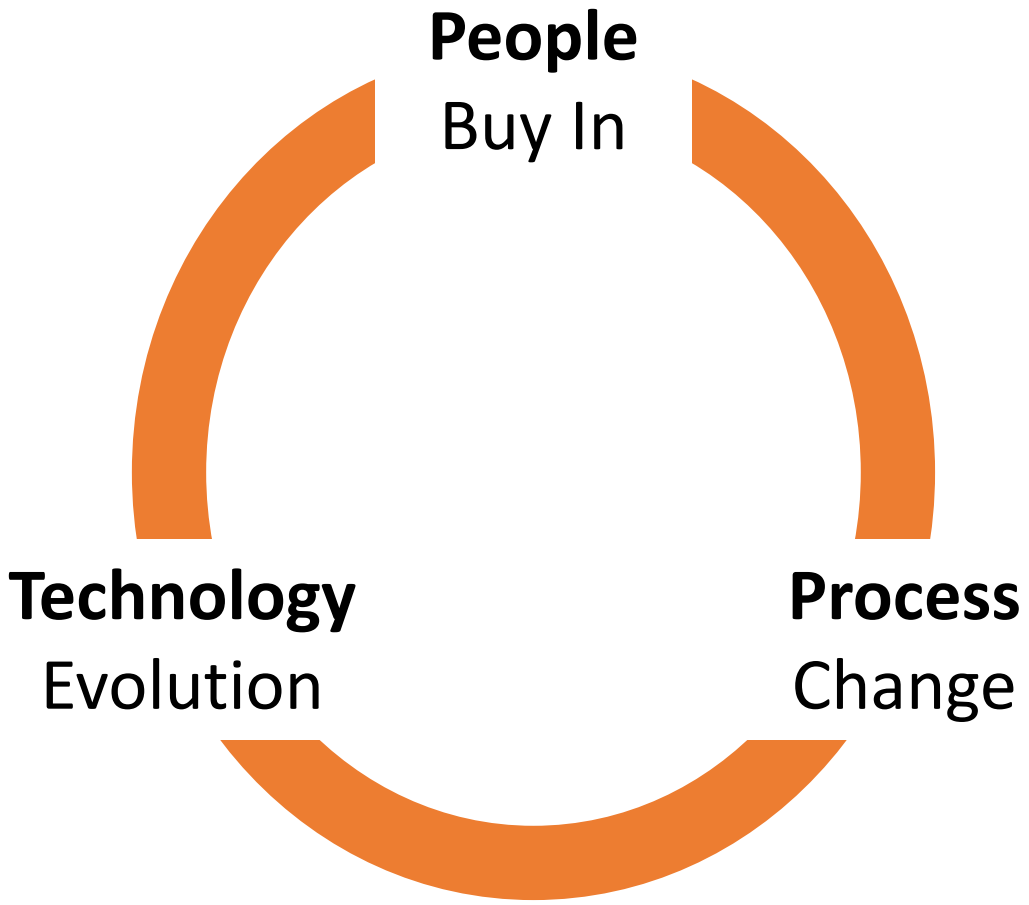
Small Bubbles

- Volume of air provided is the same for both.
- Case B has a better air void distribution.

How do we measure this?

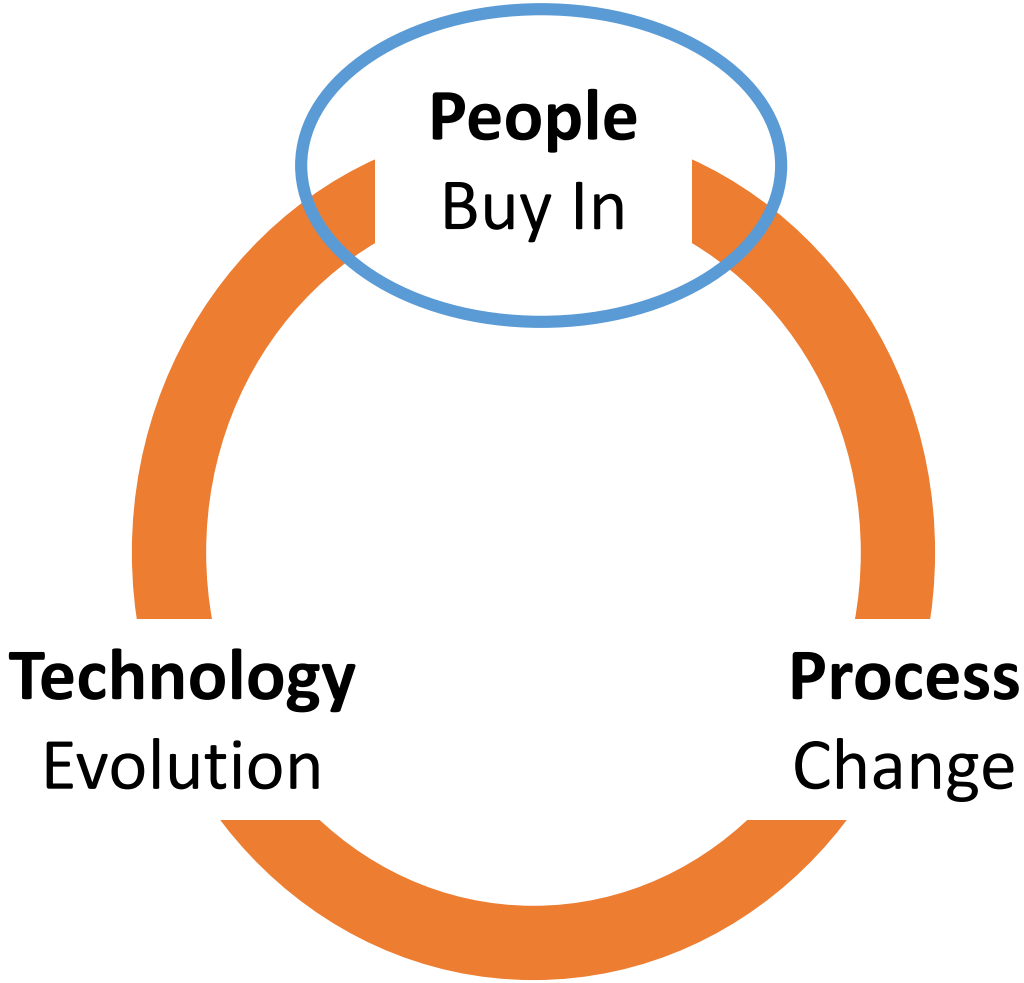
Method	Time
Field performance	years
Rapid freeze thaw	months
Petrographic	days
Super Air Meter	minutes

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

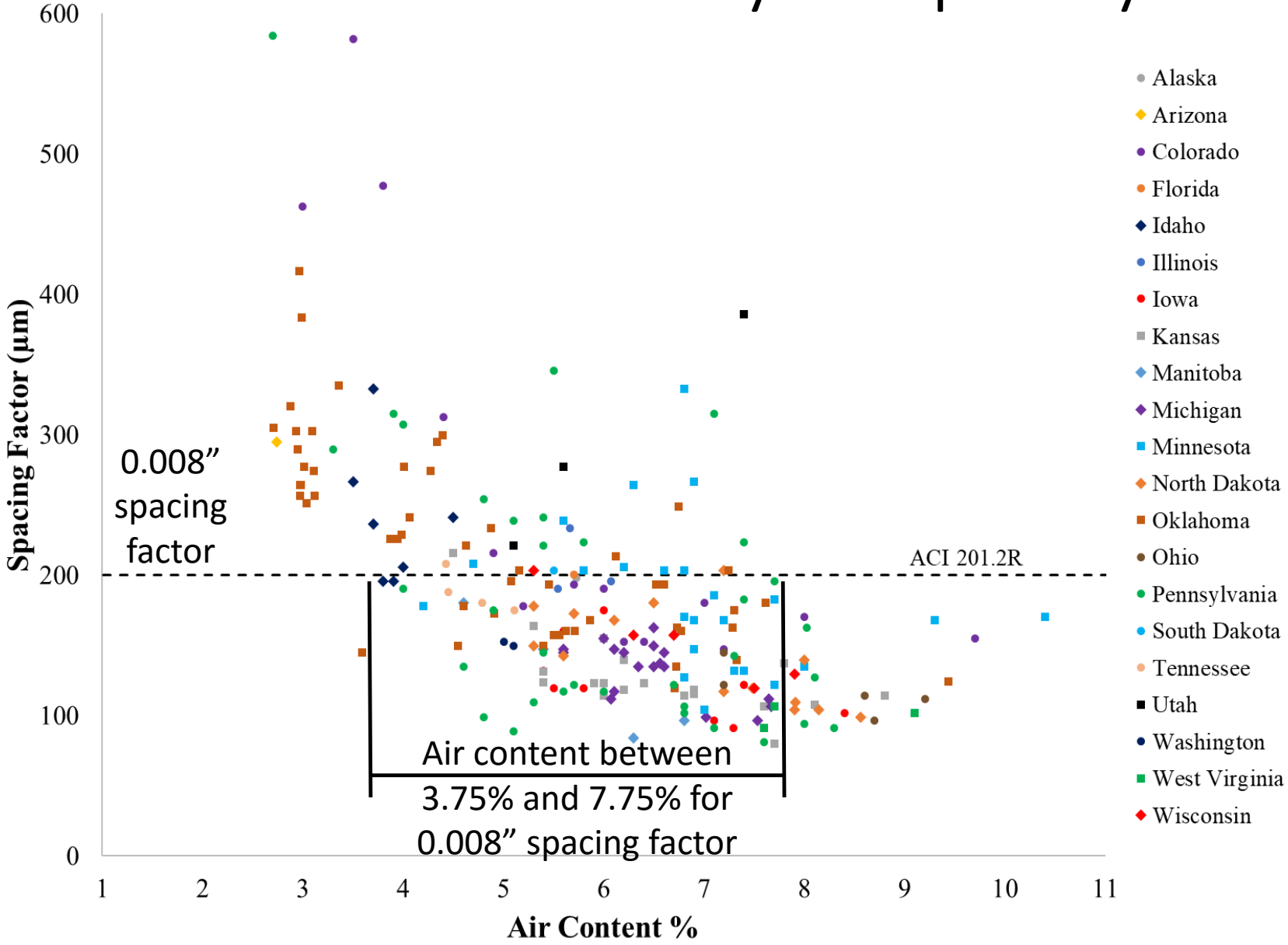
60% pavements, 20% bridge decks, and 20% other

self-consolidating, precast, ready mix, and central mix concrete

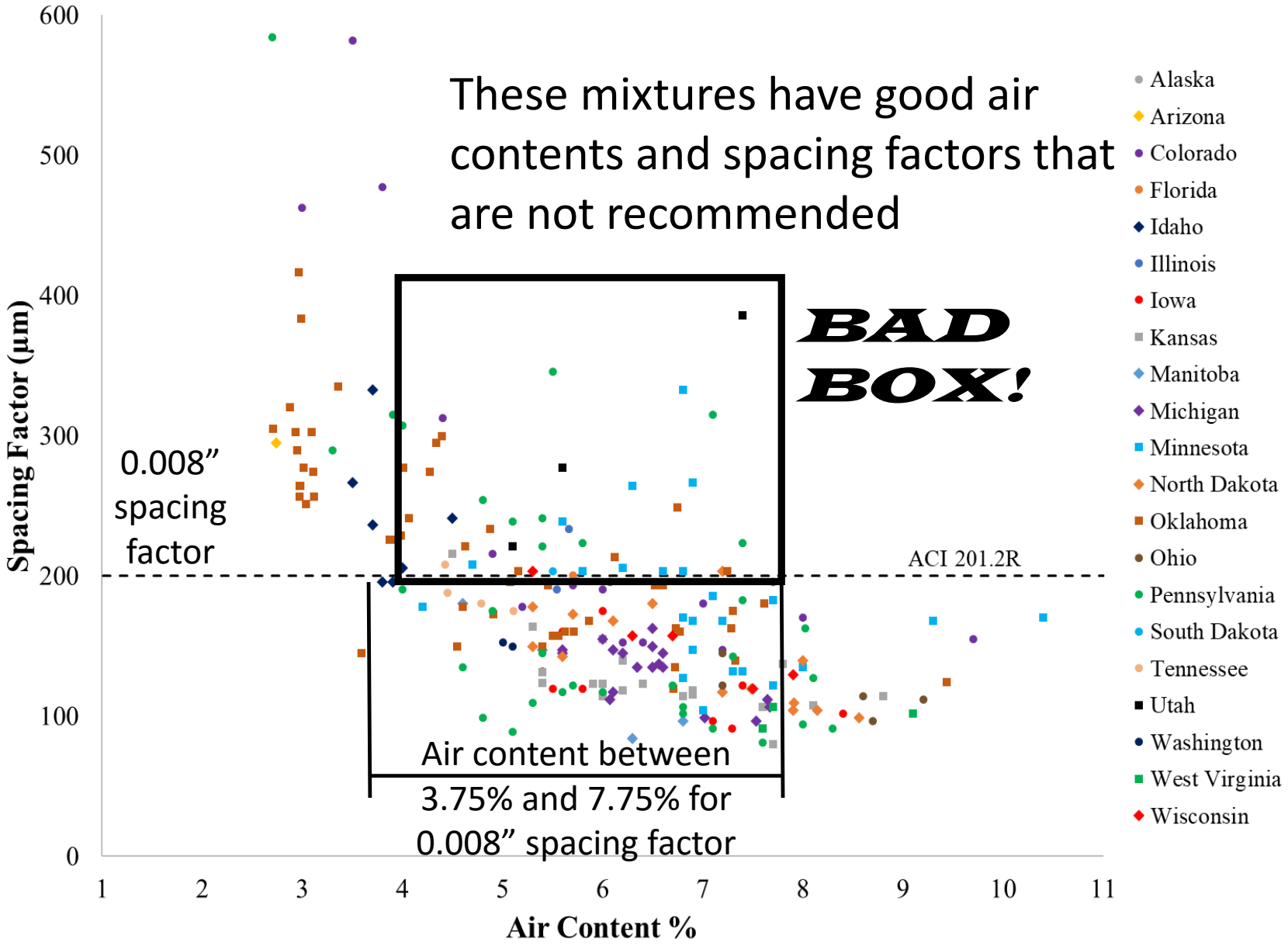
Thank you to all that helped!

231 field mixes

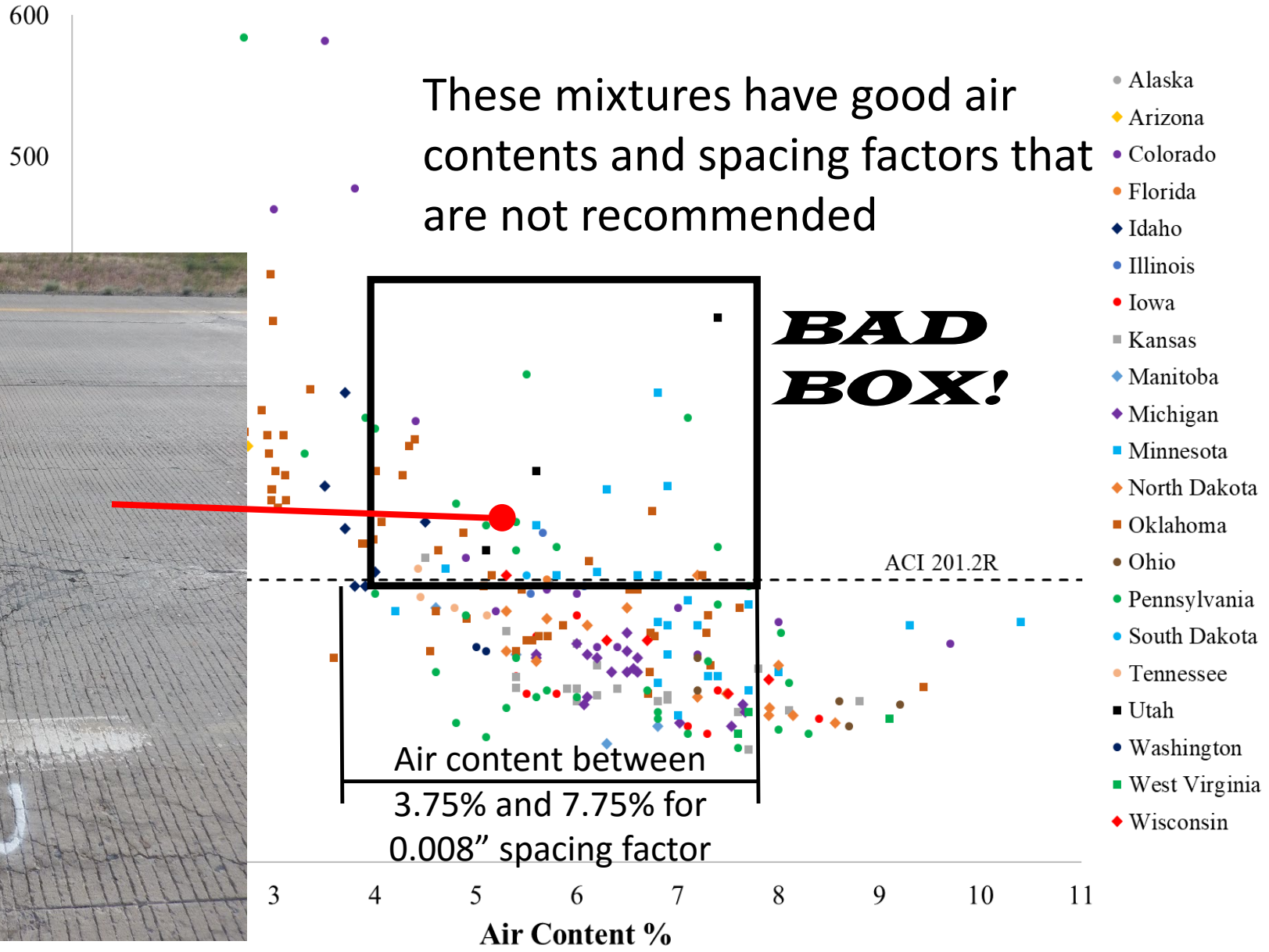
What air content do you specify?



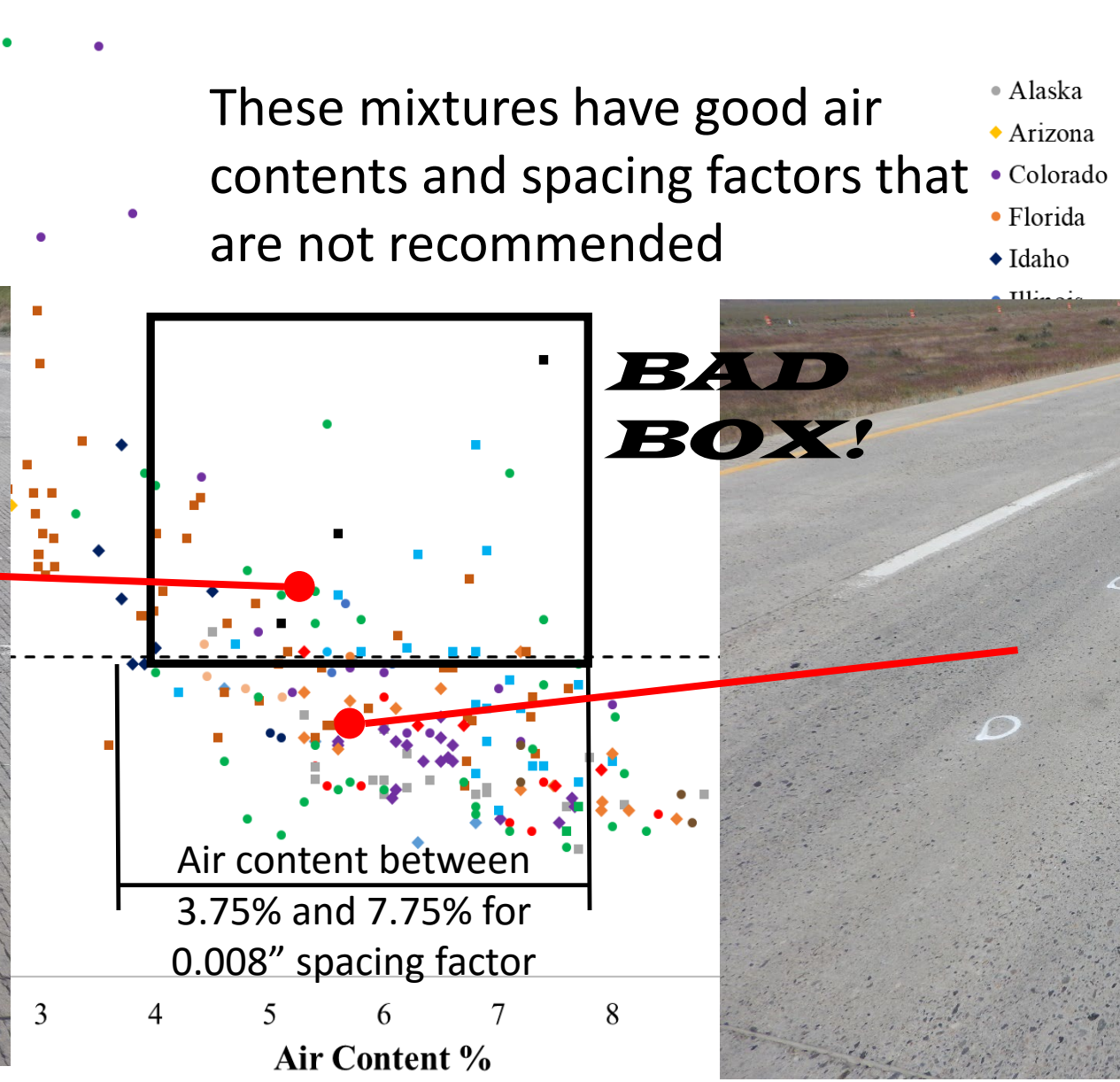
231 field mixes



231 field mixes



231 field mixes



Summary

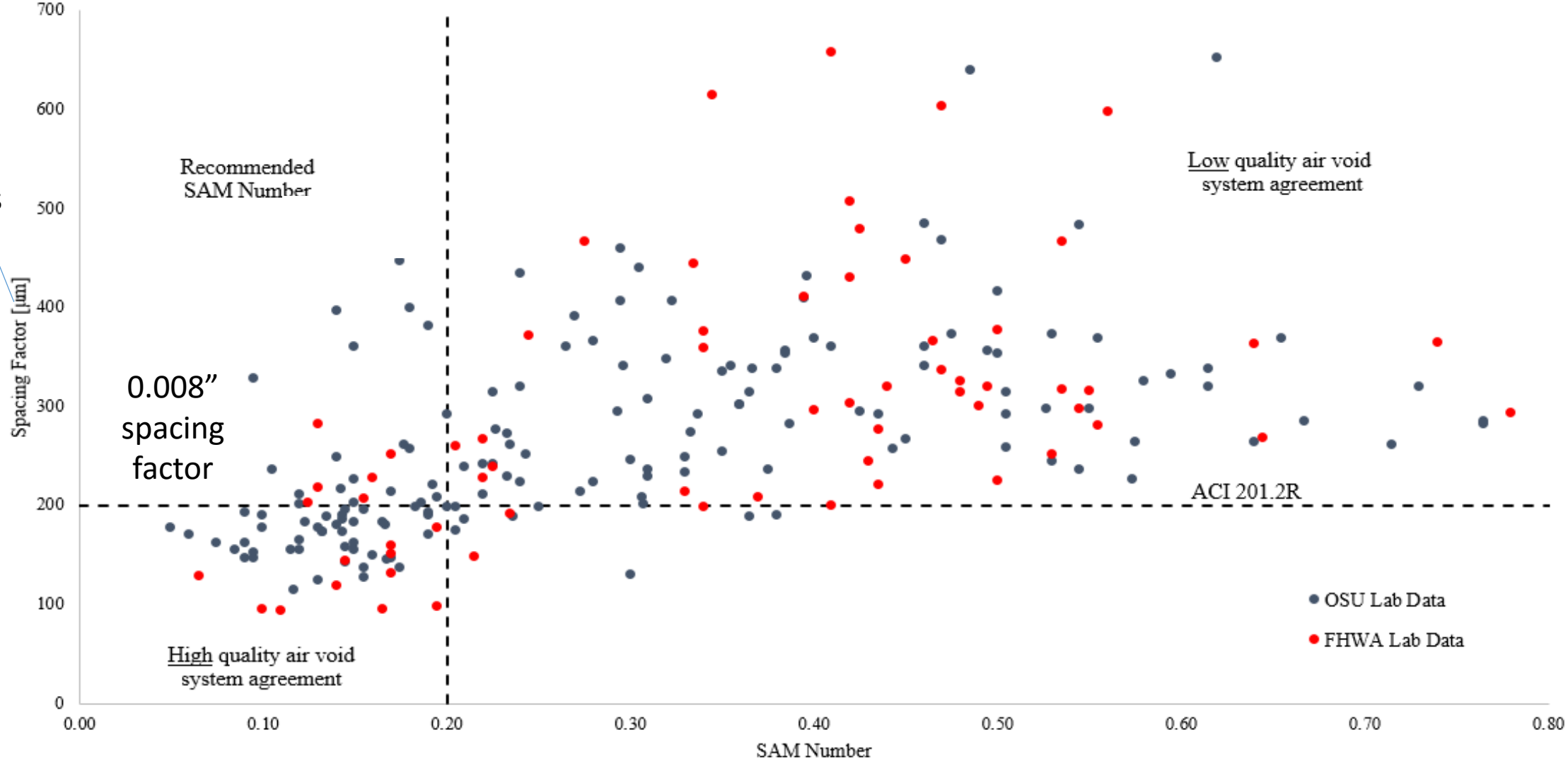
- **We need to know the size of bubbles within the concrete**

- *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)

14 days



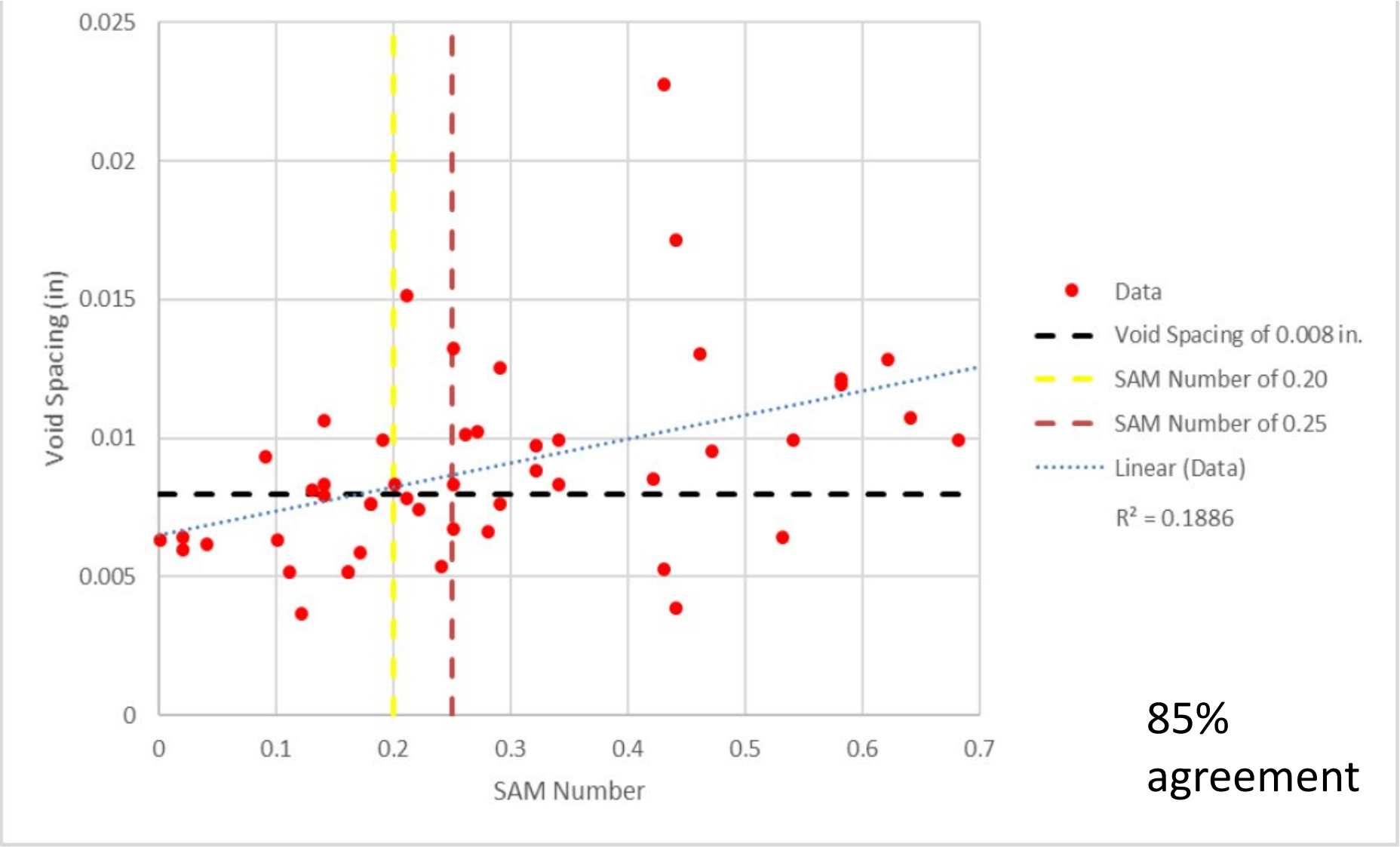
10 mins in fresh concrete

Over 227 lab mixtures from two different research groups

88% agreement

Ley et al., 2017

Vermont DOT 46 field mixtures



85% agreement

Figure 1: SAM Agreement of All Data

Vermont quote!

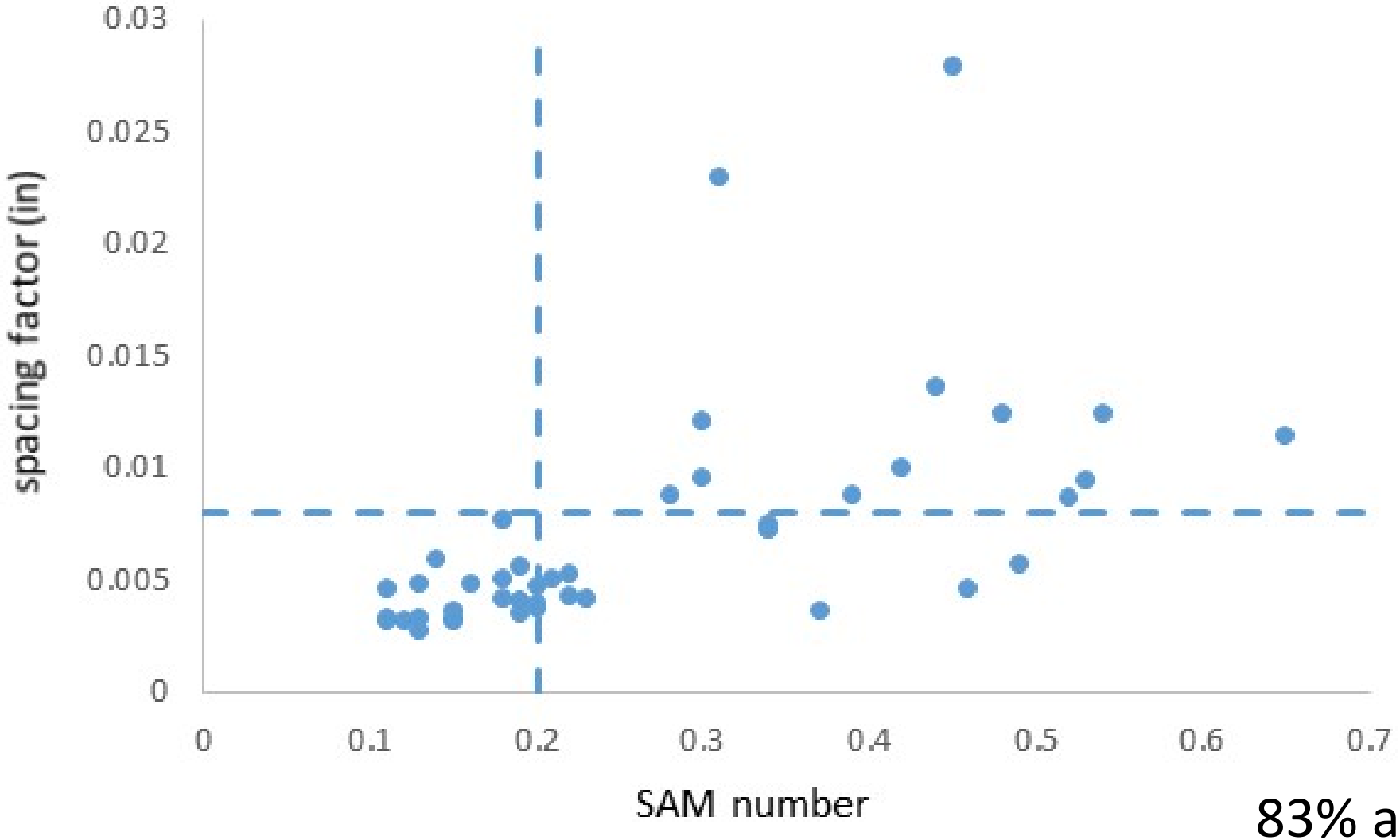
21 SCC field samples investigated

100% of samples had correct air content

20% of them had a spacing factor > 0.008”

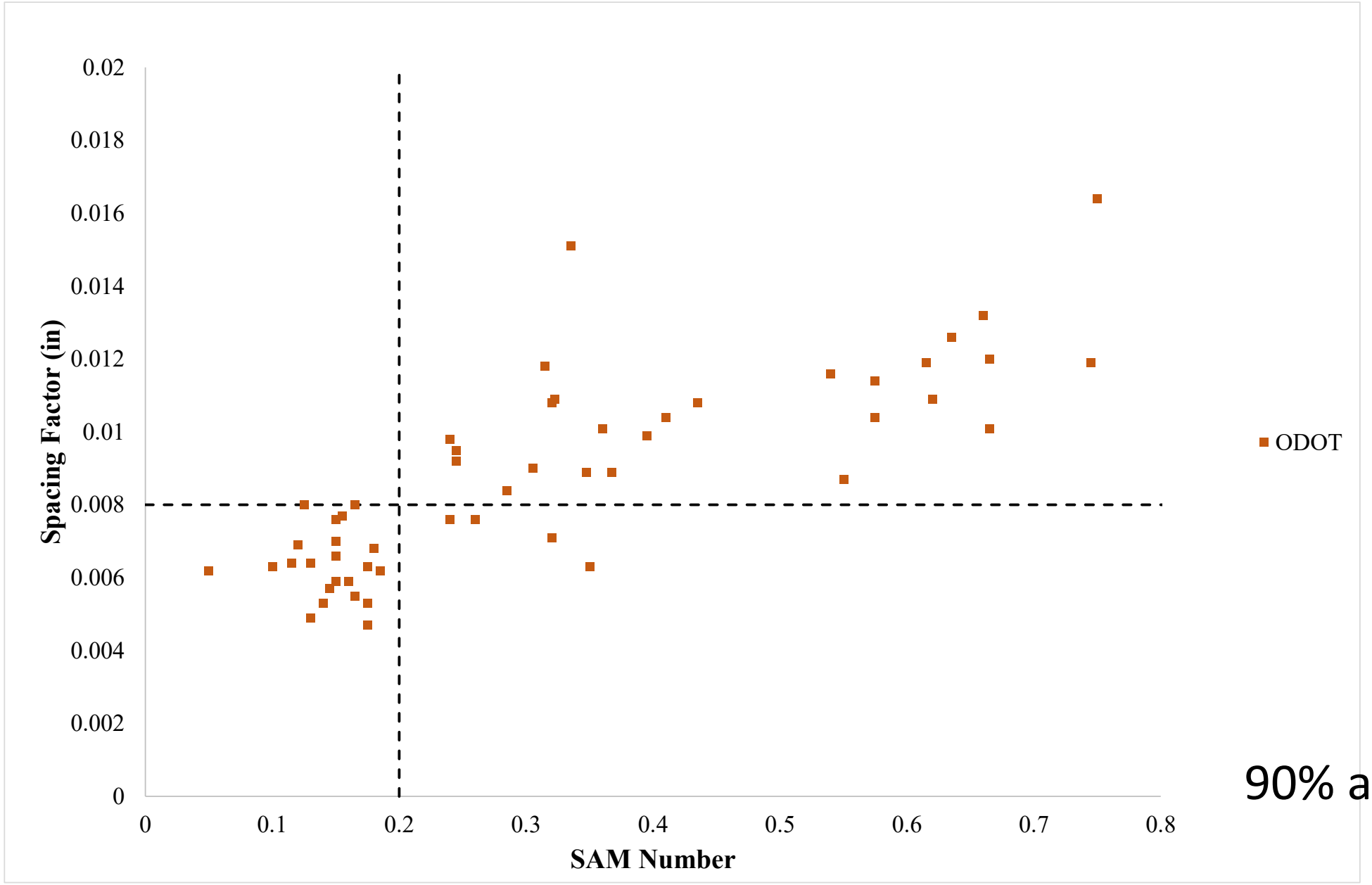
85% of the SAM testing accurately predicted the spacing factor

PennDOT 50 field mixtures

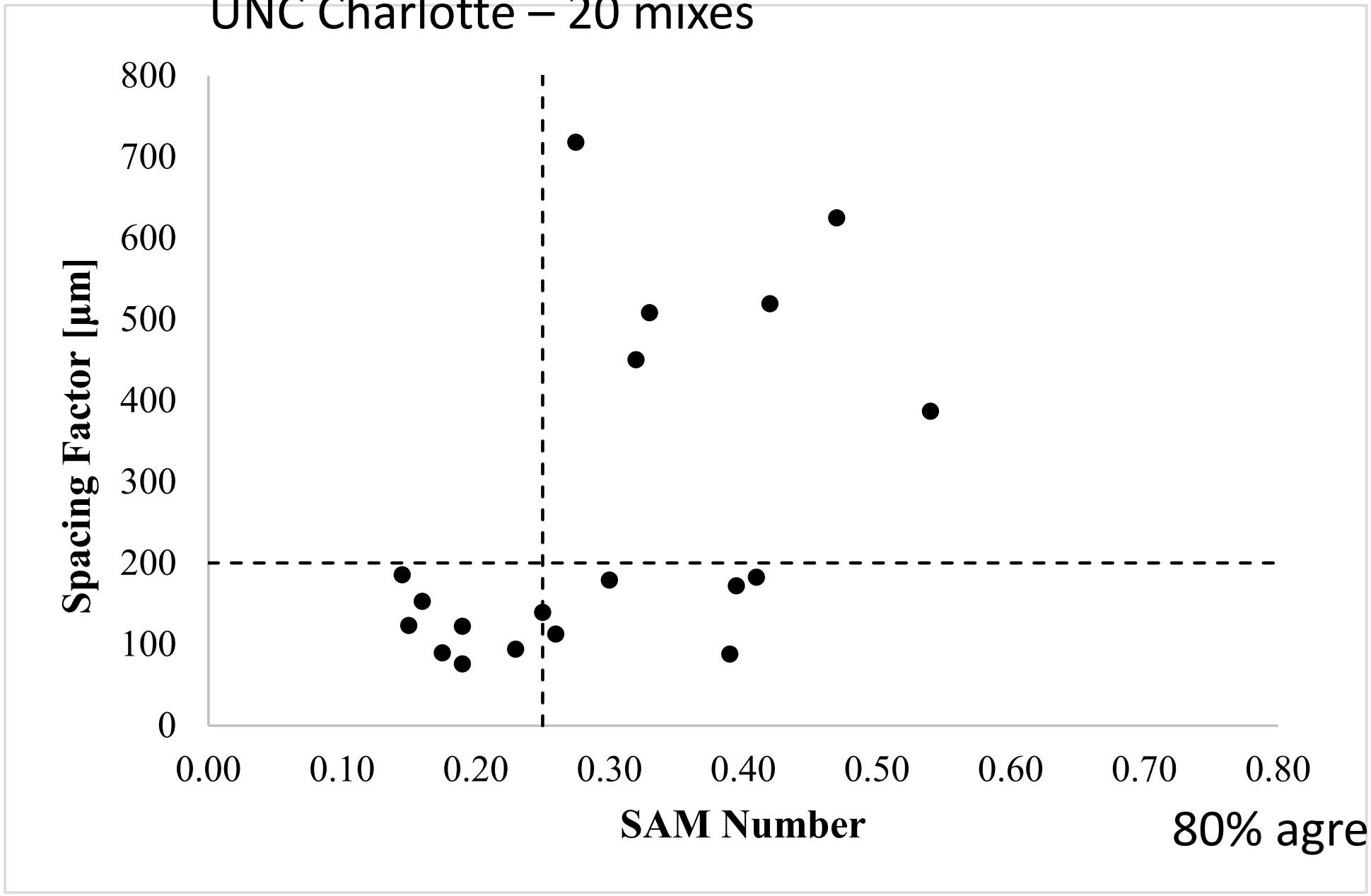


83% agreement

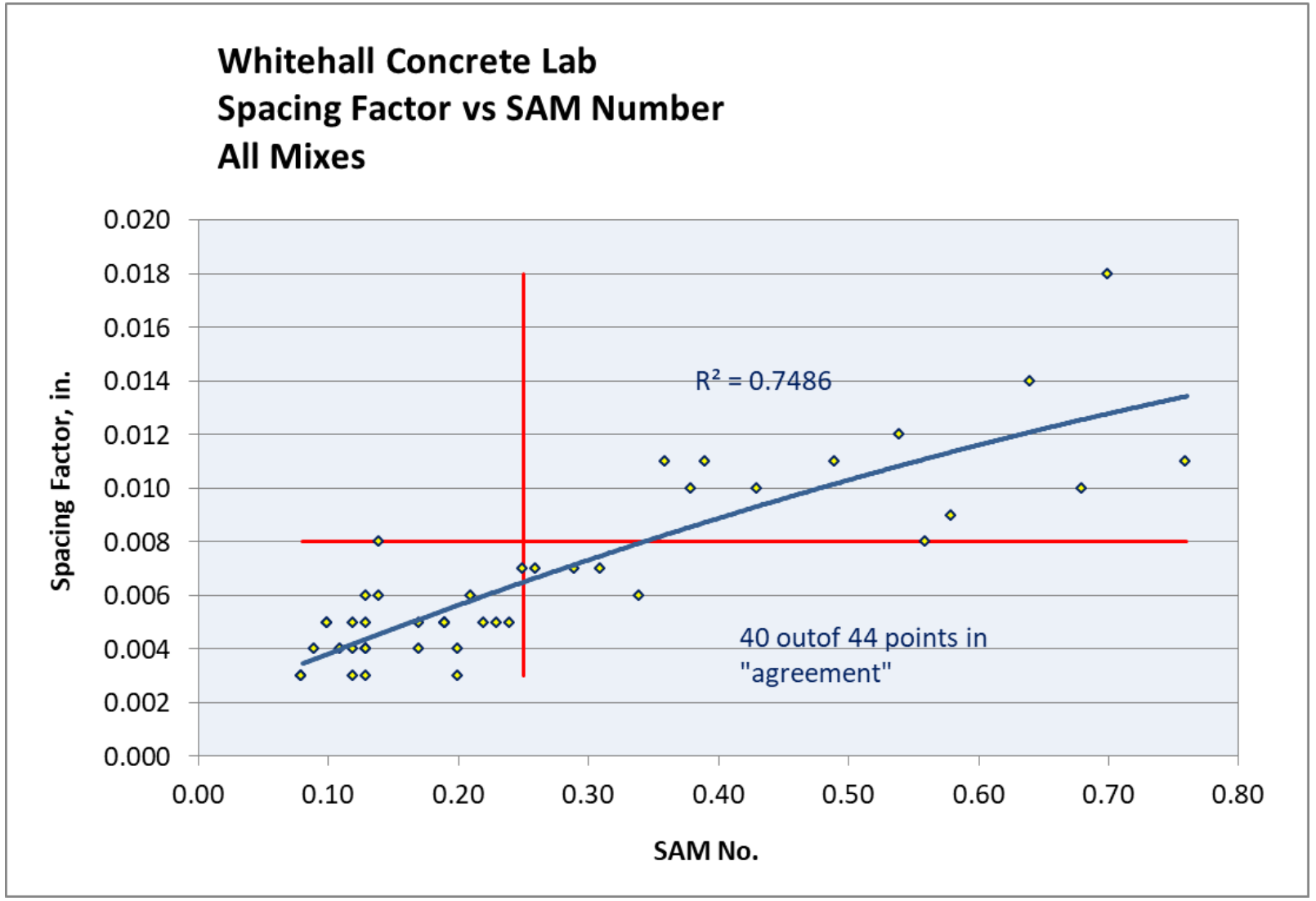
ODOT – 53 field mixtures



90% agreement


UNC Charlotte – 20 mixes
Spacing Factor [µm]
800
700
600
500
400
300
200
100
0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
SAM Number
80% agreement

Lafarge Holcim - Innis NCC 2018



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

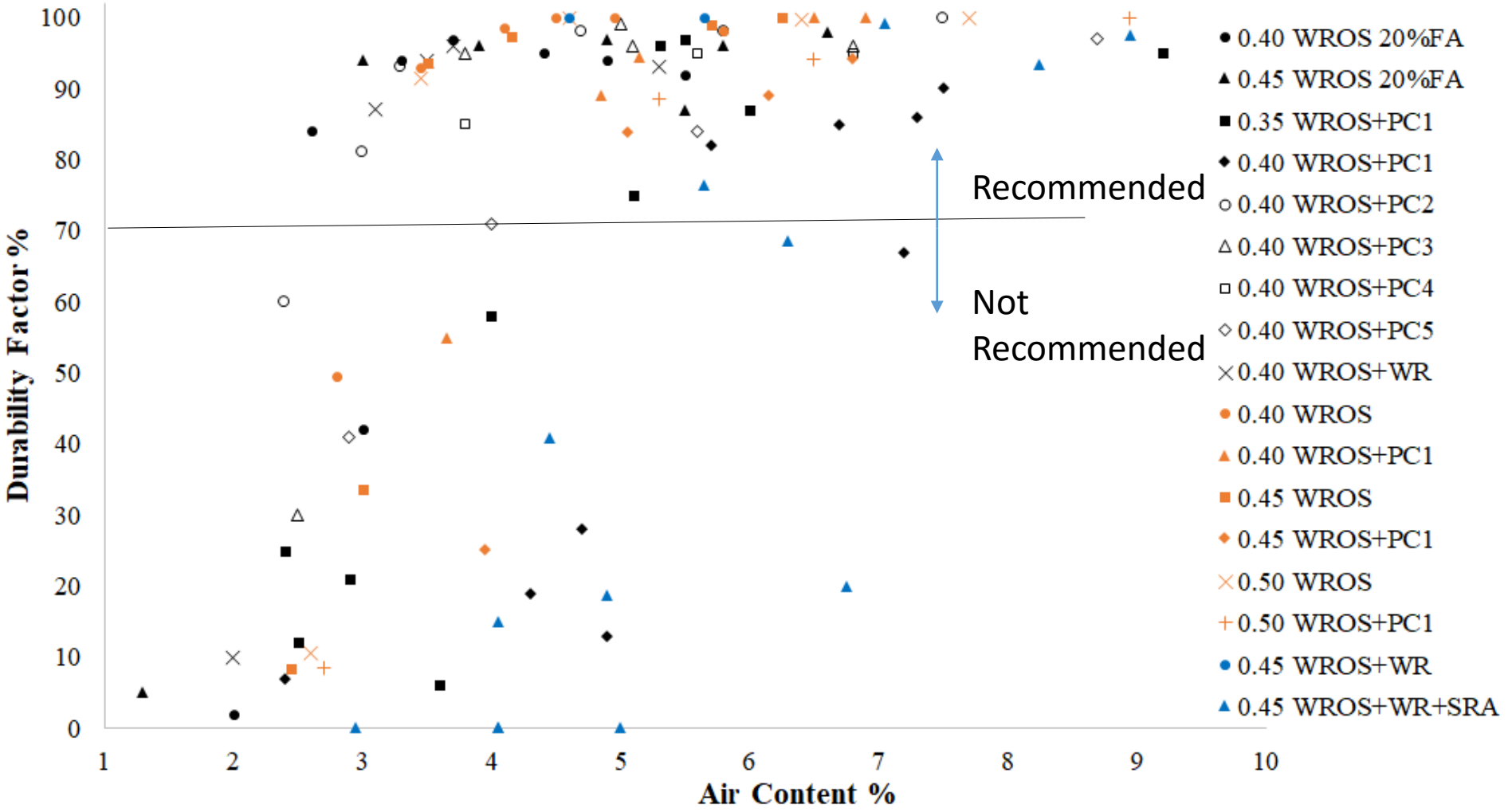
Seven independent studies show that the SAM Number tells you about the bubble size distribution in fresh concrete.

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?

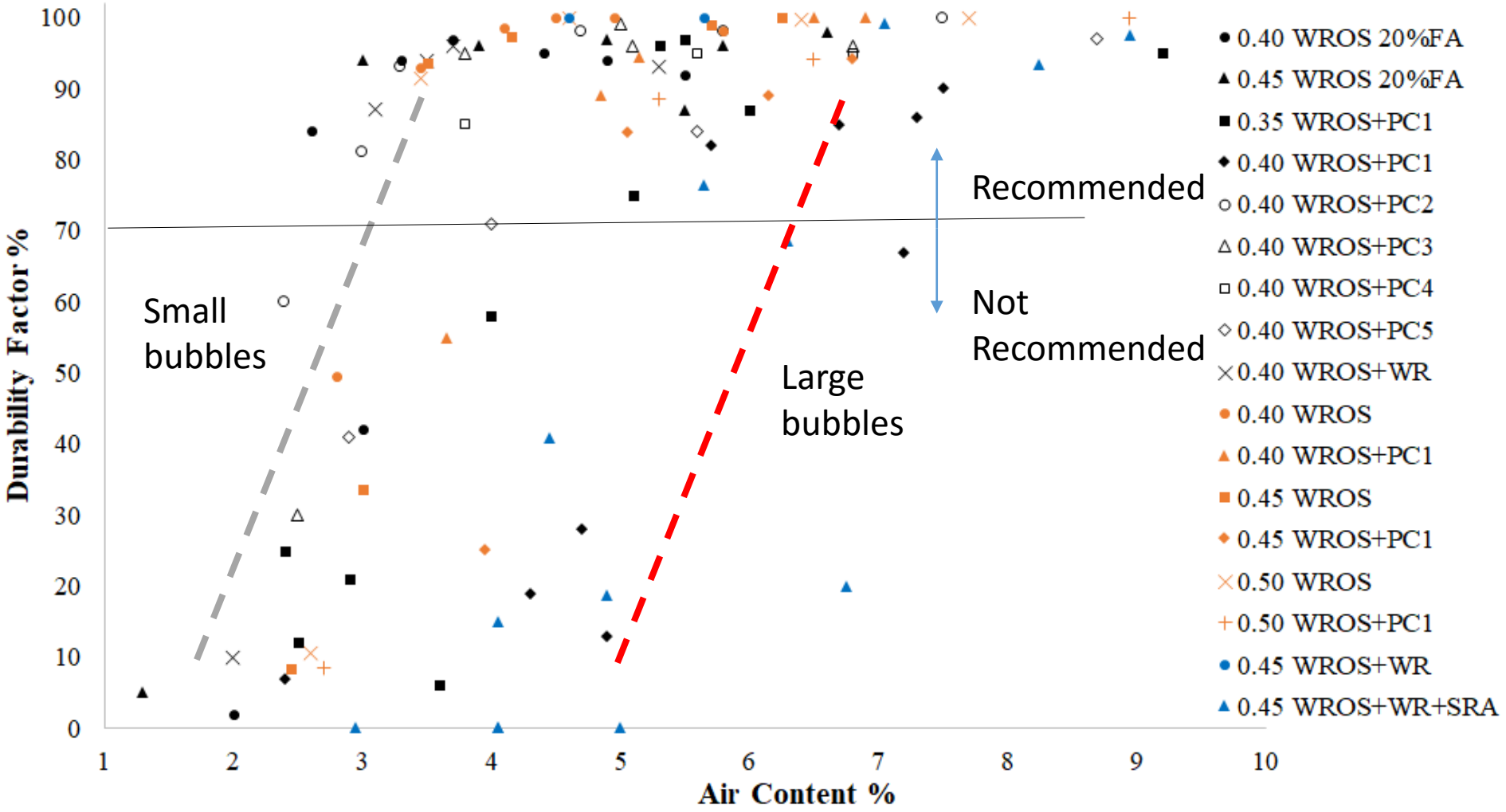
3.5 Months



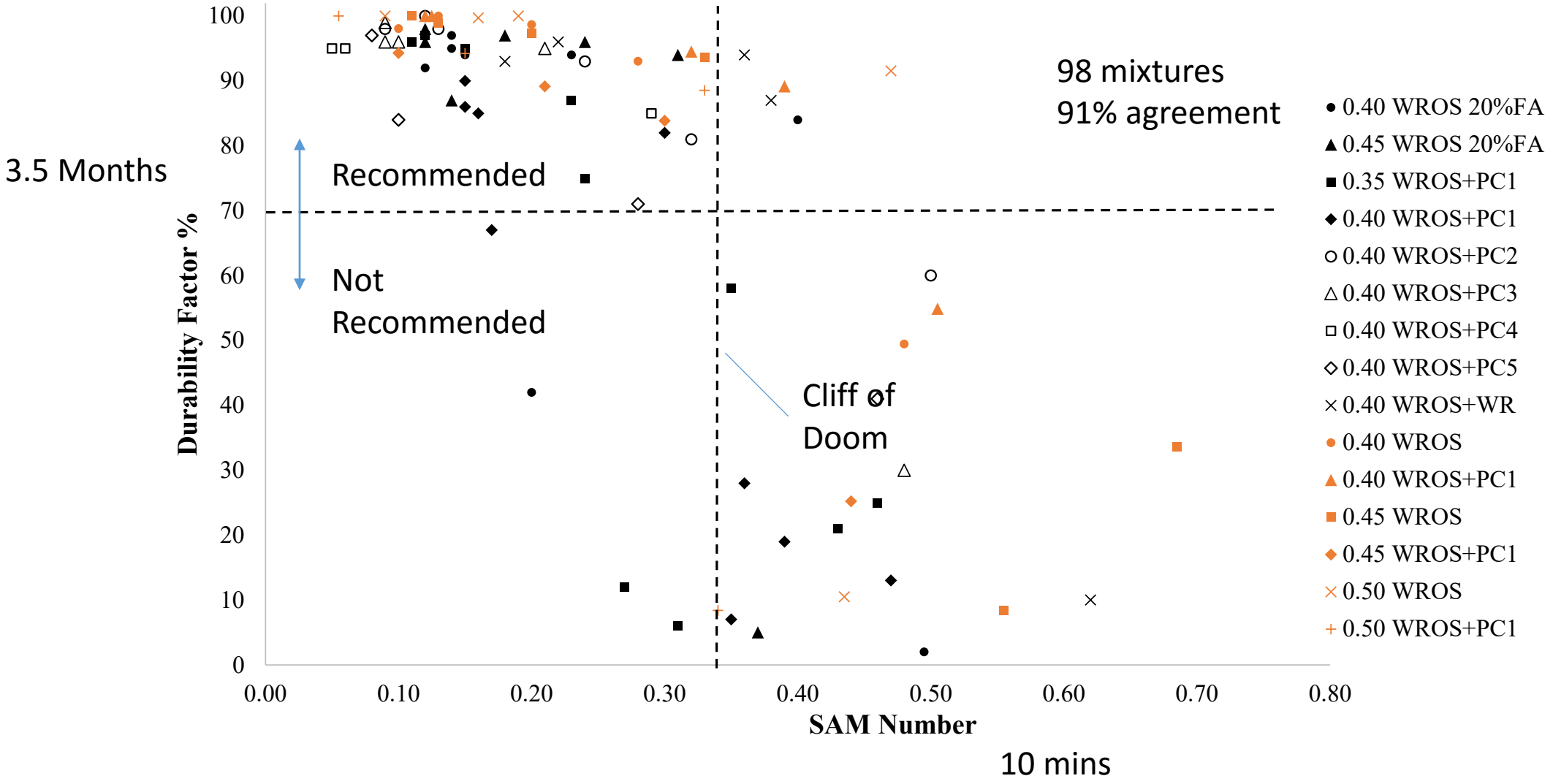
5 mins

What air content do you use?

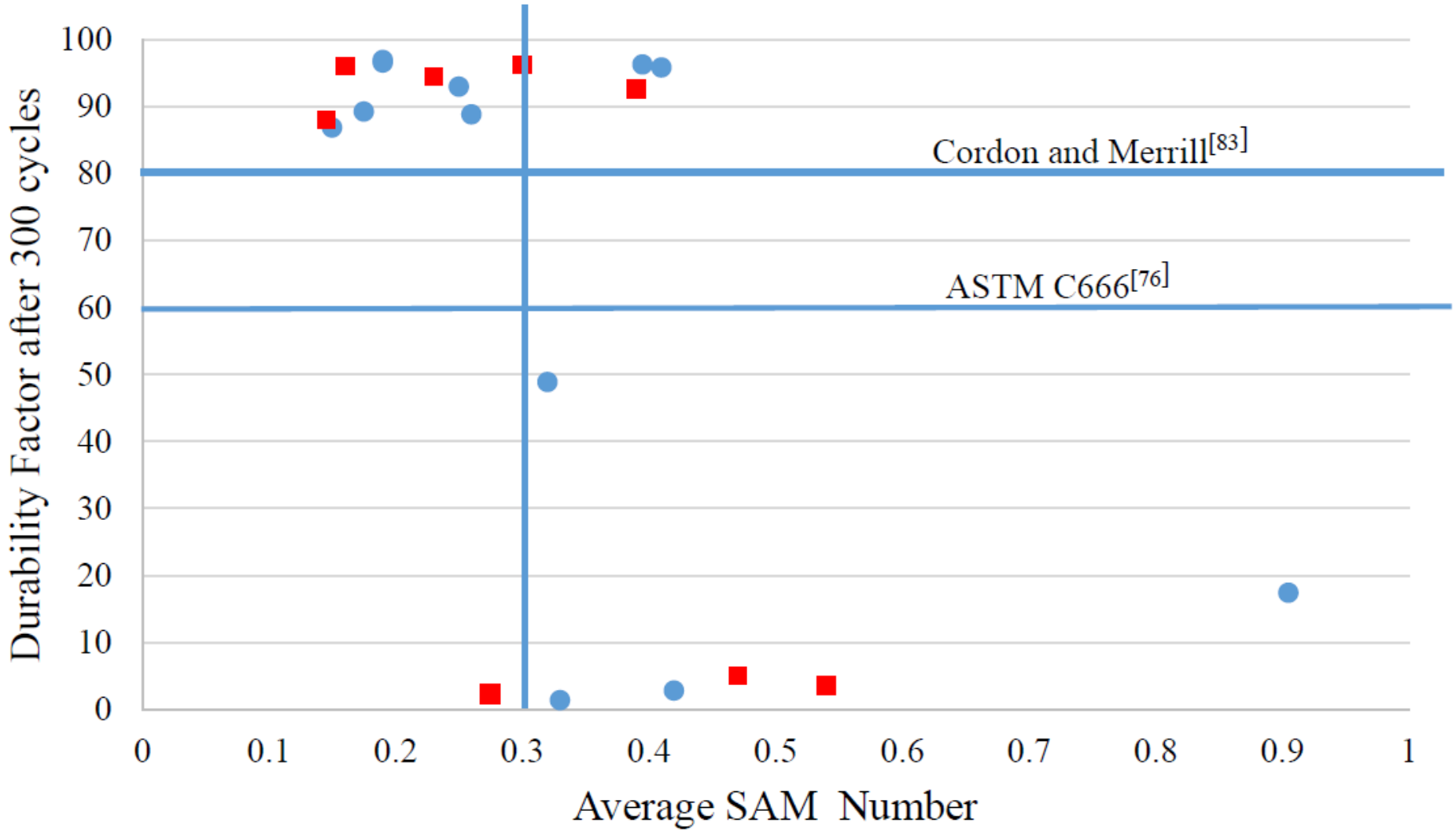
3.5 Months



5 mins


3.5 Months
Durability Factor %
100
90
80
70
60
50
40
30
20
10
0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
SAM Number
10 mins
Recommended
Not Recommended
Cliff of Doom
98 mixtures
91% agreement
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
0.40 WROS+PC1
0.45 WROS
0.45 WROS+PC1
0.50 WROS
0.50 WROS+PC1

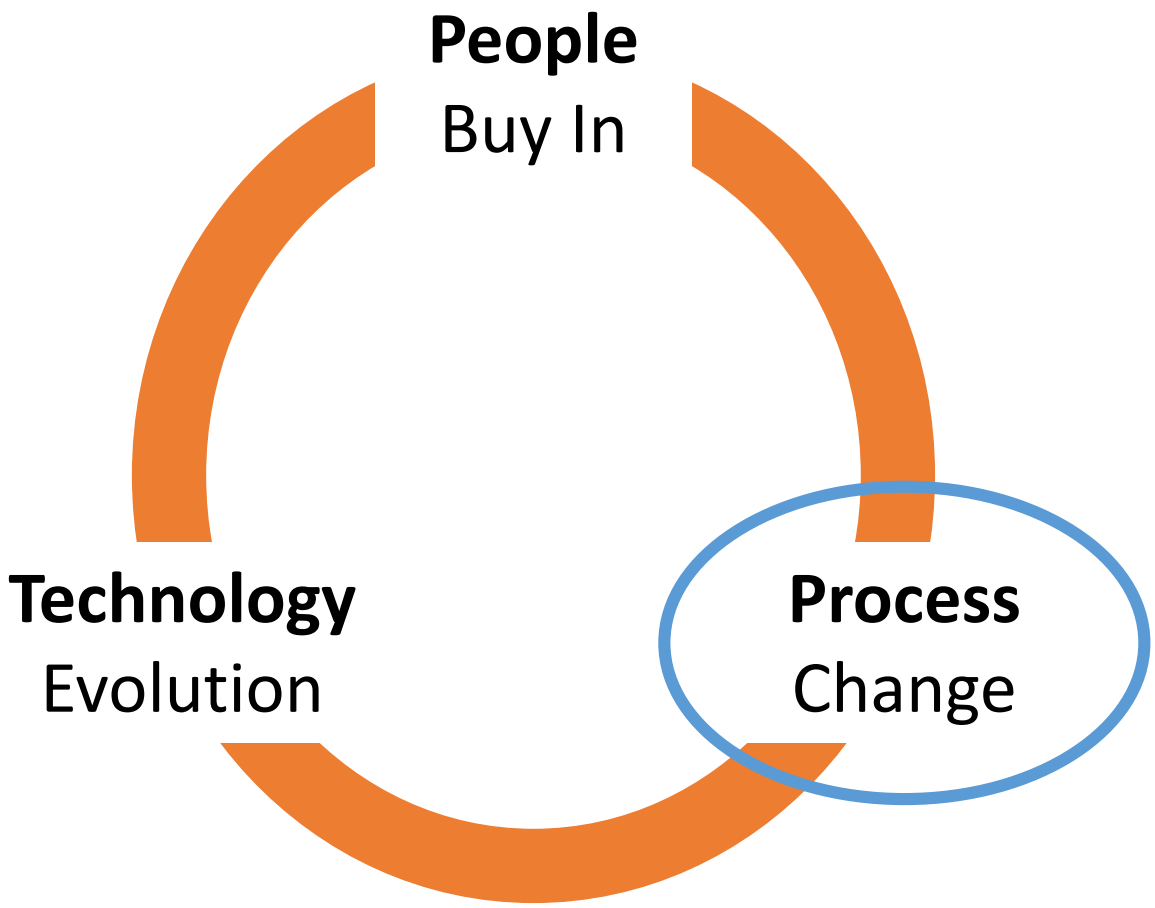
UNC Charlotte



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	
Training	3
Shadow Pavements	2
Shadow Bridges	2019
Full Spec Pavements	2020?

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	
Training	2 + 3
Shadow Pavements	3
Shadow Bridges	
Full Spec	

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.

Wisconsin	
Training	2
Shadow Pavements	2019
Shadow Bridges	2020
Full Spec Pavements	2020
Full Spec Bridges	2021

Wisconsin has sponsored their own research project over the SAM.

Colorado	
Training	1
Shadow Pavements	2020
Shadow Bridges	
Full Spec	2021

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,).

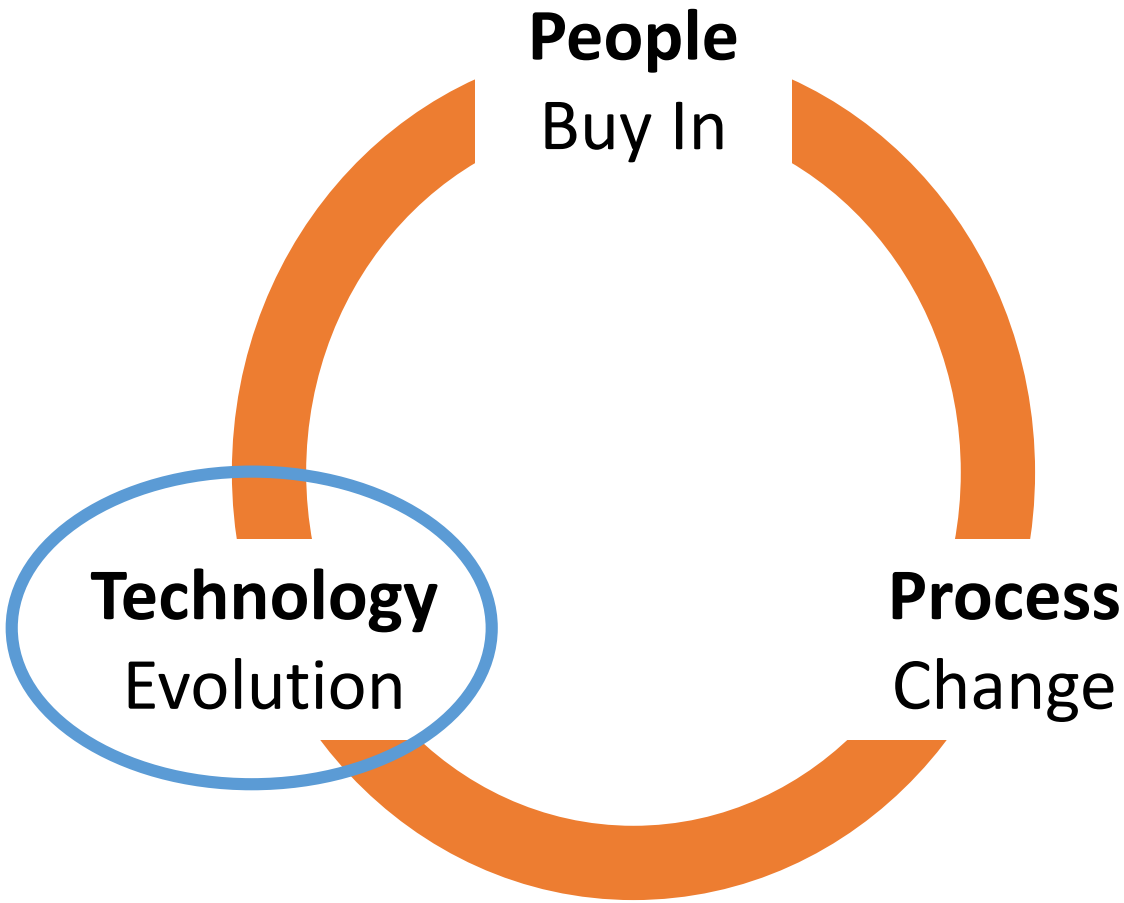
Discussion

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

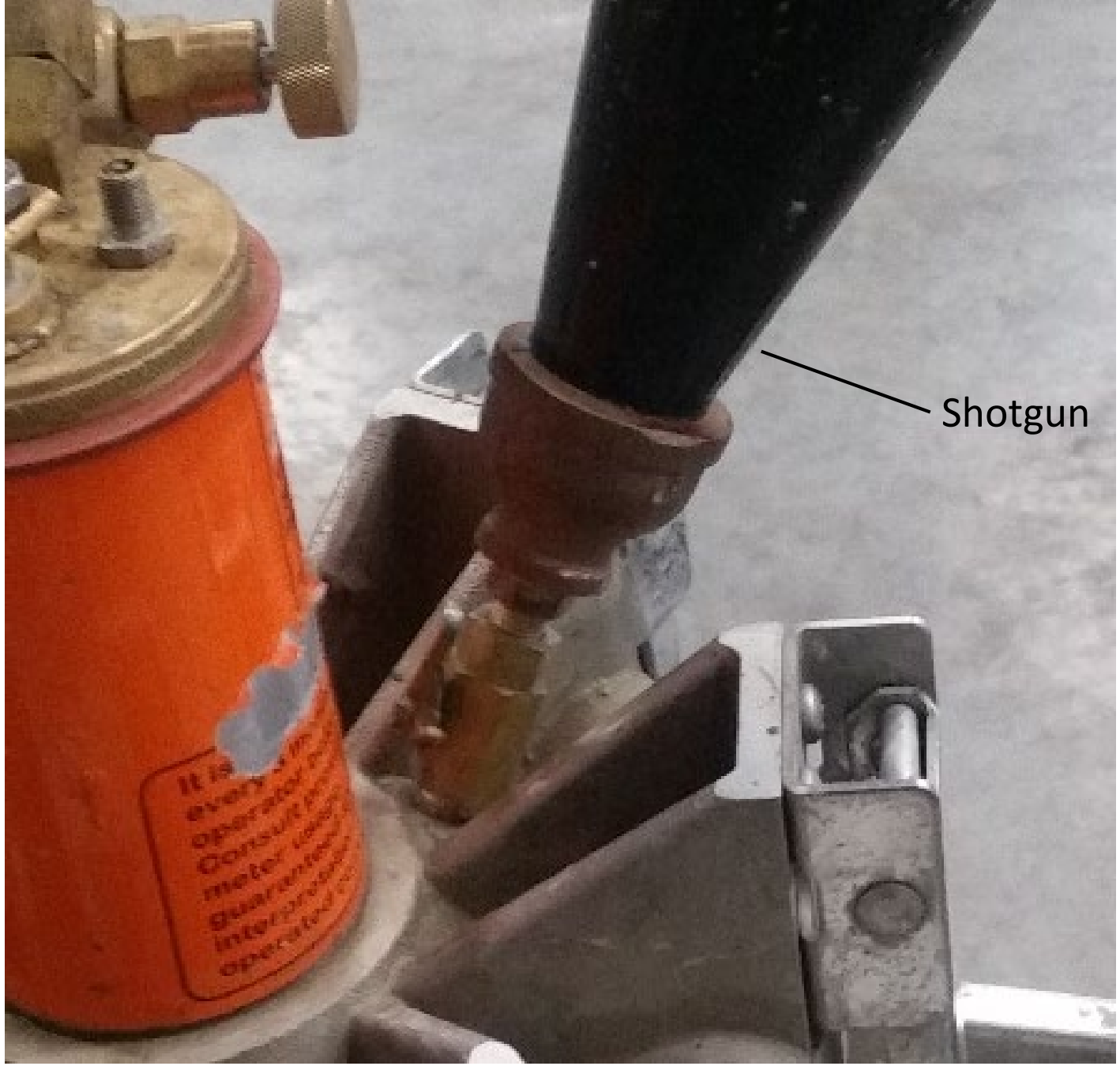
Improvements to the SAM

- Shotgun/Cape
- Leak check
- Reliability
- Tools to help design mixtures
- Internal curing
- Impact of vibration on air

Controlled Air Pressure Extender aka **CAPE**

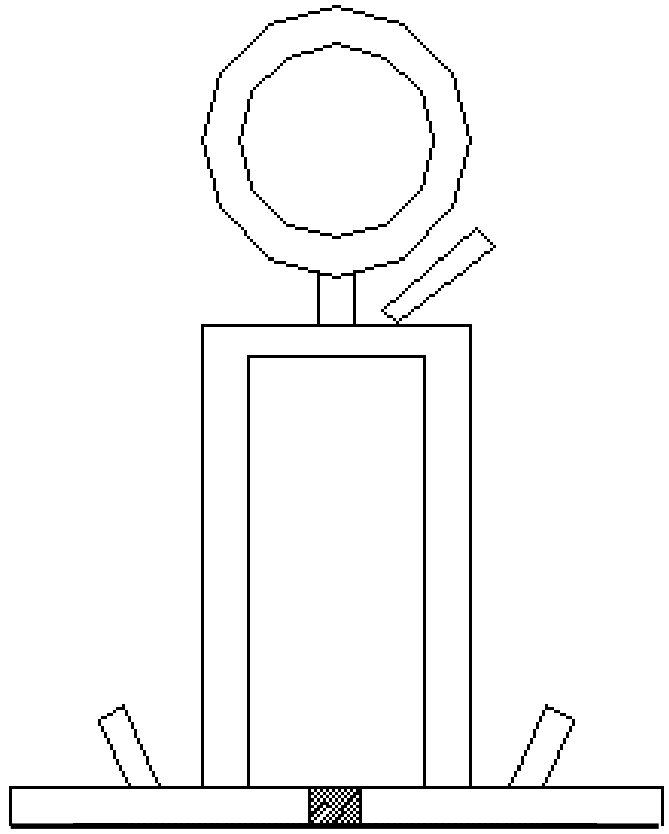

Shotgun


Shotgun


Shotgun

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

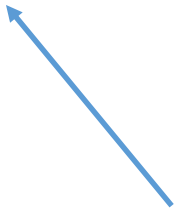
Not getting air out of bottom chamber when adding water

Slow leak in top chamber

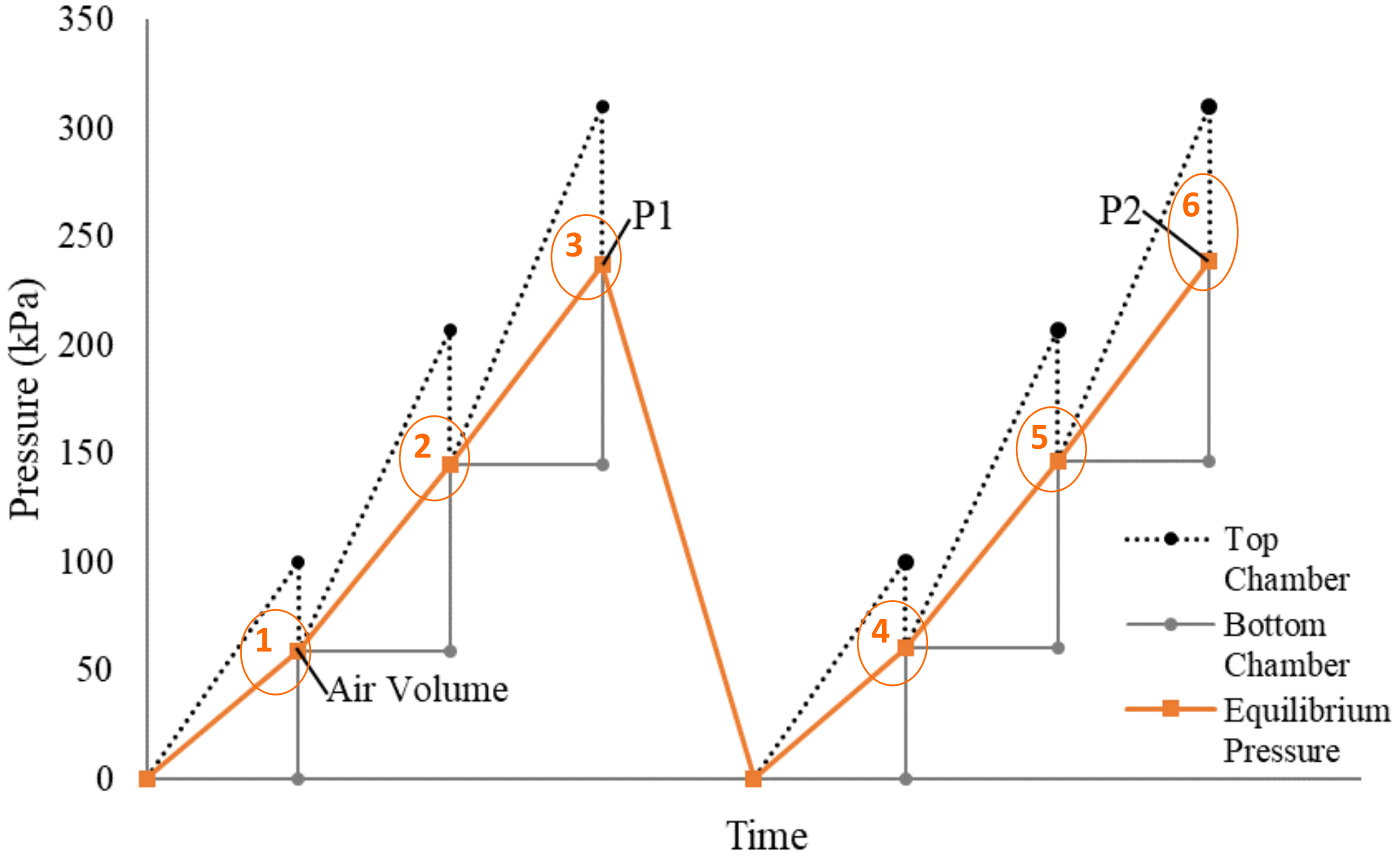
How do you use it (for now)?

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”



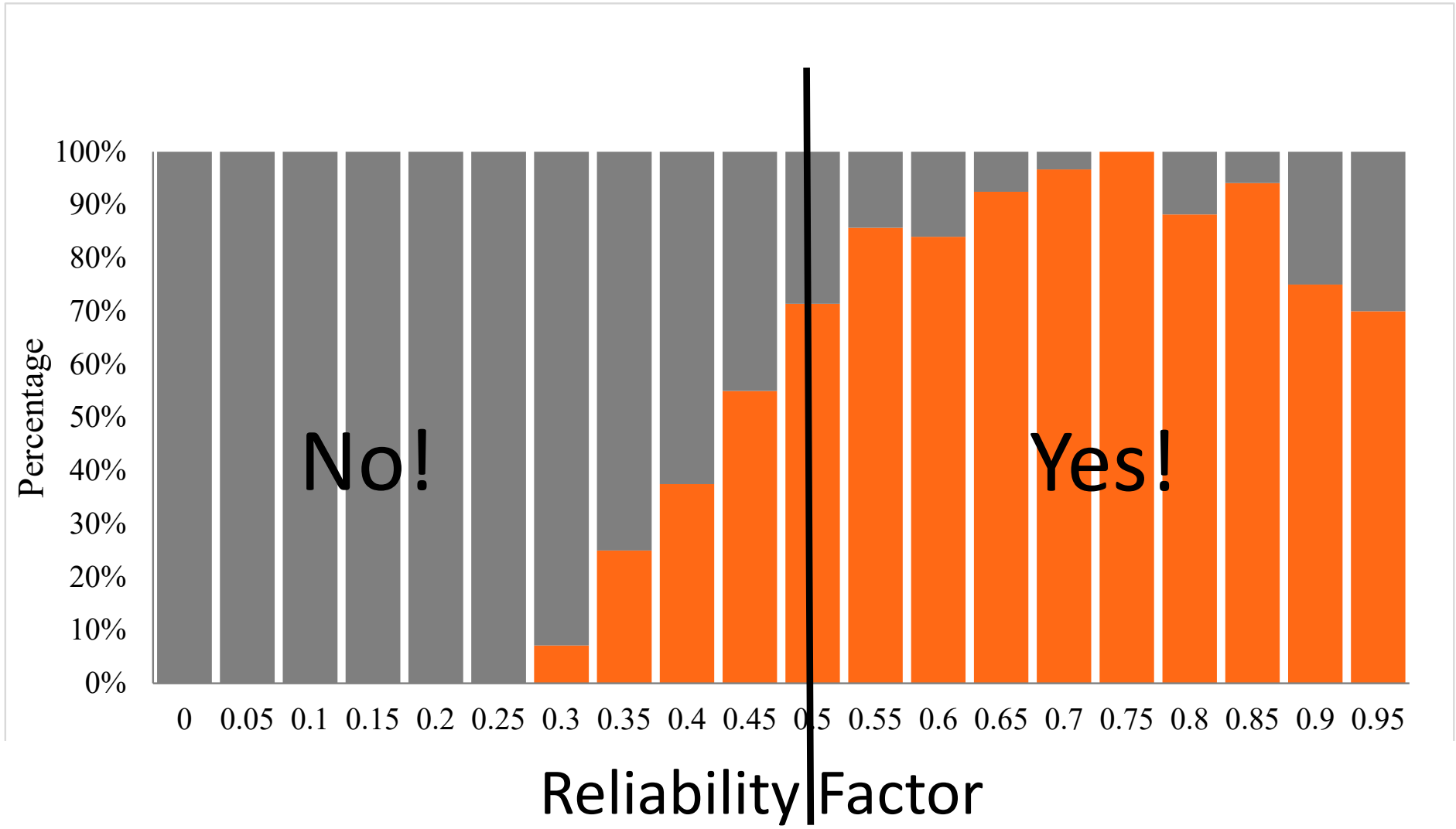
This will be changed to be done within the gauge.


350
300
250
200
150
100
50
0
Pressure (kPa)
Time
P1
P2
1
2
3
4
5
6
Air Volume
Top Chamber
Bottom Chamber
Equilibrium Pressure

I will send the spreadsheet out to anyone that wants it!!!

	Date:		10/10/2018	10/10/2018
	Test No.		**Example**	**Example**
First Run	**14.5 psi**	1	9.93	9.27
	30 psi	2	23.38	22.30
	45 psi	3	37.65	36.37
Second Run	**14.5 psi**	4	10.43	9.49
	30 psi	5	24.02	22.55
	45 psi	6	38.32	36.61
	Air Content (%)		2.53	3.12
	SAM @ 14.5 psi		0.5	0.22
	SAM @ 30 psi		0.64	0.25
	SAM @ 45 psi		0.67	0.24
	Reliability Factor		0.52	0.26
	Result:		**Likely Correct**	*Ran Incorrect*

> 0.50 likely correct
< 0.50 likely incorrect


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Percentage
No!
Yes!
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
Reliability Factor

Discussion

The Reliability Factor estimates if the SAM test was completed correctly.

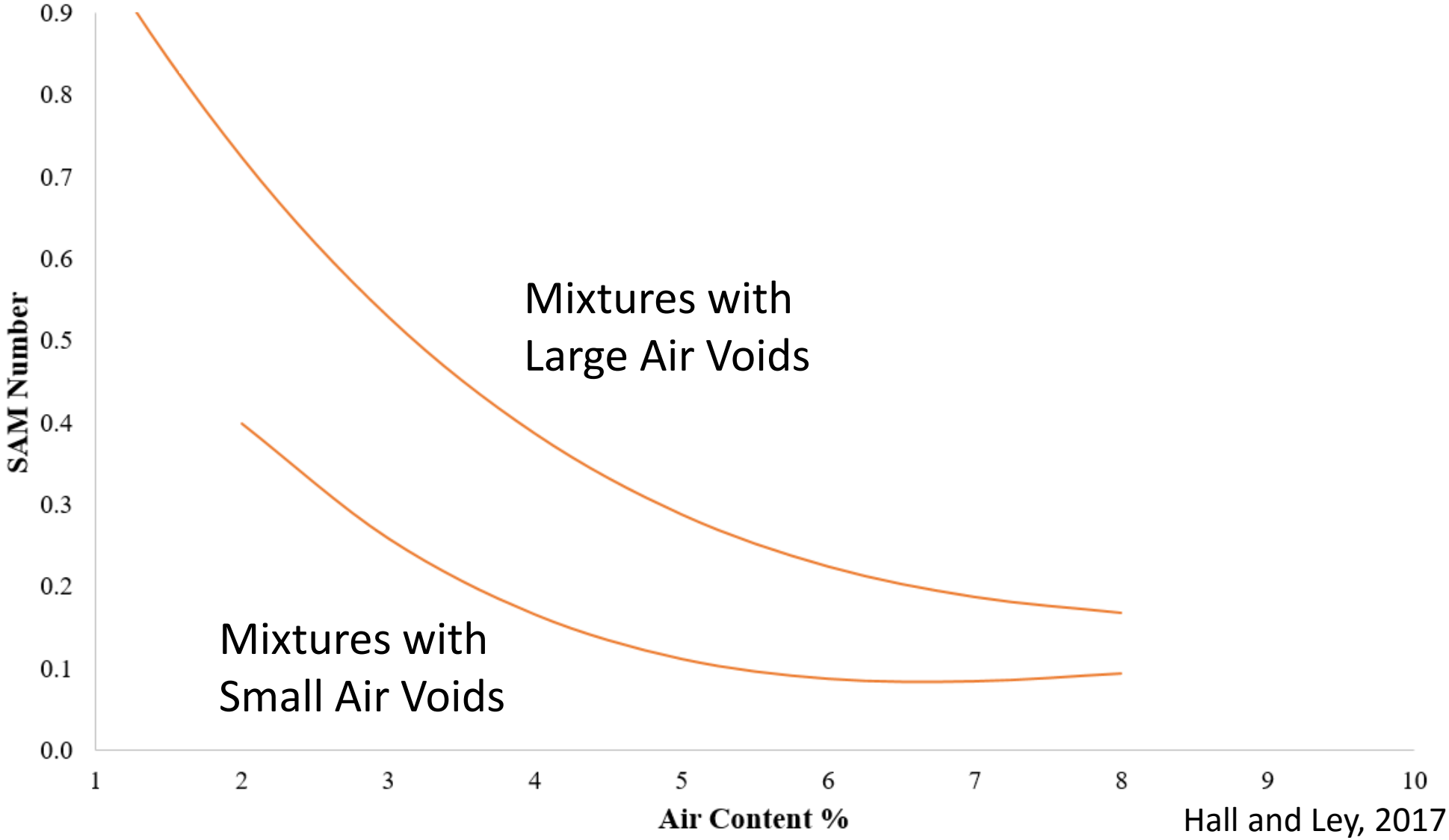
This will reduce the number of bad SAM tests and make people more confident in their results.

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.

SAM Curve!!!

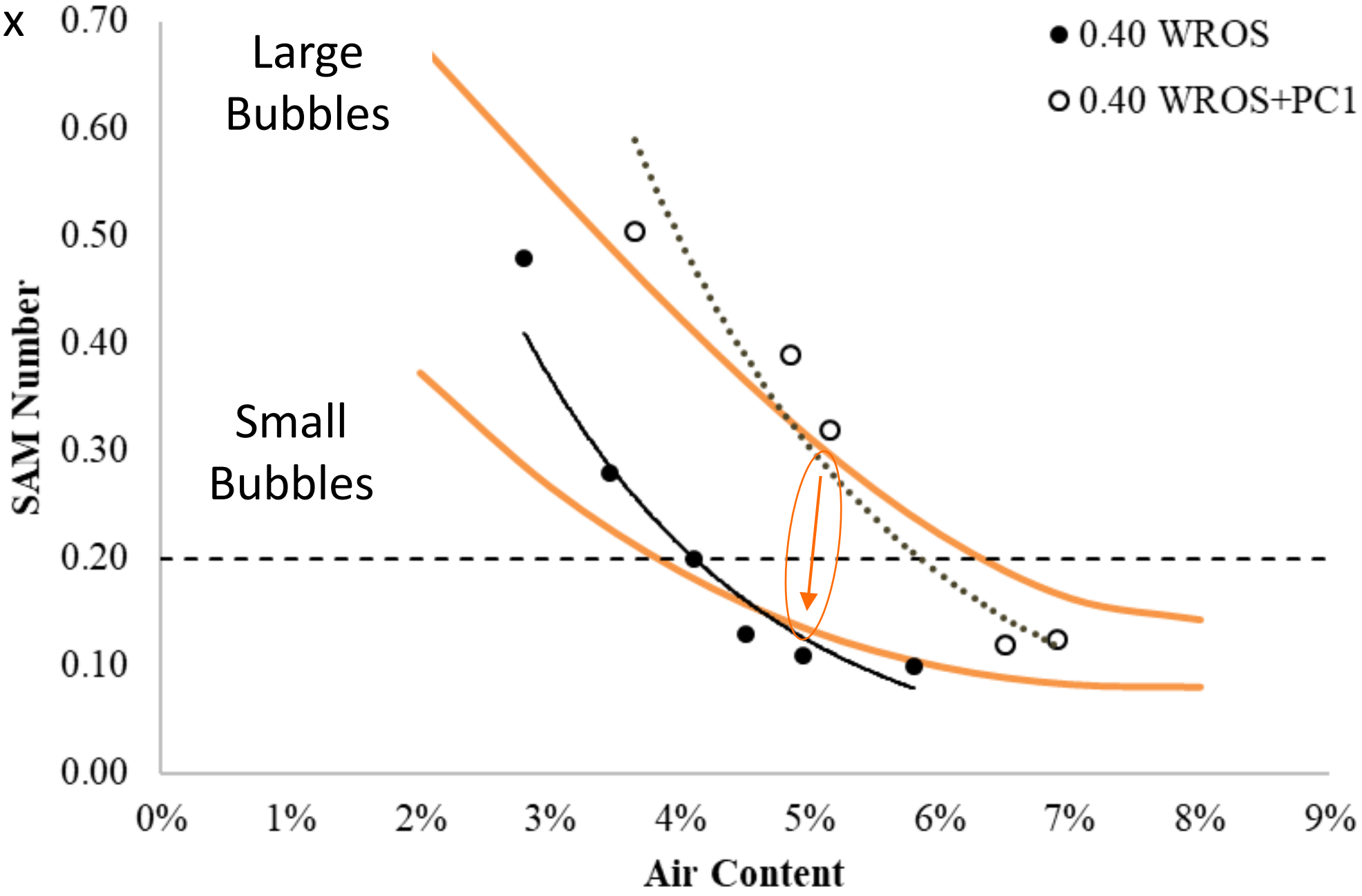


Hall and Ley, 2017

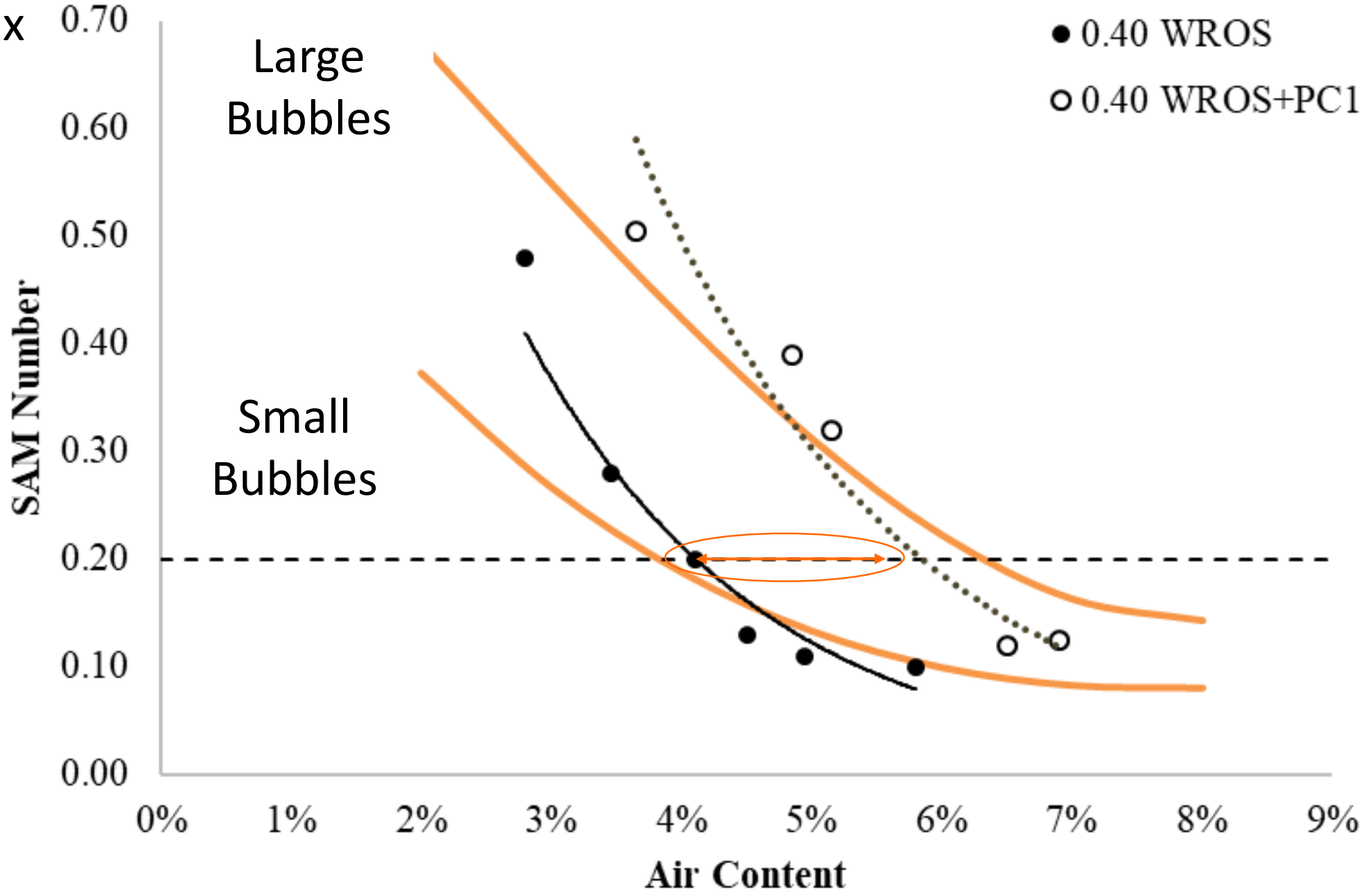
Comparisons

- Comparing admixture combinations
- Comparing cements

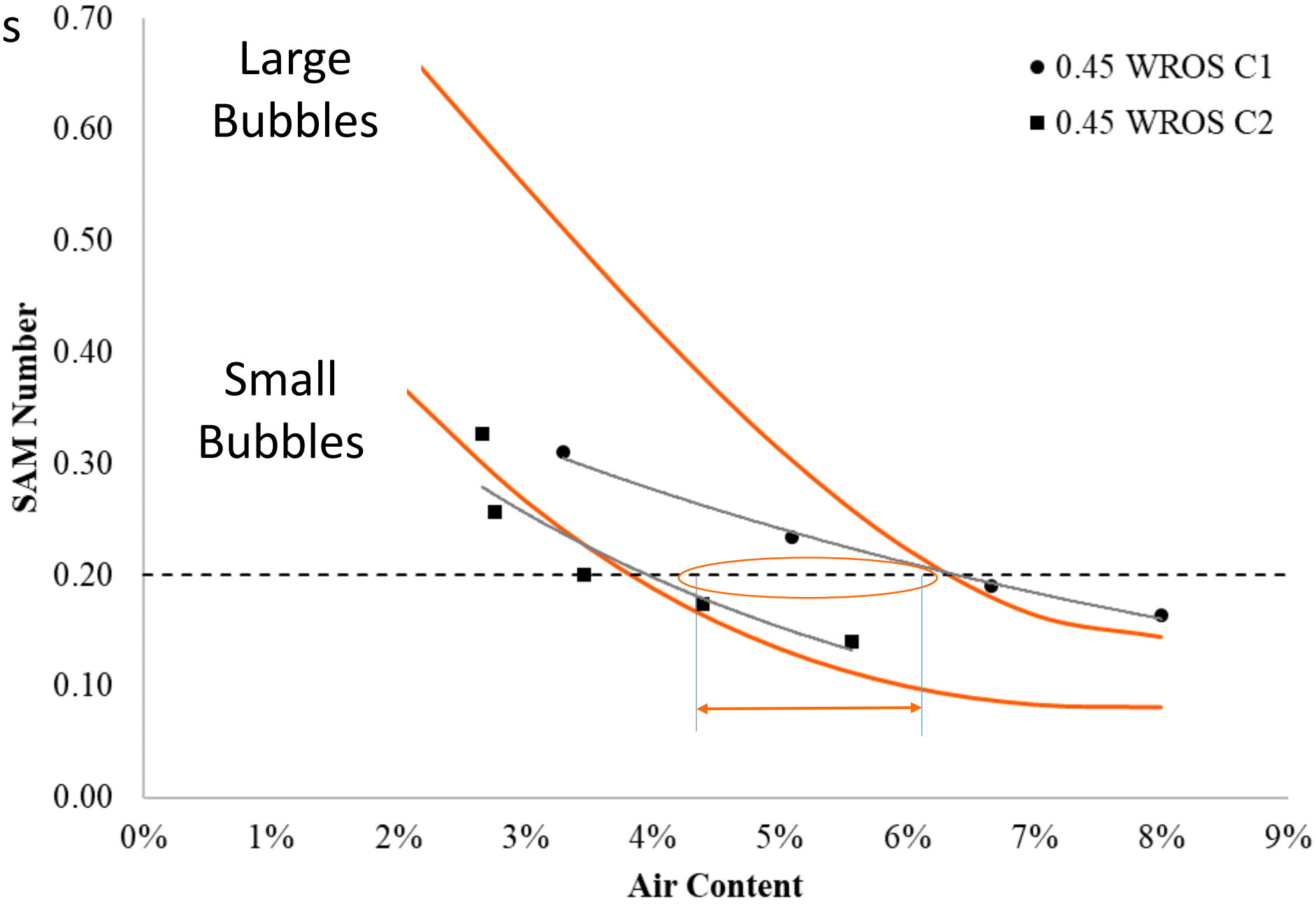
Admix


Large Bubbles
Small Bubbles
0.40 WROS
0.40 WROS+PC1
SAM Number
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0%
1%
2%
3%
4%
5%
6%
7%
8%
9%
Air Content

Admix


Large Bubbles
Small Bubbles
0.40 WROS
0.40 WROS+PC1
SAM Number
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0%
1%
2%
3%
4%
5%
6%
7%
8%
9%
Air Content

Cements


Large Bubbles
Small Bubbles
0.45 WROS C1
0.45 WROS C2
SAM Number
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0%
1%
2%
3%
4%
5%
6%
7%
8%
9%
Air Content

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.

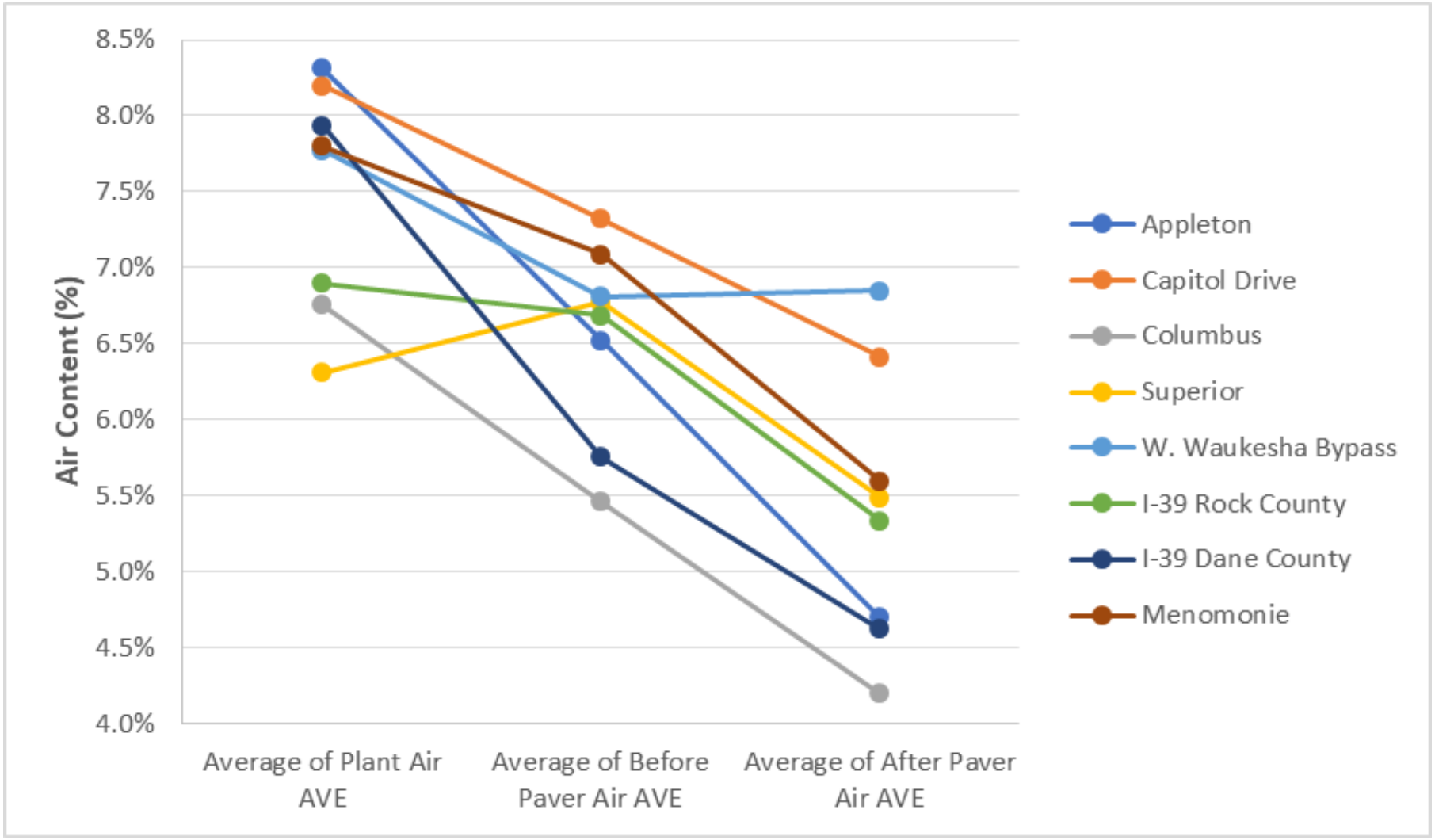
- This immediate feedback can be used to rapidly iterate to a mix with a good air void system.

Internal curing with SAM

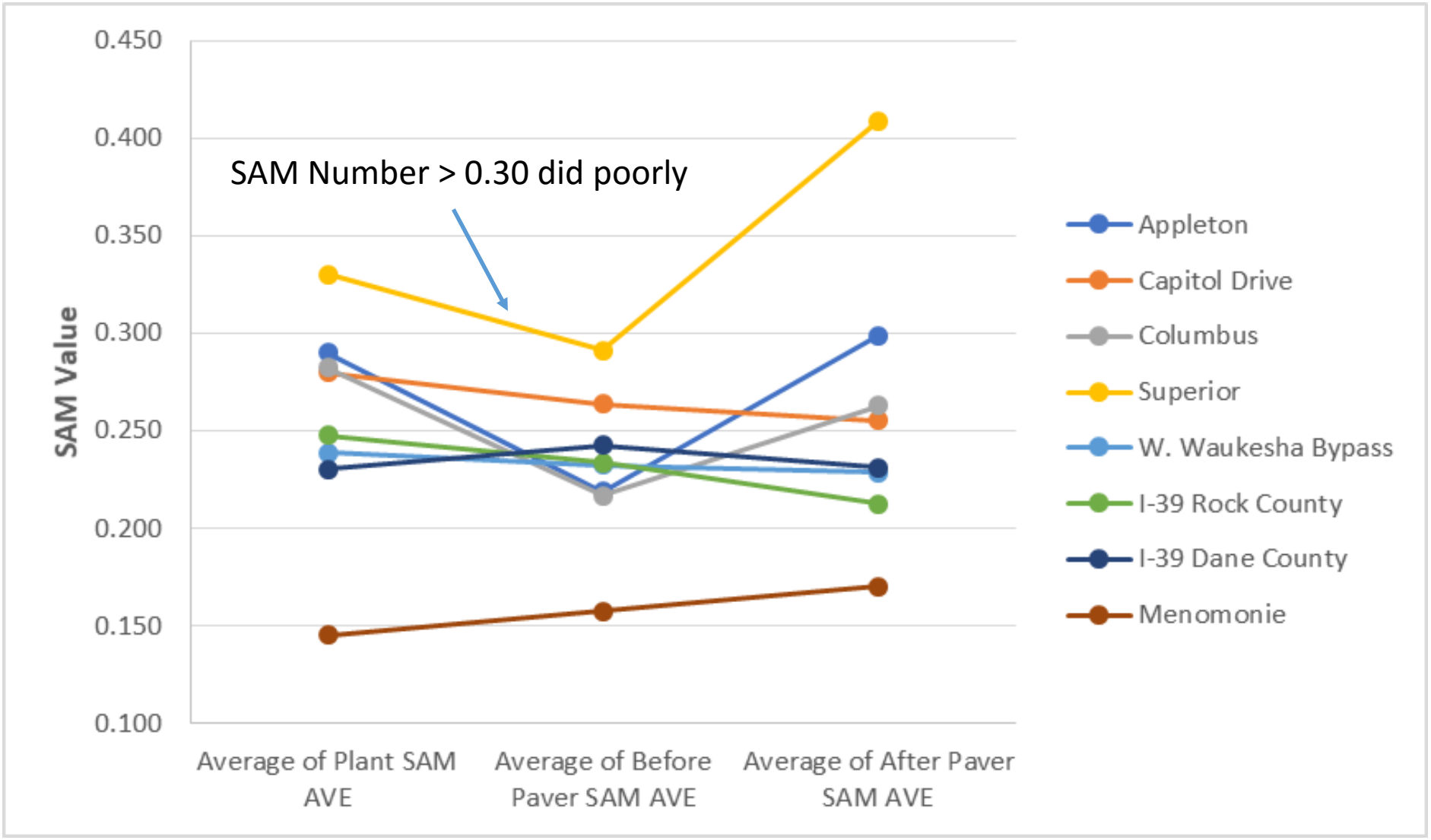
If you use < 30% replacement of light weight by volume and the material is properly saturated then you can use the SAM for the air content and SAM Number

How does vibration from a paver impact the air void system in concrete?

WisDOT Research Project



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.

www.youtube.com/tylerley

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?

Test Method	Parameter	COV	Time to complete the test
SAM	SAM Number[1]	15.2%	10 min
ASTM C457	Spacing Factor[2]	20.1%	7 days
ASTM C666	Durability Factor[3]	22.7%	3.5 months

AASHTO PP84-19 Specification

Mixture Design

SAM < 0.20 and Air > 4%

Field

SAM < 0.30 and Air > 4%

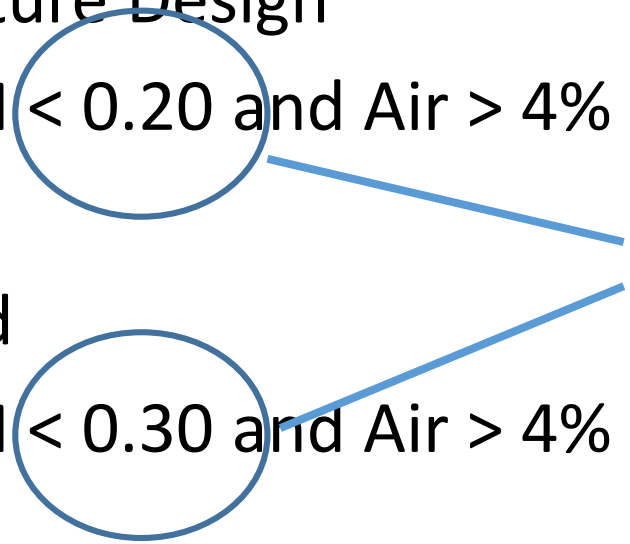
AASHTO PP84-19 Specification

Mixture Design

SAM < 0.20 and Air > 4%

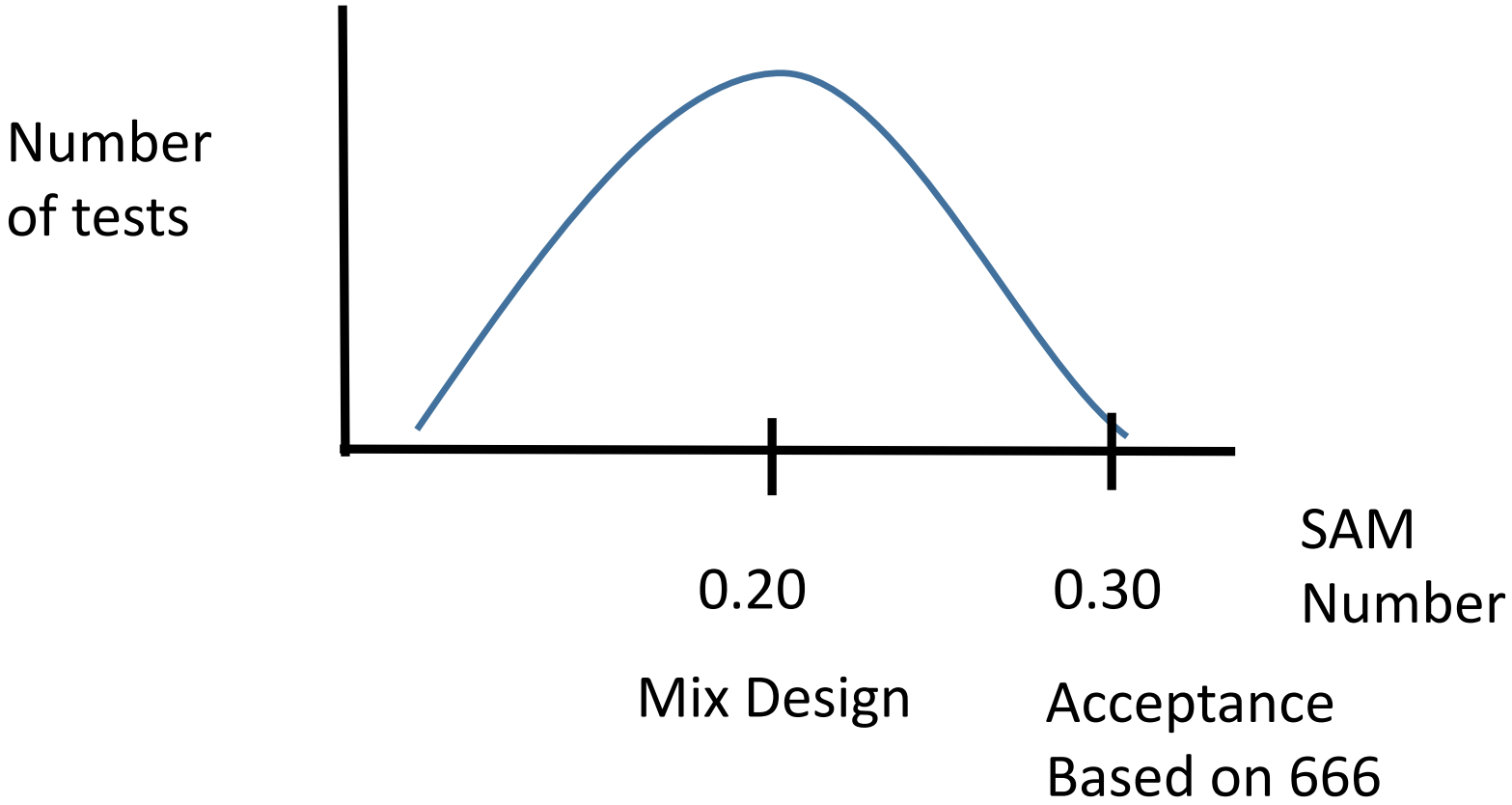
Field

SAM < 0.30 and Air > 4%

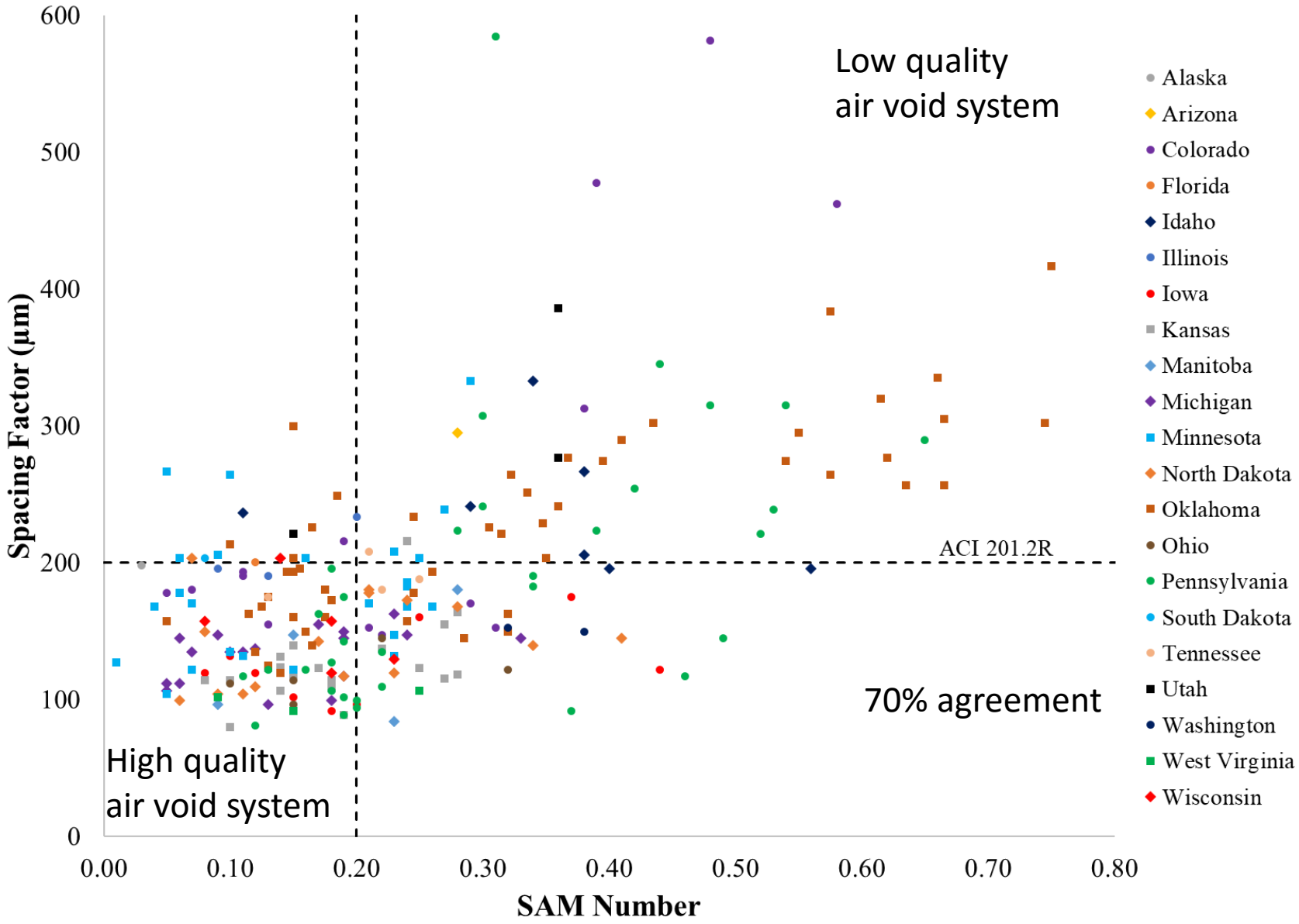


Why are they different??

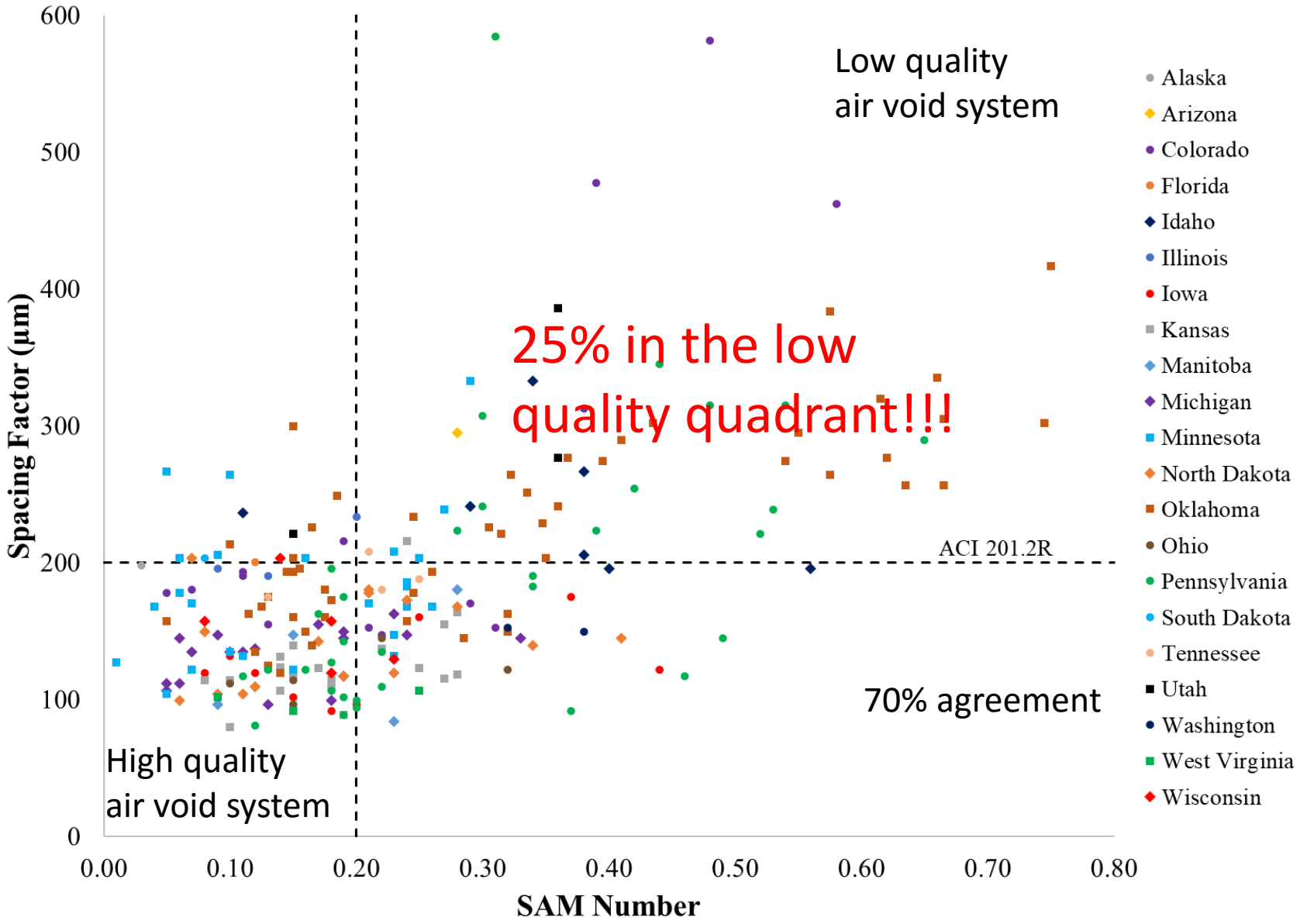
Why are they different?

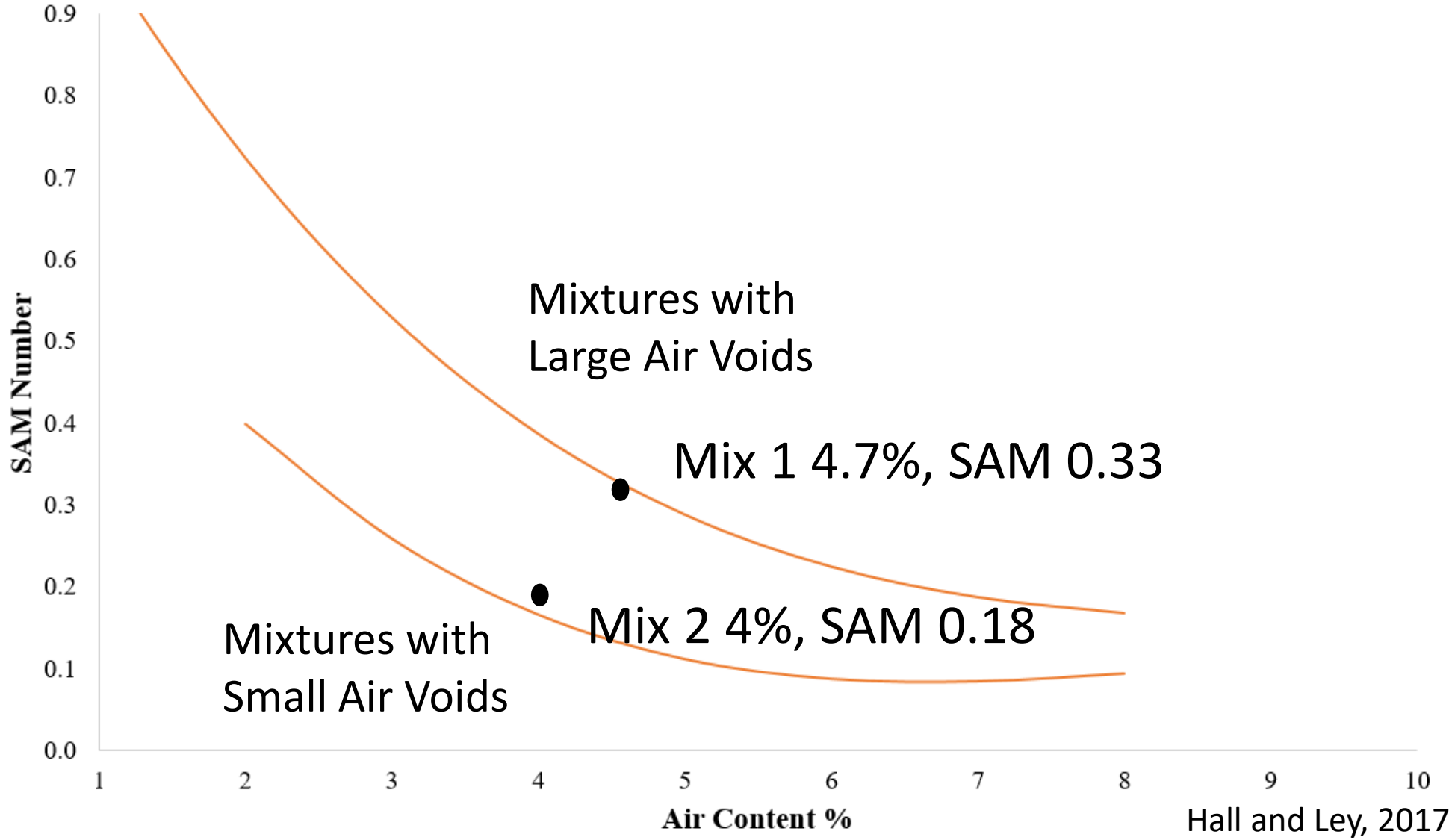


231 field mixes

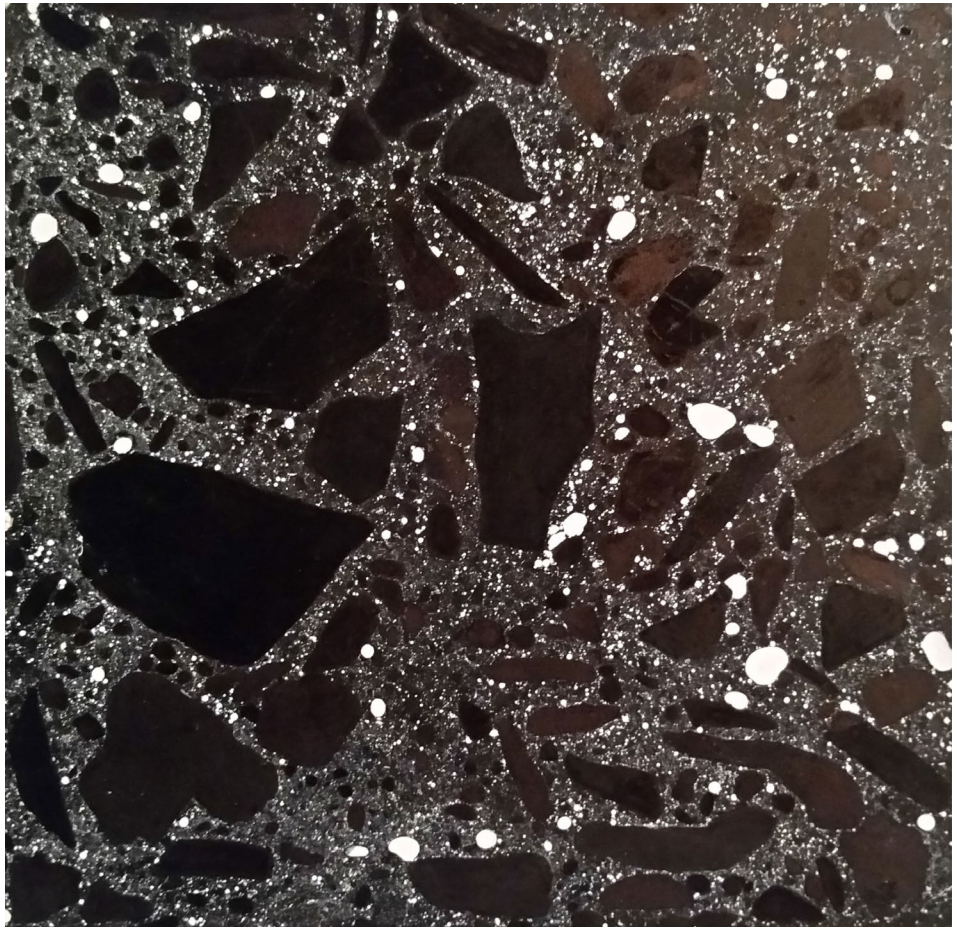


231 field mixes

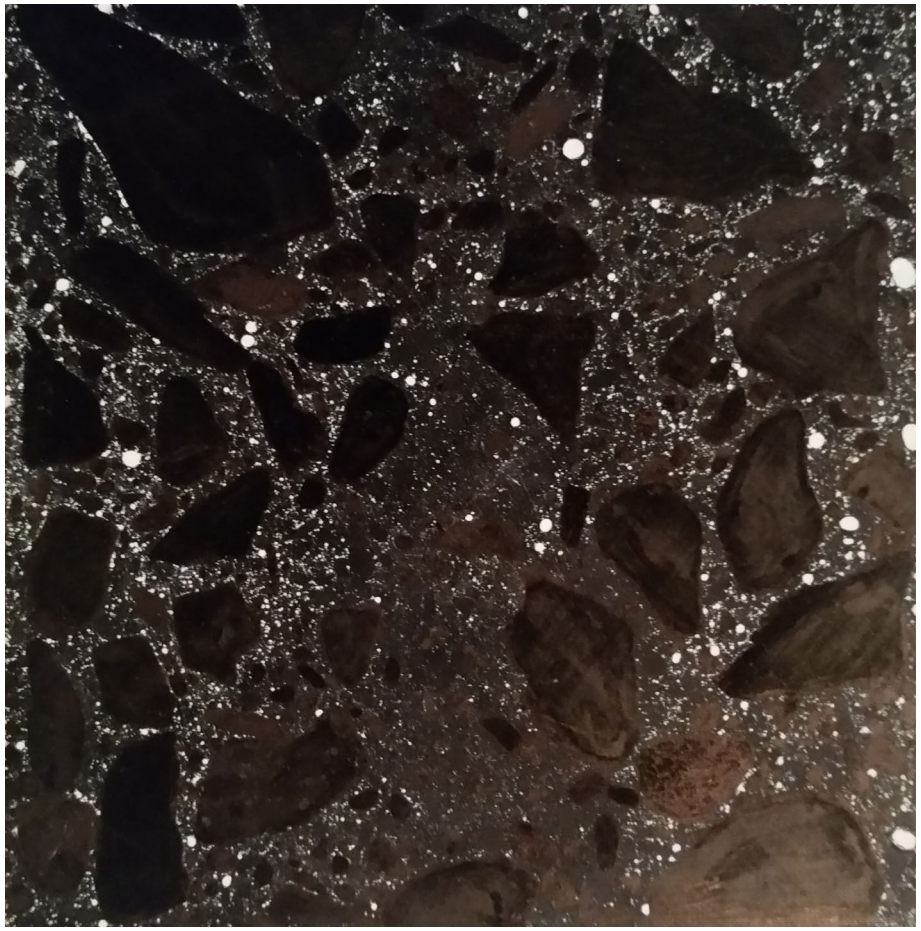




Hall and Ley, 2017

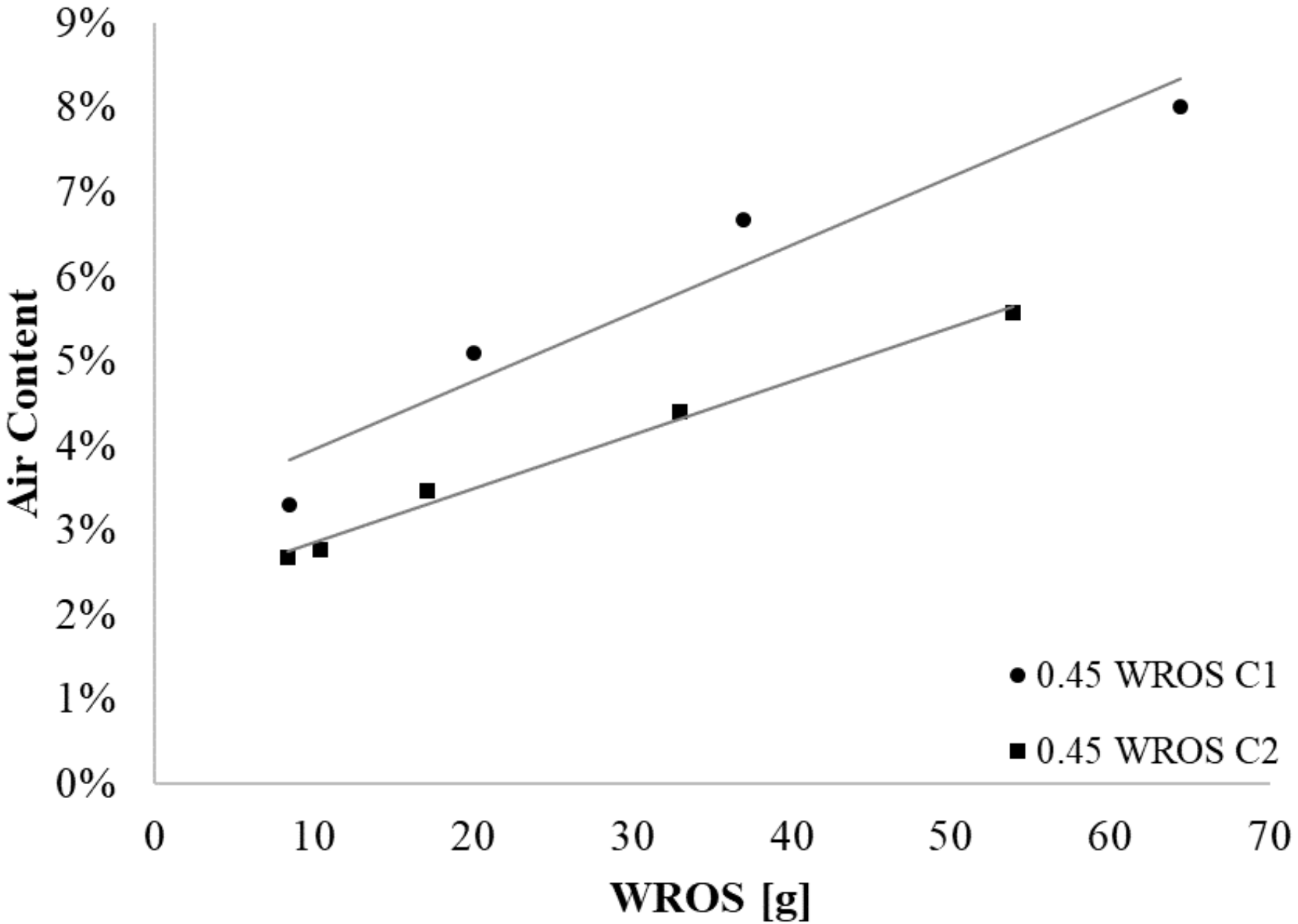


Mix 1 – large air voids
4.7% SAM 0.33



Mix 2 – small air voids
4.0% SAM 0.18

Cements


9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
Air Content
0
10
20
30
40
50
60
70
WROS [g]
0.45 WROS C1
0.45 WROS C2