

Update on the Freeze Thaw Pooled Fund



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Acknowledgements

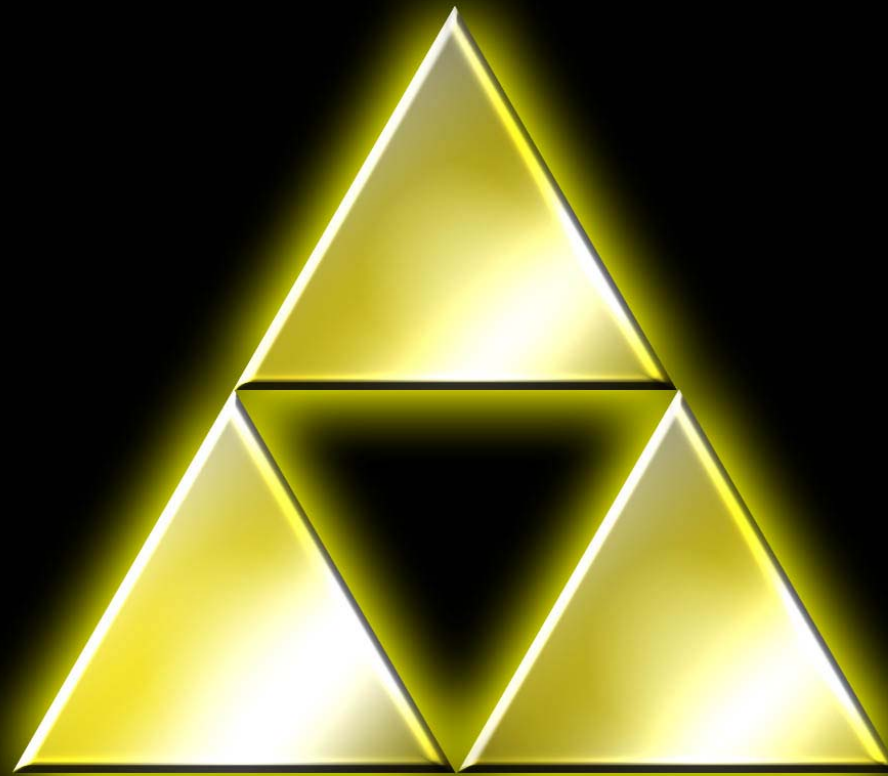
- Oklahoma DOT
- FHWA
- Kansas DOT
- Nebraska DOT
- Iowa DOT
- Minnesota DOT
- Idaho DOT
- South Dakota DOT
- Pennsylvania DOT
- Connecticut DOT
- Illinois DOT
- Indiana DOT
- Michigan DOT
- Wisconsin DOT
- RMC Foundation

Summary

- Introduction
- Update on Super Air Meter
- Discussion

The Freeze Thaw Durability Triforce!!!

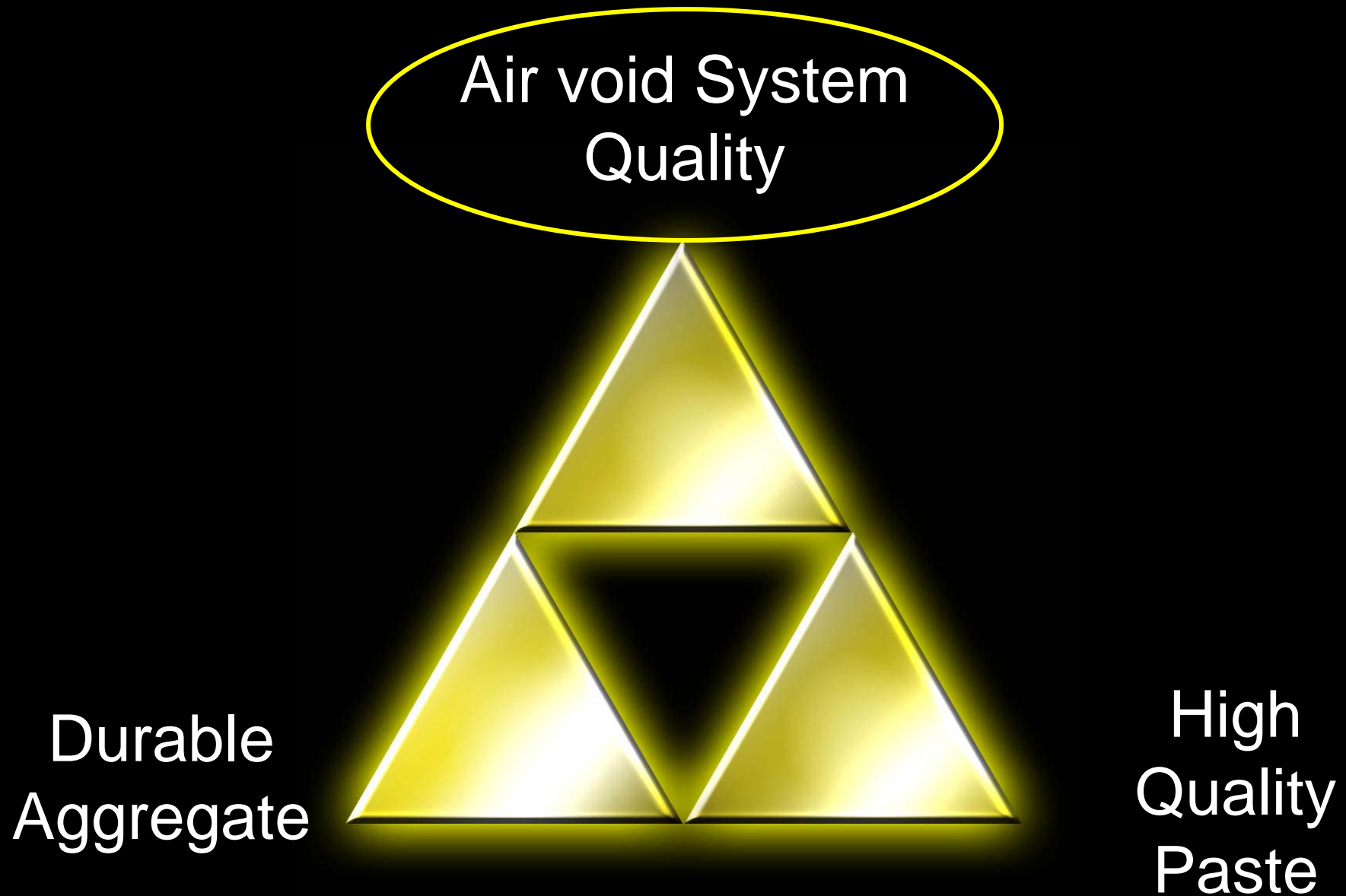
Air void System
Quality



Durable
Aggregate

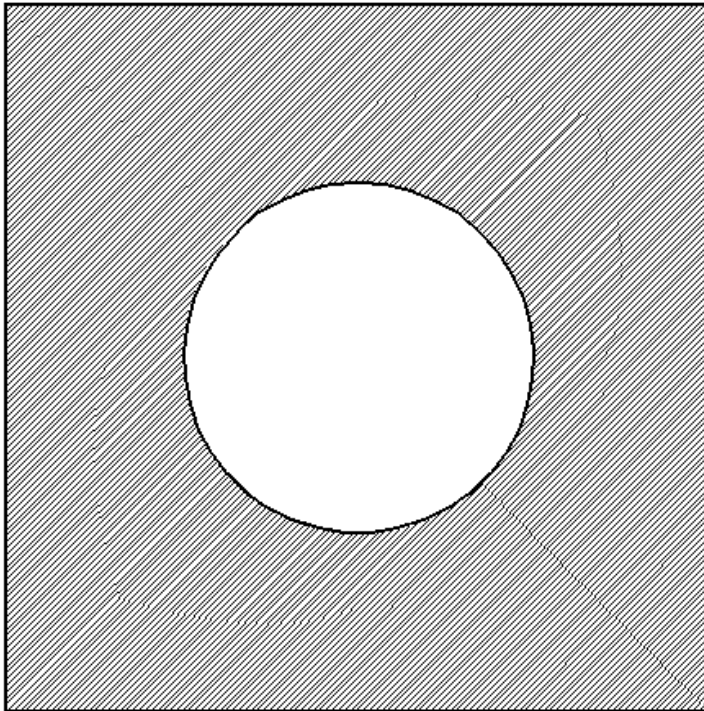
High
Quality
Paste

The Freeze Thaw Durability Triforce!!!

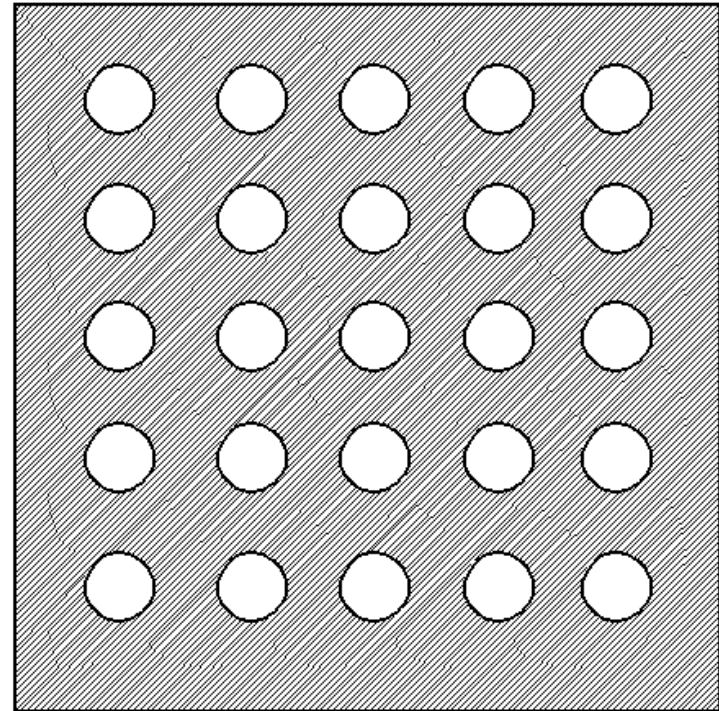


What Do You Want in an Air-Void System?

A



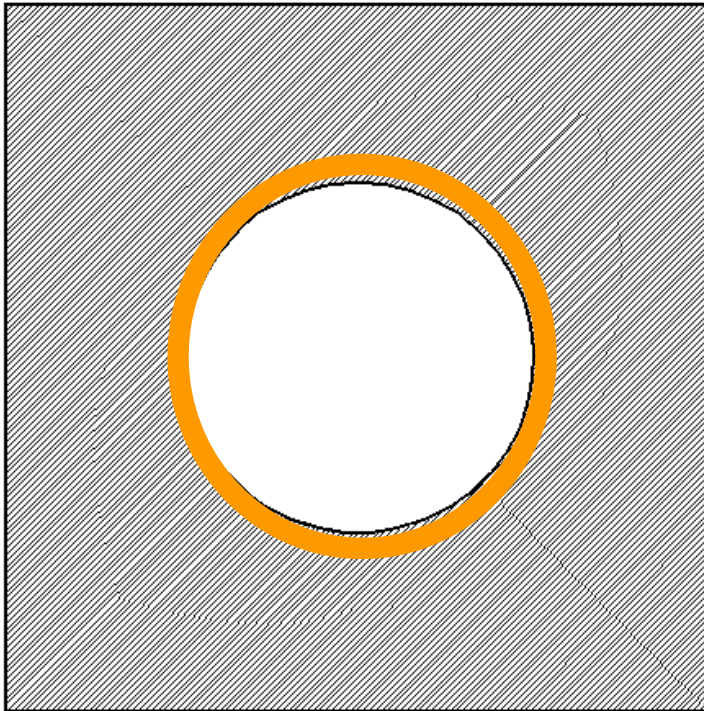
B



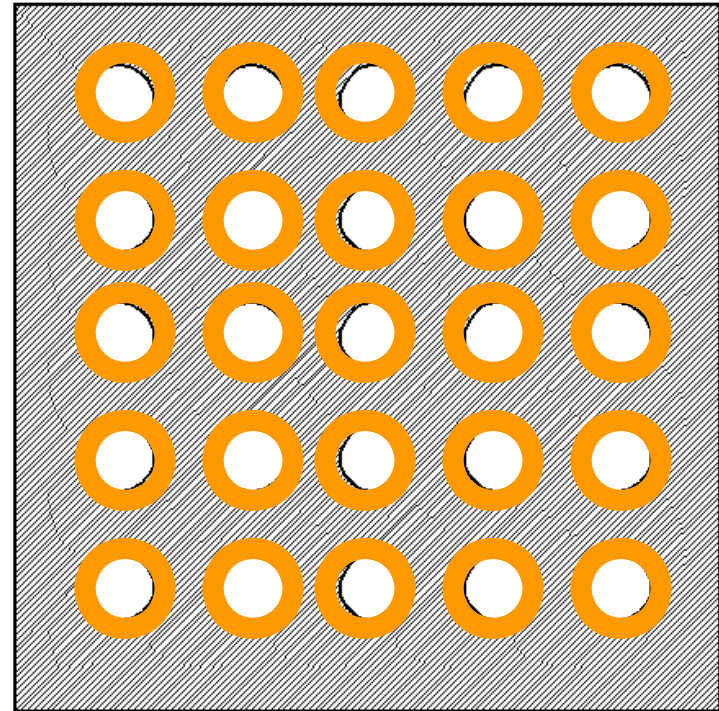
- Volume of air provided is the same for both circumstances.
- Case B has a lower spacing factor and a higher specific surface.

What Do You Want in an Air-Void System?

A

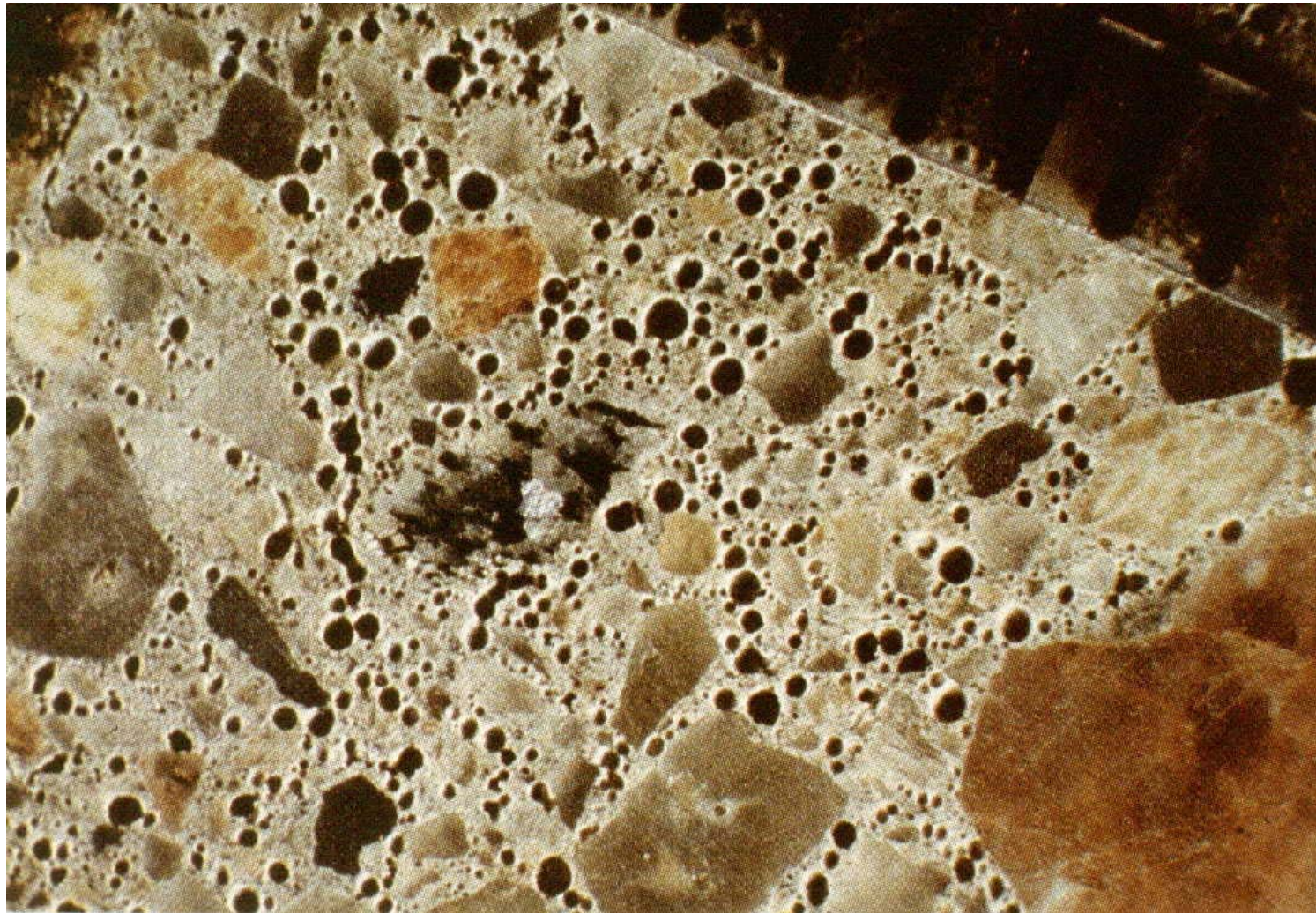


B



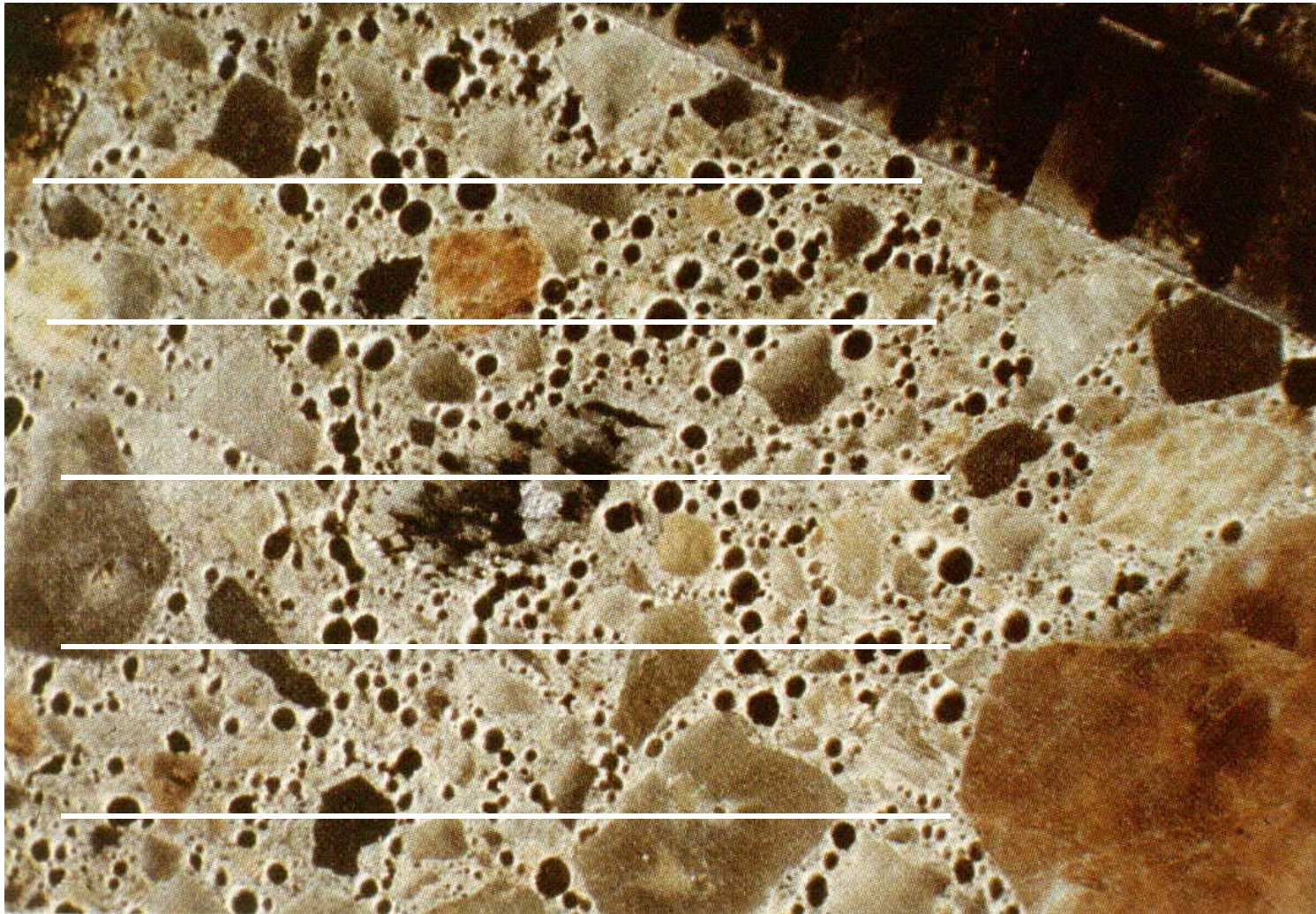
- Volume of air provided is the same for both circumstances.
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Hardened Air Void Analysis



From Hover

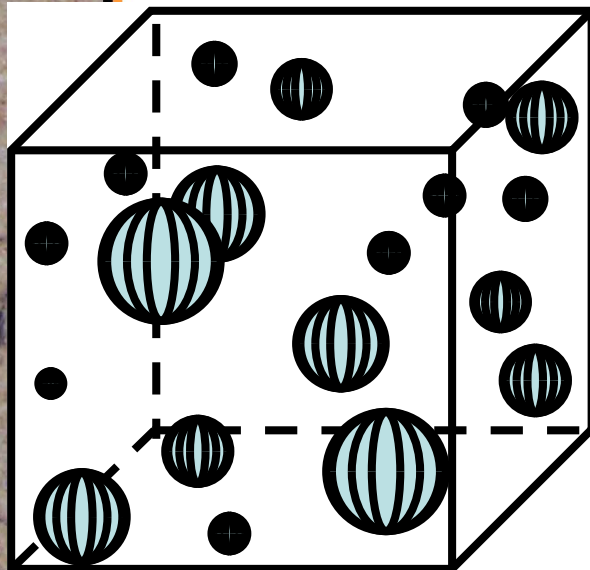
Hardened Air Void Analysis



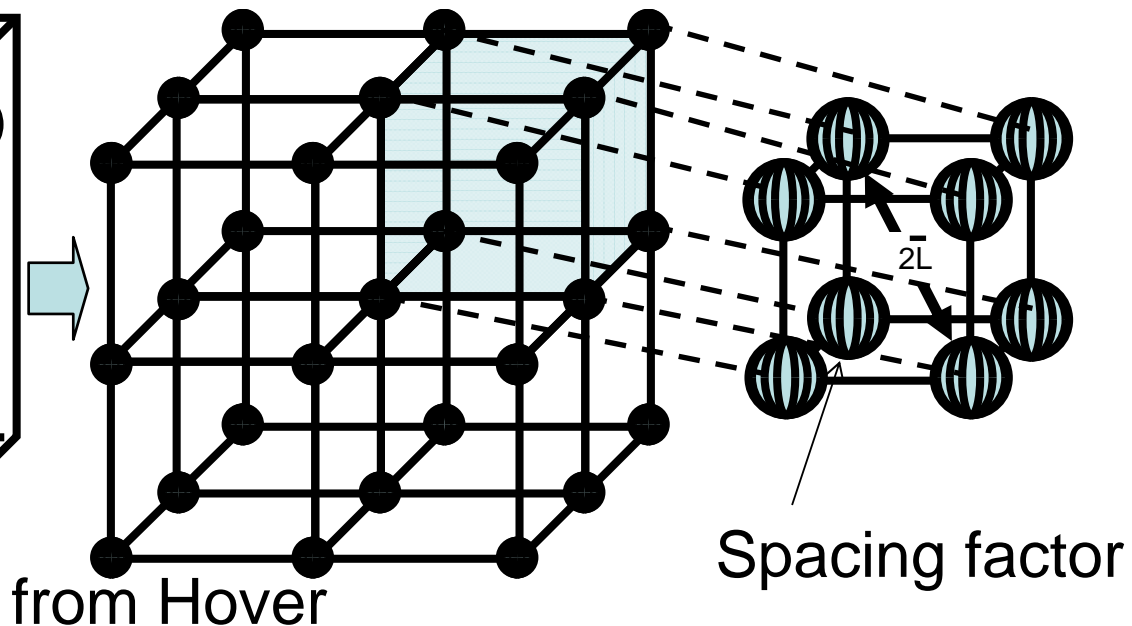
From Hover

- Spacing Factor – $\frac{1}{2}$ of the average distance of an average sized void uniformly distributed in the paste
- **Desired Value < 0.008 in (ACI 201)**

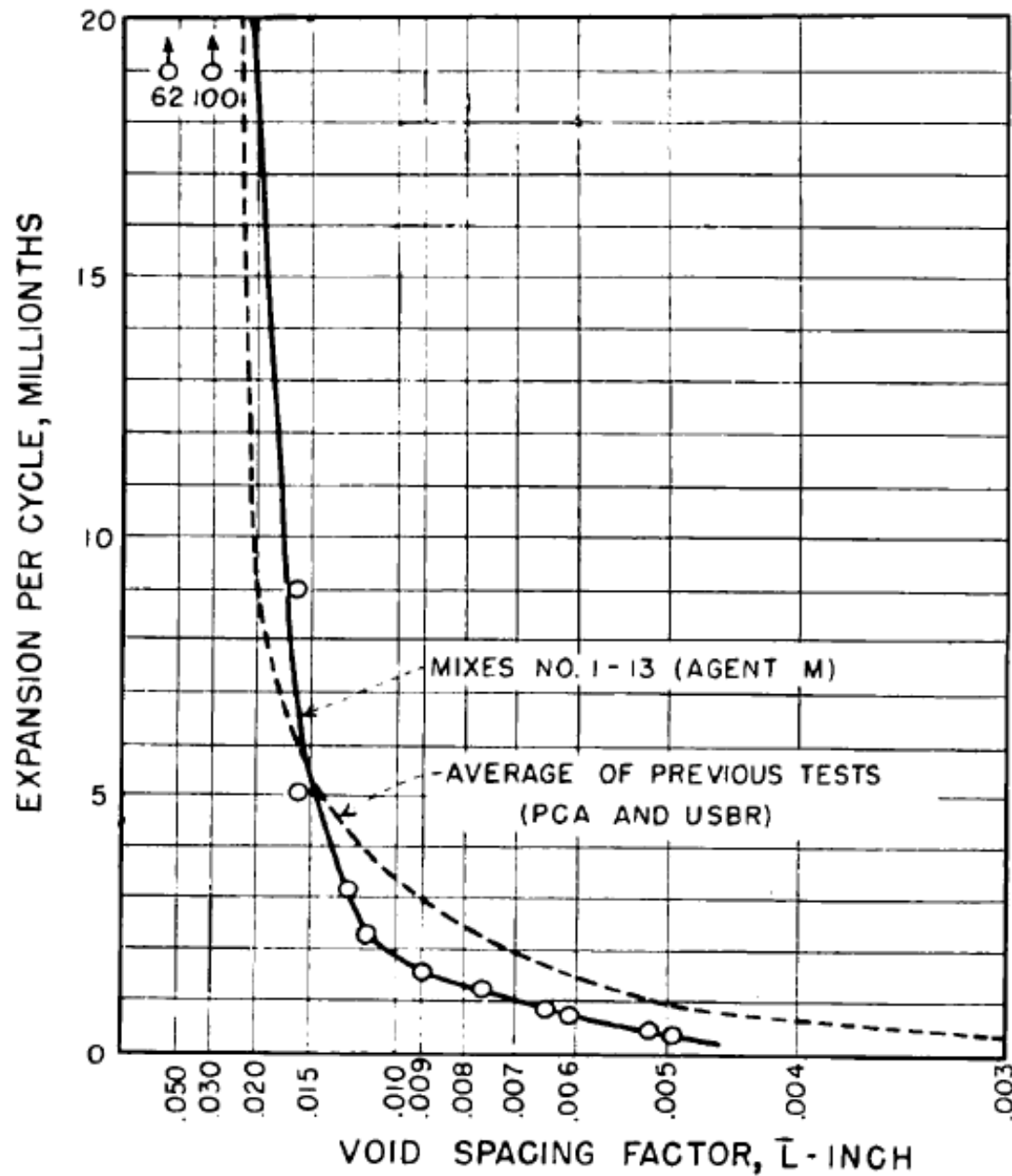
real concrete



idealized concrete



Length change
in a "freeze
thaw test"
divided by # of
cycles



Backstrom, Burrows, Mielenz, and Wolkodoff 1958

Spacing factor limit

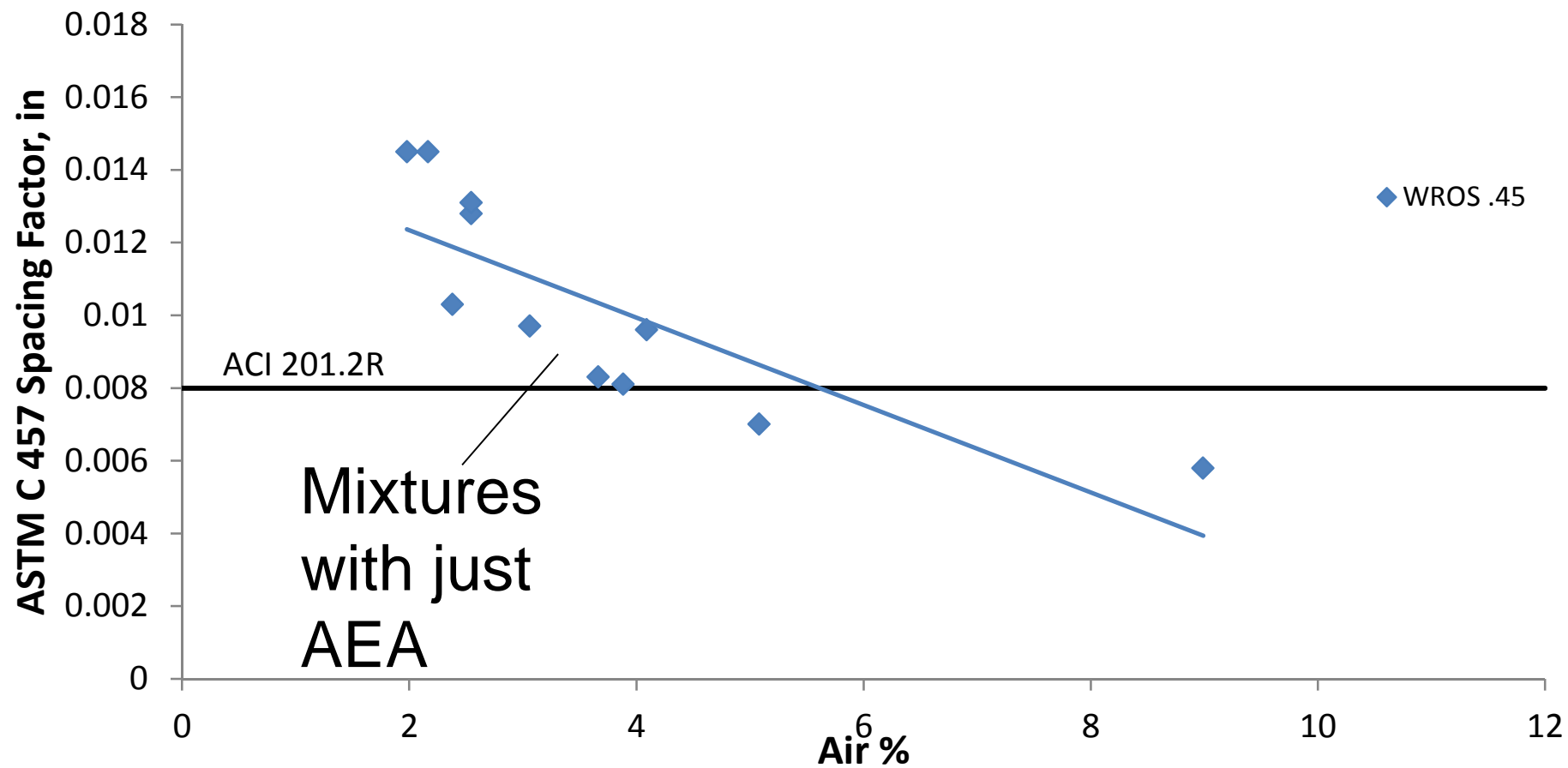
- The freeze thaw test is not the same as ASTM C 666
- Length change was used to determine failure
- The testing matrix had only one type of cement, one AEA (Vinsol resin), no water reducers, no SCMs

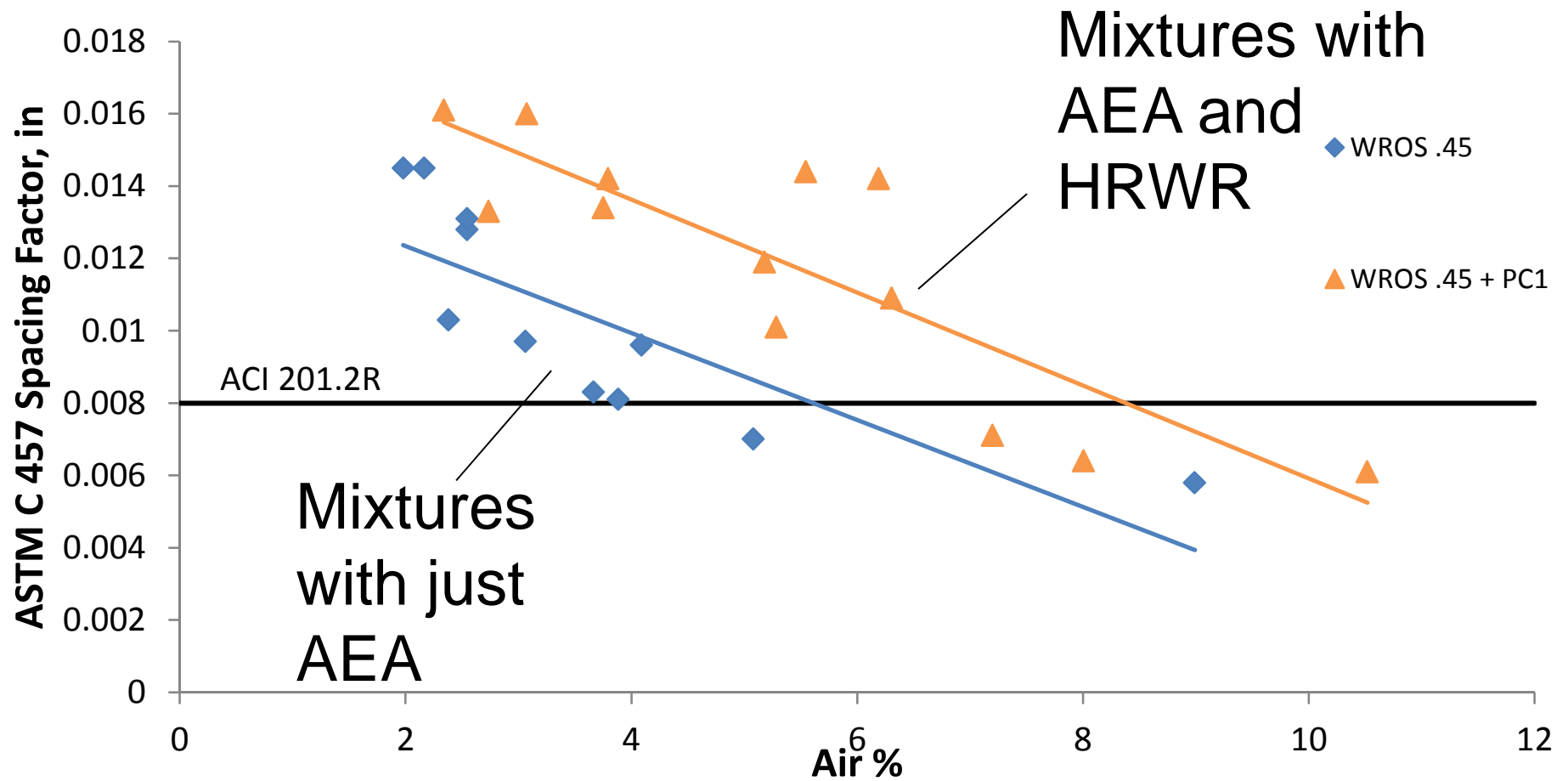
Testing Summary

Test	Time	Info.
Pressure meter	minutes	air volume
Petrographic	7-14 days	air system
Rapid freeze thaw	3 months	freeze thaw data

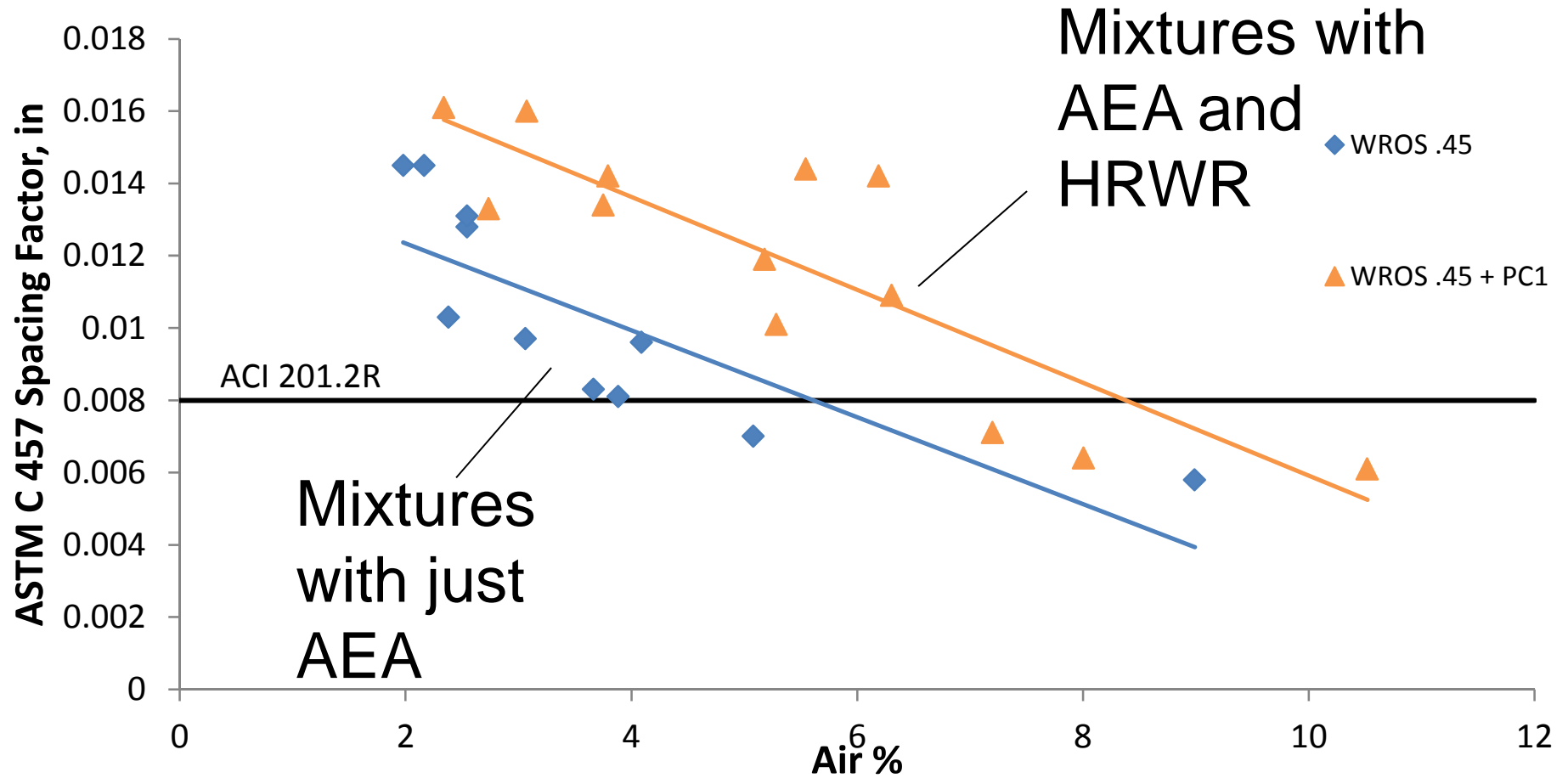
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Rapid freeze thaw	3 months	freeze thaw data





Yikes!



Summary

- It is common to require a certain volume of air in concrete in order to obtain freeze thaw durability
- *The volume of air does not equal air void system quality*
- Although, a hardened air void analysis (ASTM C 457) can measure the air-void quality it is not practical to run regularly

Super Air Meter (SAM)

- We have modified a typical ASTM C 231 pressure meter so that it can hold larger pressures
- We have replaced the typical gage with a digital one
- The test takes 8 minutes

digital
gauge



Six
clamps!

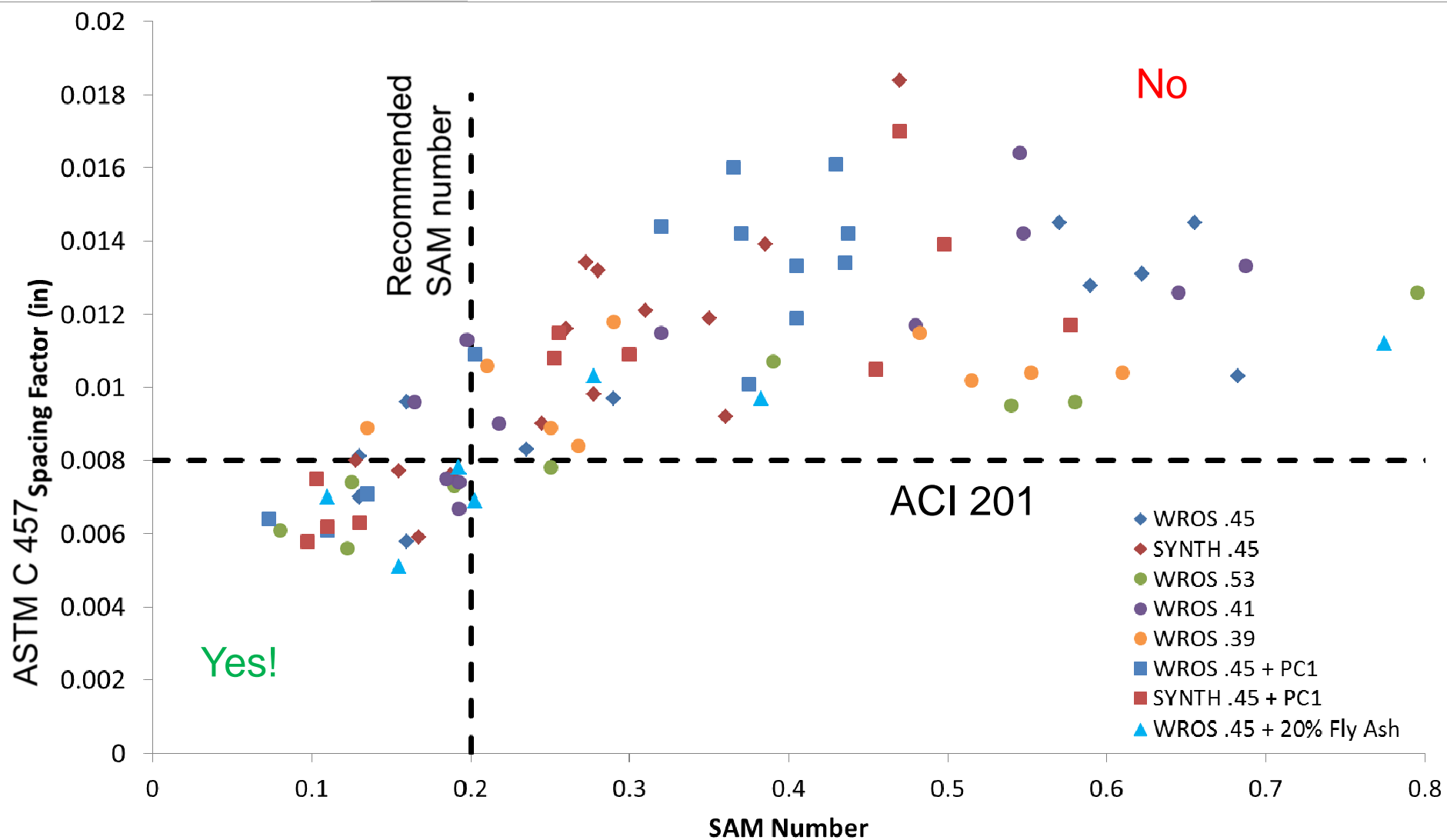
How does it work?

- We use an algorithm to find a **SAM number**.
- The SAM number correlates to air void size distribution
- The meter also measures air volume

How can we prove it?

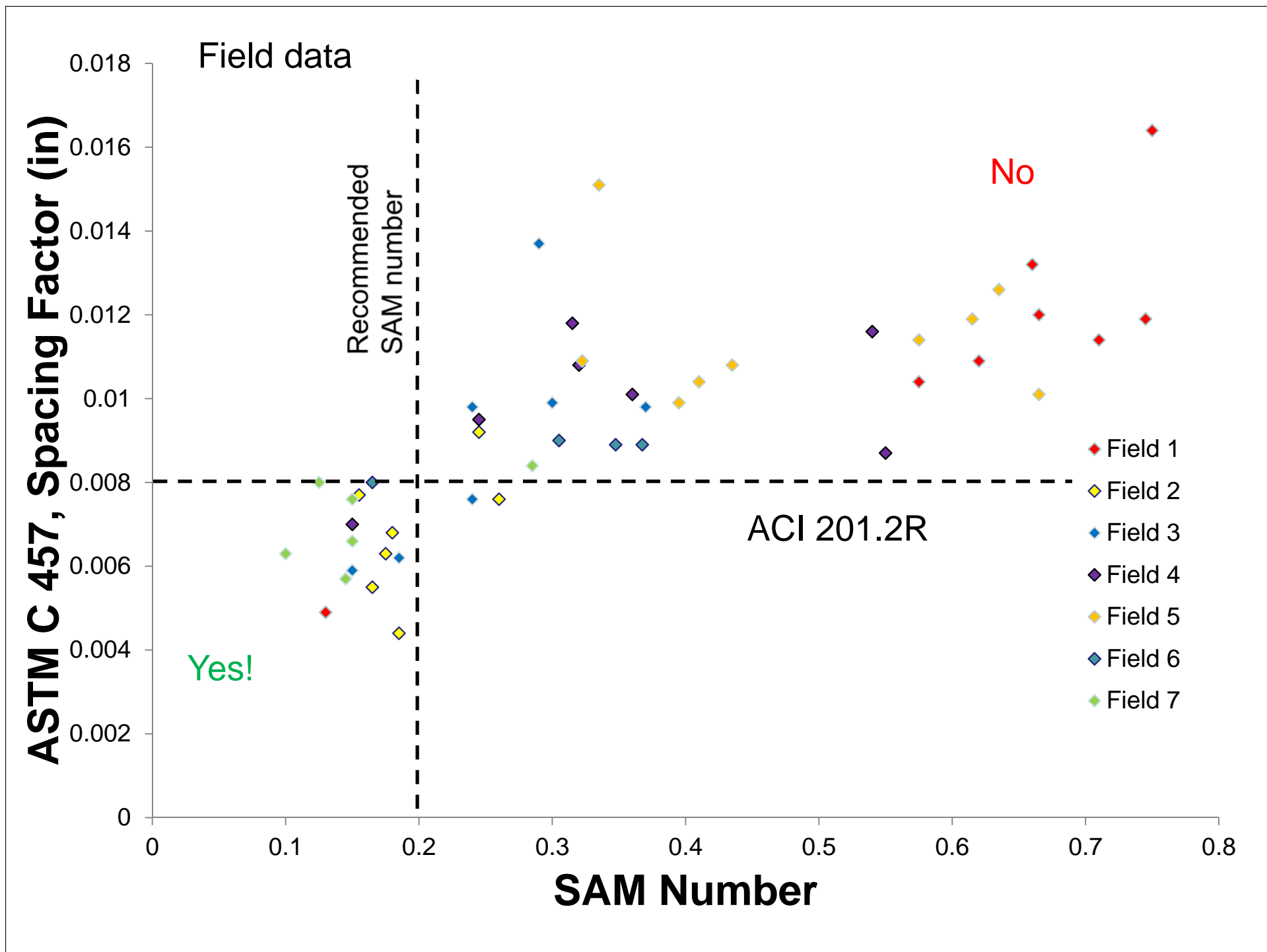
- We made 95 concrete mixtures
- Different AEAs
- Combinations of AEAs and PCs
- Different w/cm (0.39 - 0.53)
- Slumps from 0.25" to 10"
- Air contents from 1.25% to 10%
- ***Hardened air void analysis (ASTM C 457) was completed on each mixture***
- Values were compared to the SAM number

Lab data

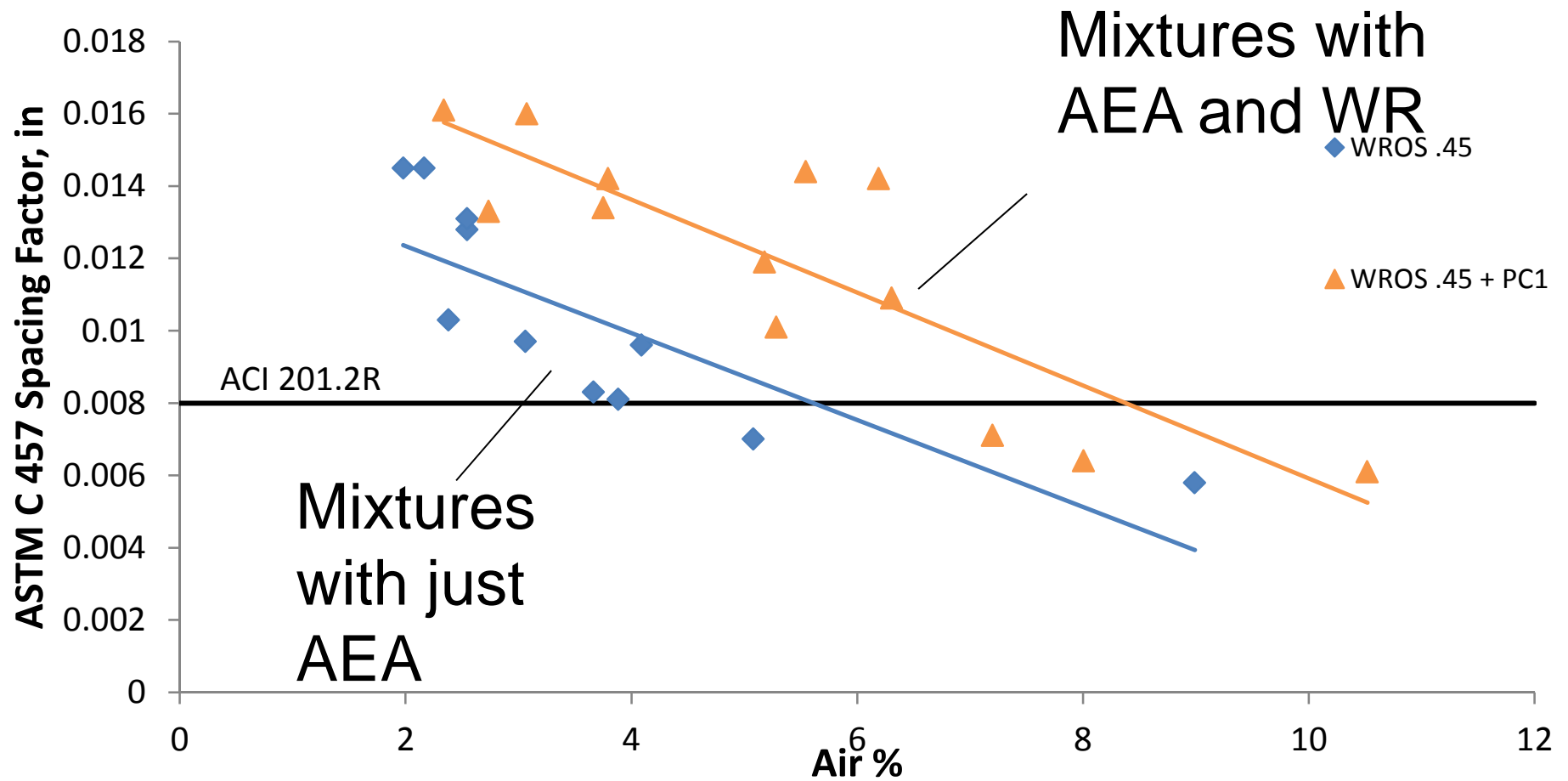


How else can we prove it?

- We have measured 60 different field mixtures
- Central mix and hand placed paving
- Ready mix
- Different AEAs
- Combinations of AEAs and WRs
- ***Hardened air void analysis (ASTM C 457) was completed on each mixture***
- Values were compared to the SAM number



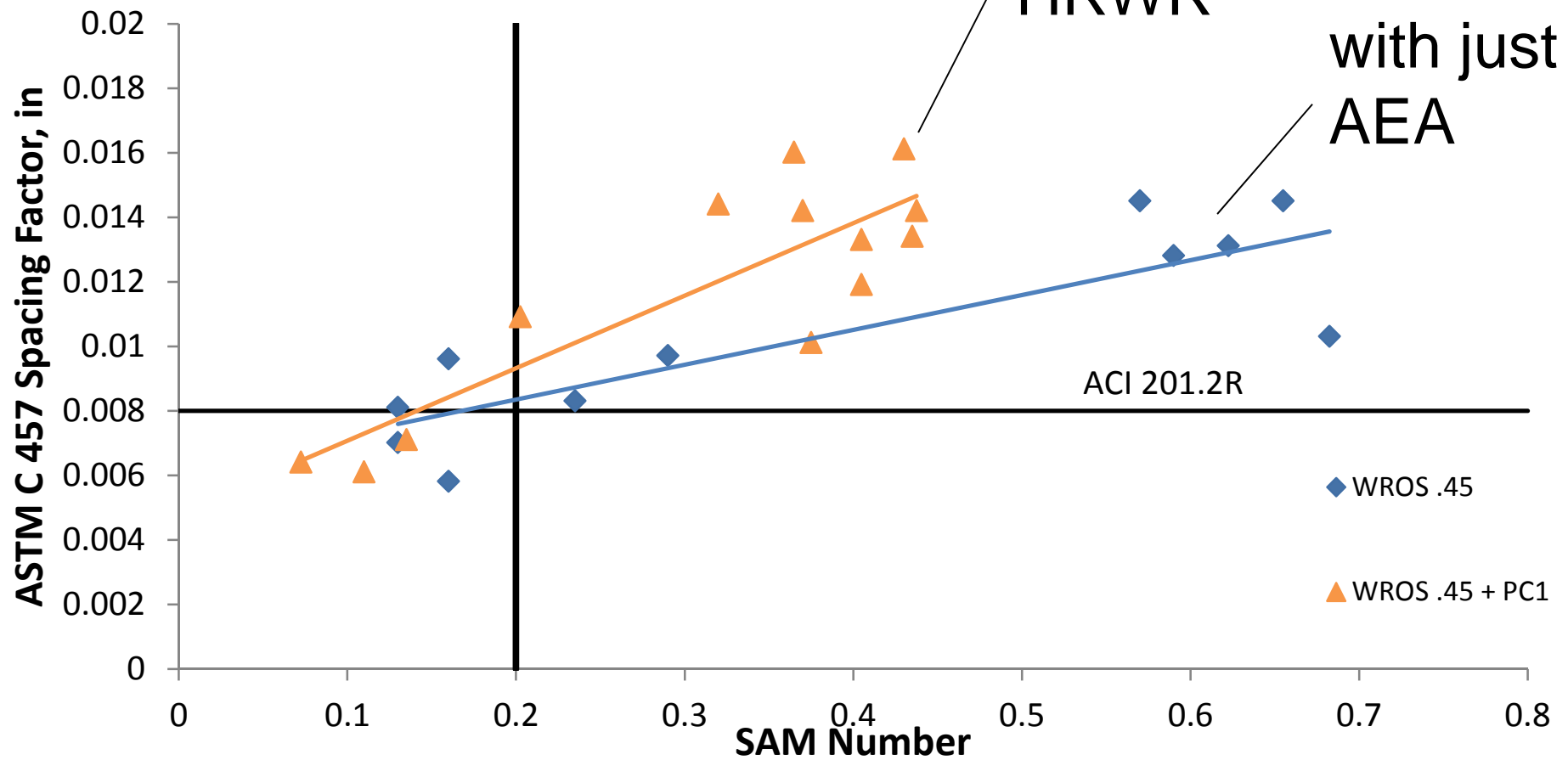
Yikes!



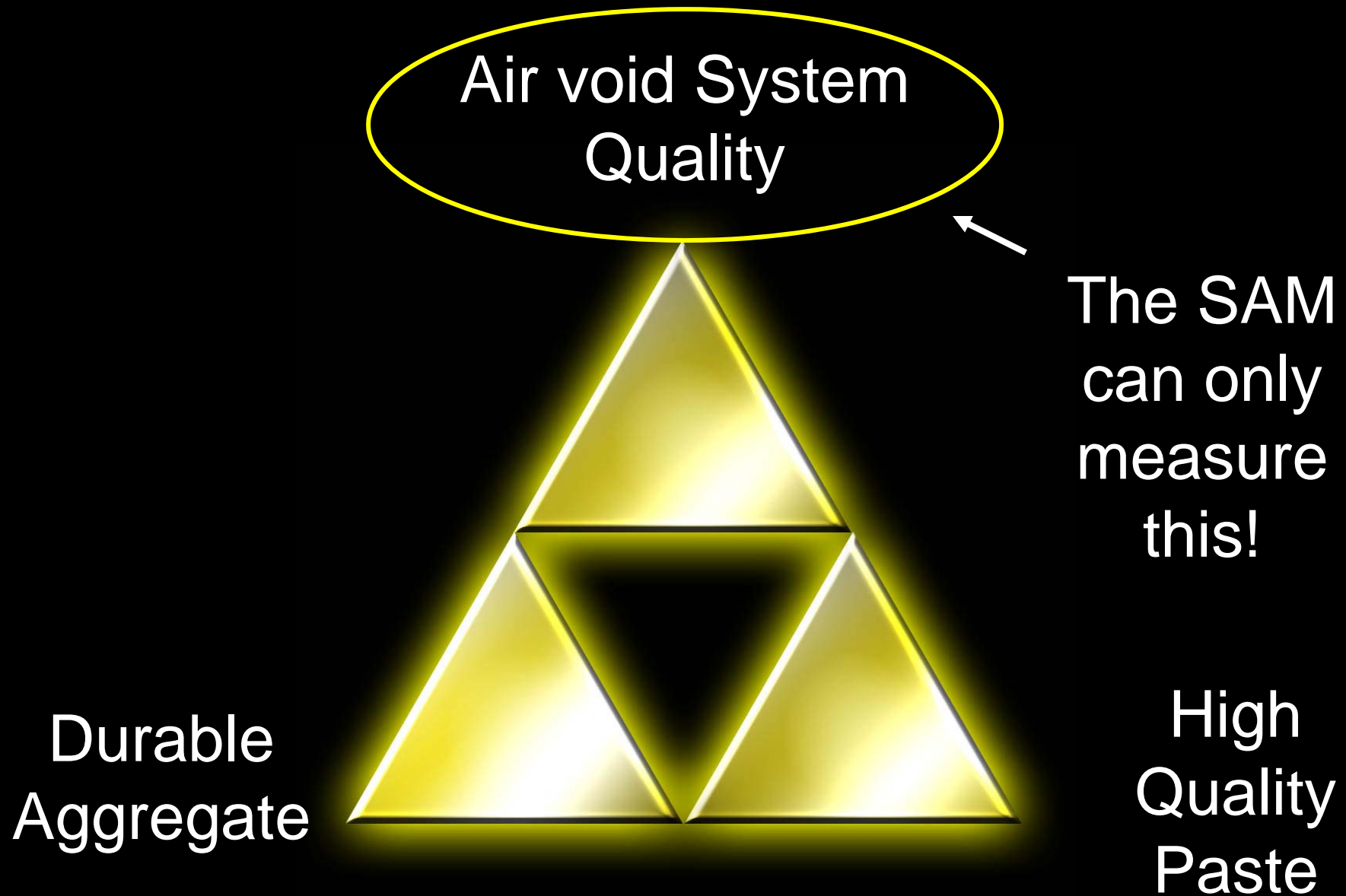
Yes!

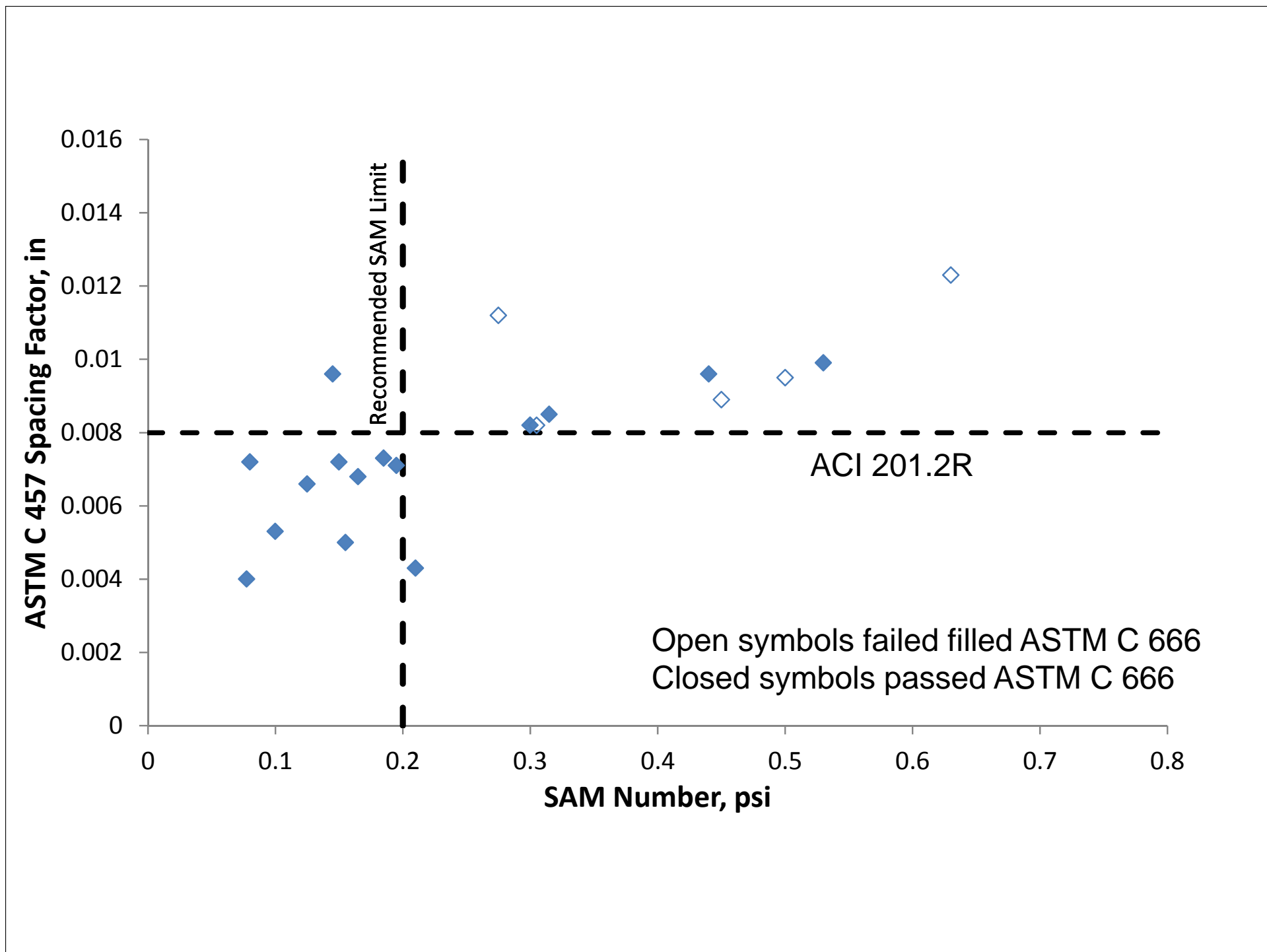
Mixtures with
AEA and
HRWR

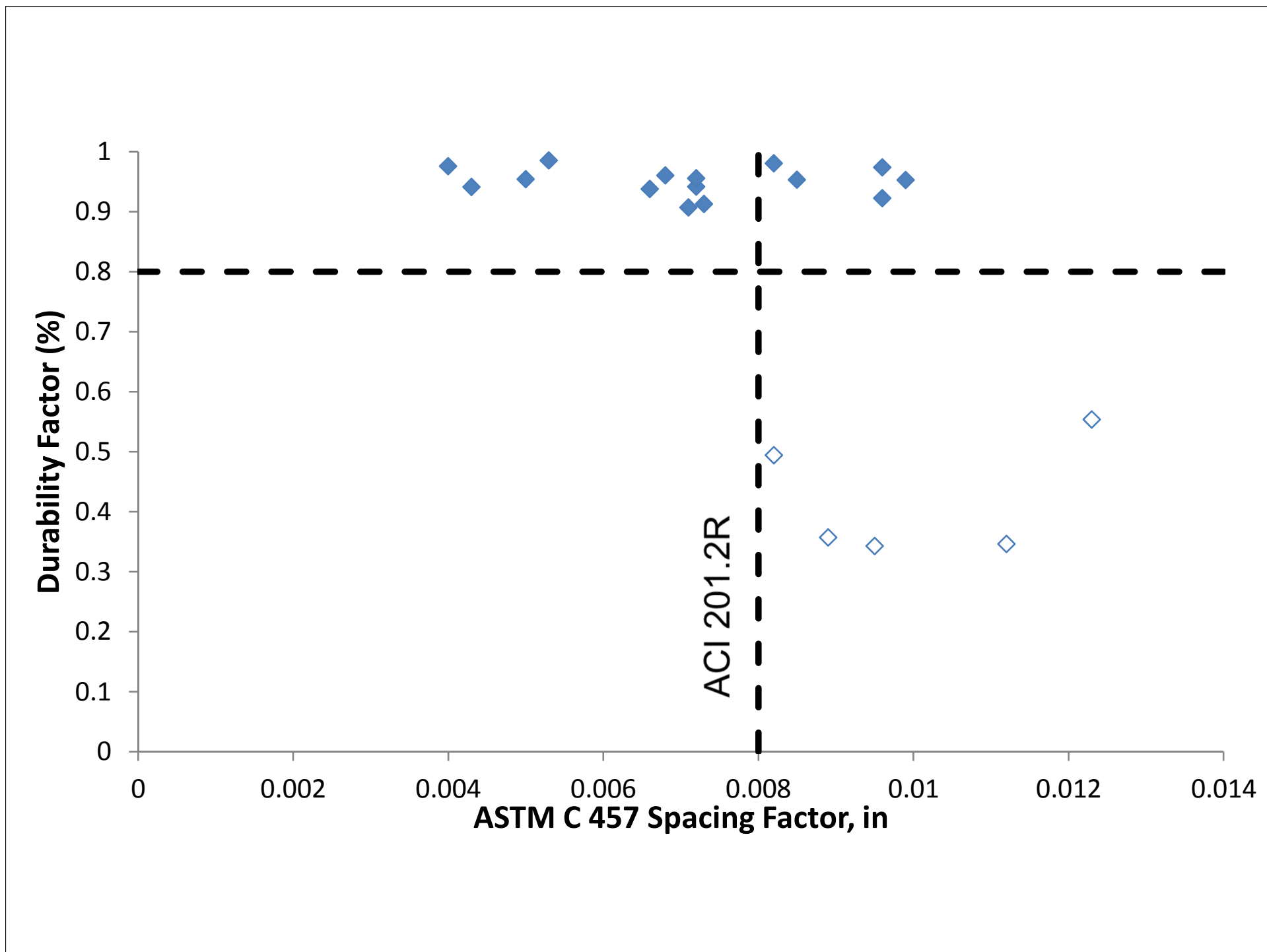
Mixtures
with just
AEA



The Freeze Thaw Durability Triforce!!!







Observations

- When the SAM number is below 0.20 then the spacing factor is below 0.008" for 90% of the lab and field samples
- For modern concrete mixtures the SAM number shows better correlation than just air content
- The SAM limit of 0.20 seems to correlate with limited ASTM C 666 testing

Why is this useful?

- Air content is not adequate to evaluate some modern concrete mixtures
- The SAM number gives us great tool to make sure we get high quality air void systems in the fresh concrete
- The SAM does not need hardened air void analysis to give us an indication of the void size distribution

Why is this useful?

- It could be a useful tool during the mixture design stage to help understand how admixture combinations impact air void size distribution
- It could be useful to help trouble shoot the construction process to see how the air void system changes with hauling, consolidation from vibration, and pumping

What else have we done?

- Hot and Cold weather concrete
- High aggregate correction factor aggregates
- Light weight aggregate
- Precision and Bias Statement
- **Provisional AASHTO Test Method is being reviewed for Fall publication**

What are we going to do?

- Concrete before and after a pump
- Further study on how WR impact air void system quality
- More freeze thaw testing

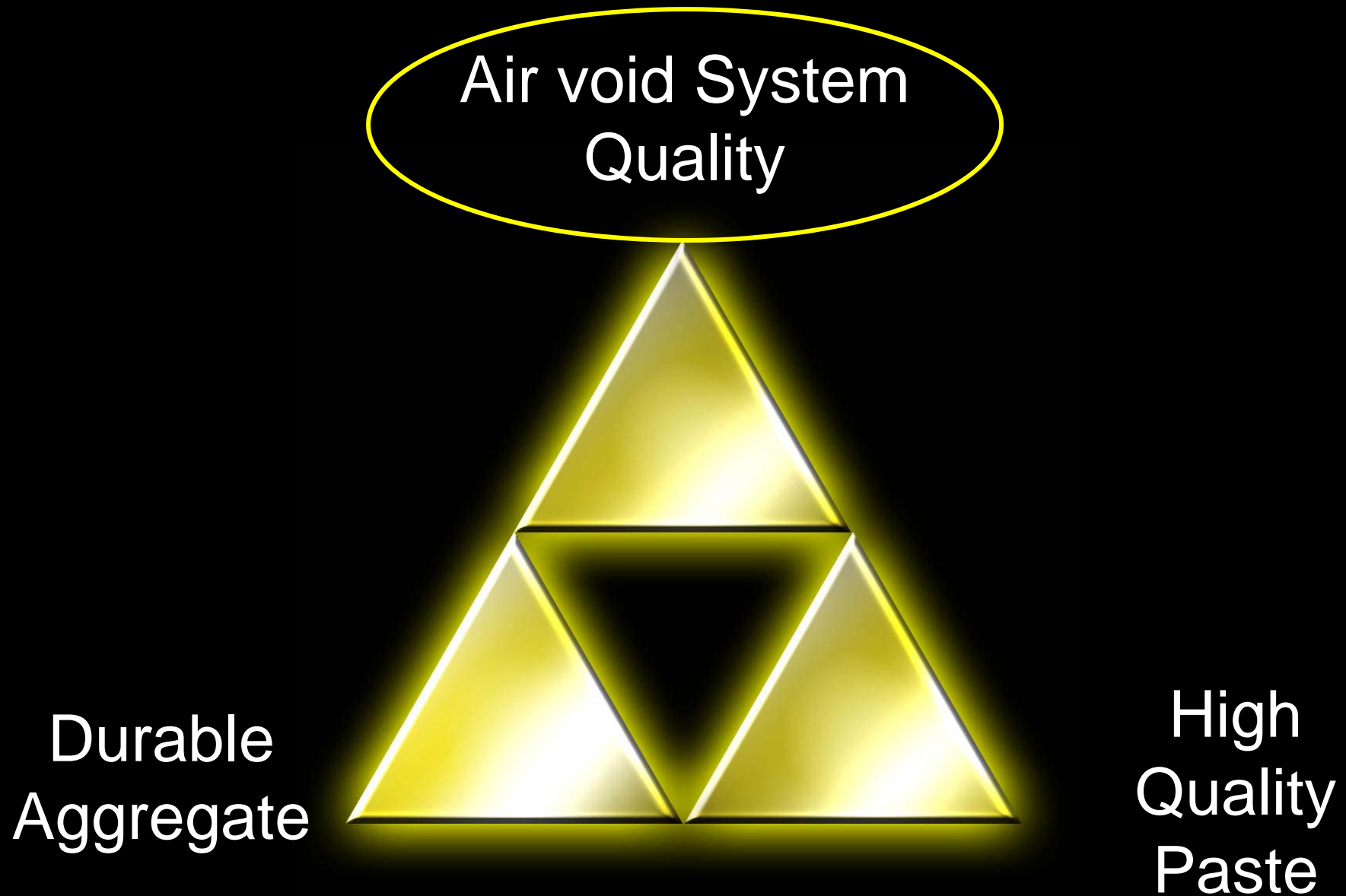
The following states have a SAM

- Michigan (5)
- Kansas (3)
- Utah
- Colorado (2)
- Iowa (2)
- Illinois (3)
- Indiana (2)
- Wisconsin (2)
- Massachusetts
- Pennsylvania
- Missouri
- N. Carolina
- N. Dakota
- Oklahoma (5)
- Nebraska (2)
- Ohio (2)
- Minnesota (2)
- FHWA (4)
- Manitoba

How can this group help?

- Tell someone else about the SAM!
- Try the SAM for yourself
- Take part in the discussion

The Freeze Thaw Durability Triforce!!!





www.superairmeter.com

SAMs are available!!!

Questions???

www.tylerley.com



Discussion

- What additional materials and mixtures should be investigated with the SAM for validation?

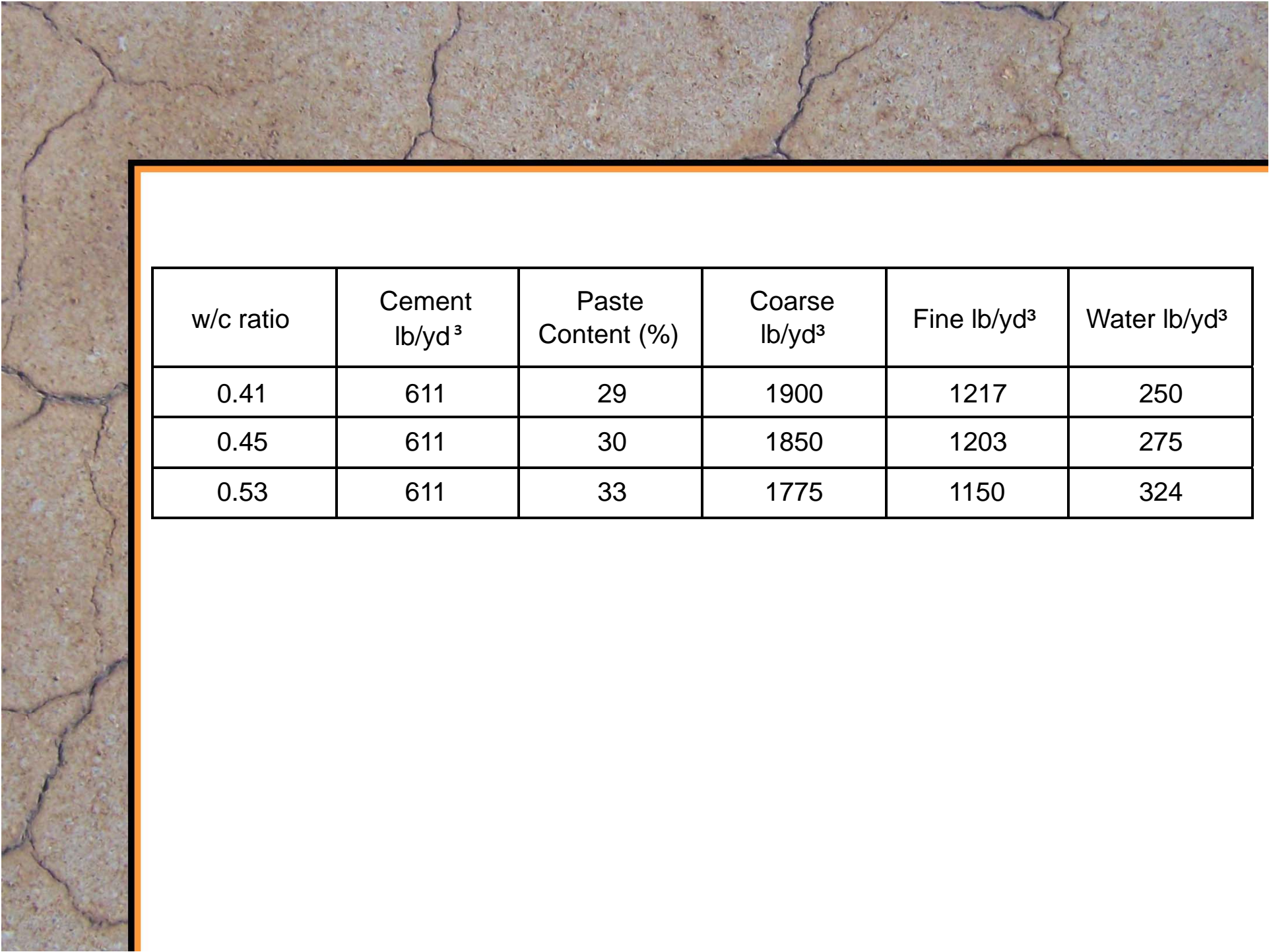
Discussion

- What is the largest barrier to using the SAM on your projects?

Discussion

- Would you be interesting in trying the SAM on a project?





w/c ratio	Cement lb/yd ³	Paste Content (%)	Coarse lb/yd ³	Fine lb/yd ³	Water lb/yd ³
0.41	611	29	1900	1217	250
0.45	611	30	1850	1203	275
0.53	611	33	1775	1150	324

Observations

- Recall that the spacing factor calculation is dependent on the specific surface calculation which is dependent on the voids per inch.

$$\bar{L} = \frac{3}{\alpha} \left[1.4 \left(1 + \frac{p}{A} \right)^{1/3} - 1 \right]$$

$$\alpha = \frac{4N}{T_a}$$

number of chords
traverse length

digital
gauge

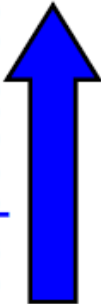


Six
clamps!

How Much air do we need?

**TABLE 4.4.1 — TOTAL AIR CONTENT FOR
CONCRETE EXPOSED TO CYCLES OF FREEZING
AND THAWING**

Increased paste content



Nominal maximum aggregate size, in.*	Air content, percent	
	Exposure Class F1	Exposure Classes F2 and F3
3/8	6	7.5
1/2	5.5	7
3/4	5	6
1	4.5	6
1-1/2	4.5	5.5
2 [†]	4	5
3 [†]	3.5	4.5

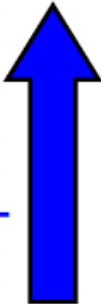
*See ASTM C33 for tolerance on oversize for various nominal maximum size designations.
[†]Air contents apply to total mixture. When testing concretes, however, aggregate particles larger than 1-1/2 in. are removed by sieving and air content is measured on the sieved fraction (tolerance on air content as delivered applies to this value). Air content of total mixture is computed from value measured on the sieved fraction passing the 1-1/2 in. sieve in accordance with ASTM C231.

If $f'_c > 5,000$ psi then these recommendations can be reduced by 1%

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If $f'_c > 5,000$ psi then these recommendations can be reduced by 1%

Klieger

- Current air volume specifications are based on work by Klieger at PCA (1952 and 1954)
- He used a non standard freeze thaw test and length change to determine failure
- The testing matrix had only one type of cement, one AEA (Vinsol resin), no water reducers, no SCMs

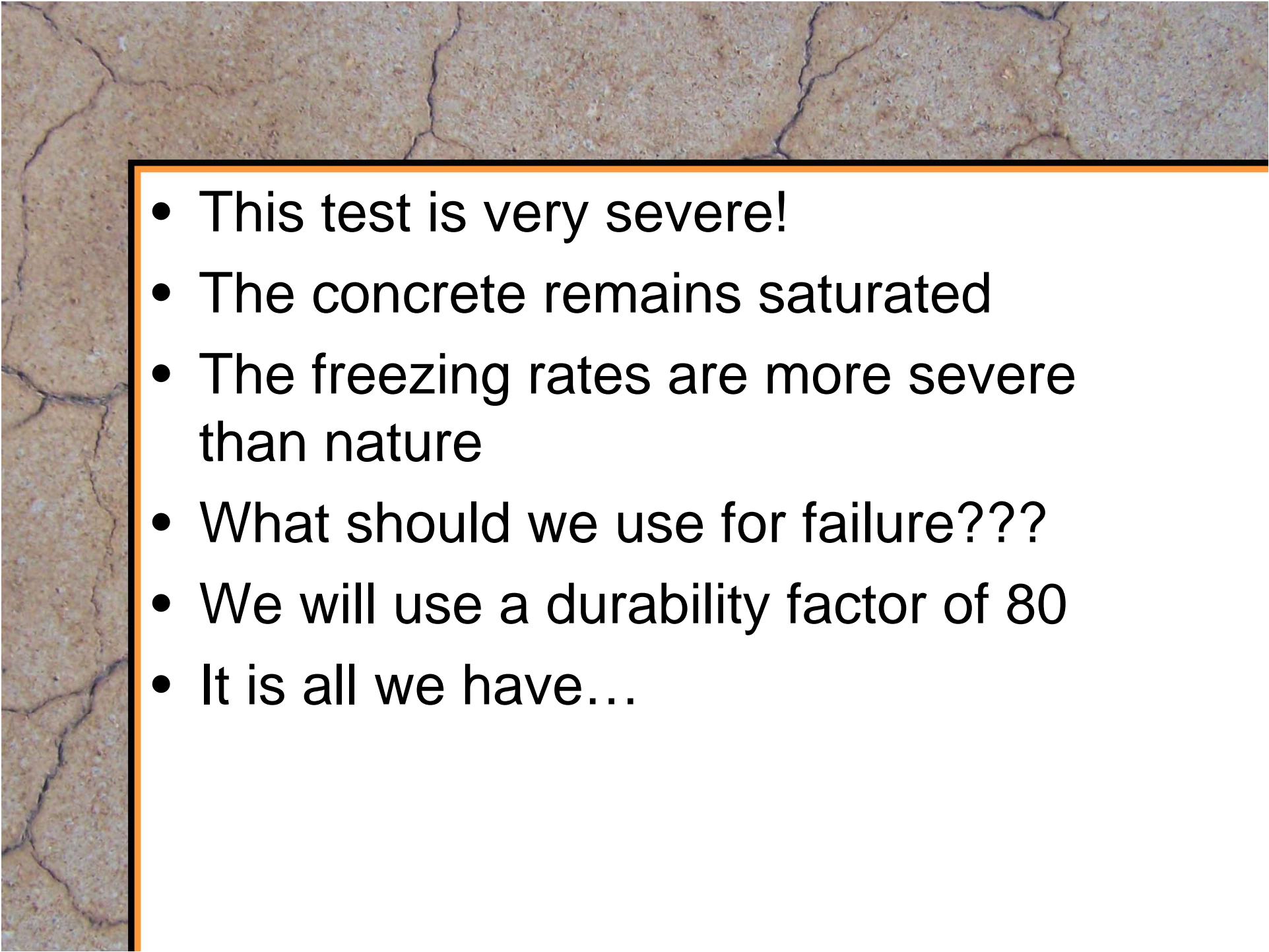
Rapid Freeze Thaw Testing



Humboldt photo

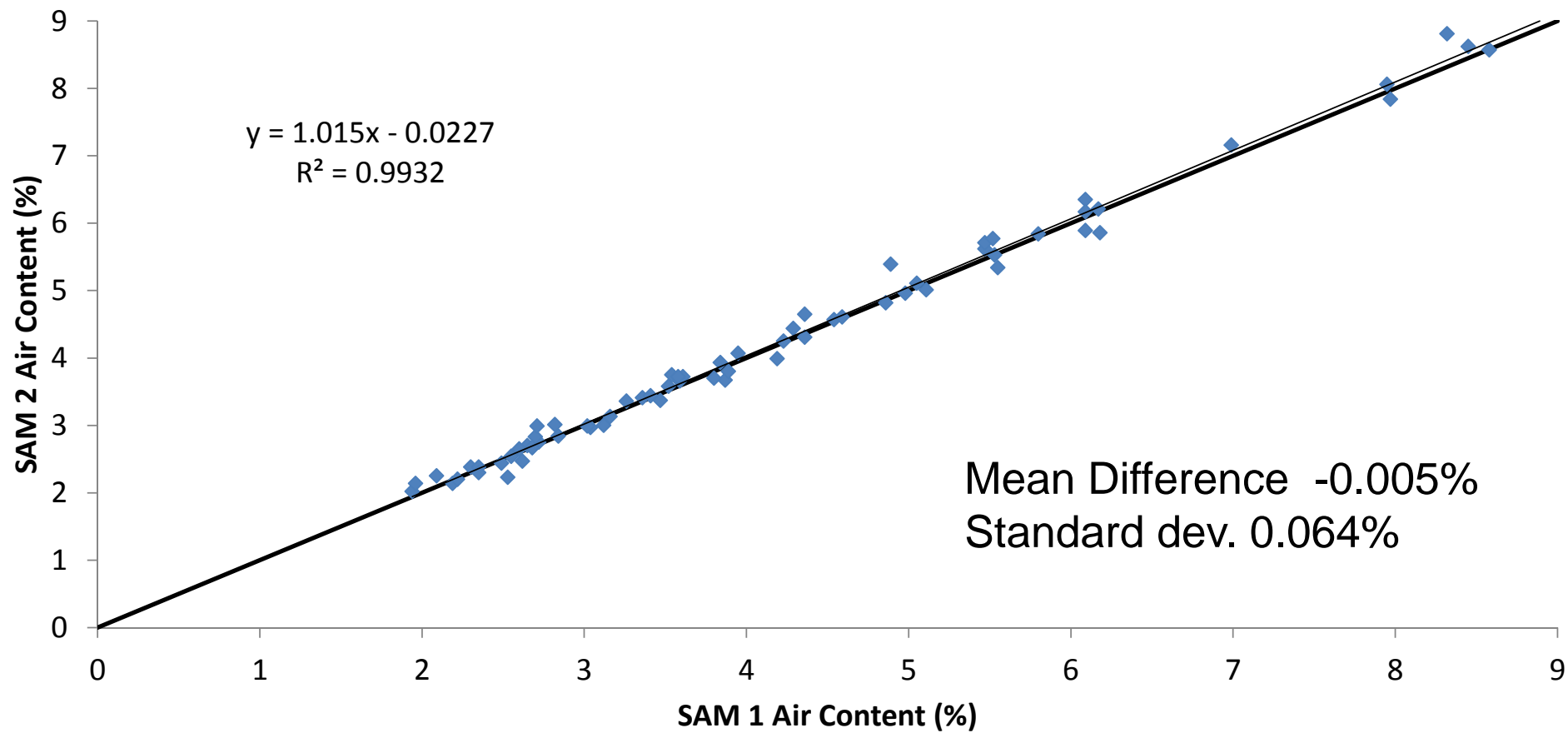
ASTM C 666

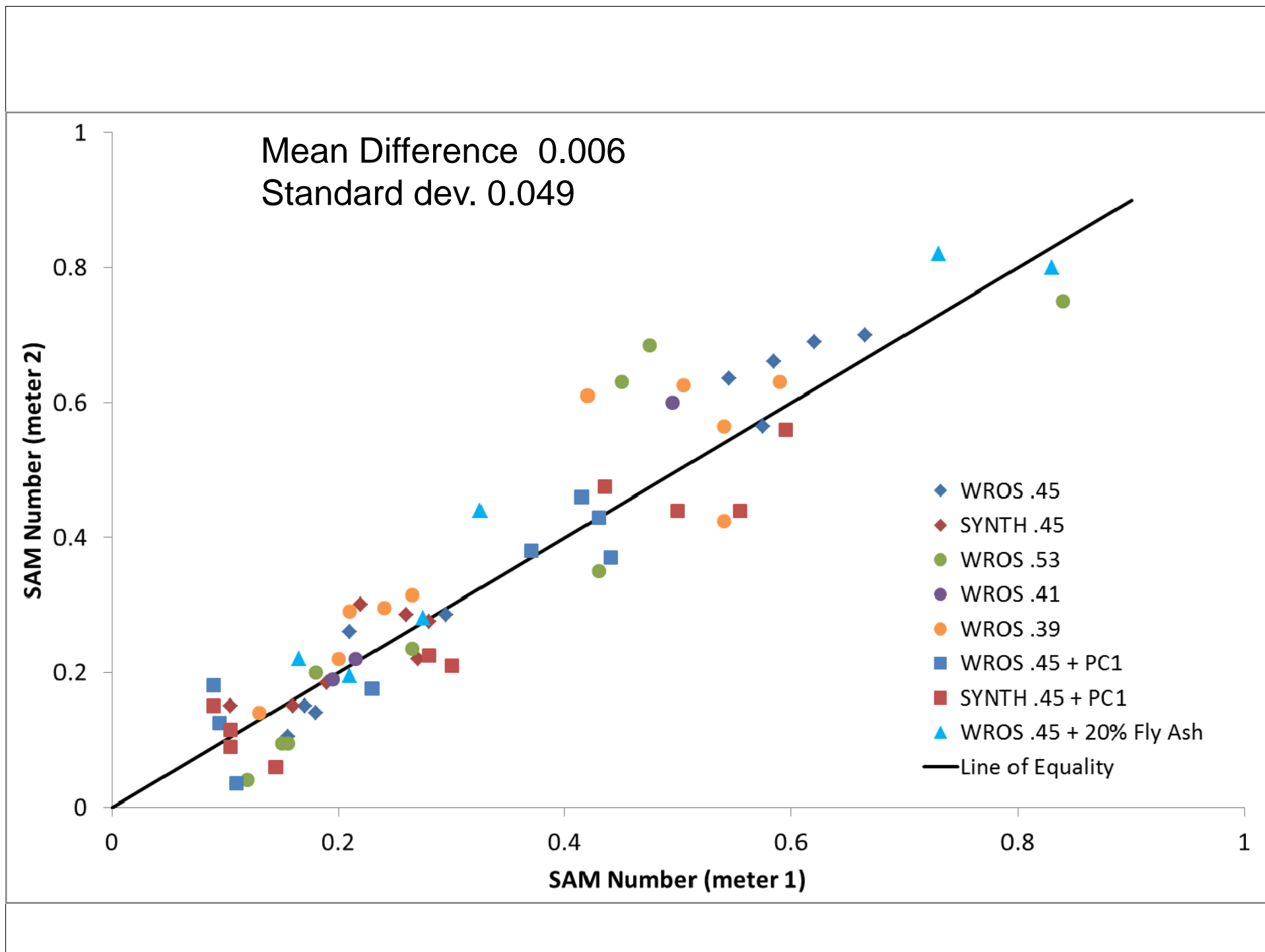
AASHTO T 161

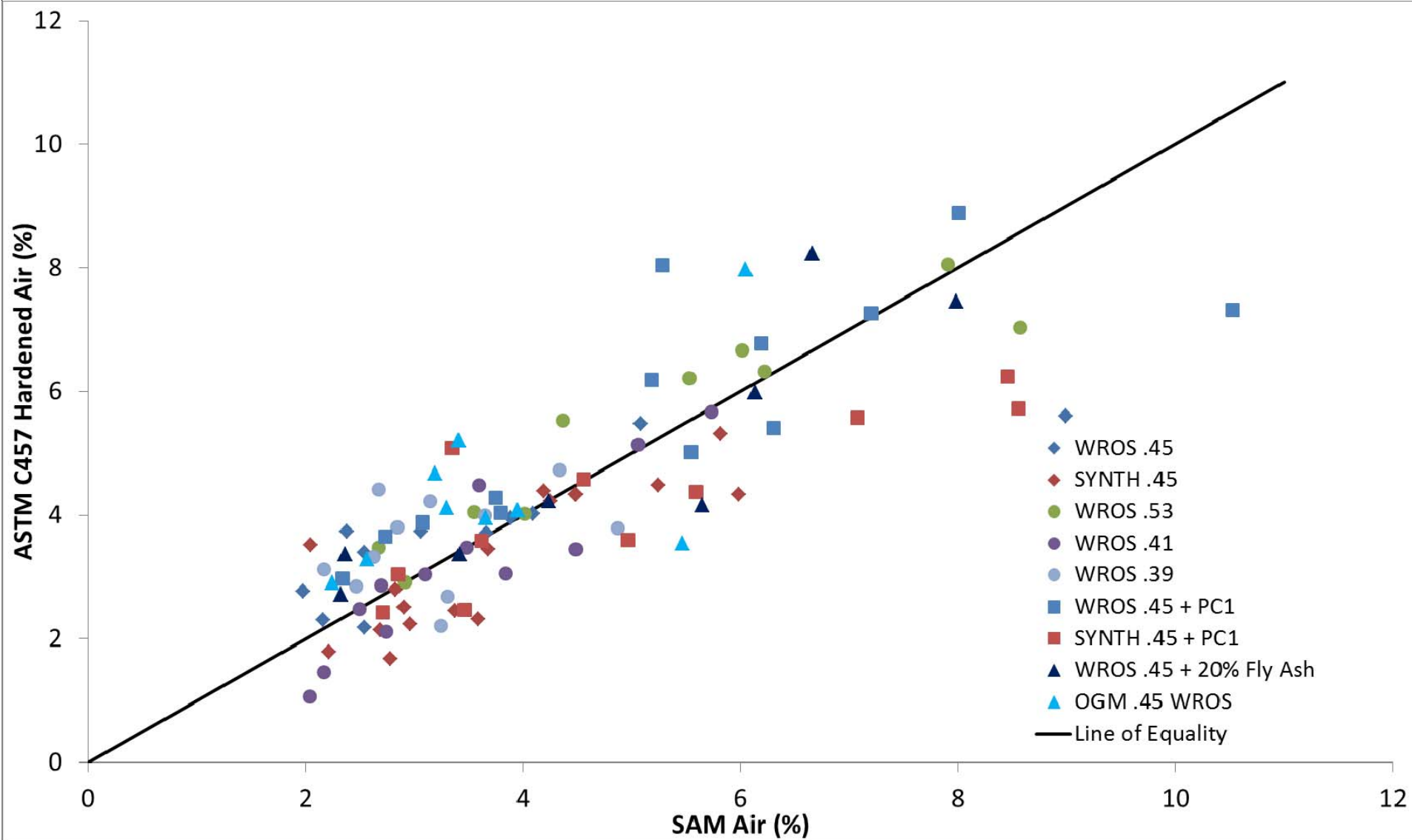
- 
- The background of the slide is a close-up photograph of a light-colored, textured surface, likely concrete or stone, which is heavily cracked and weathered. The cracks are irregular and run in various directions across the frame. A thin orange border is visible on the left side of the slide, framing the text area.
- This test is very severe!
 - The concrete remains saturated
 - The freezing rates are more severe than nature
 - What should we use for failure???
 - We will use a durability factor of 80
 - It is all we have...

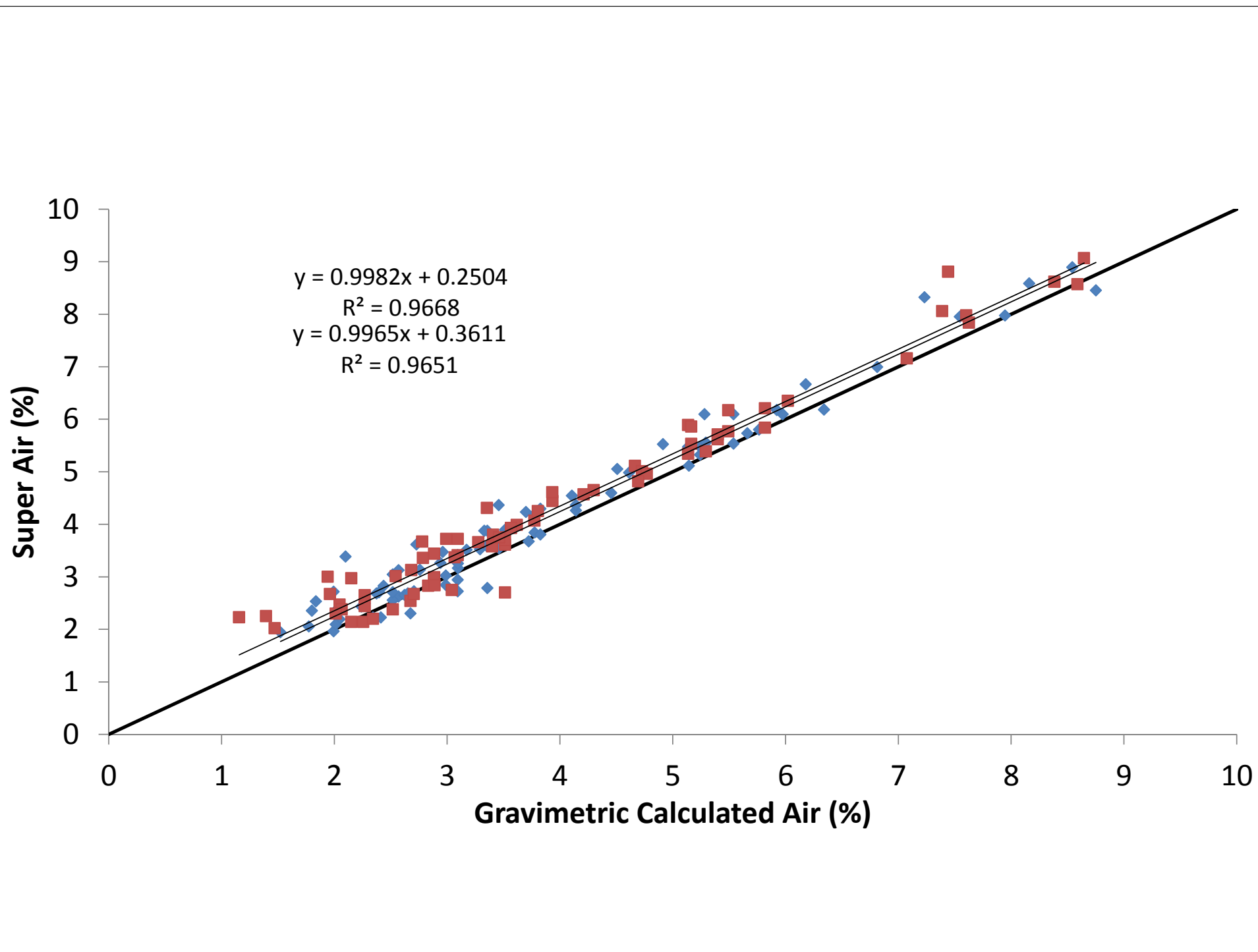
How Consistent Is It?

- We ran the following on each of the 95 mixtures with two separate SAMs:
 - Air contents
 - SAM numbers
 - ASTM C 457 hardened air void analysis
 - Unit Weight









Testing Summary

Test	Time	Info.
Pressure meter	minutes	air volume
Petrographic	7-14 days	air system
Rapid freeze thaw	3 months	freeze thaw data
SAM	minutes	air system

Current Measuring Techniques



PCA photo

ASTM C 231



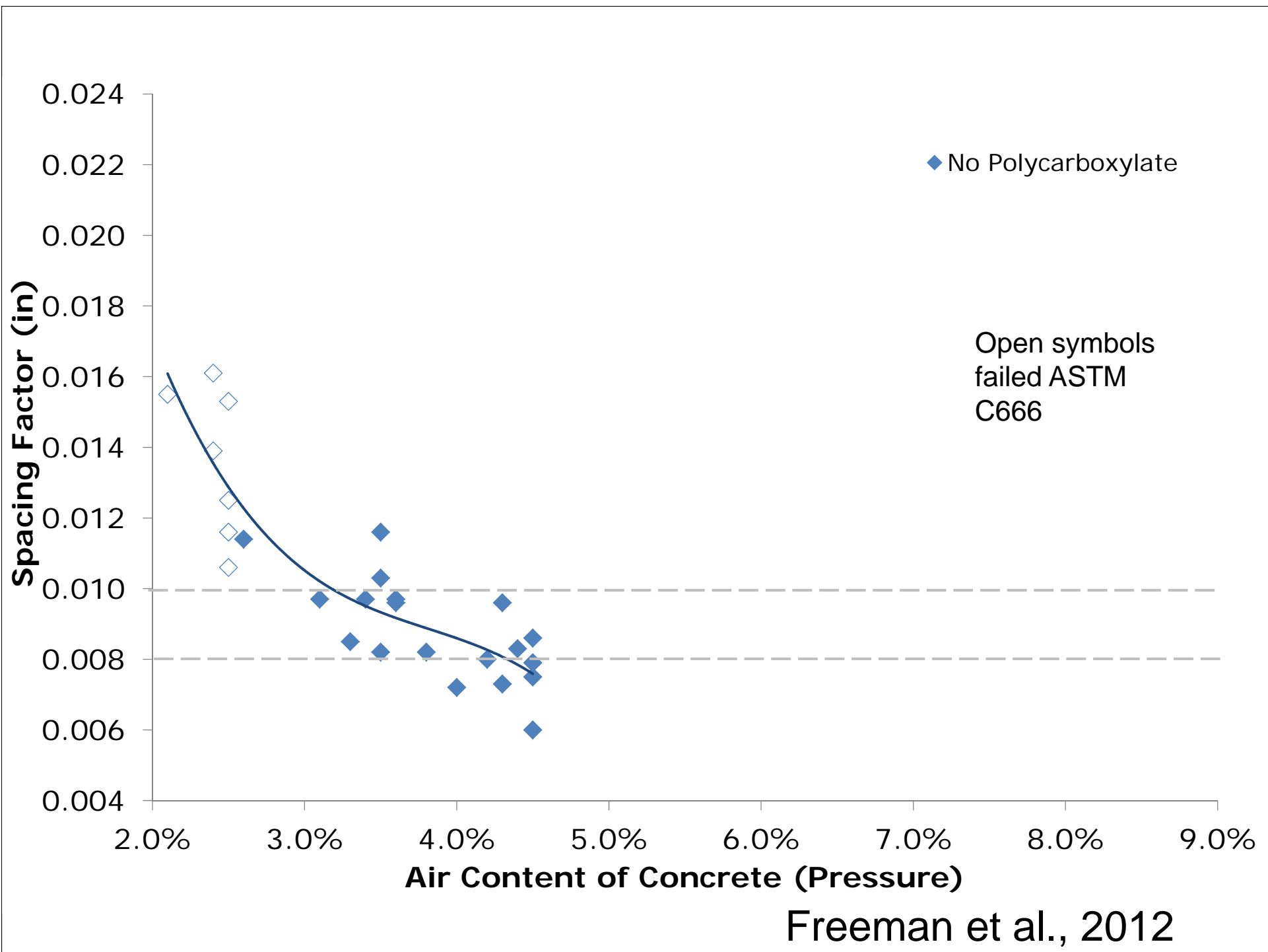
PCA photo

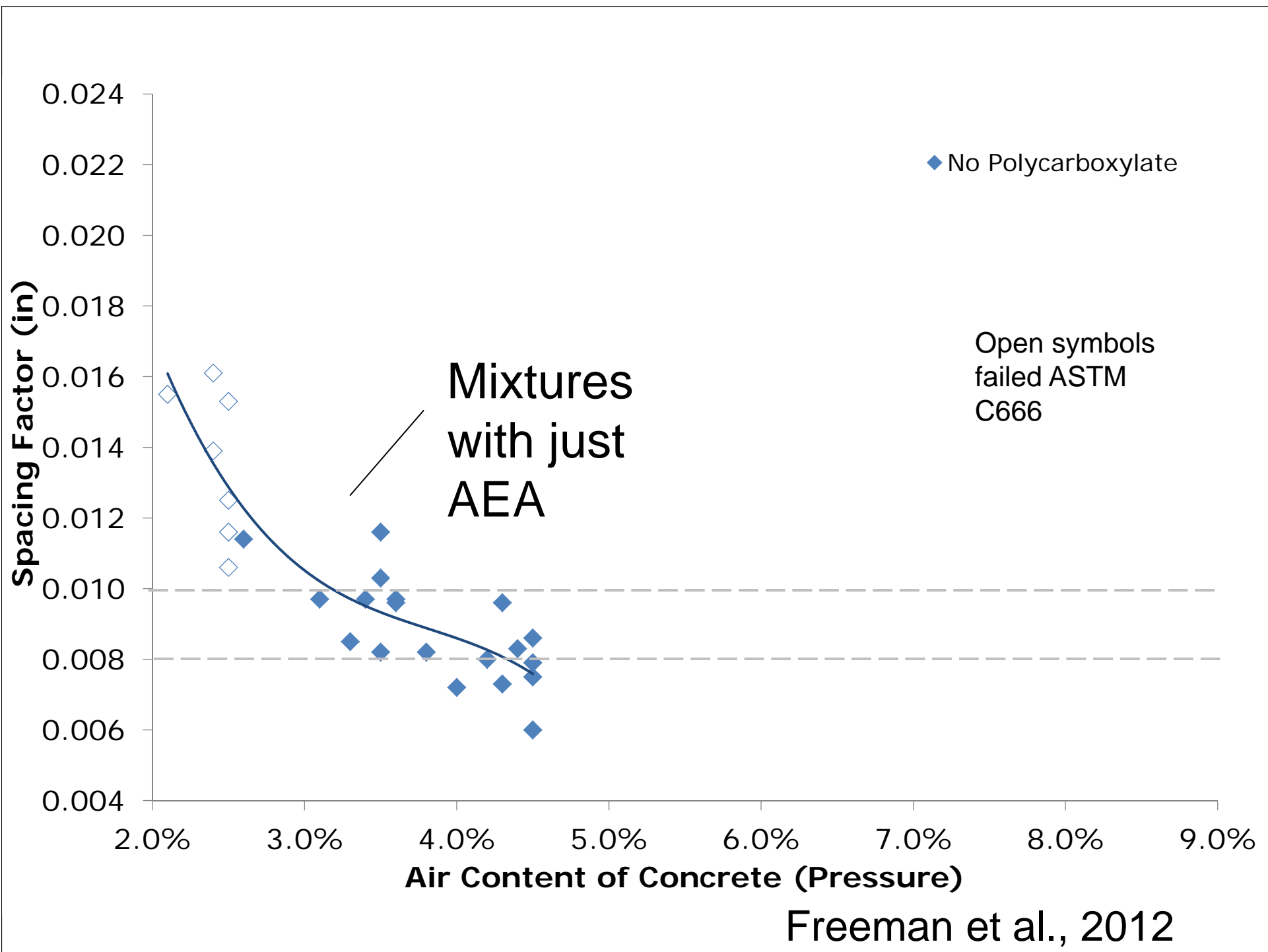
ASTM C 173

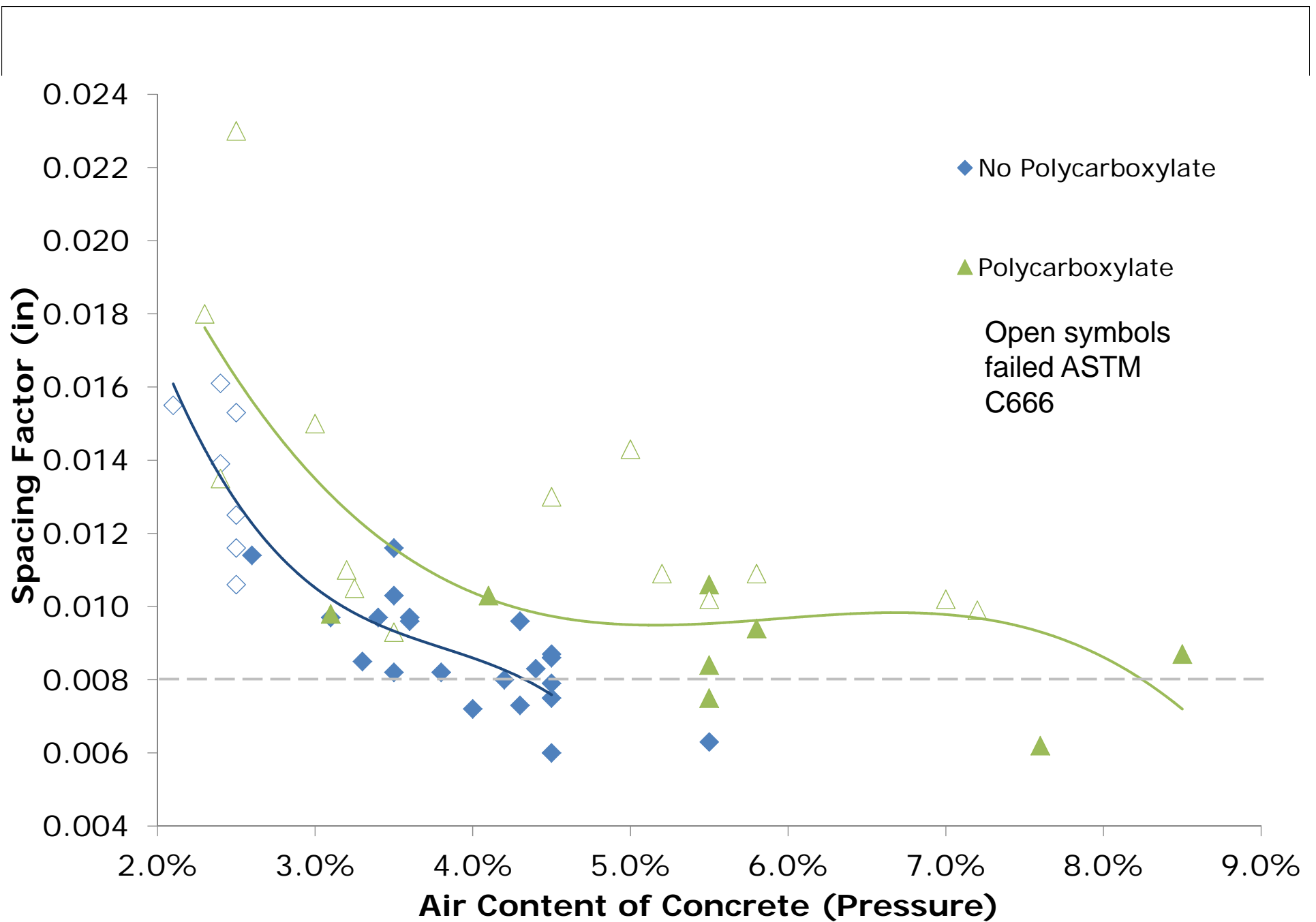


ASTM C 138

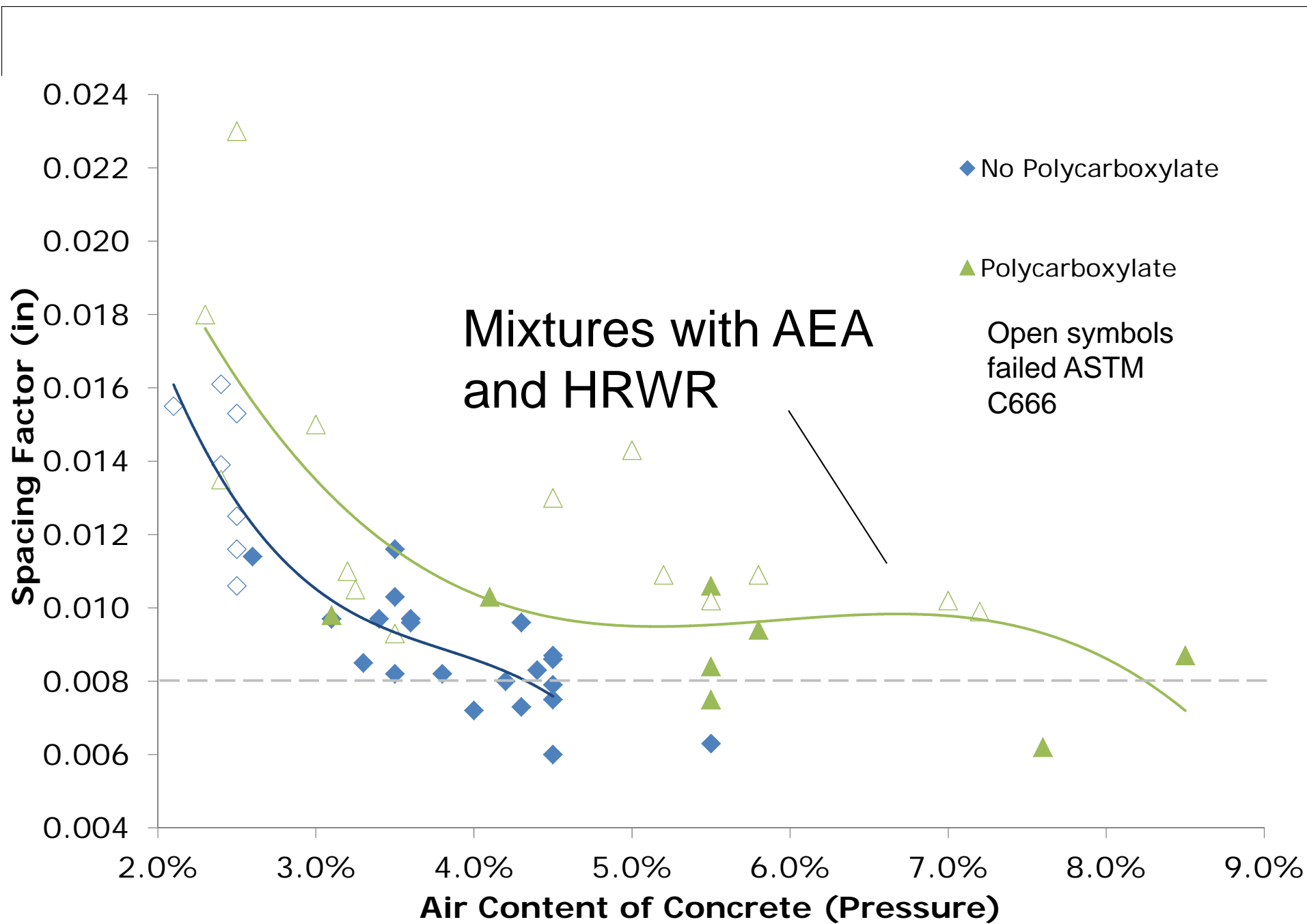
These only measure volume!!!



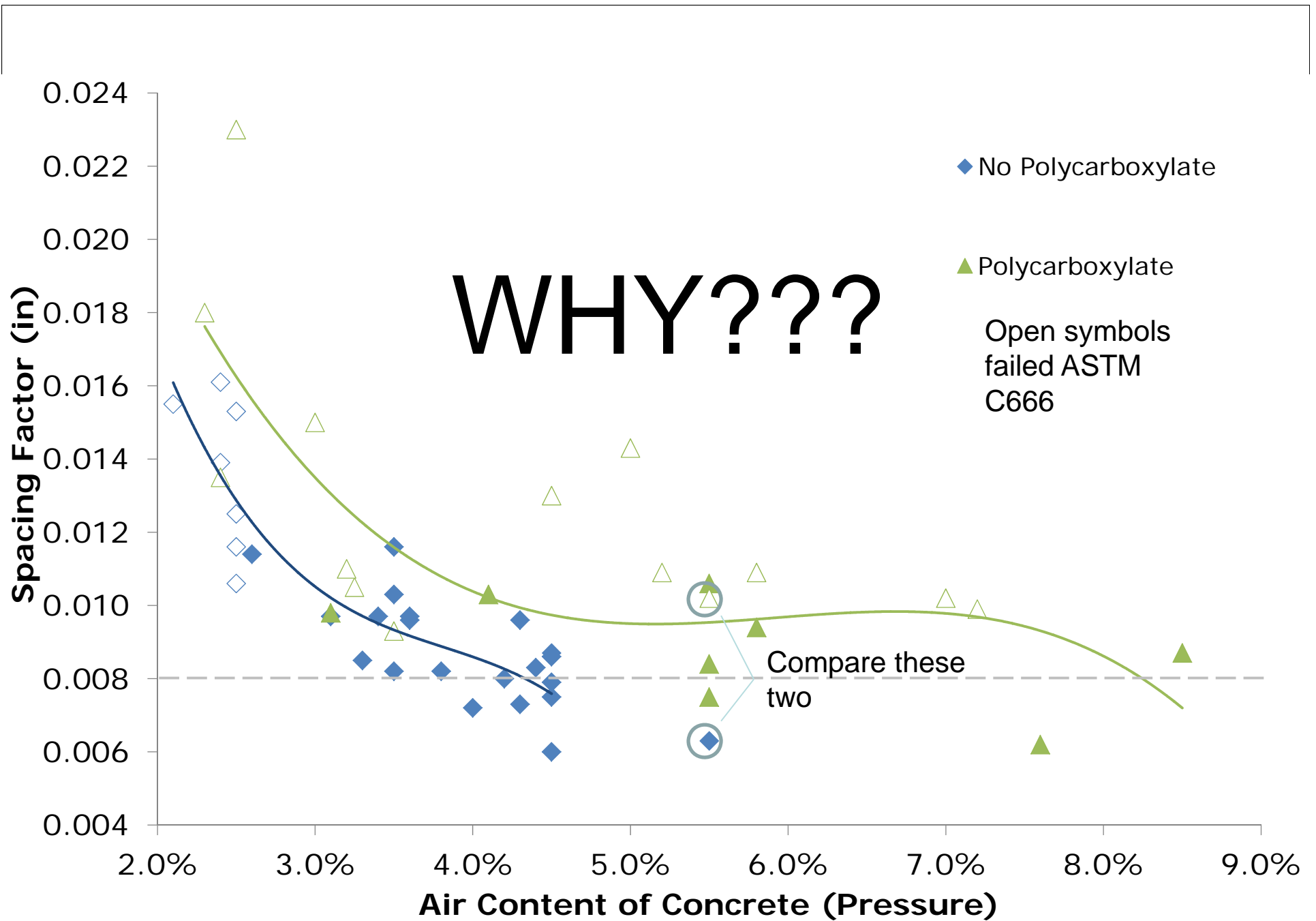




Freeman et al., 2012

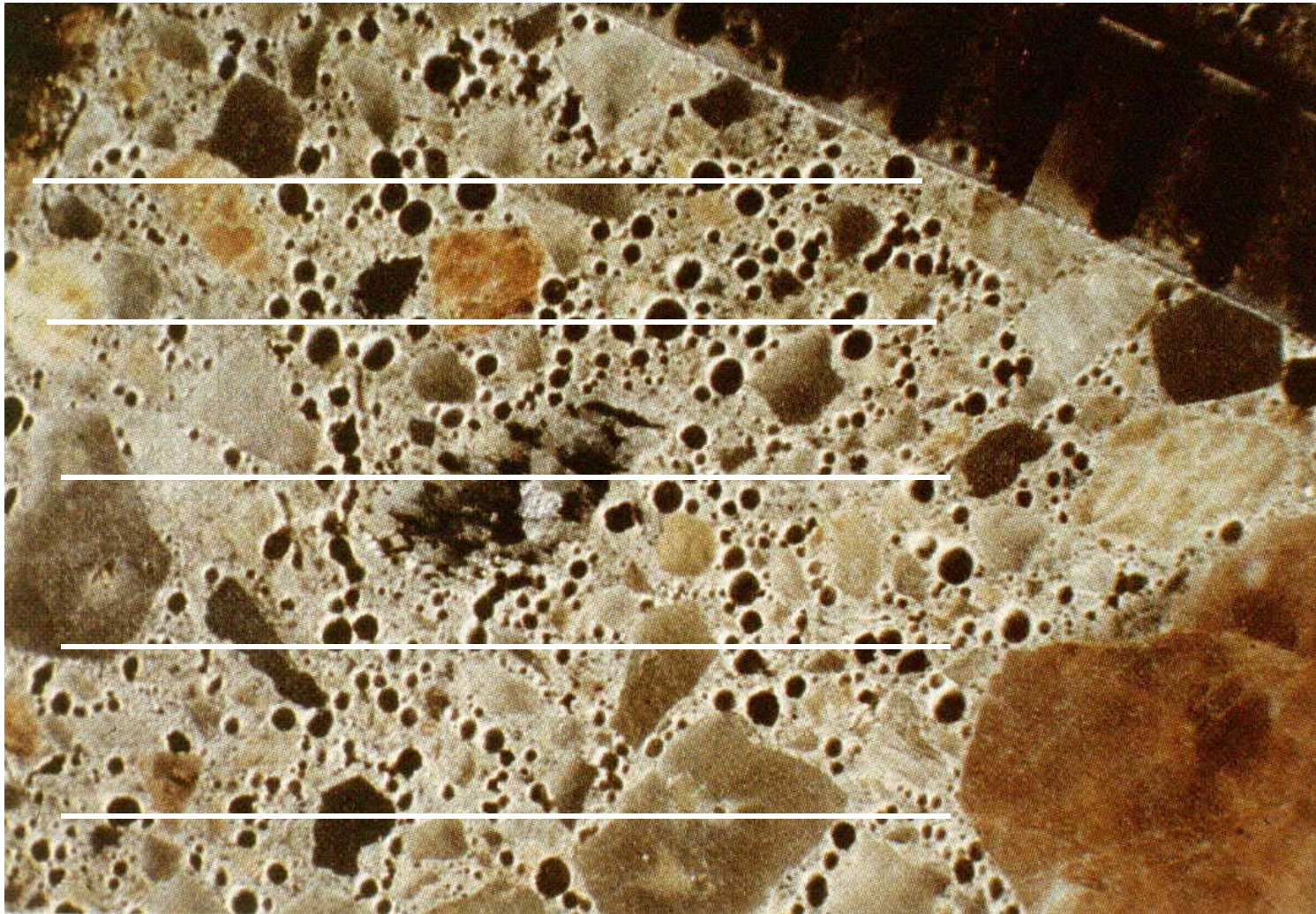


Freeman et al., 2012

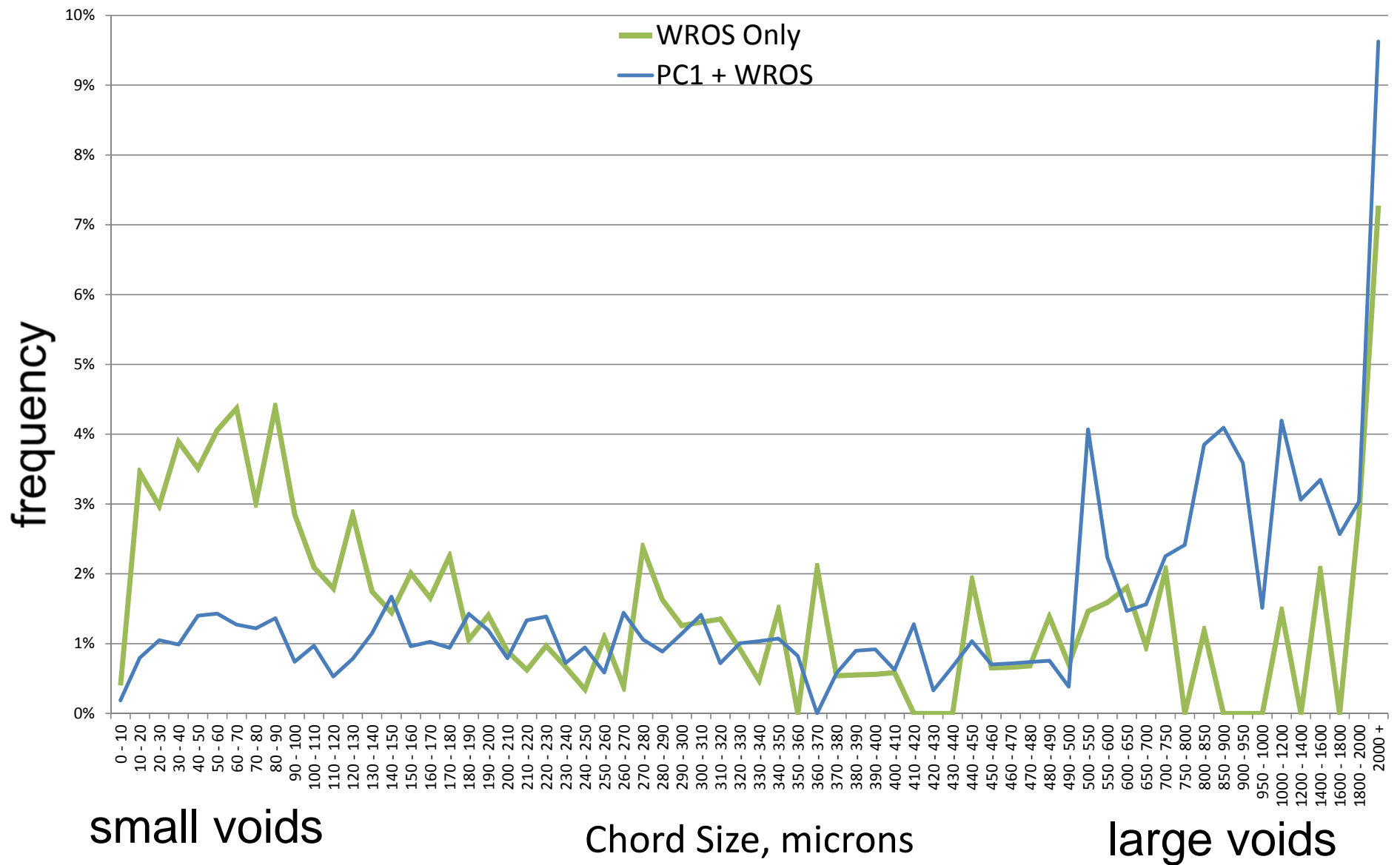


Freeman et al., 2012

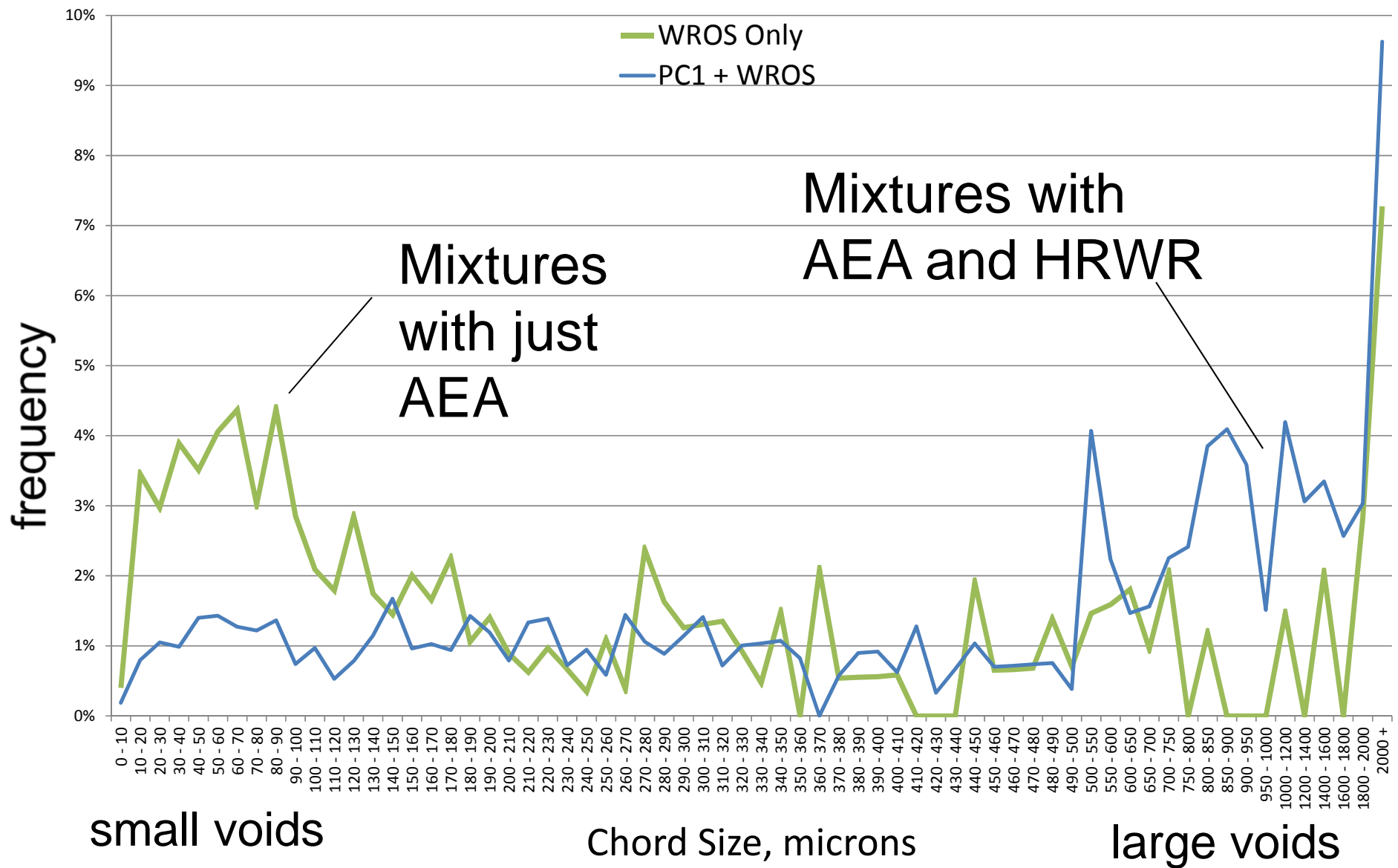
Hardened Air Void Analysis



From Hover



Freeman et al., 2012



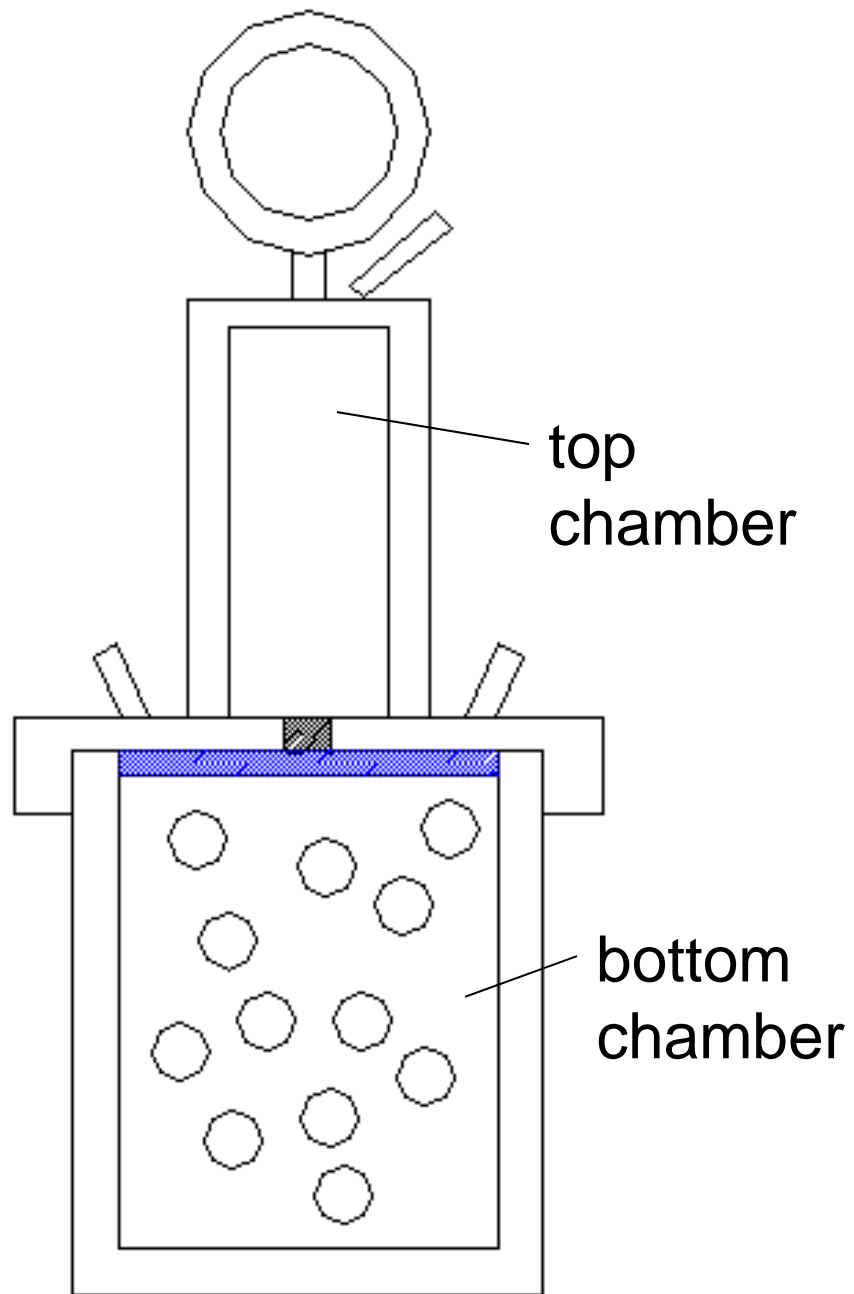
Freeman et al., 2012

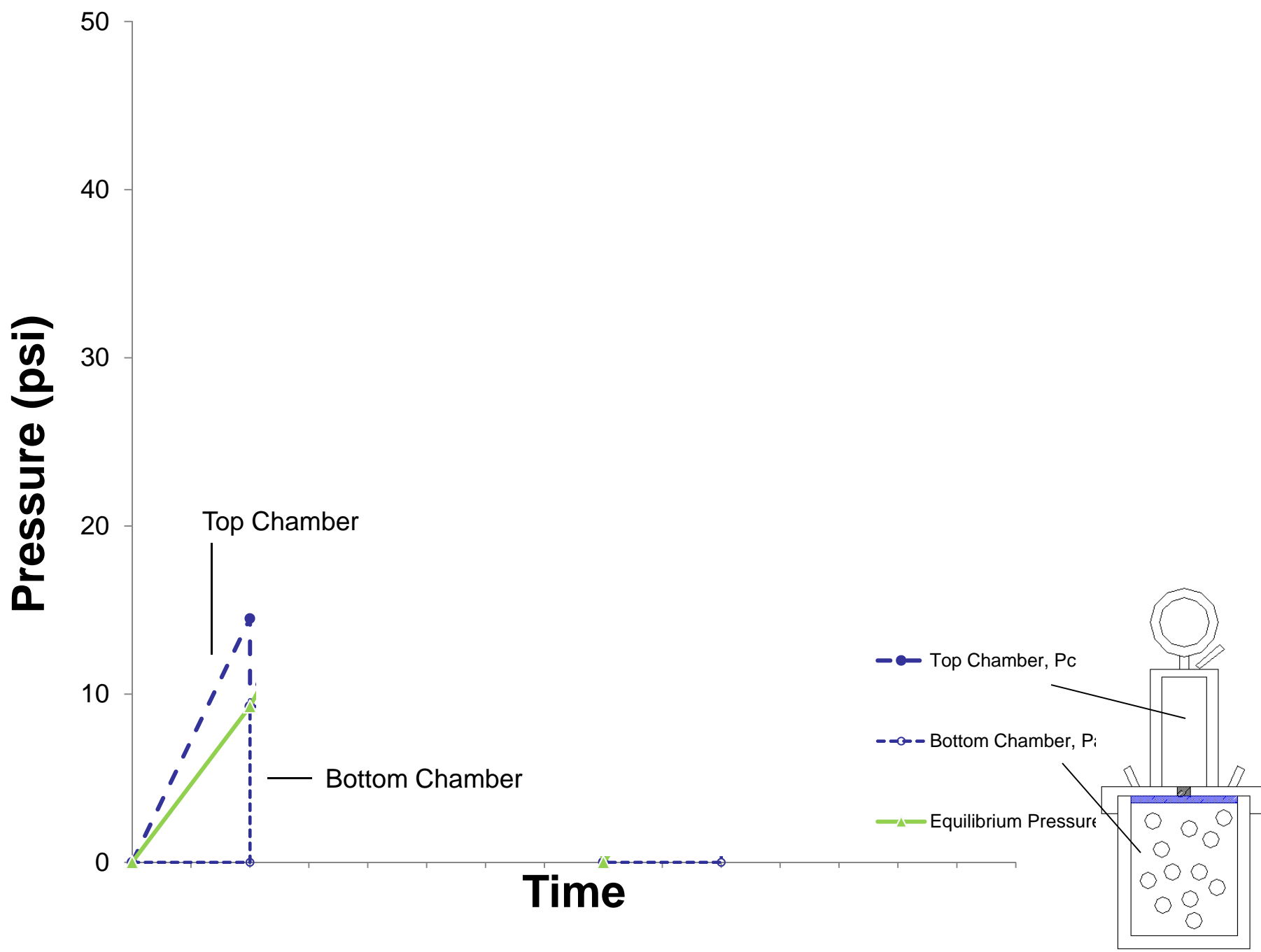
What do we need?

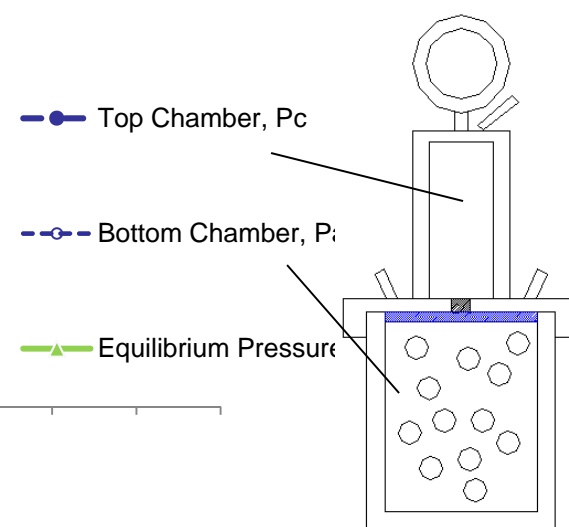
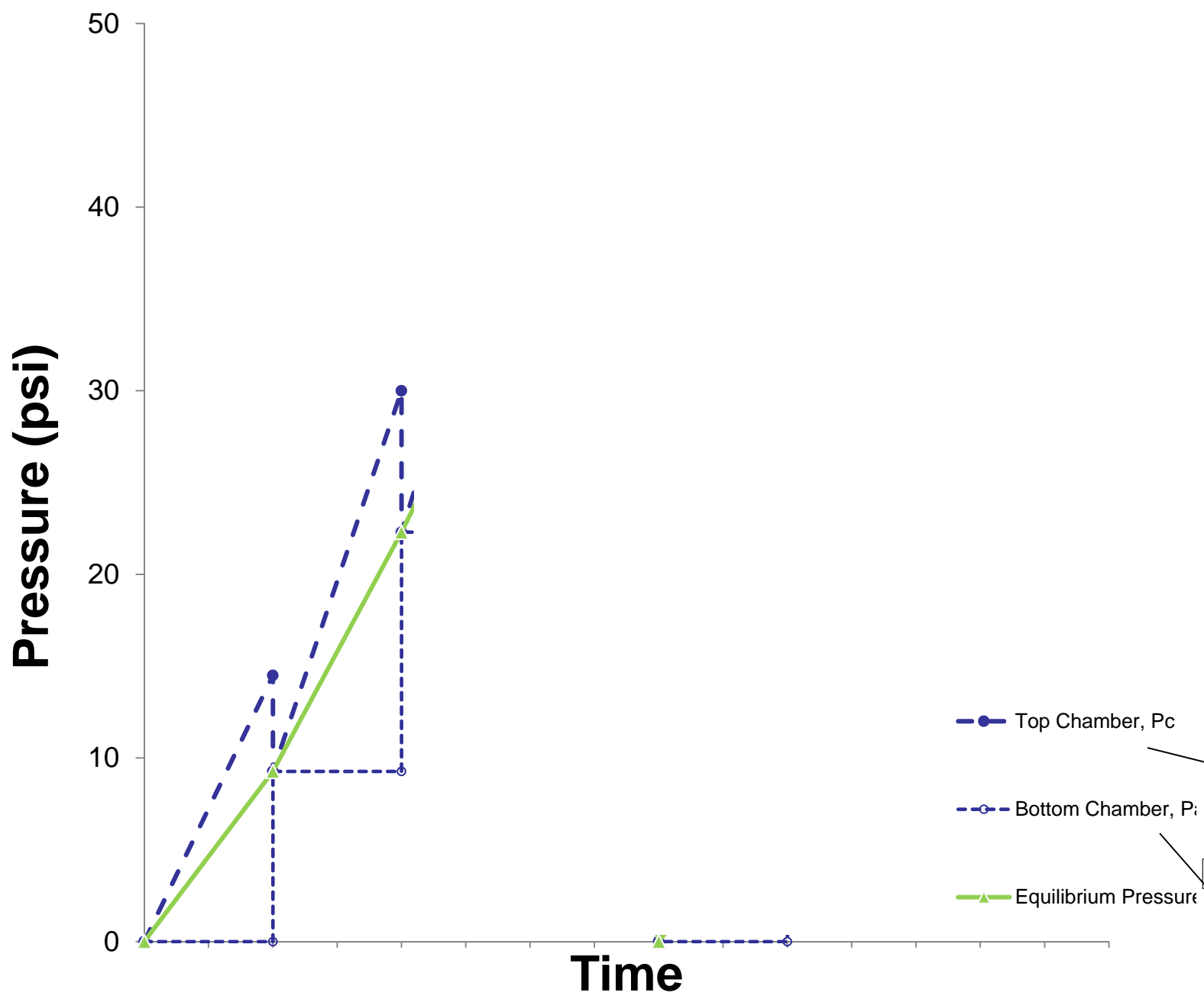
- We need a test that can quantify air-void systems quickly in fresh concrete
- Investigate a sample of significant size
- Economical
- Field ready

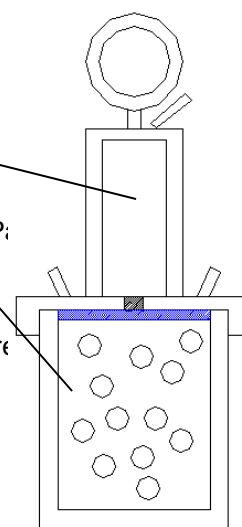
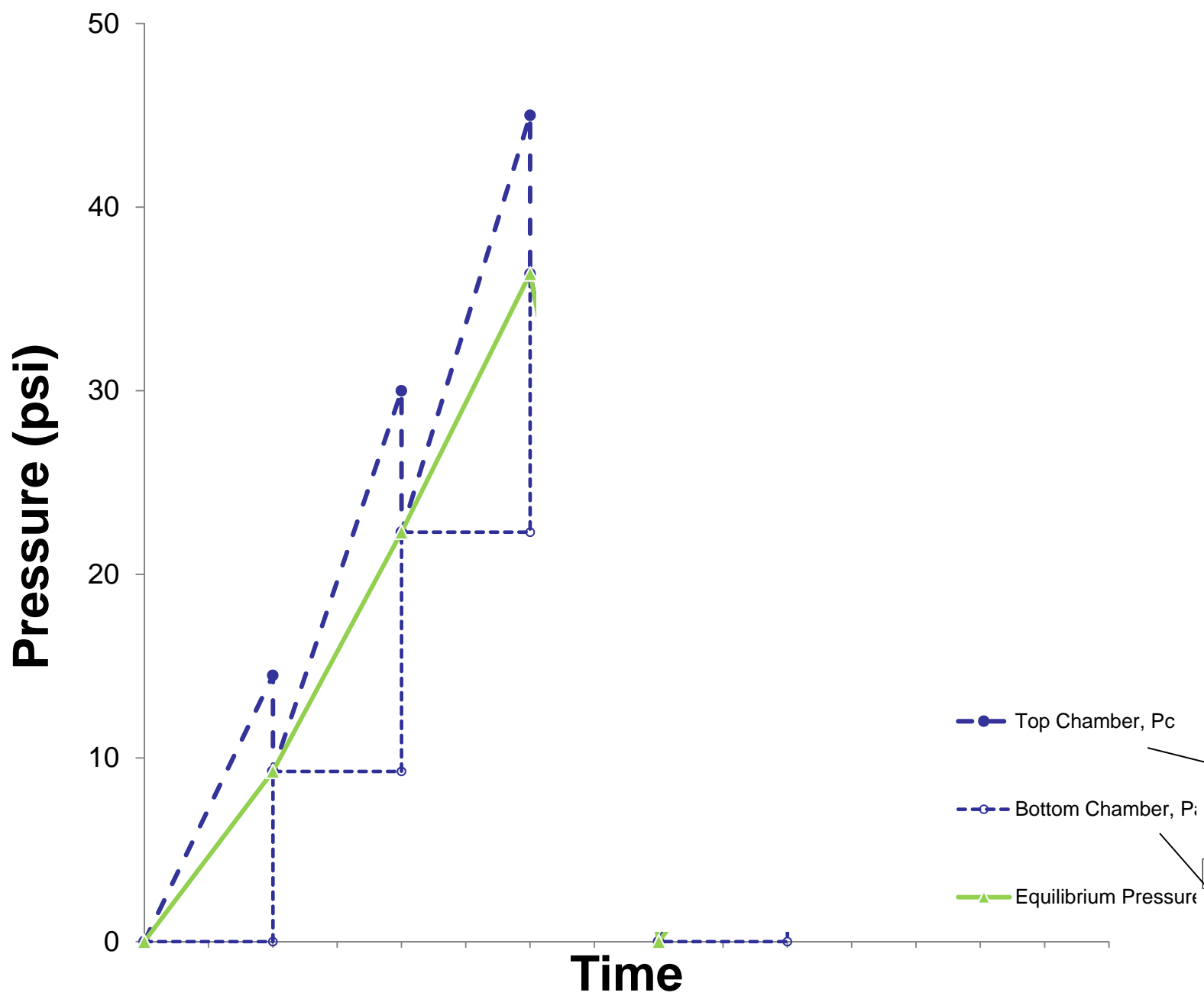
How does it work?

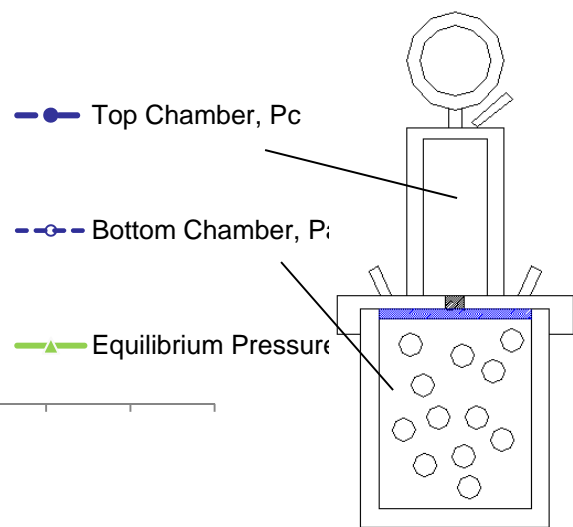
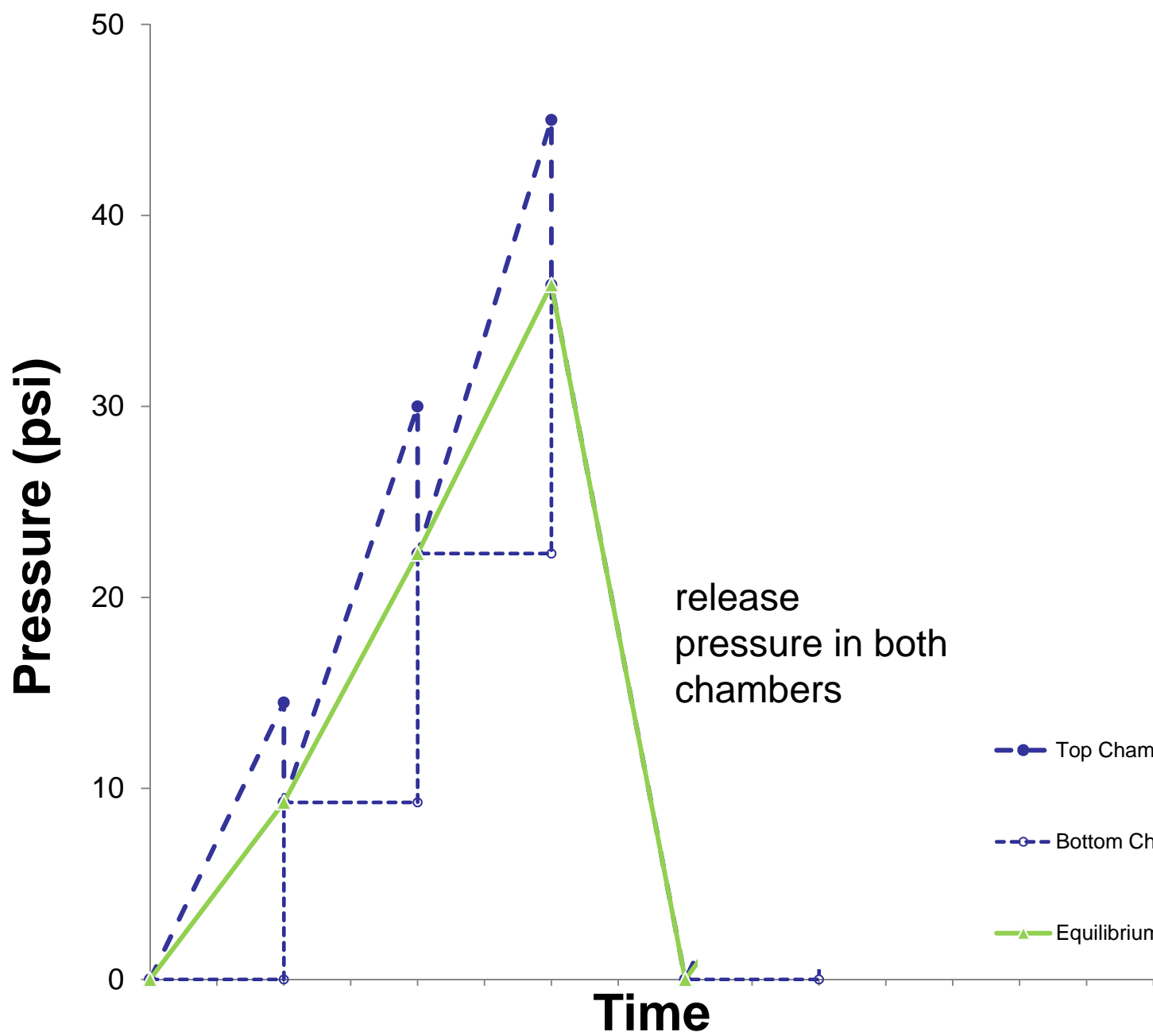
- Use ASTM C 231 procedures to fill the measurement bowl
- Secure the lid
- Add water through the petcocks

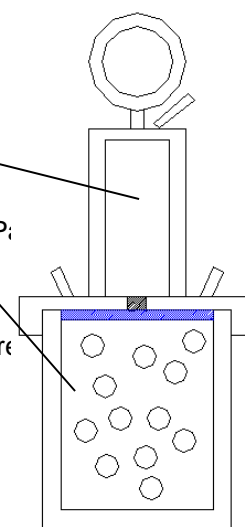
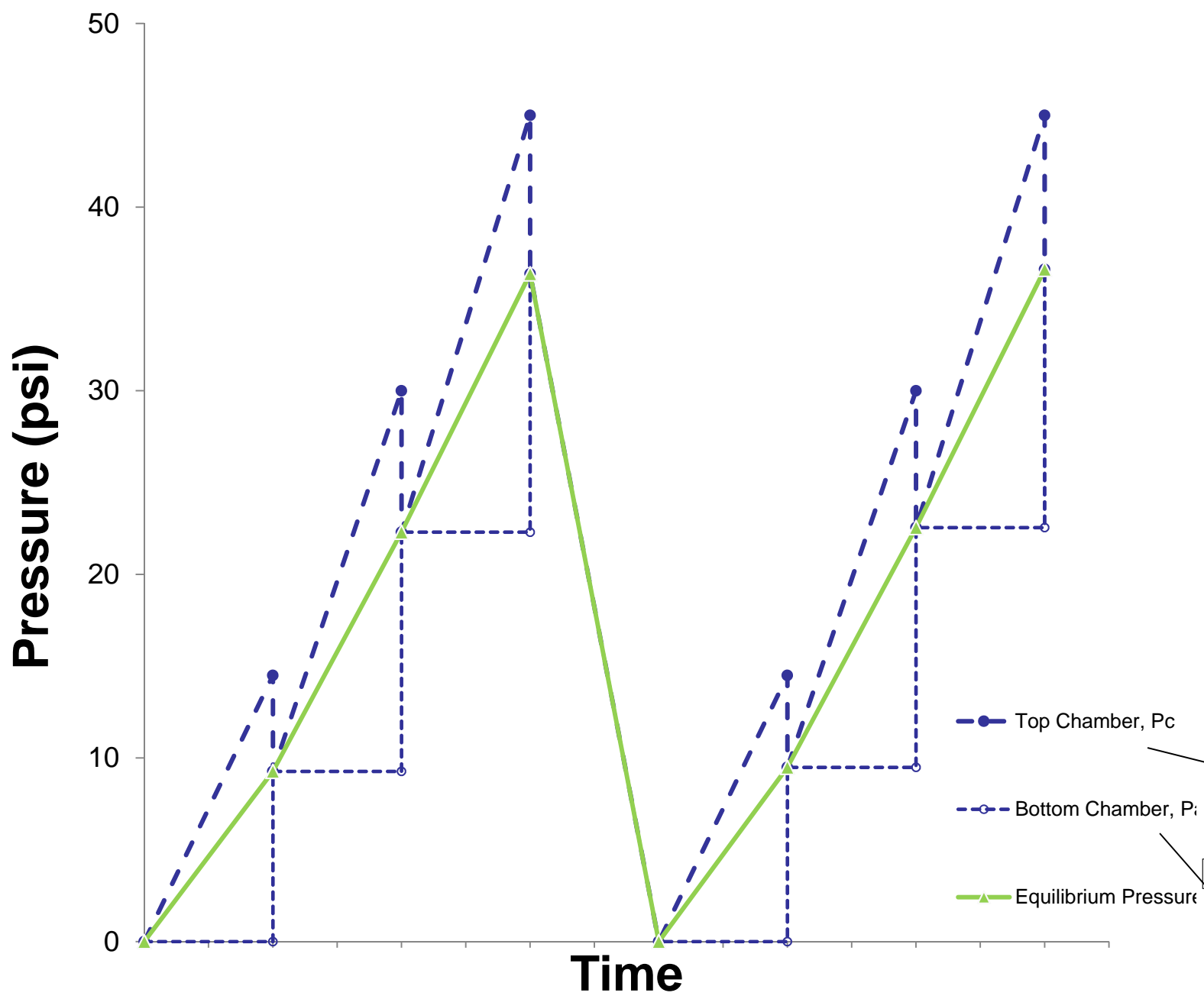


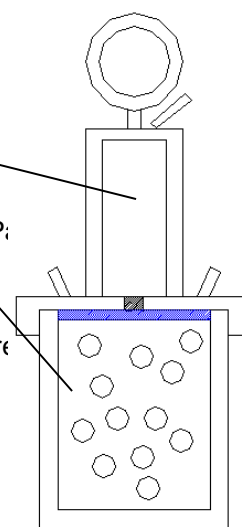
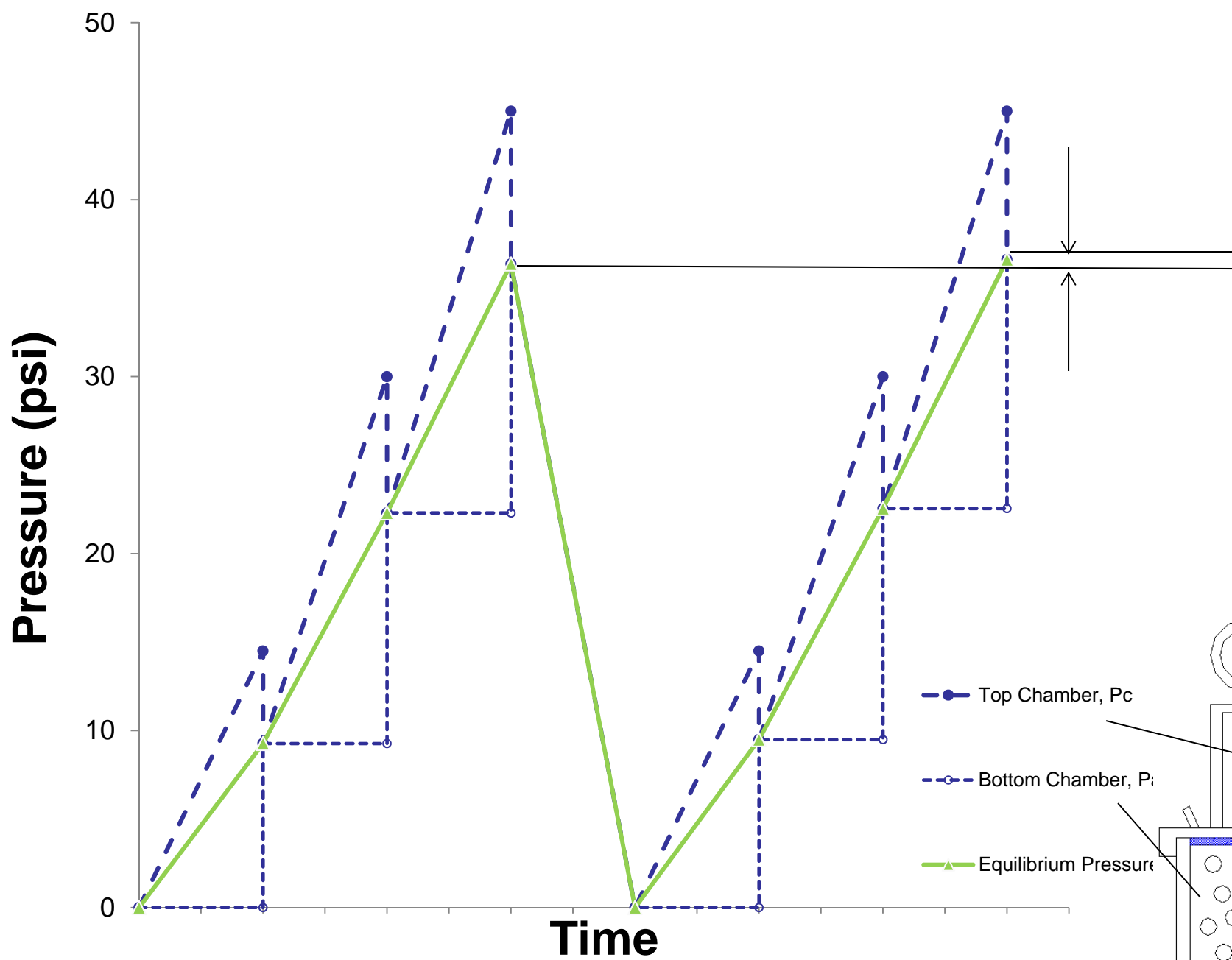












How do we get this?

1. Specify a certain volume of air
 - We hope to get a certain air void spacing
2. Specify a maximum w/cm
 - We hope to get a certain permeability and tensile strength
3. Specify frost durable aggregates