Air void systems in pumped concrete

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Acknowledgements

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Freeze-Thaw Pooled Fund Project

ODOT led - 16 states supporting

Dolese Bros. Co

Outline

- Introduction / Mechanisms
- Lab Testing
- Field Testing
- Recommendations
- Conclusions

Concrete Pumping

Concrete pumps are used to place over 60% of ready mix concrete.

When you pump air entrained concrete one of three things will happen:

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1. The air will go down

When you pump air entrained concrete one of three things will happen:

1. The air will go down
2. The air will go up

When you pump air entrained concrete one of three things will happen:

1. The air will go down
2. The air will go up
3. The air will stay the same

- Ken Hover

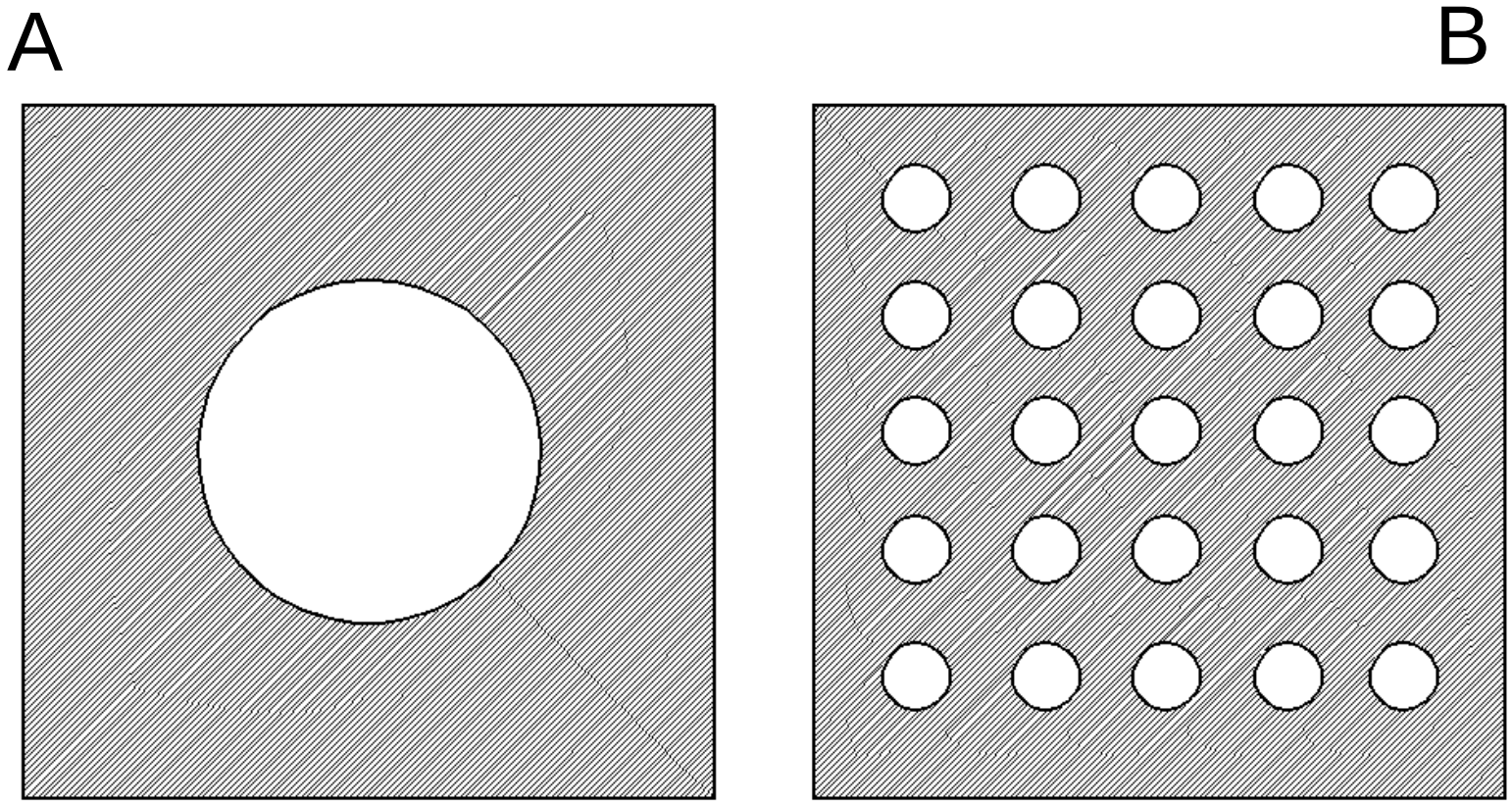
When you pump air entrained concrete one of three things will happen:

1. The air will go down
2. The air will go up
3. The air will stay the same

- Ken Hover

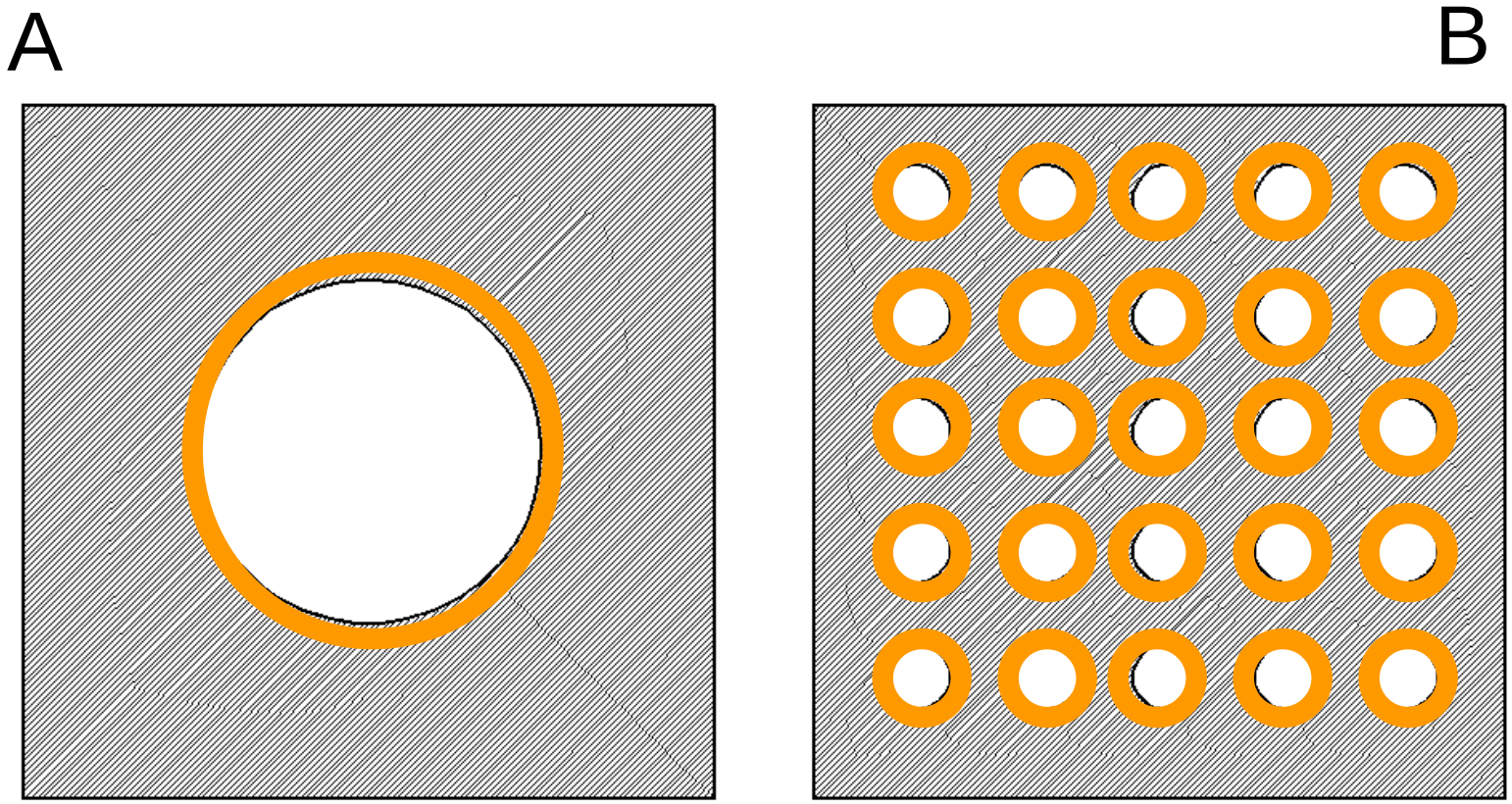
Most people are worried about this and so it is common to sample after the concrete pump.

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.

Why does pumping impact air?

Why does pumping impact air?

Mechanisms

1. Pressure

2. Vacuum

3. Impact

Why does pumping impact air?

Mechanisms

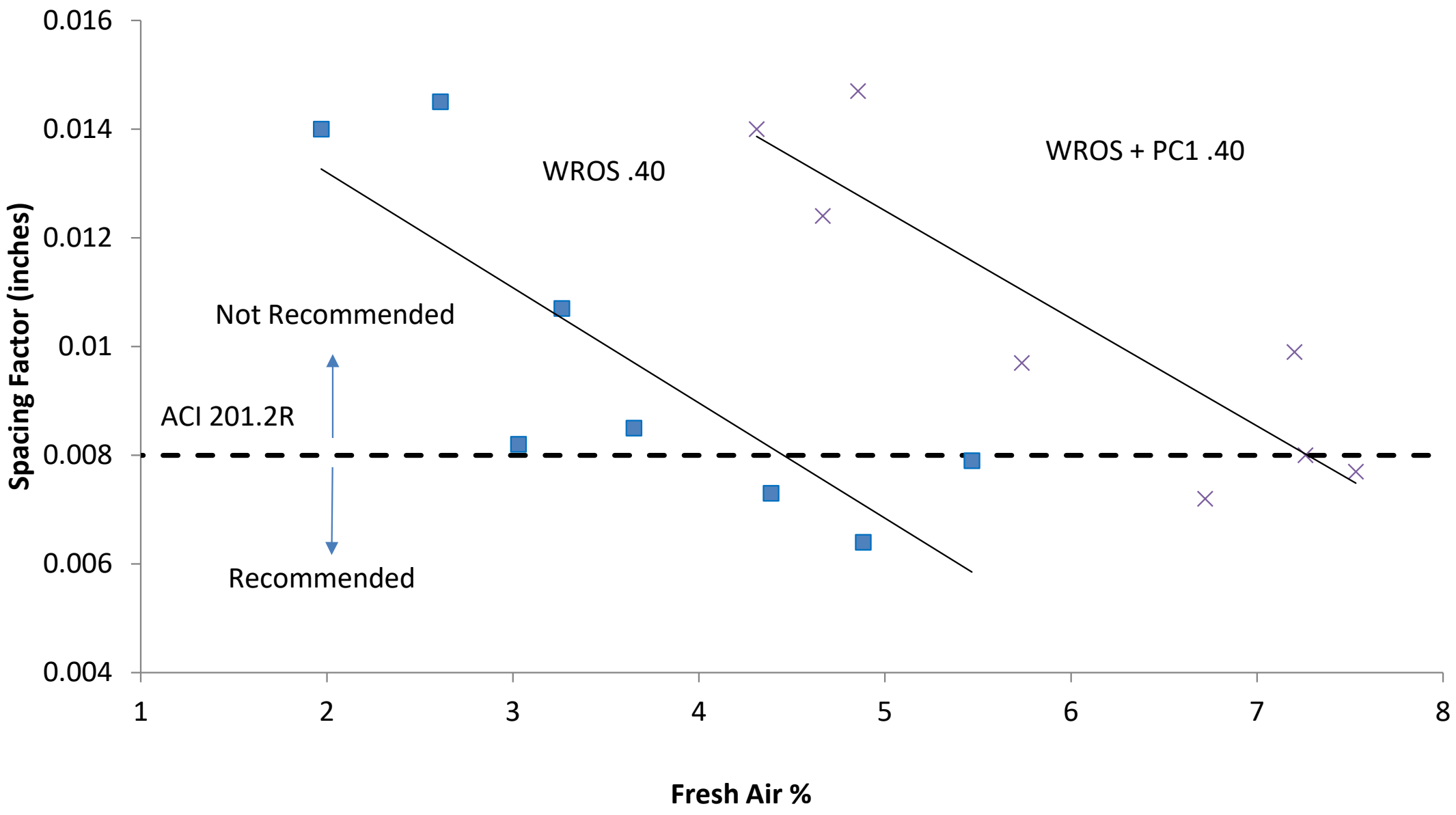
1. Pressure

2. Vacuum

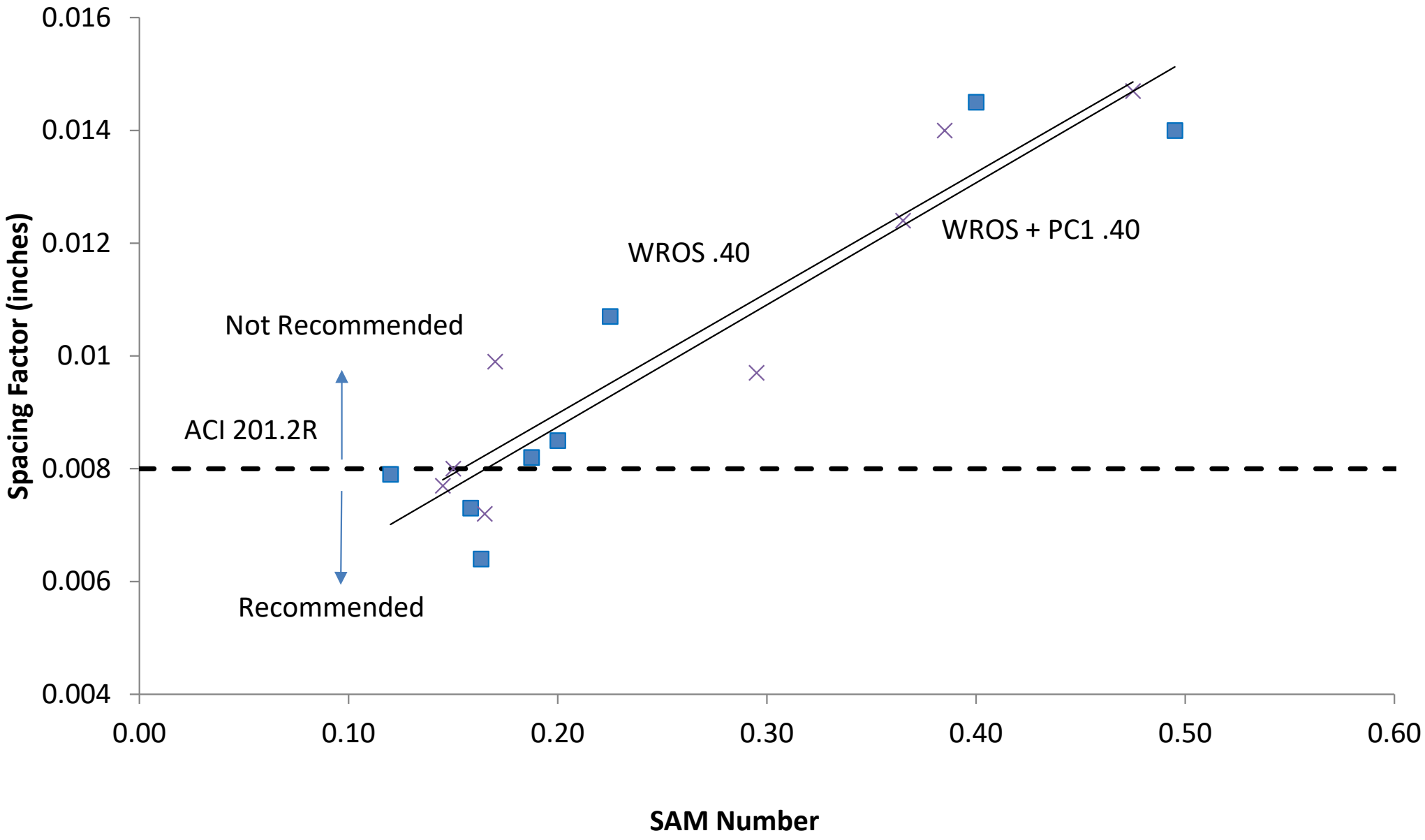
3. Impact

Methods

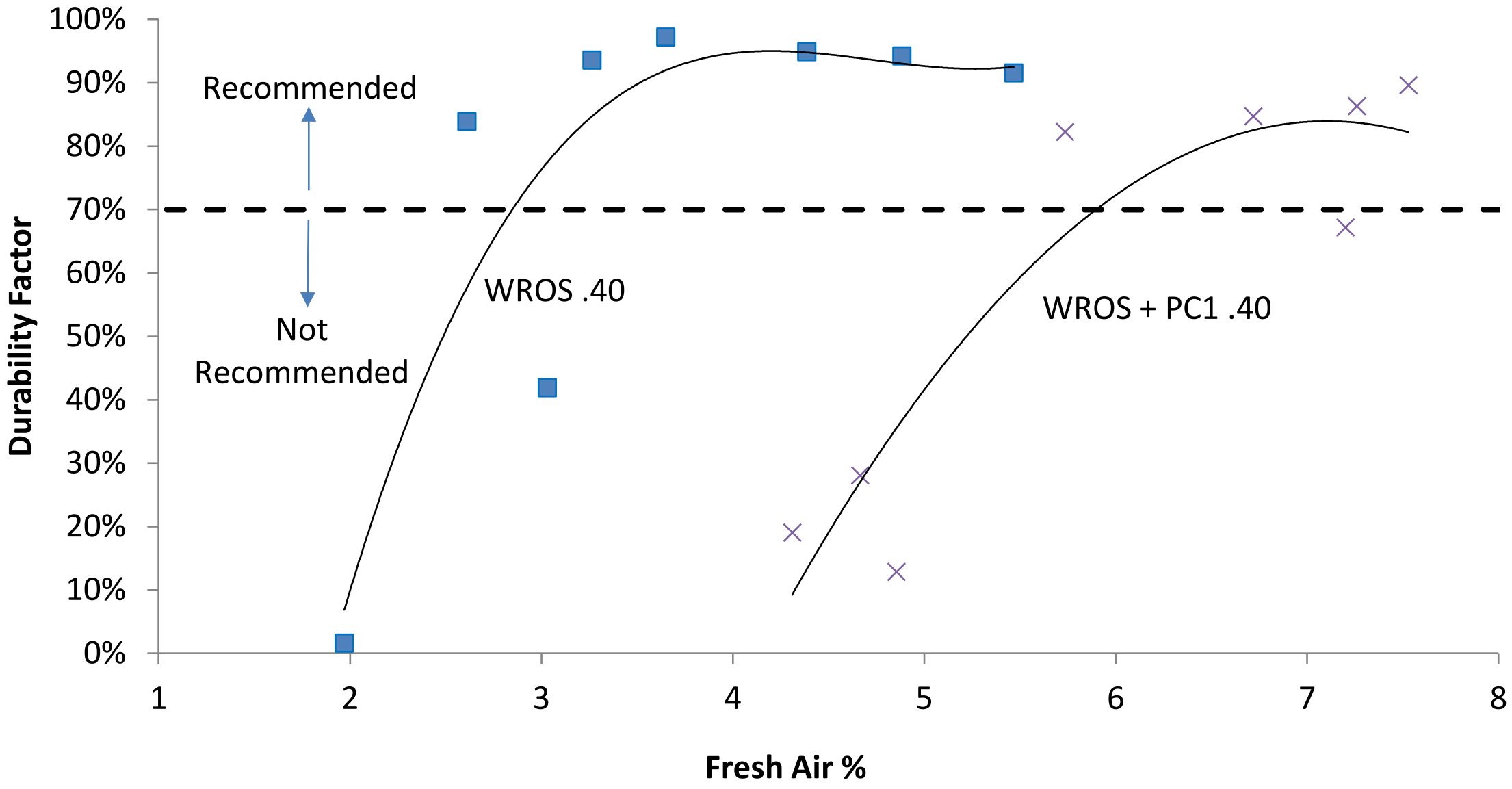
- Investigate the following before and after pumping:
  - Air volume
  - SAM Number (air void spacing) AASHTO TP 118
  - Spacing factor (petrographic analysis) ASTM C 457
  - Freeze-thaw performance ASTM C 666



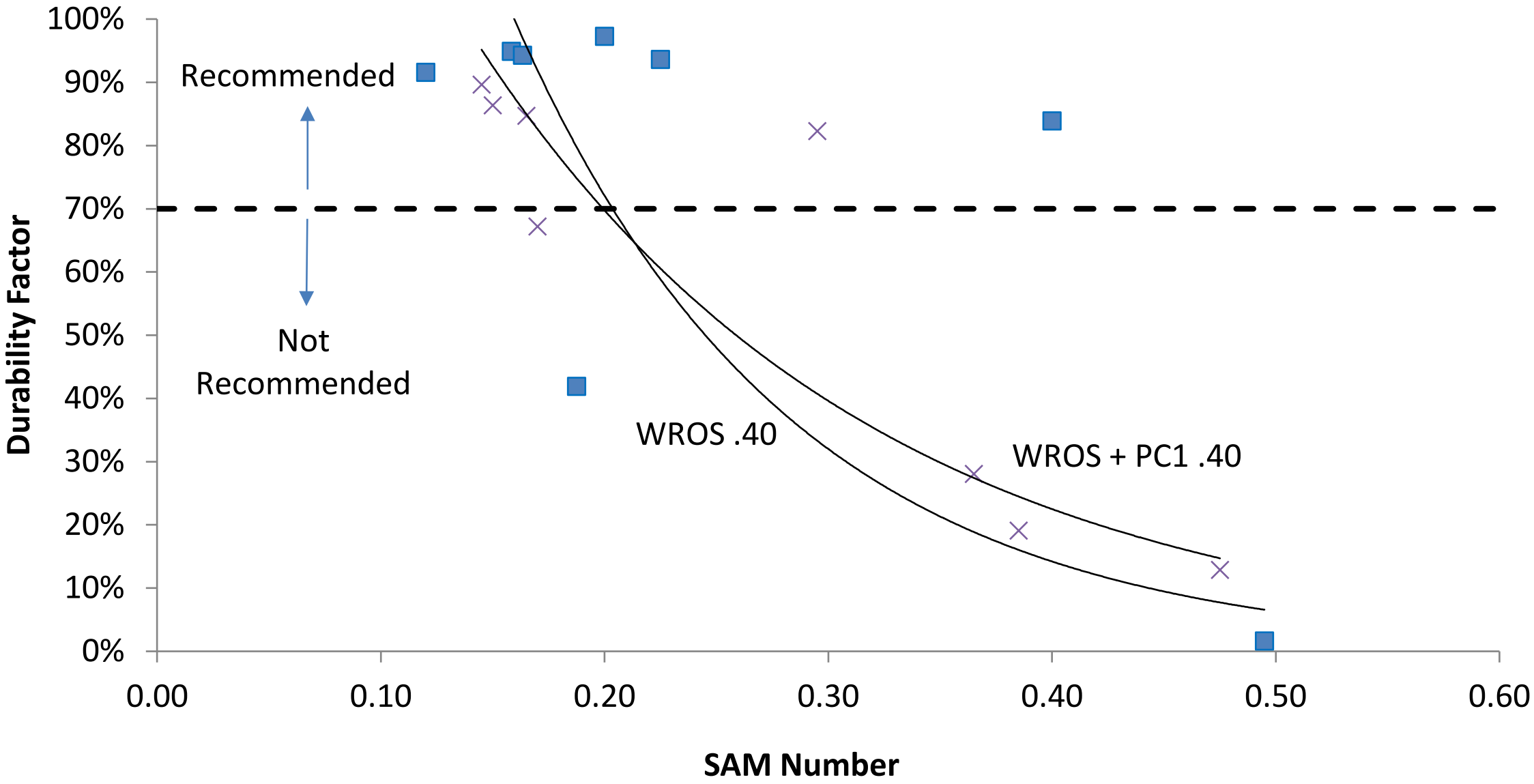
Ley et al., 2017



Ley et al., 2017



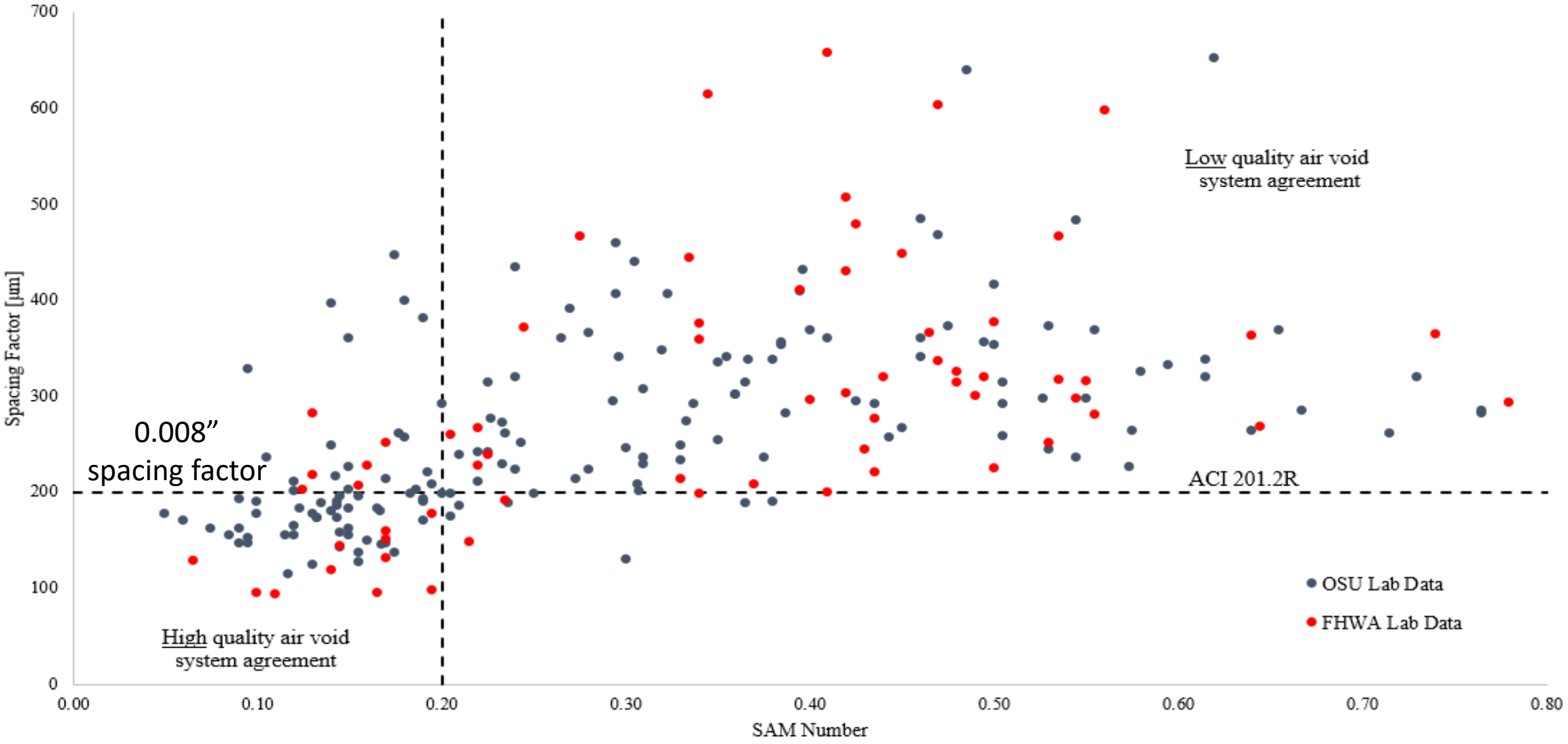
Ley et al., 2017



Ley et al., 2017

Discussion

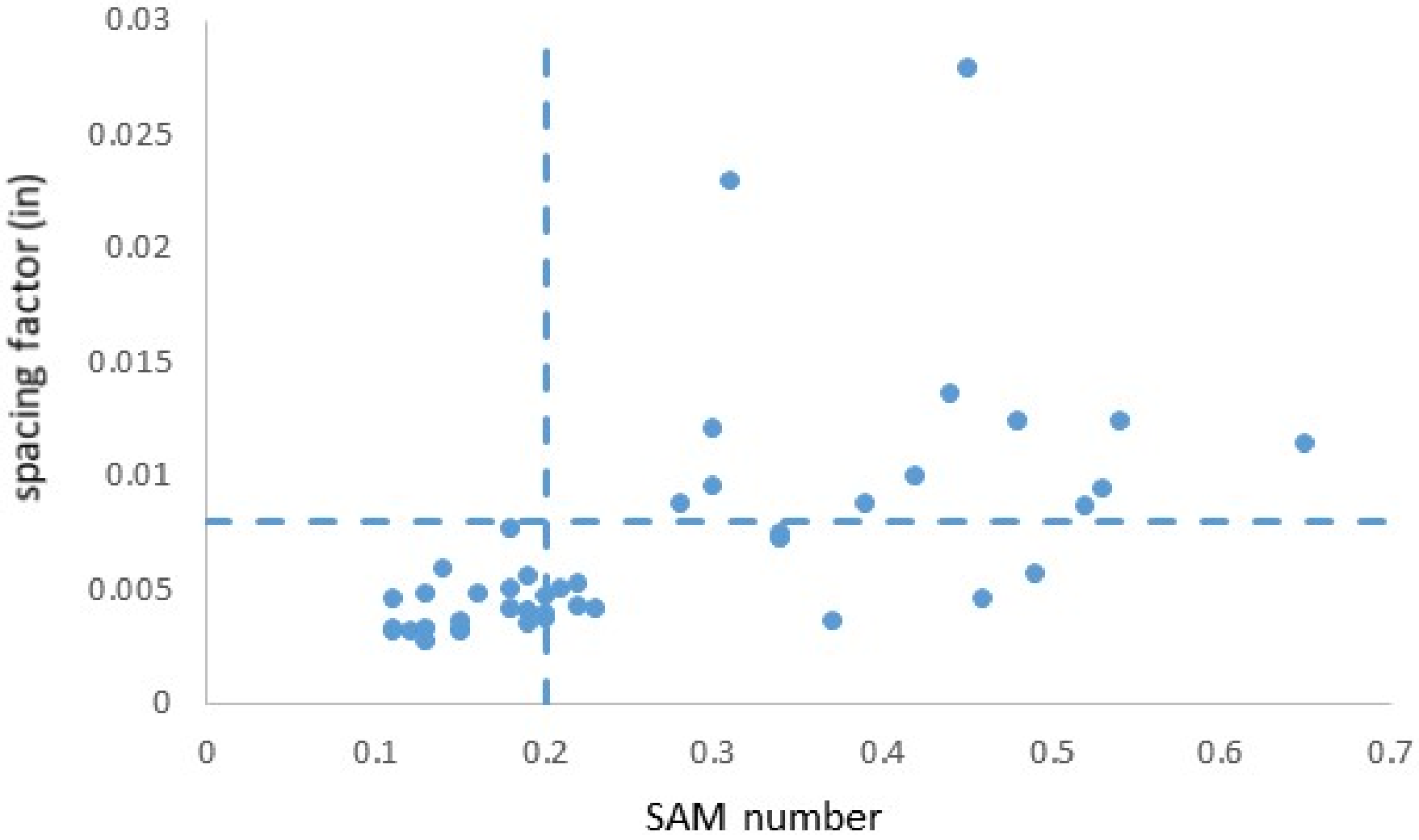
The SAM Number tells you about the bubble size distribution in fresh concrete and the total air does not do this.



Over 227 lab mixtures from two different research groups
88% agreement

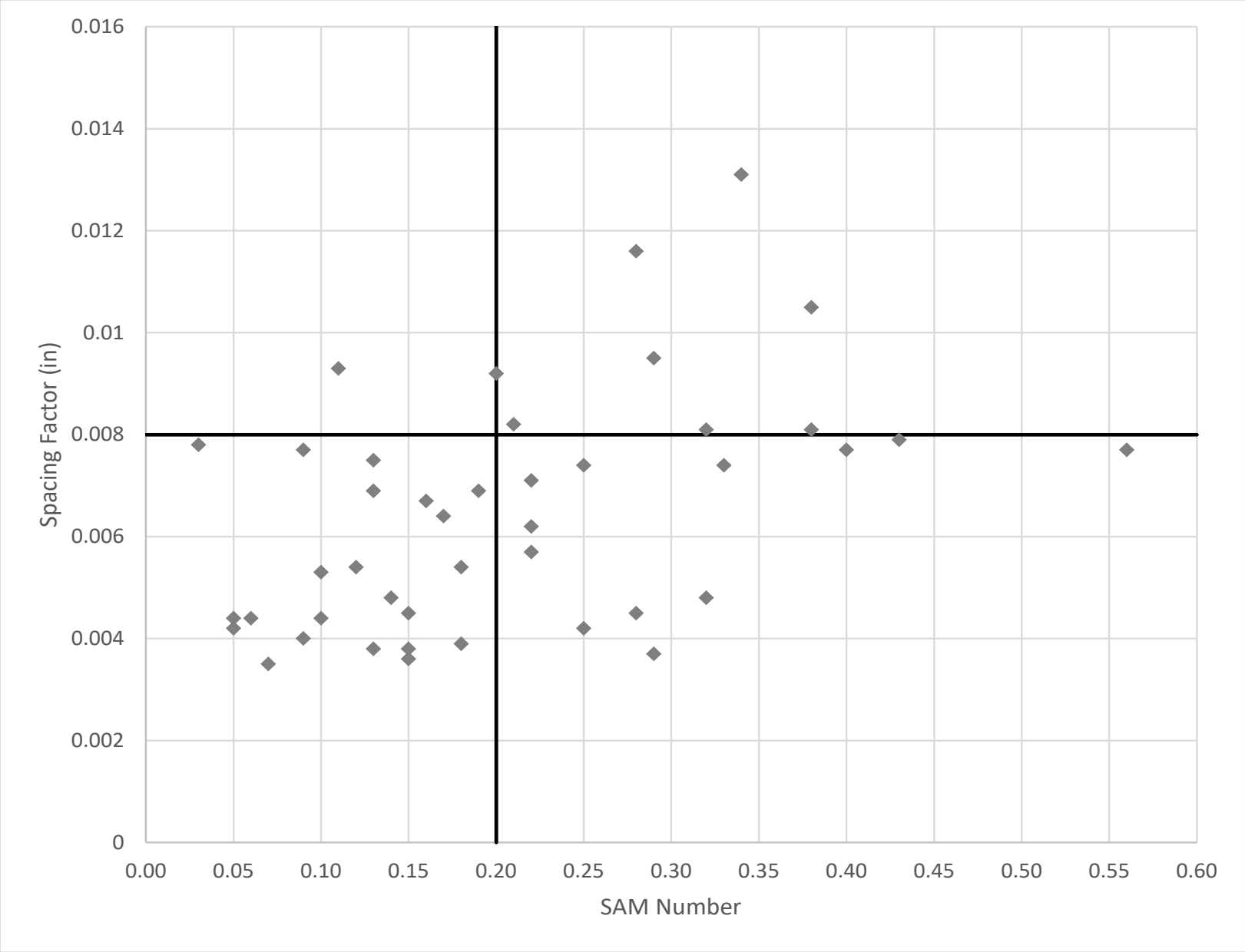
Ley et al., 2017

PennDOT 50 field mixtures



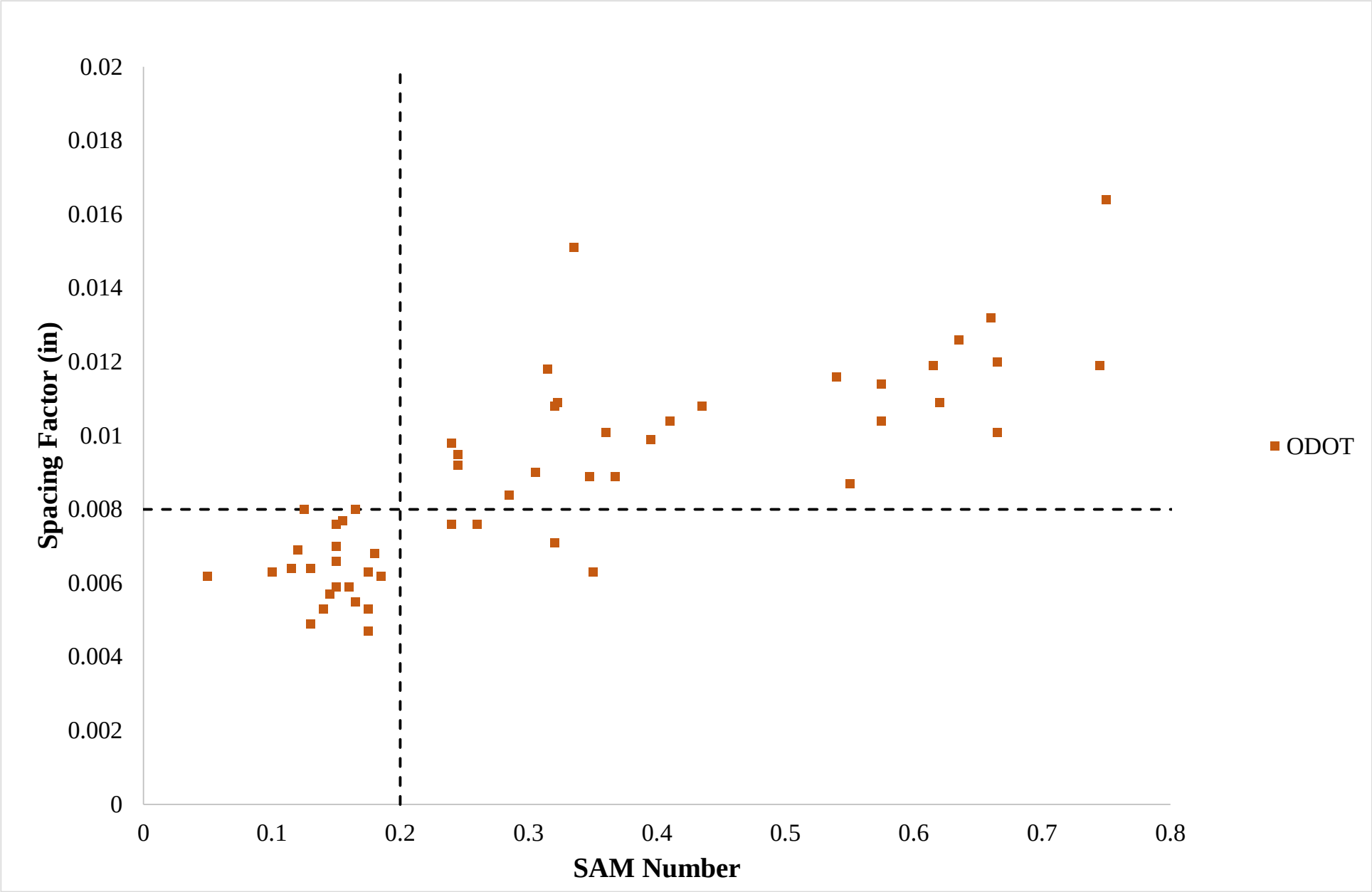
83% agreement

FHWA Mobile Concrete Lab 2014 and 2015 – 50 mixtures

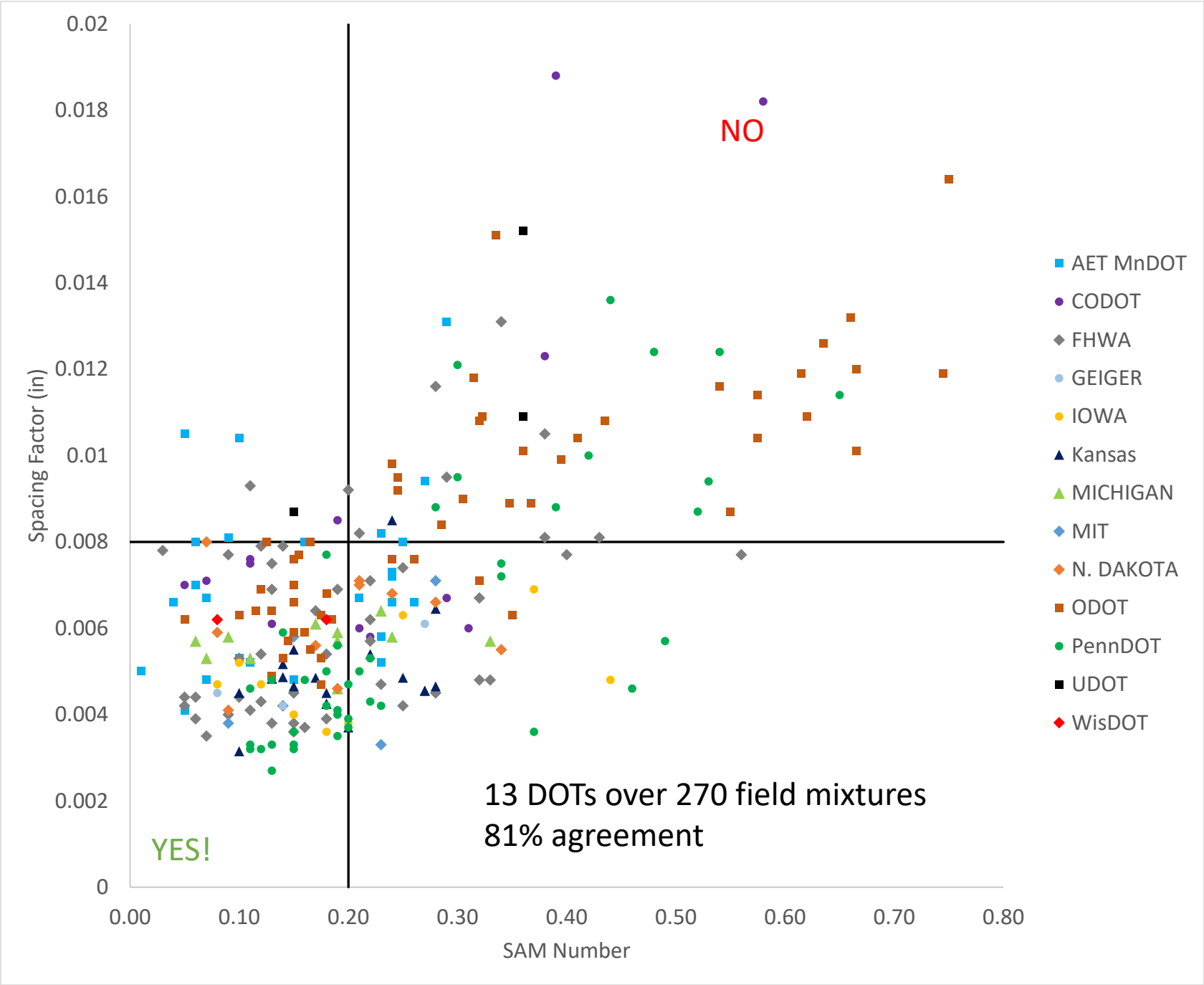


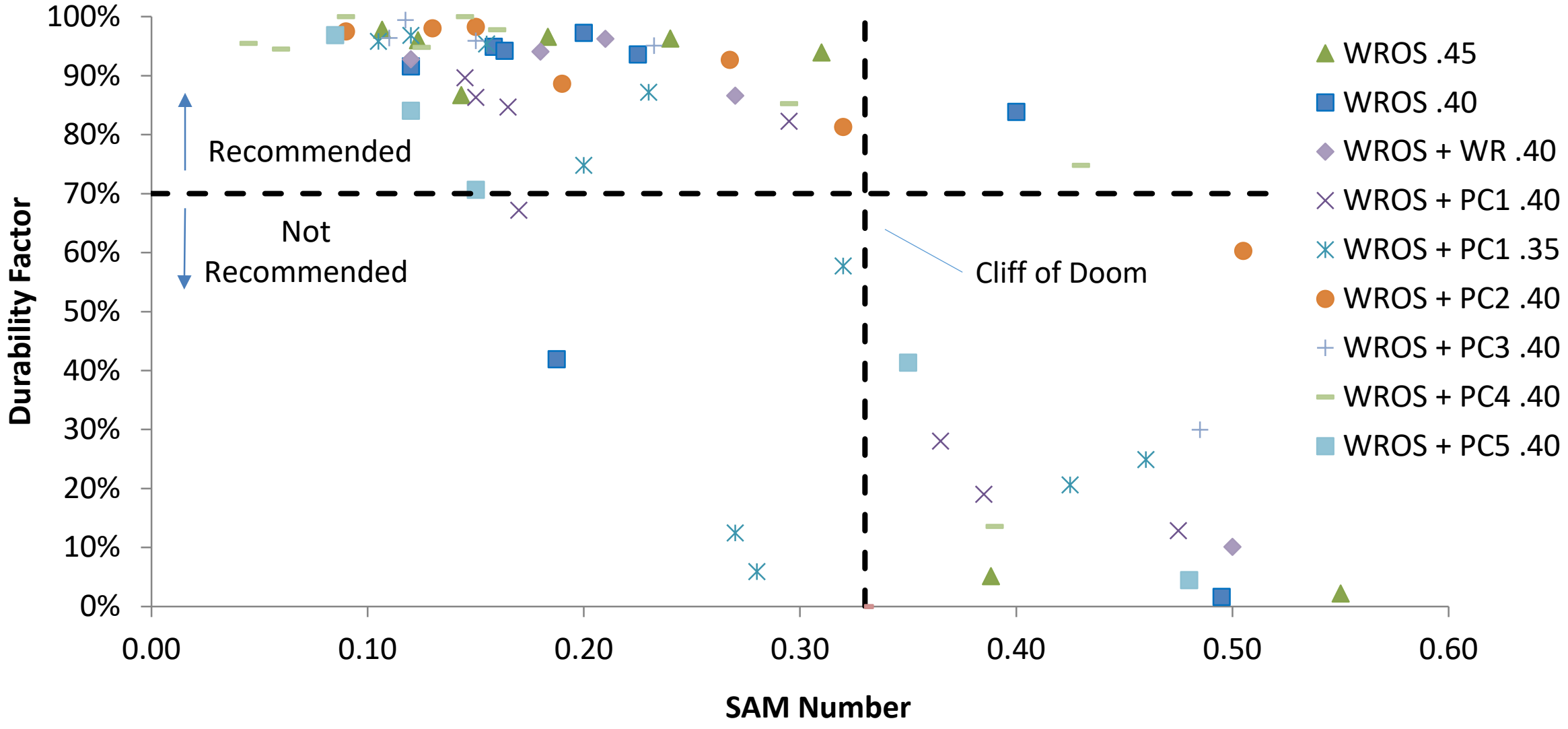
75% agreement

ODOT – 53 mixtures



90% agreement


0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Spacing Factor (in)
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
SAM Number
NO
YES!
13 DOTs over 270 field mixtures
81% agreement
AET MnDOT
CODOT
FHWA
GEIGER
IOWA
Kansas
MICHIGAN
MIT
N. DAKOTA
ODOT
PennDOT
UDOT
WisDOT



68 mixtures show a 88% agreement.

Discussion

The SAM Number correlates to performance in rapid freeze thaw testing.

A SAM Number of 0.20 correlates to a spacing factor of 0.008” for 497 concrete mixtures completed by 13 different DOTs and two research groups.

88% agreement in lab

81% agreement in the field

Mixture Design

- 0.45 w/cm
- 20% Class C ash
- 6.5 sacks (611 lbs)
- Limestone and natural sand
- 5” to 8” slump

Air contents from 4% to 8%

With and without water reducer/retarder

16 field mixtures

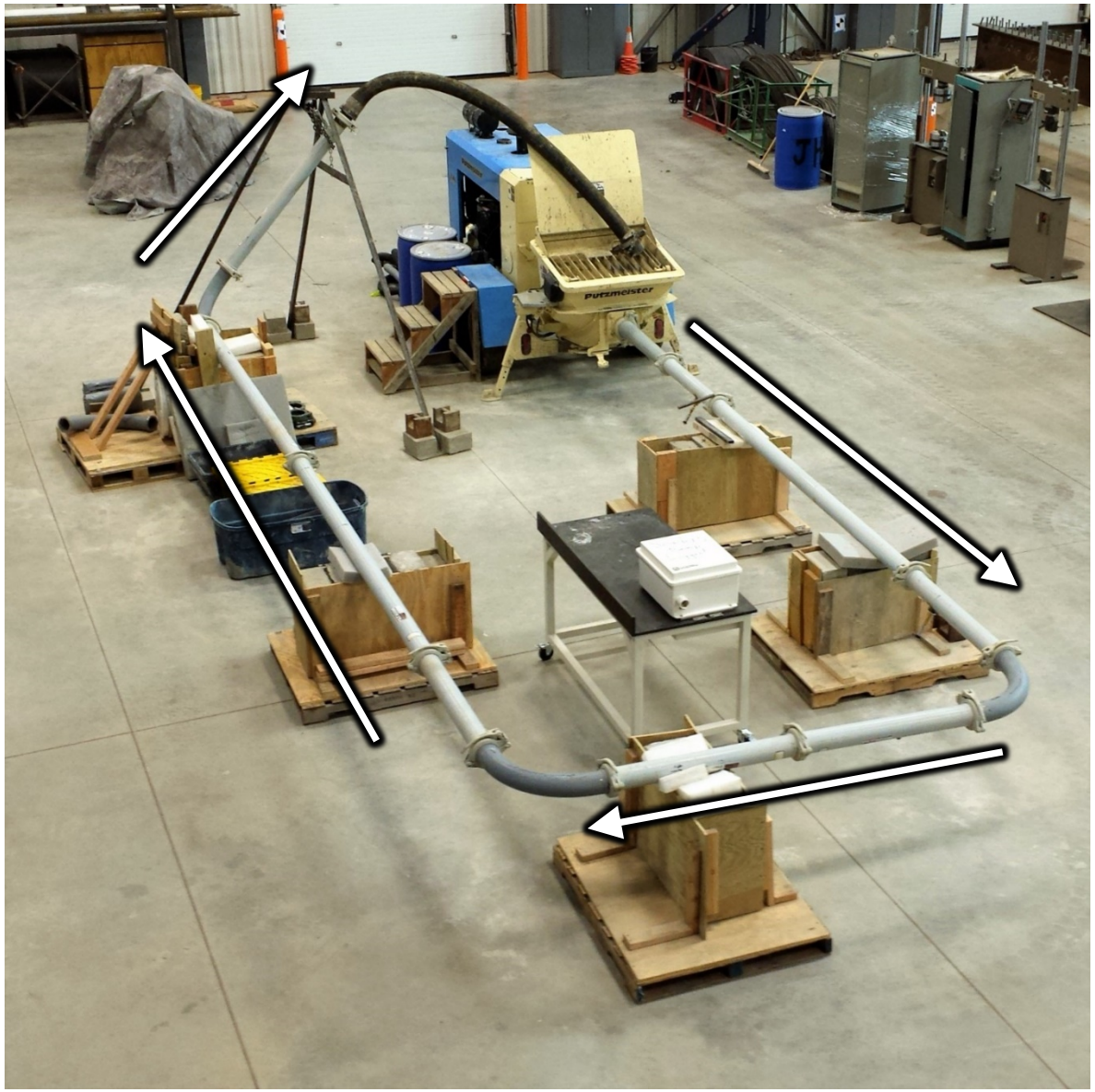
20 lab mixtures


Putzmeister
Putzmeister
TX 50

Lab Pumping Information

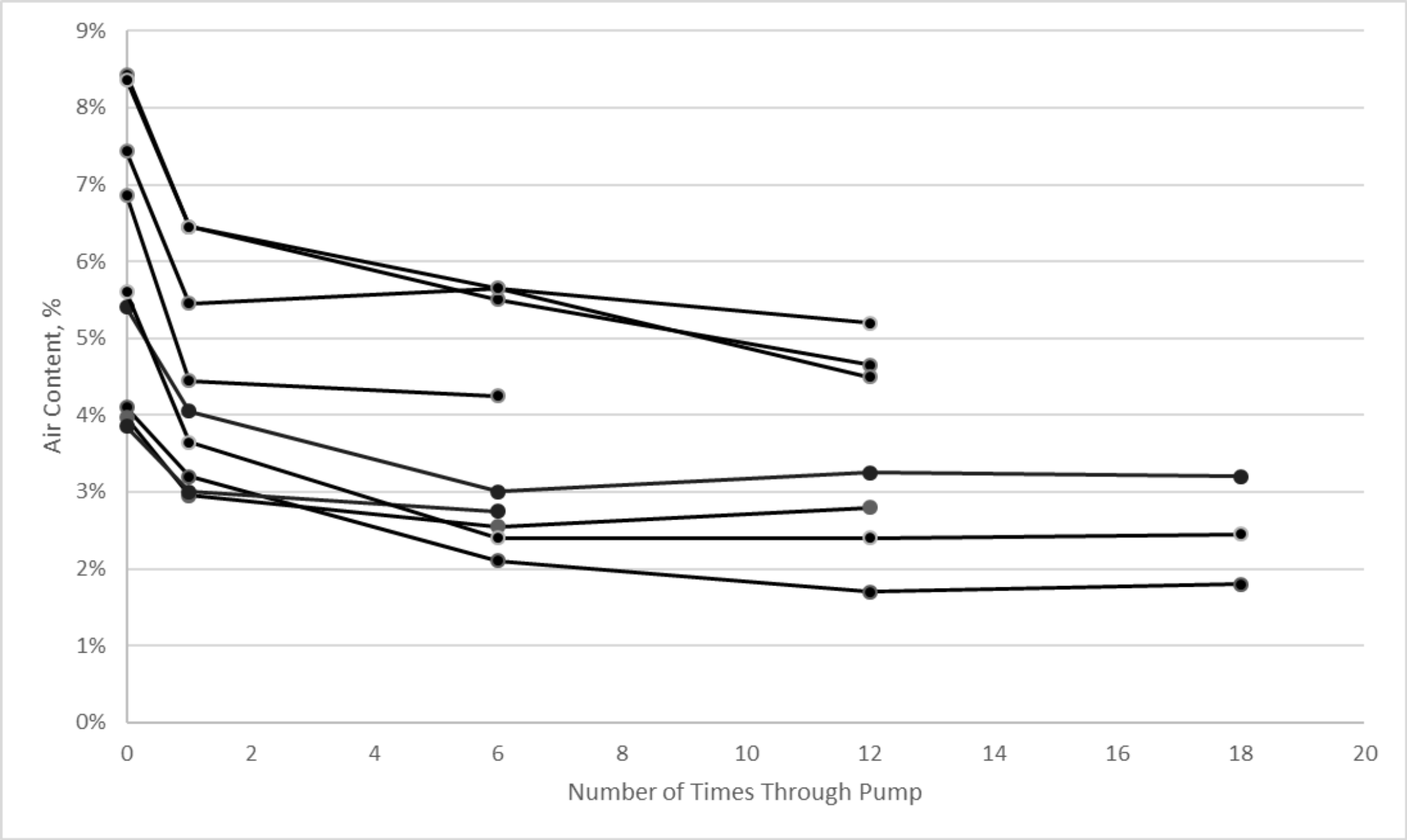
- 4” diameter pipe
- 60’ of steel pipe
- 10’ Rubber hose
- pumping pressures from 55 to 110 psi

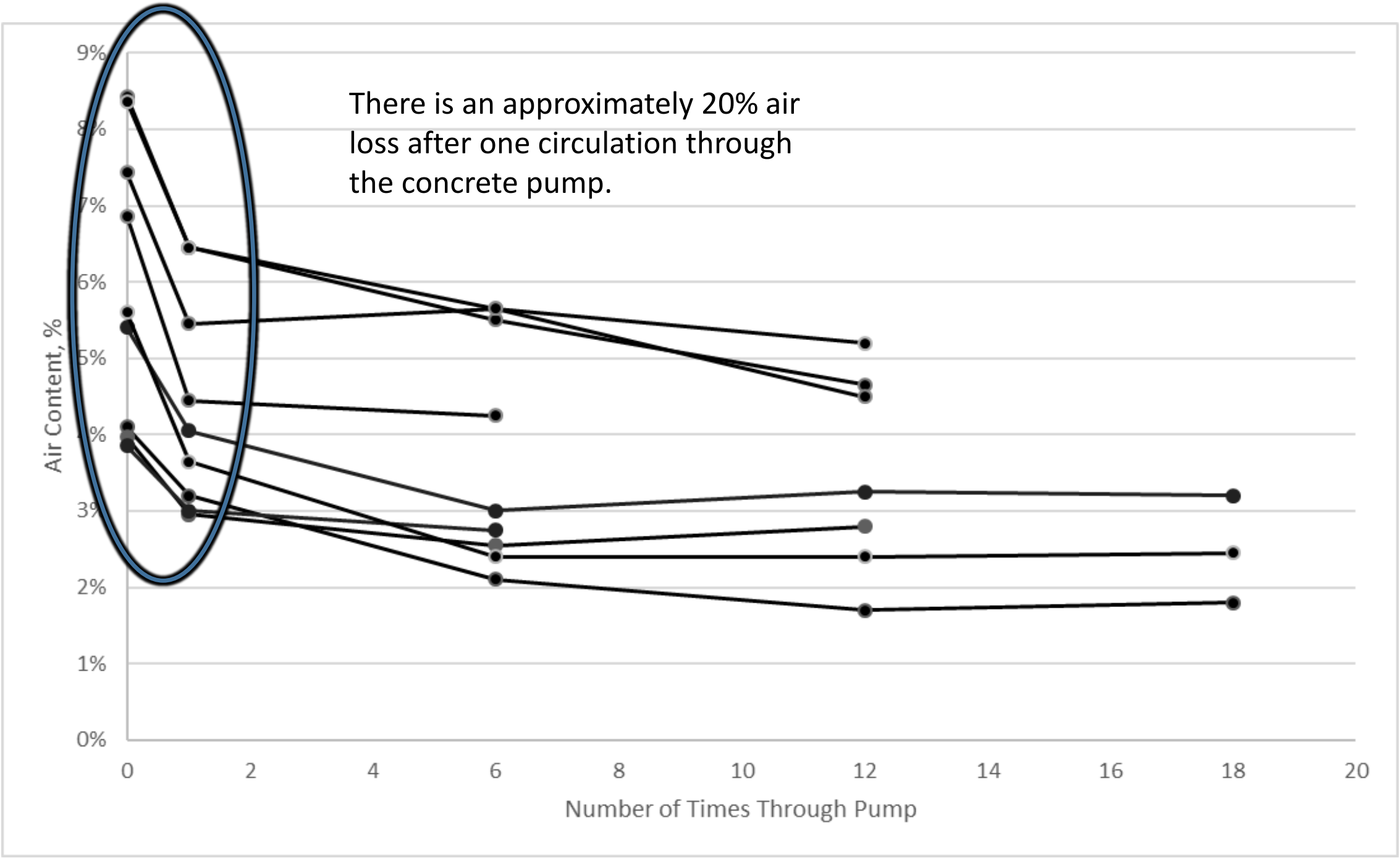
Recirculation Procedure

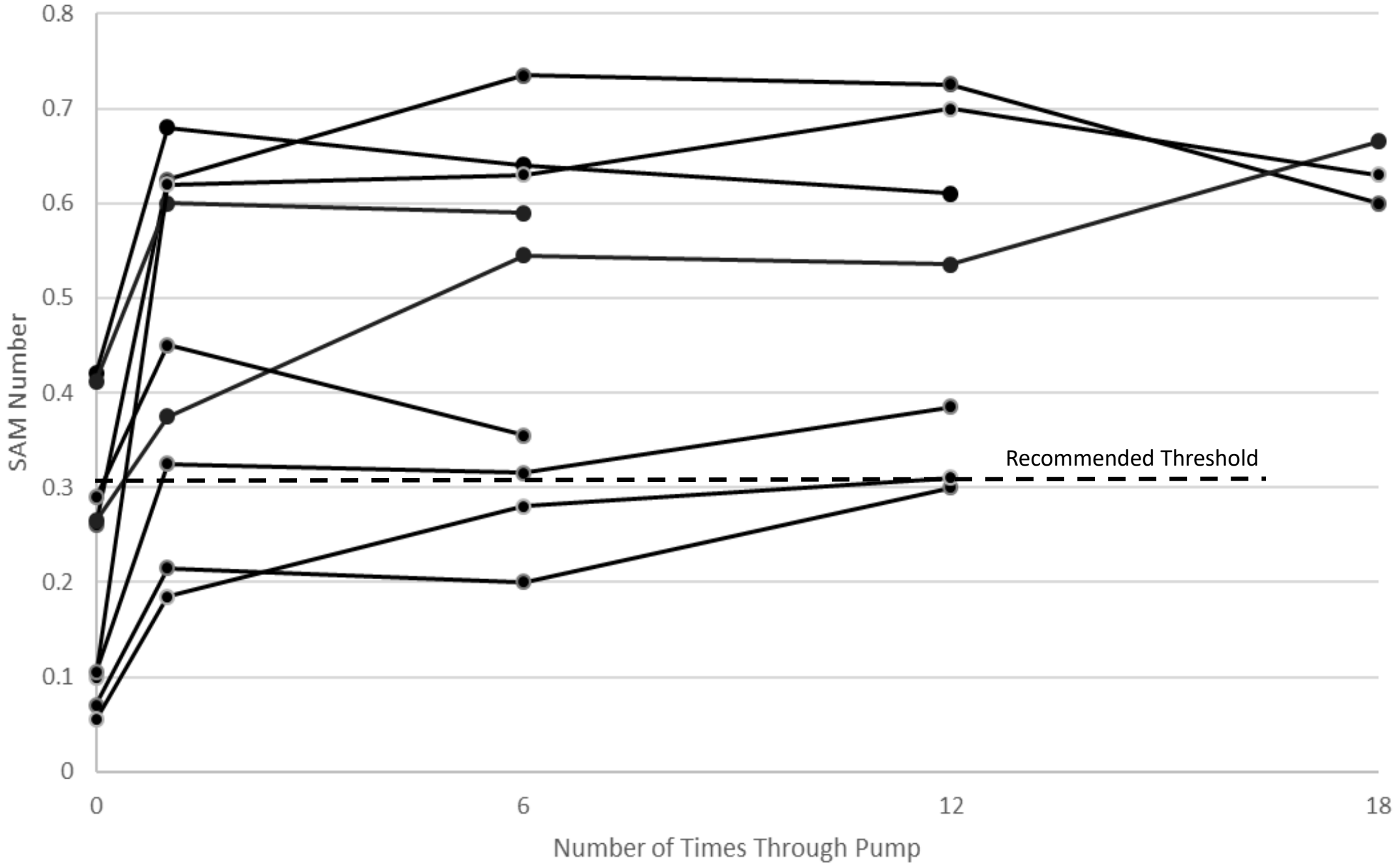


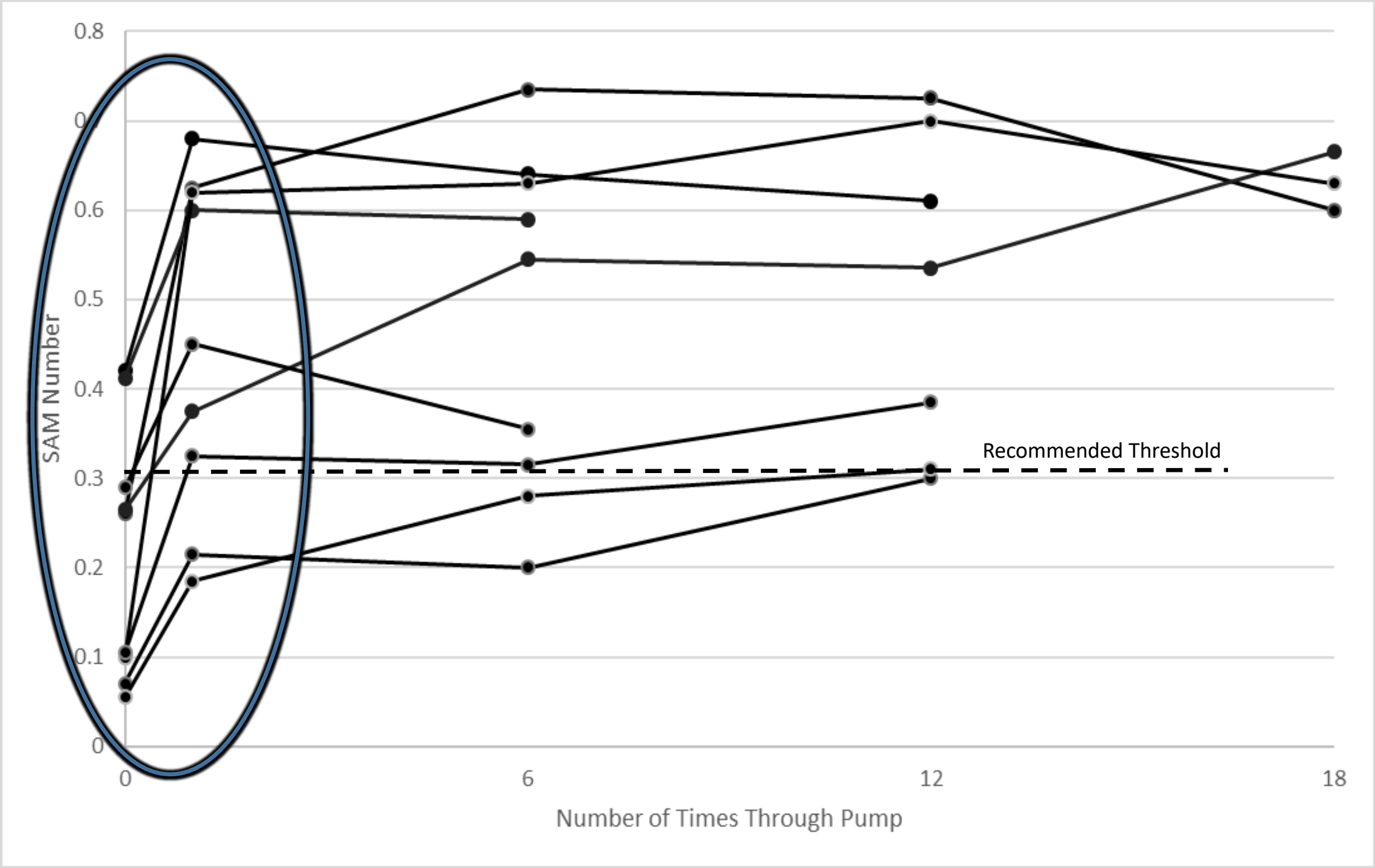
Testing Performed

1. Before Testing
2. After 1 cycle
3. Every 6 cycles after


9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
Air Content, %
0
2
4
6
8
10
12
14
16
18
20
Number of Times Through Pump


There is an approximately 20% air loss after one circulation through the concrete pump.
Air Content, %
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
0
2
4
6
8
10
12
14
16
18
20
Number of Times Through Pump


0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
SAM Number
Recommended Threshold
0
6
12
18
Number of Times Through Pump


0.8
0
0.6
0.5
0.4
0.3
0.2
0.1
0
SAM Number
Recommended Threshold
0
6
12
18
Number of Times Through Pump

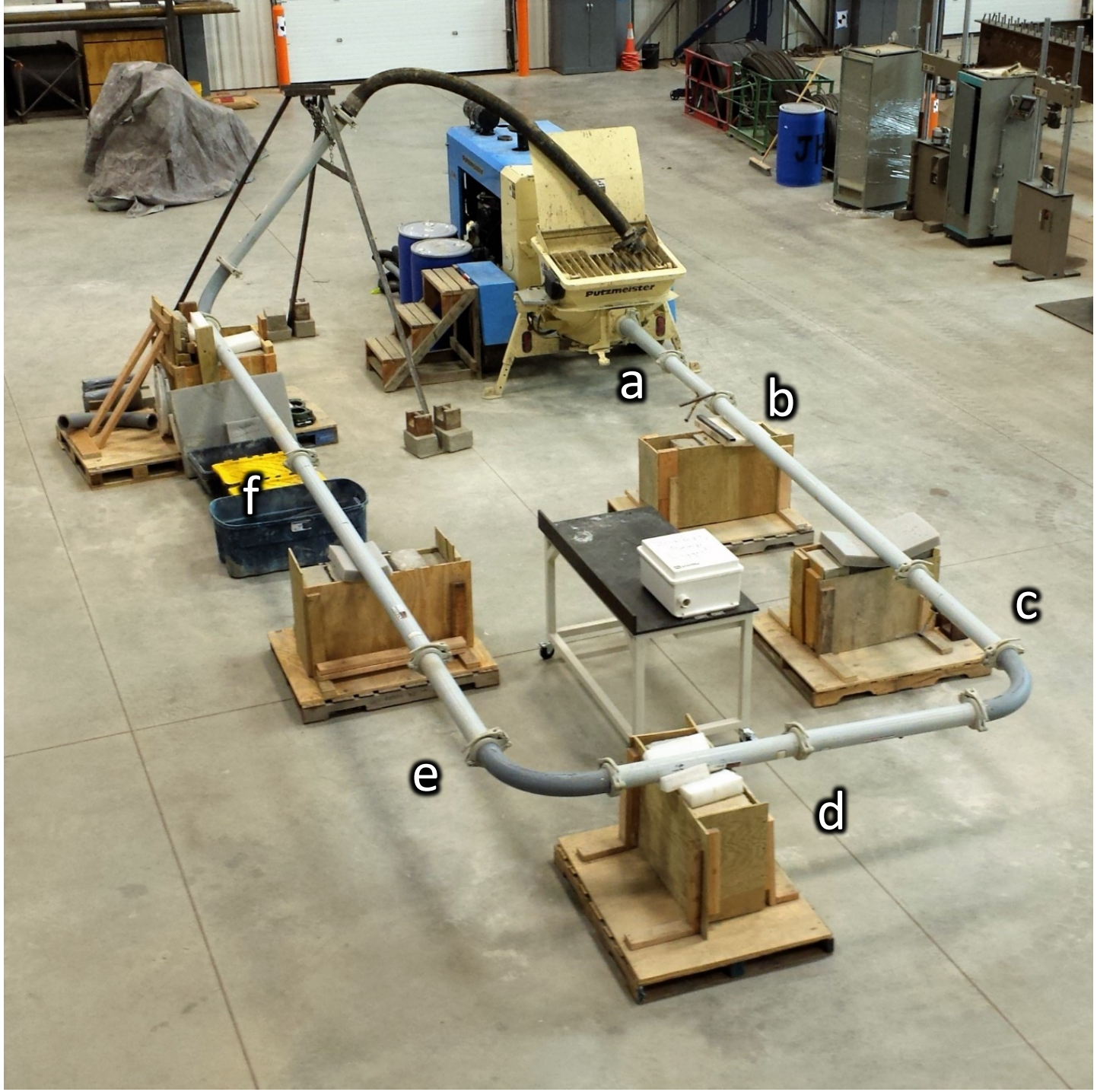
Fresh Concrete

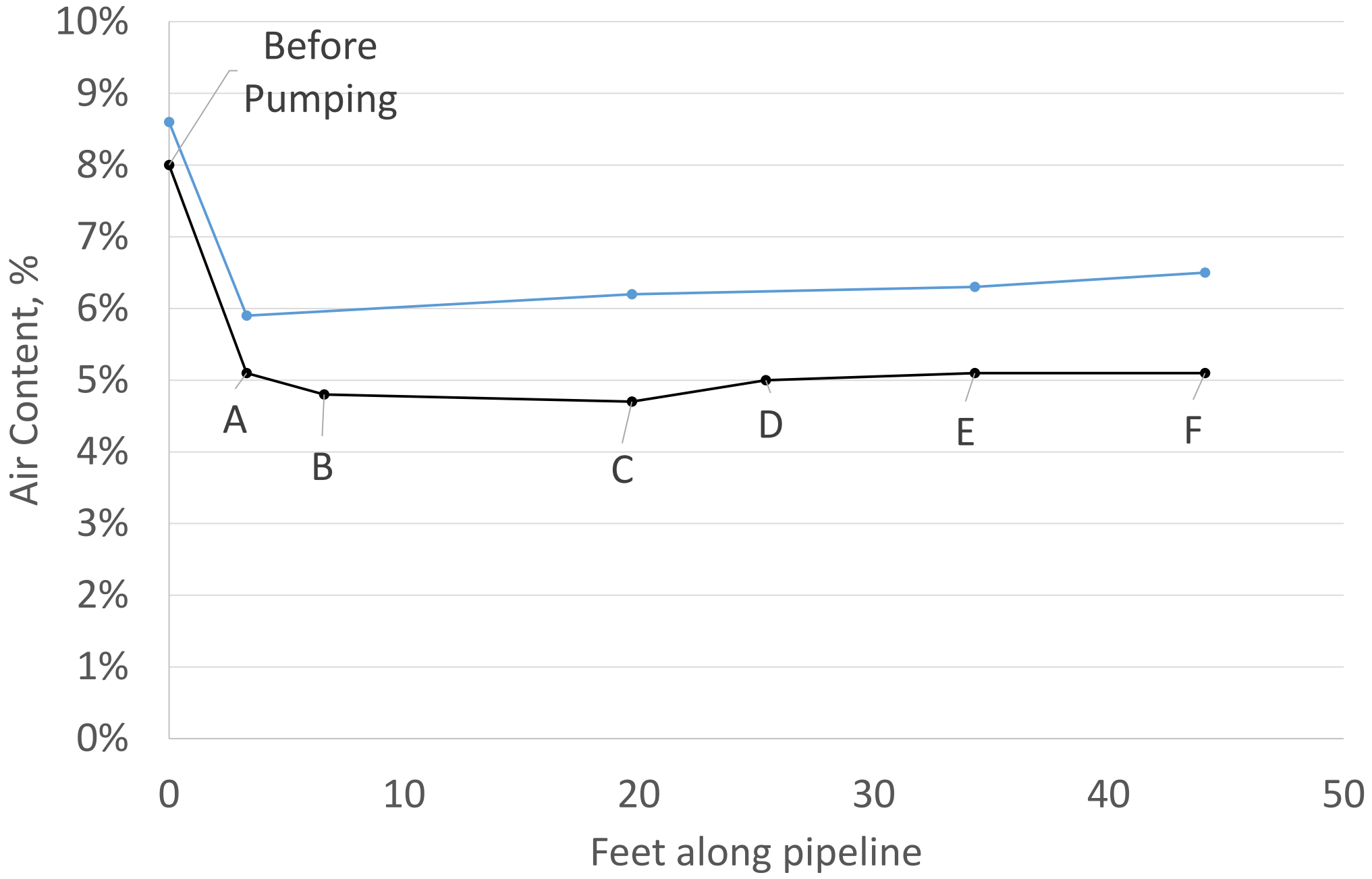
After one cycle

- Air content decreased
- SAM Number increased (air void system coarsened)

This means the air void system in the fresh concrete was changed due to pumping.

Where do the air voids change within the pump network?

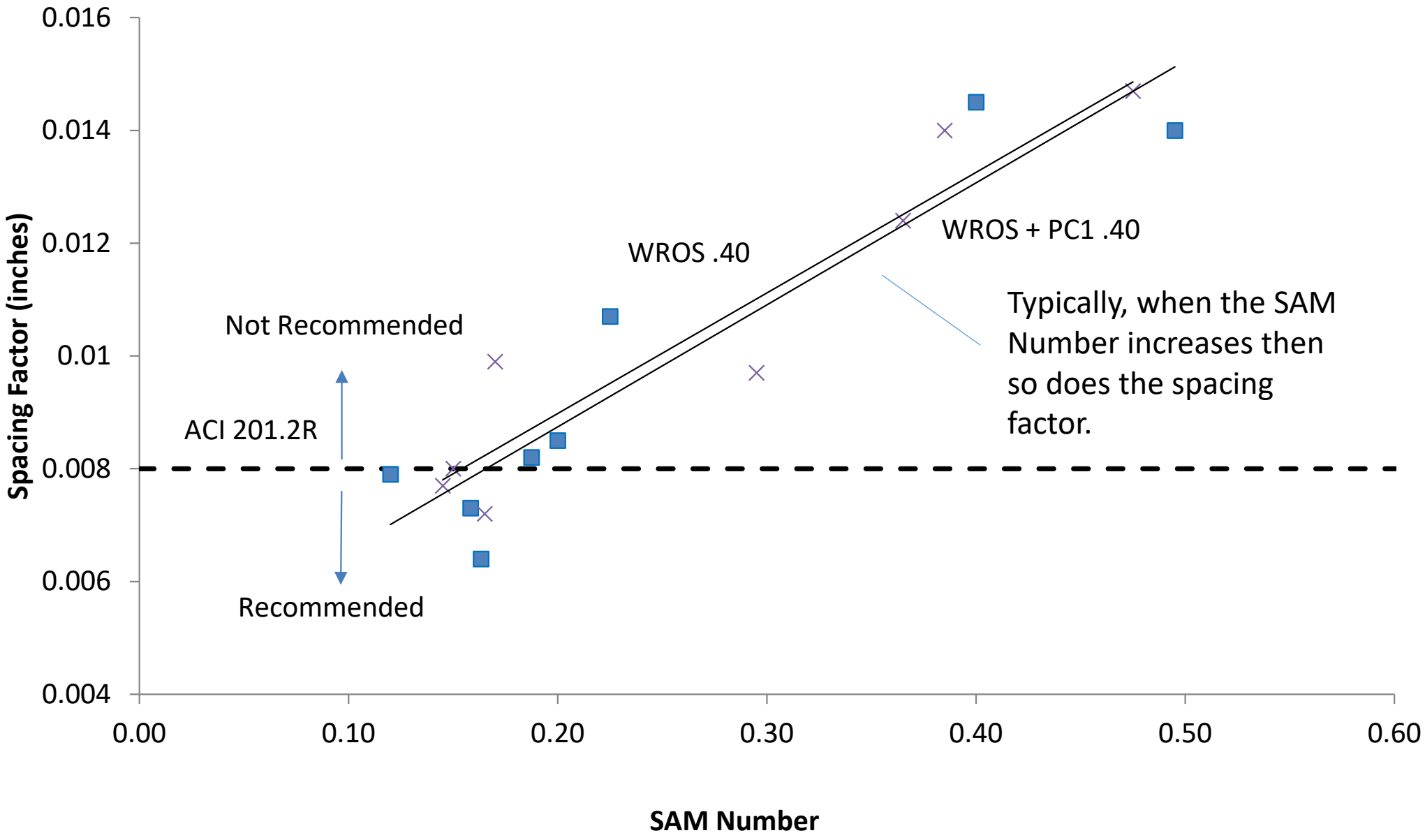

a
b
c
d
e
f
Putzmeister


10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
Air Content, %
Before
Pumping
A
B
C
D
E
F
0
10
20
30
40
50
Feet along pipeline

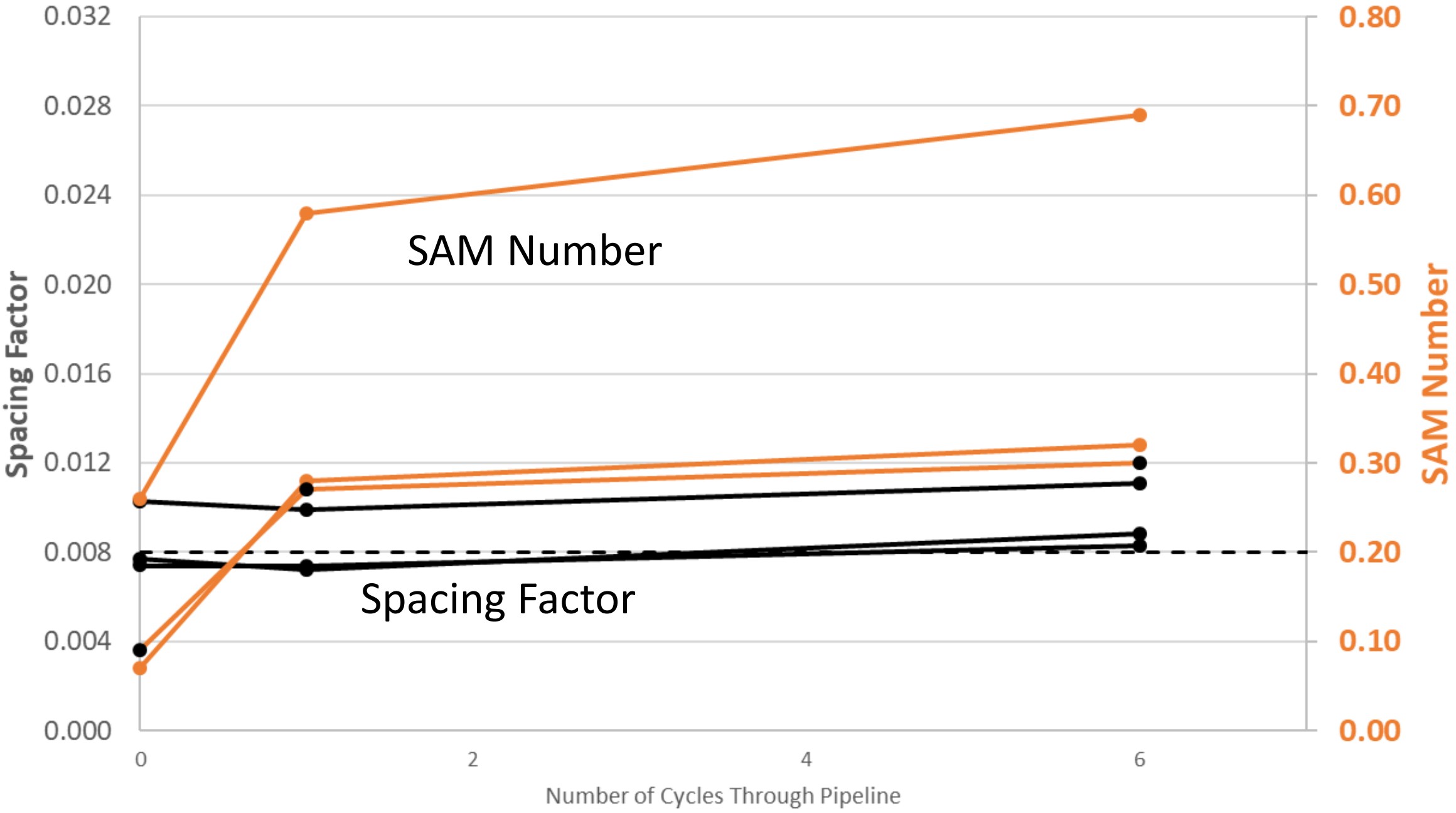
Fresh Concrete

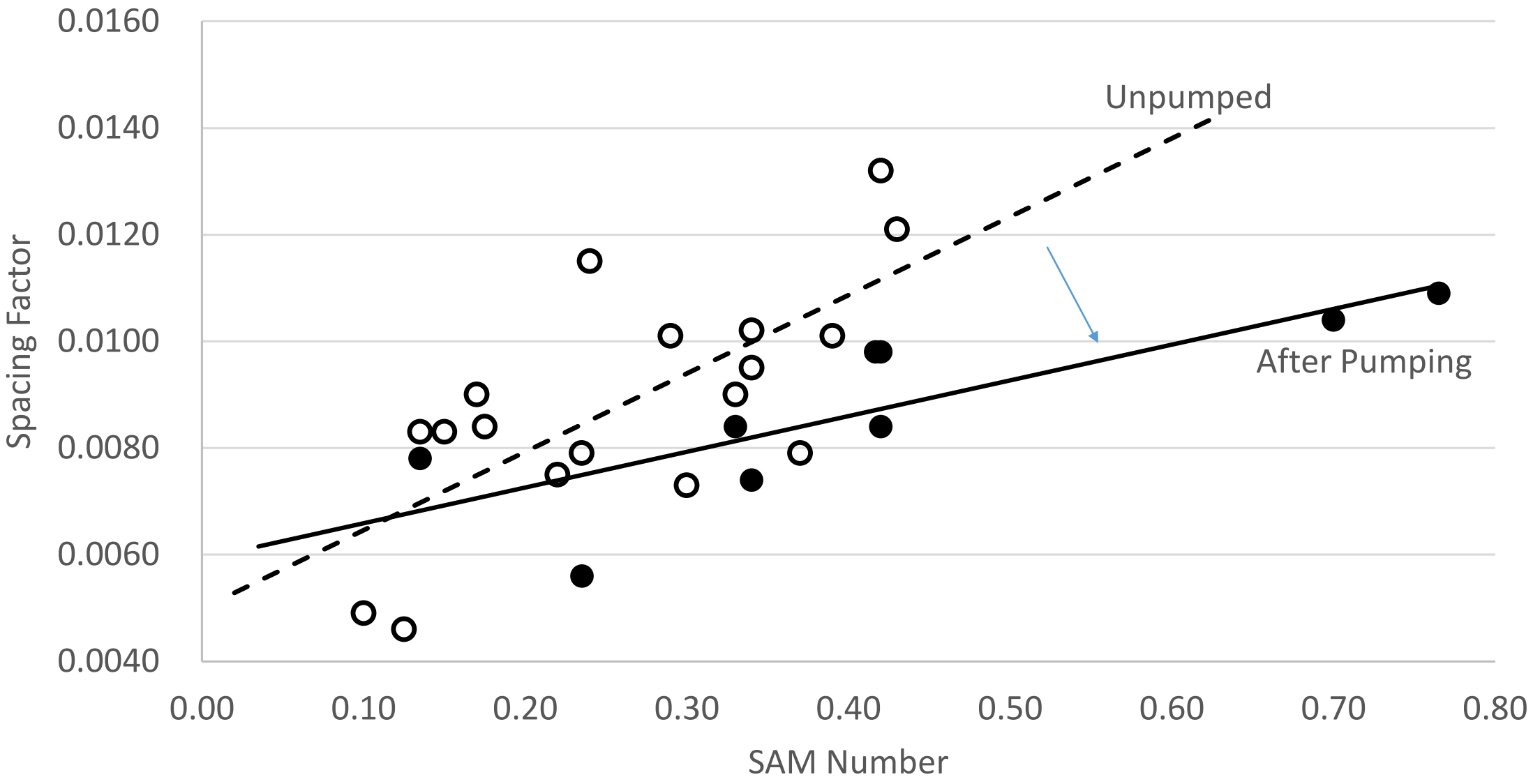
The air seems to change right after the pump and stay almost constant throughout the pipe network.

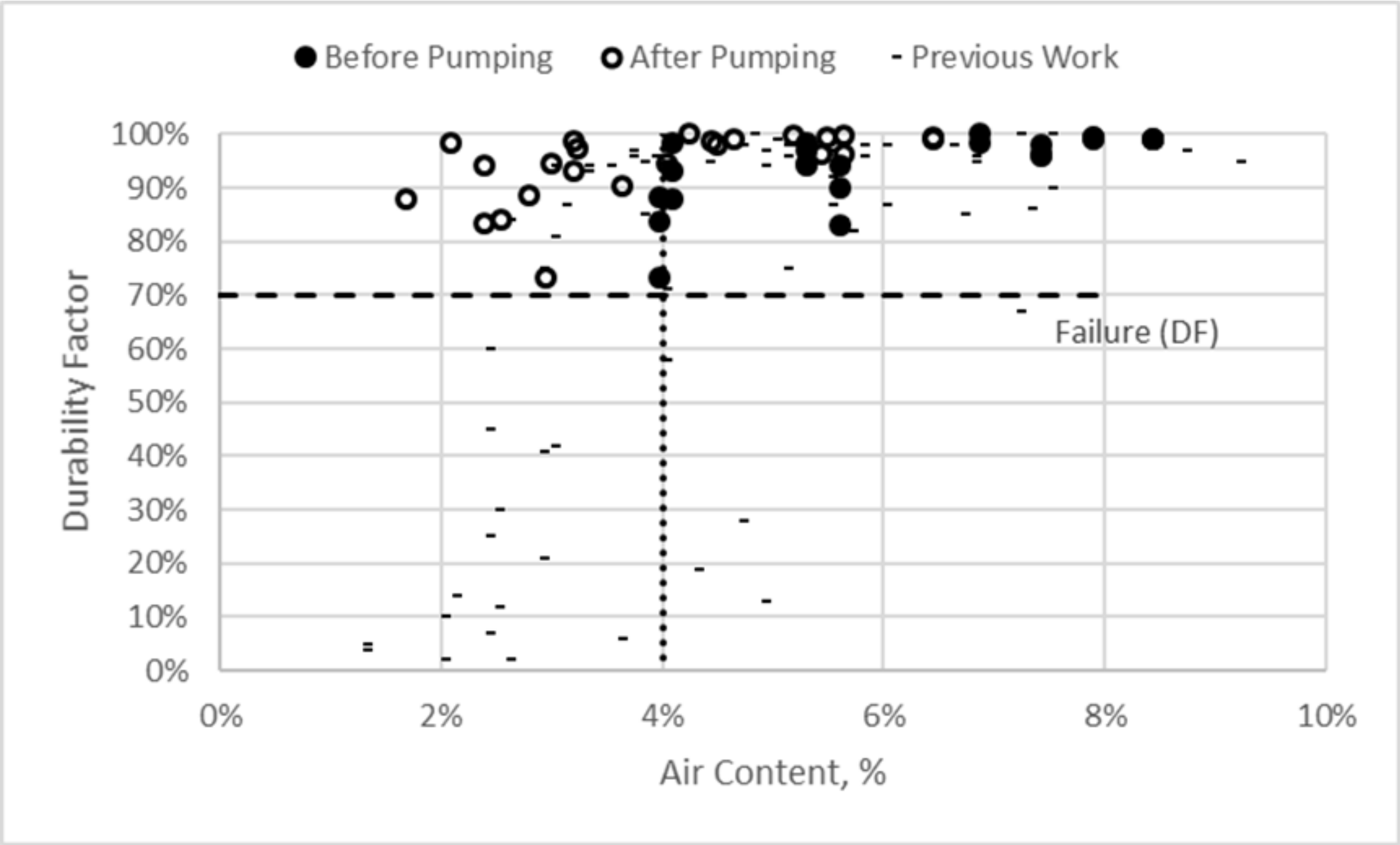
What about the hardened concrete?

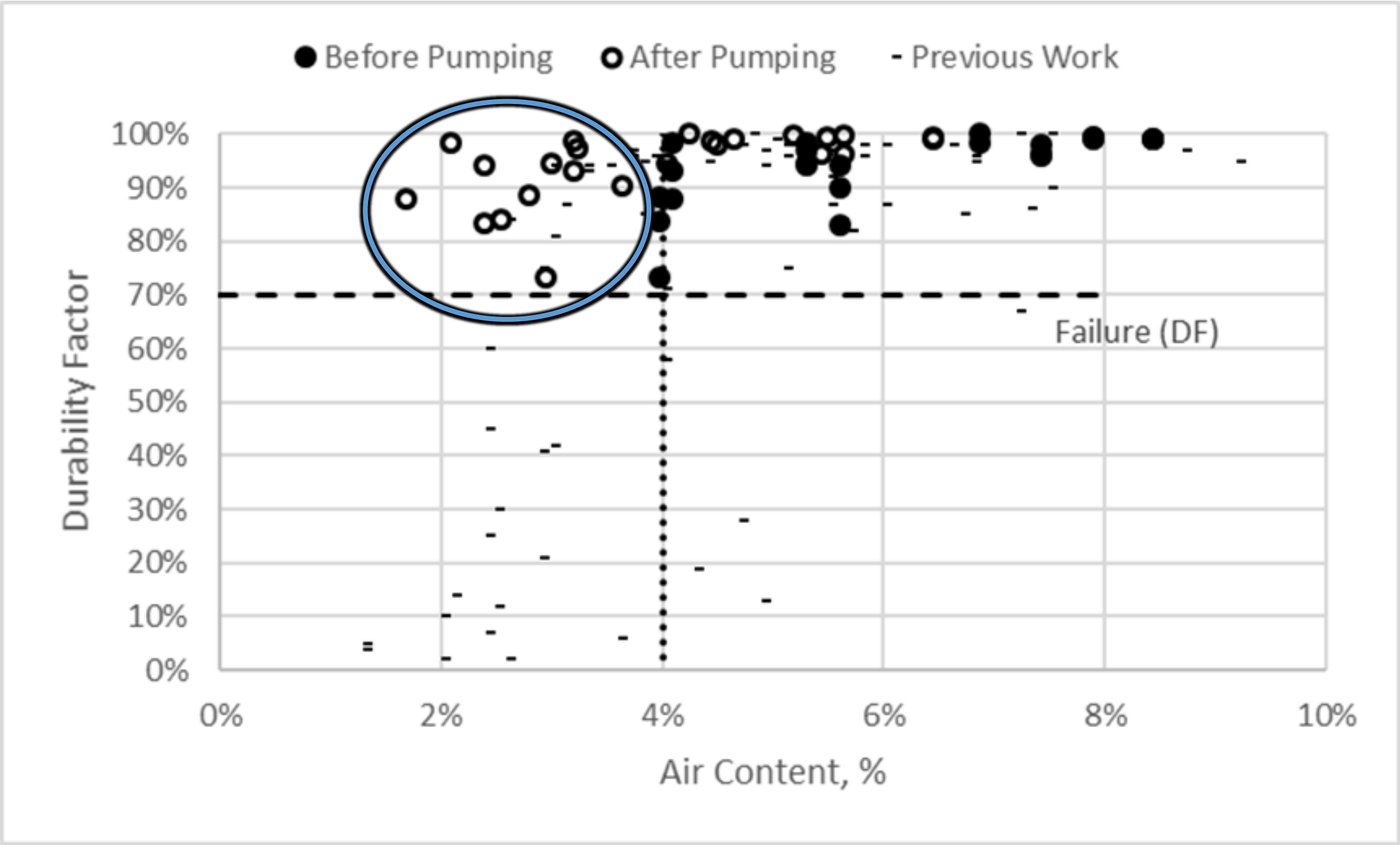


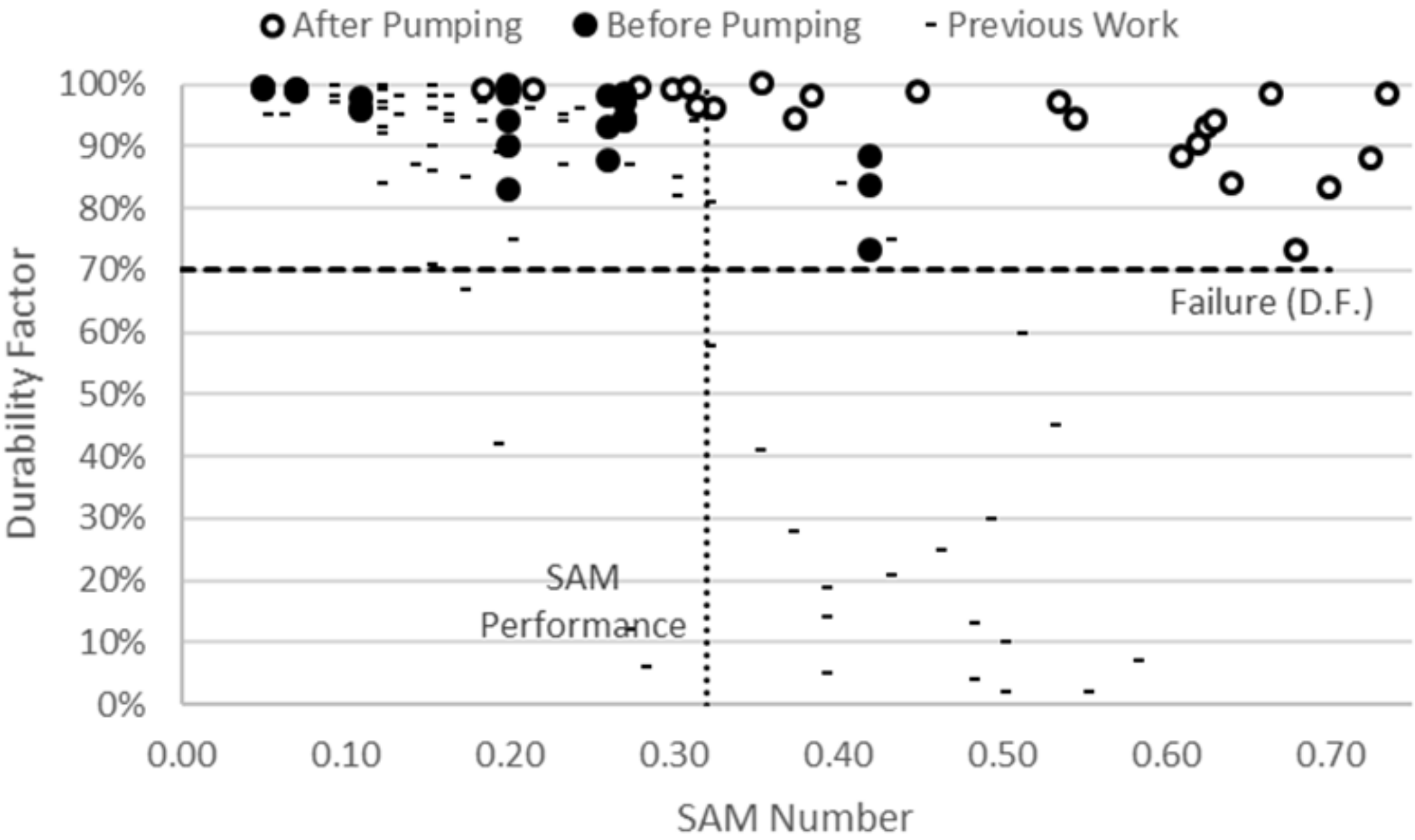
Ley et al., 2017

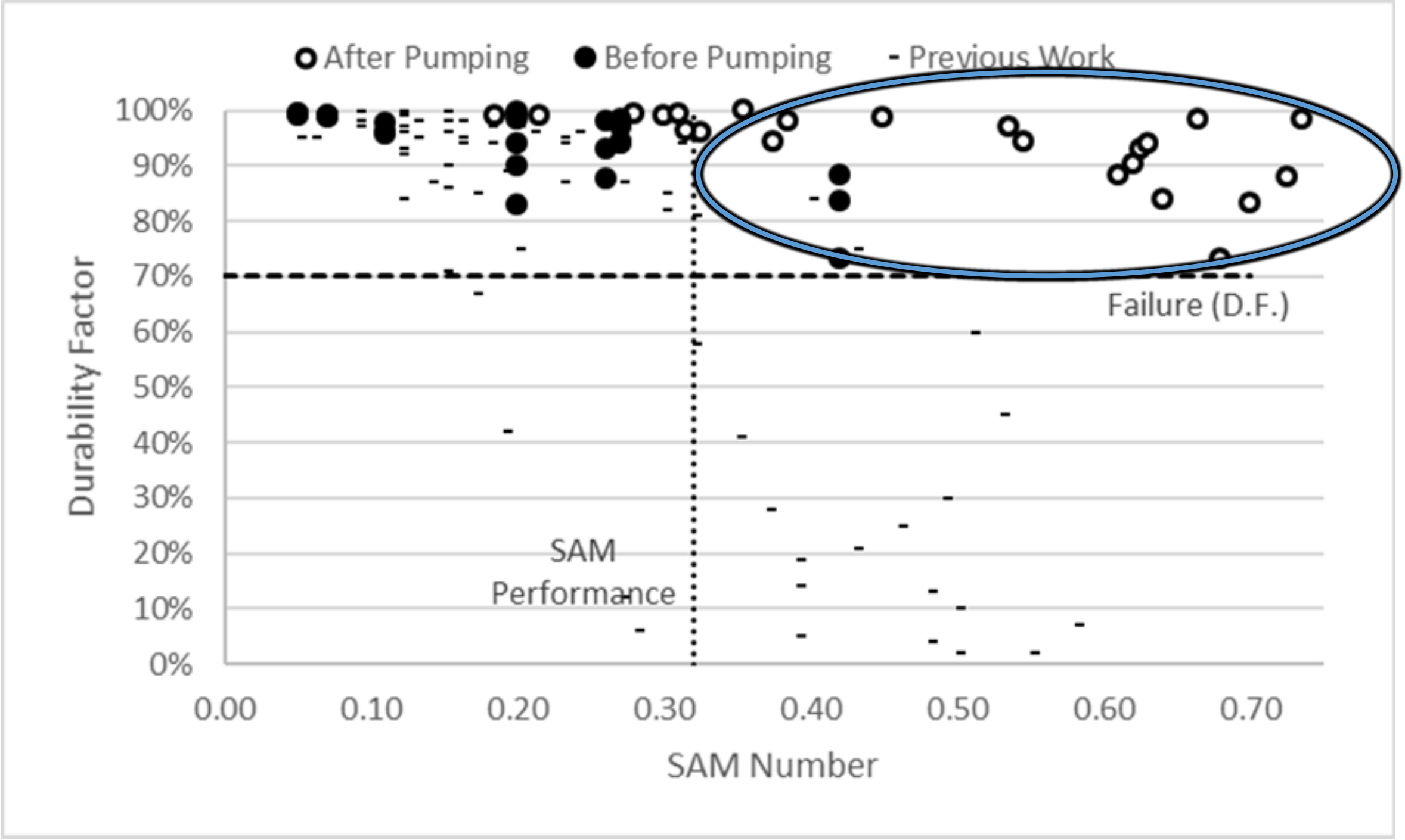

0.032
0.028
0.024
0.020
0.016
0.012
0.008
0.004
0.000
Spacing Factor
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
SAM Number
SAM Number
Spacing Factor
0
2
4
6
Number of Cycles Through Pipeline


0.0160
0.0140
0.0120
0.0100
0.0080
0.0060
0.0040
Spacing Factor
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
SAM Number
Unpumped
After Pumping


Before Pumping
After Pumping
Previous Work
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Durability Factor
Failure (DF)
0%
2%
4%
6%
8%
10%
Air Content, %


Before Pumping
After Pumping
Previous Work
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Durability Factor
Failure (DF)
0%
2%
4%
6%
8%
10%
Air Content, %


After Pumping
Before Pumping
Previous Work
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Durability Factor
Failure (D.F.)
SAM
Performance
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
SAM Number


After Pumping
Before Pumping
Previous Work
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Durability Factor
Failure (D.F.)
SAM
Performance
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
SAM Number

Hardened Concrete

- The SAM Number and spacing factor do not show the same relationship before and after pumping.
- Satisfactory freeze thaw performance of pumped concrete was observed even though there were low air contents and high SAM Numbers after pumping.
- Spacing factor results indicate little change from pumping in the quality of the air void system in the hardened concrete

Major finding

For the mixtures, equipment, and materials investigated, the measurements in the fresh concrete after pumping does not seem to be representative of the performance of the hardened concrete.

Does this hold for other equipment and mixtures?

Field Pumping Information

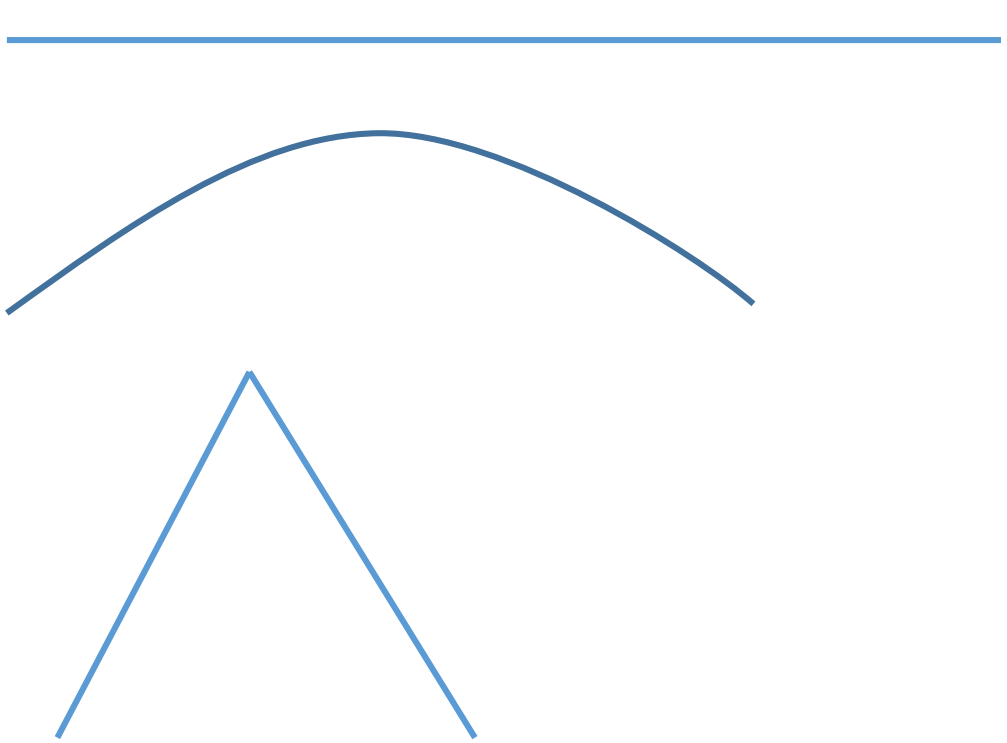
- 5” diameter pipe
- 120’ of steel pipe
- 10’ Rubber hose
- pumping pressures from 150 to 200 psi
- Used three different boom configurations

Flat

Arch

A-Frame

Pump configurations

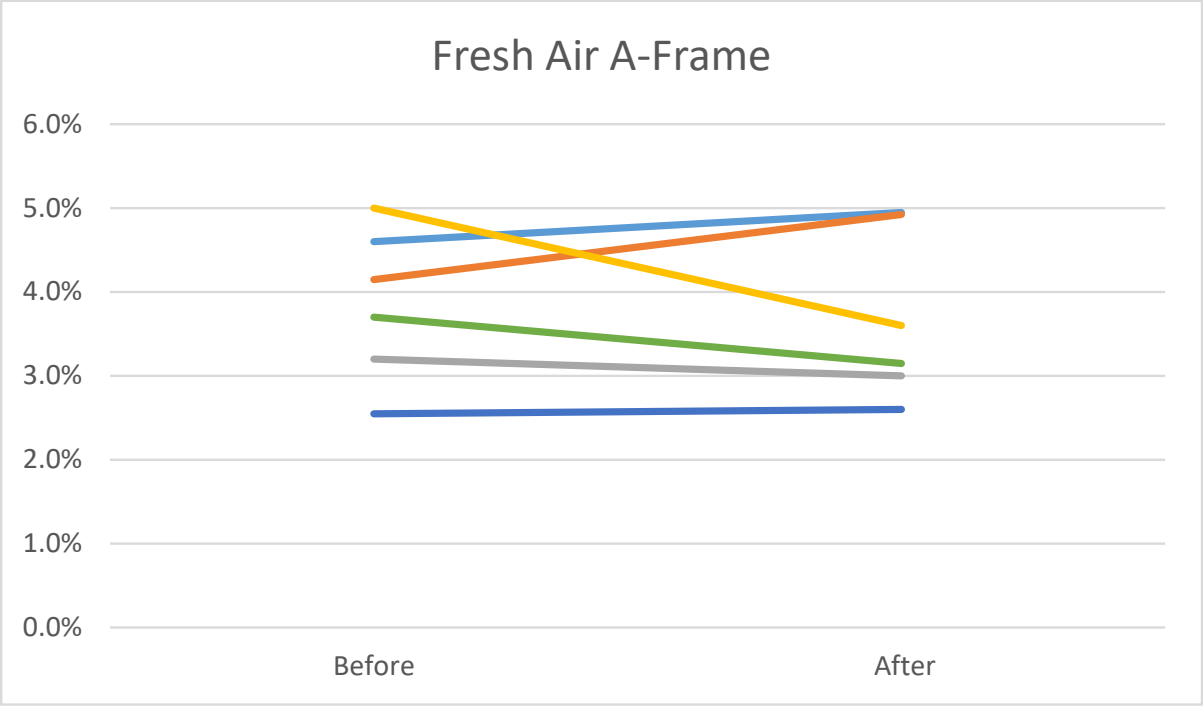


Flat

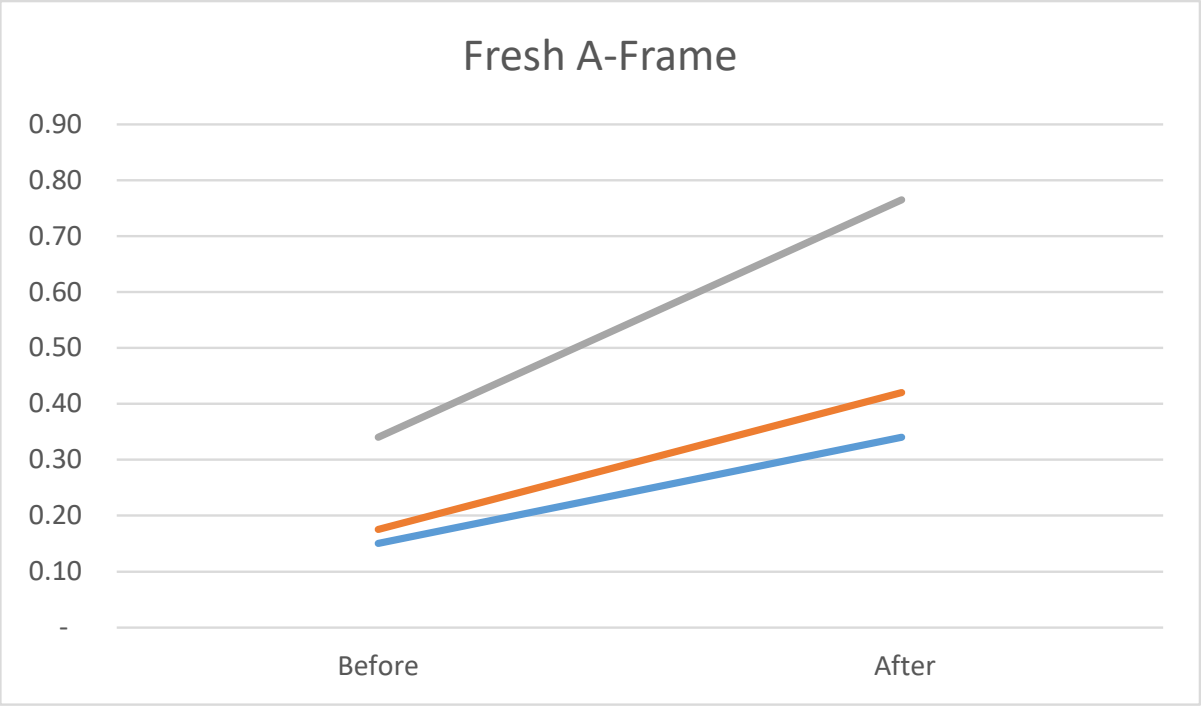
Arch

A-frame

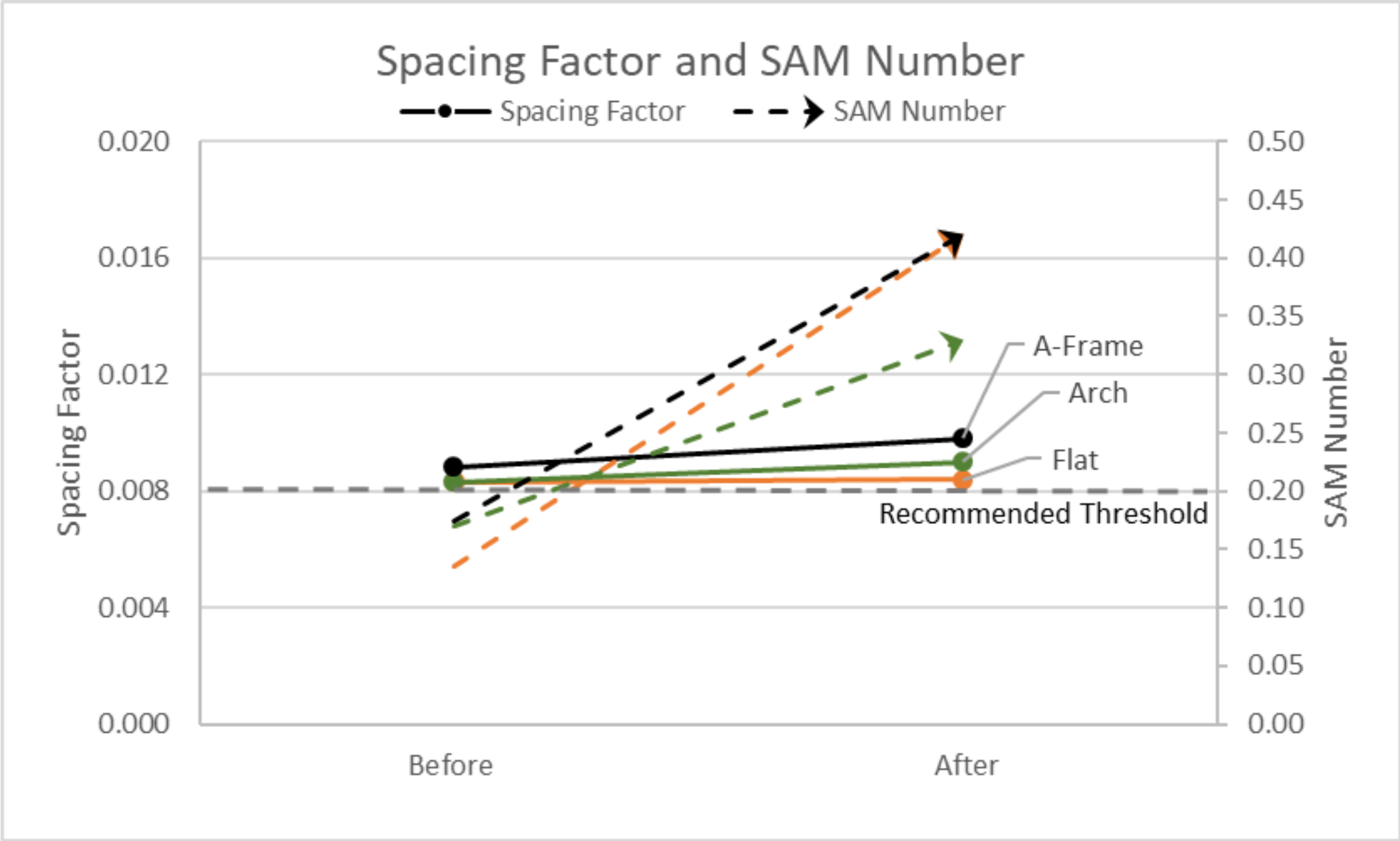
Air Content



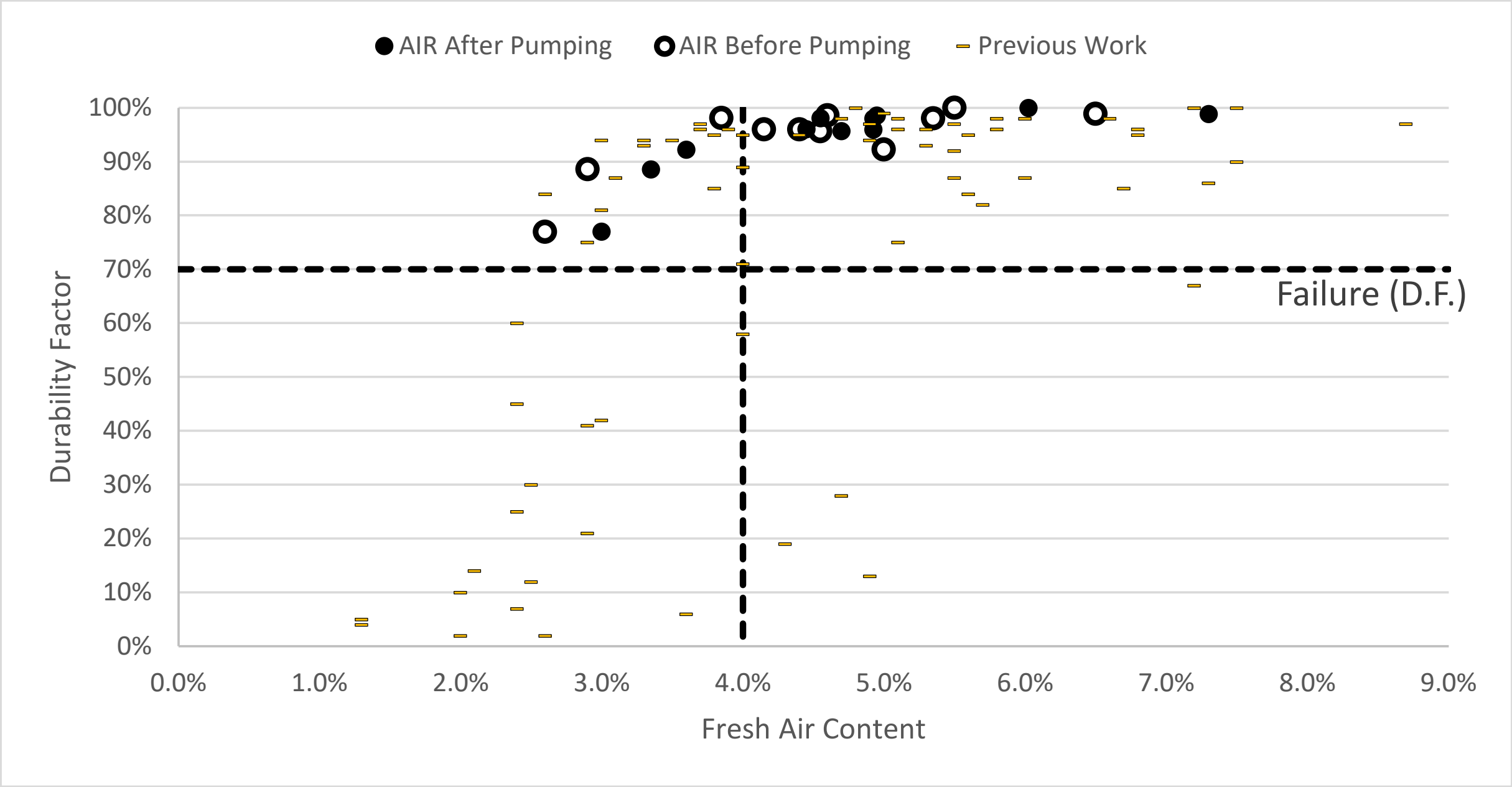
SAM Number



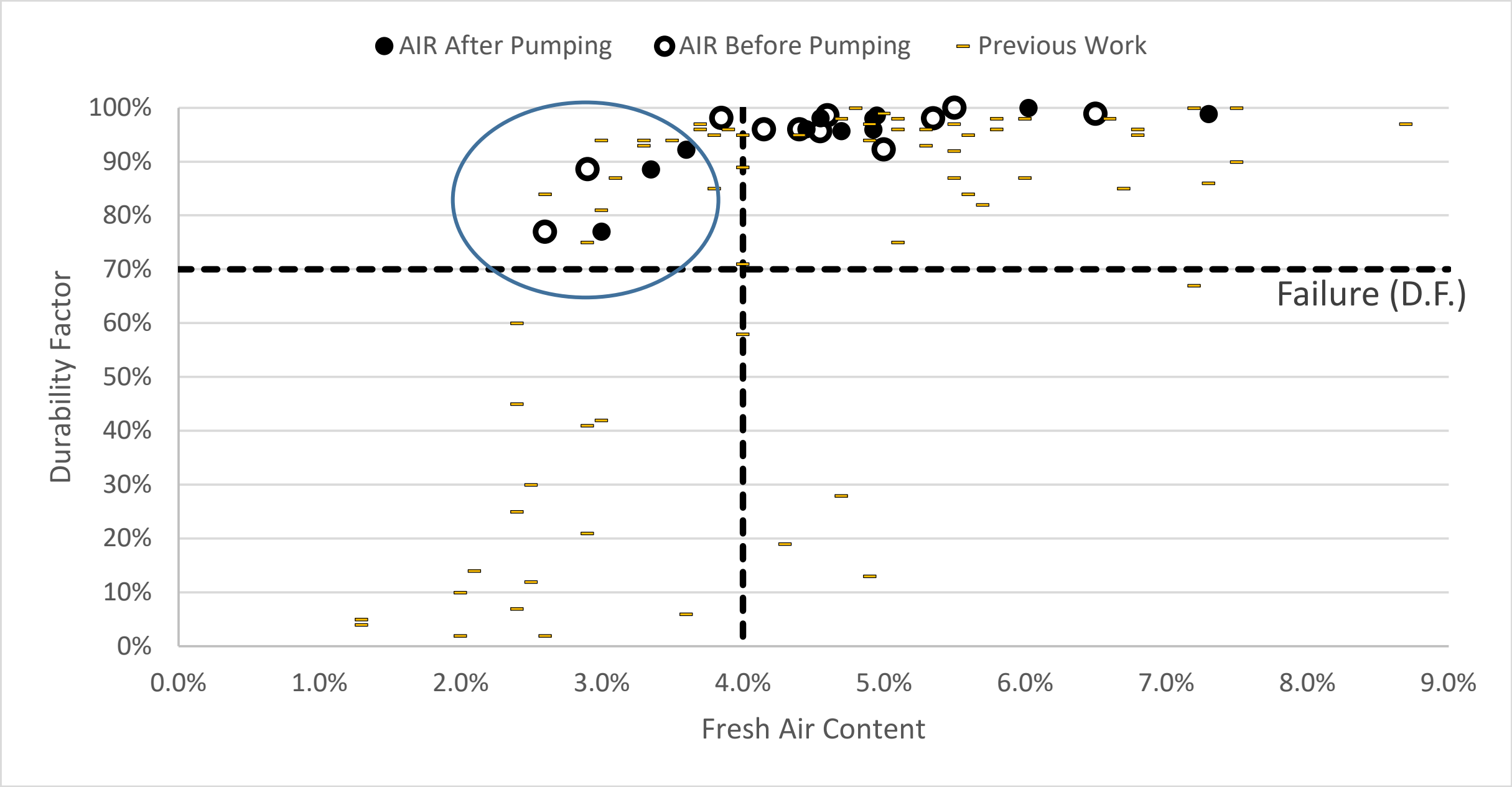
A-frame shown others have similar performance


Spacing Factor and SAM Number
Spacing Factor
SAM Number
0.020
0.016
0.012
0.008
0.004
0.000
Spacing Factor
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
SAM Number
A-Frame
Arch
Flat
Recommended Threshold
Before
After

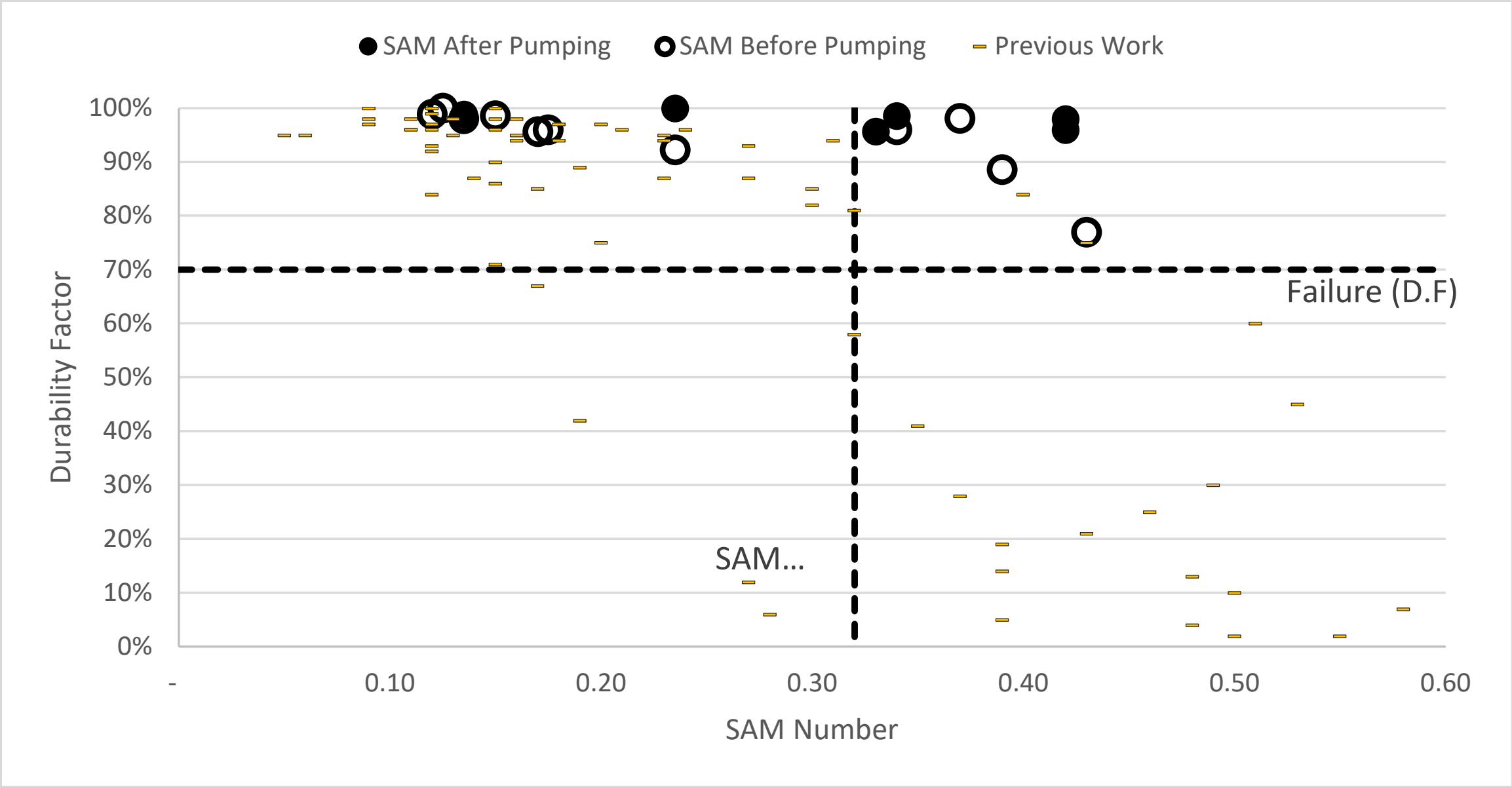
Field


AIR After Pumping
AIR Before Pumping
Previous Work
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Durability Factor
Failure (D.F.)
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Fresh Air Content

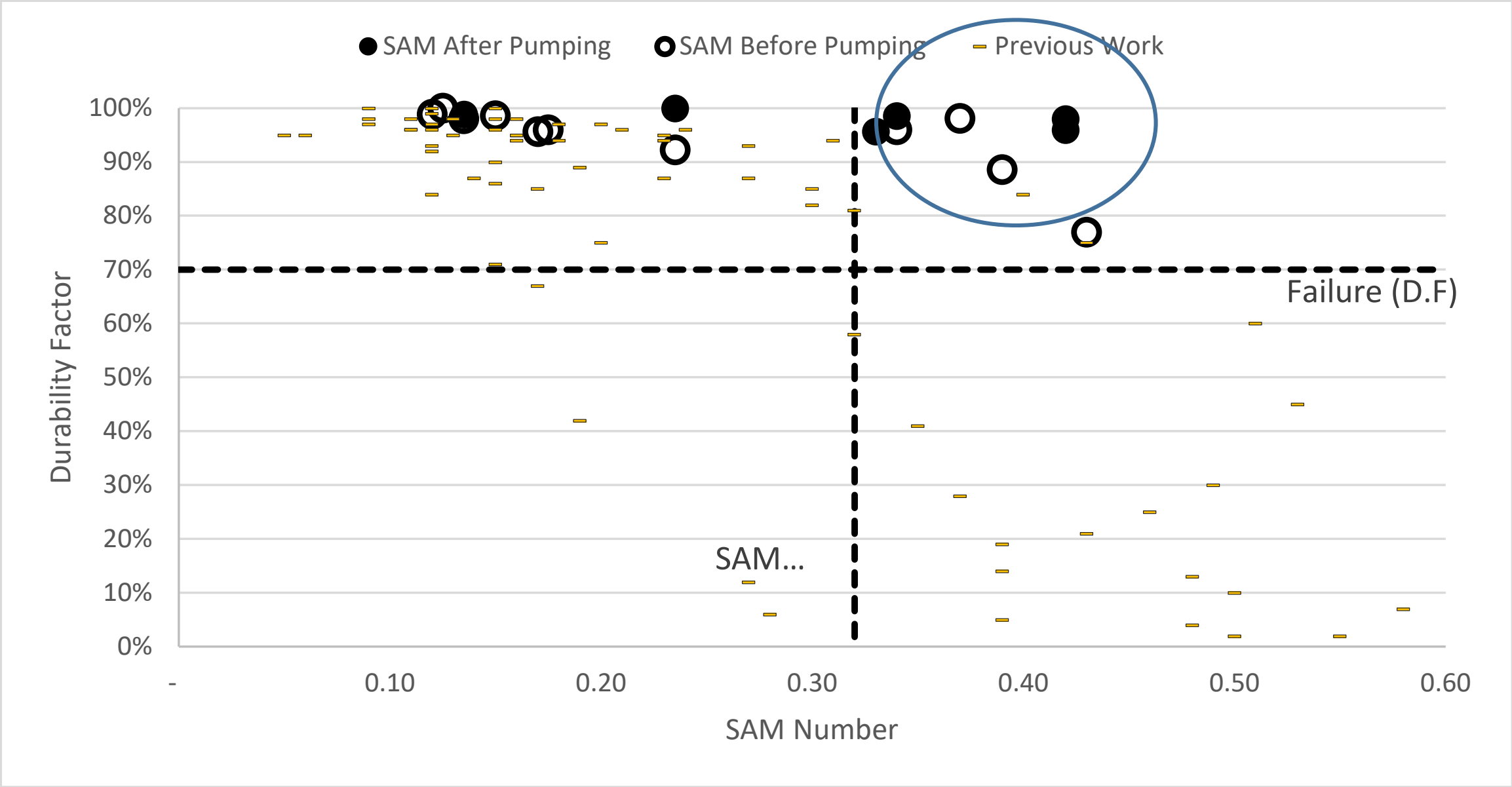
Field


AIR After Pumping
AIR Before Pumping
Previous Work
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Durability Factor
Failure (D.F.)
0.0%
1.0%
2.0%
3.0%
4.0%
5.0%
6.0%
7.0%
8.0%
9.0%
Fresh Air Content

Field


SAM After Pumping
SAM Before Pumping
Previous Work
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Durability Factor
Failure (D.F)
SAM...
-
0.10
0.20
0.30
0.40
0.50
0.60
SAM Number

Field

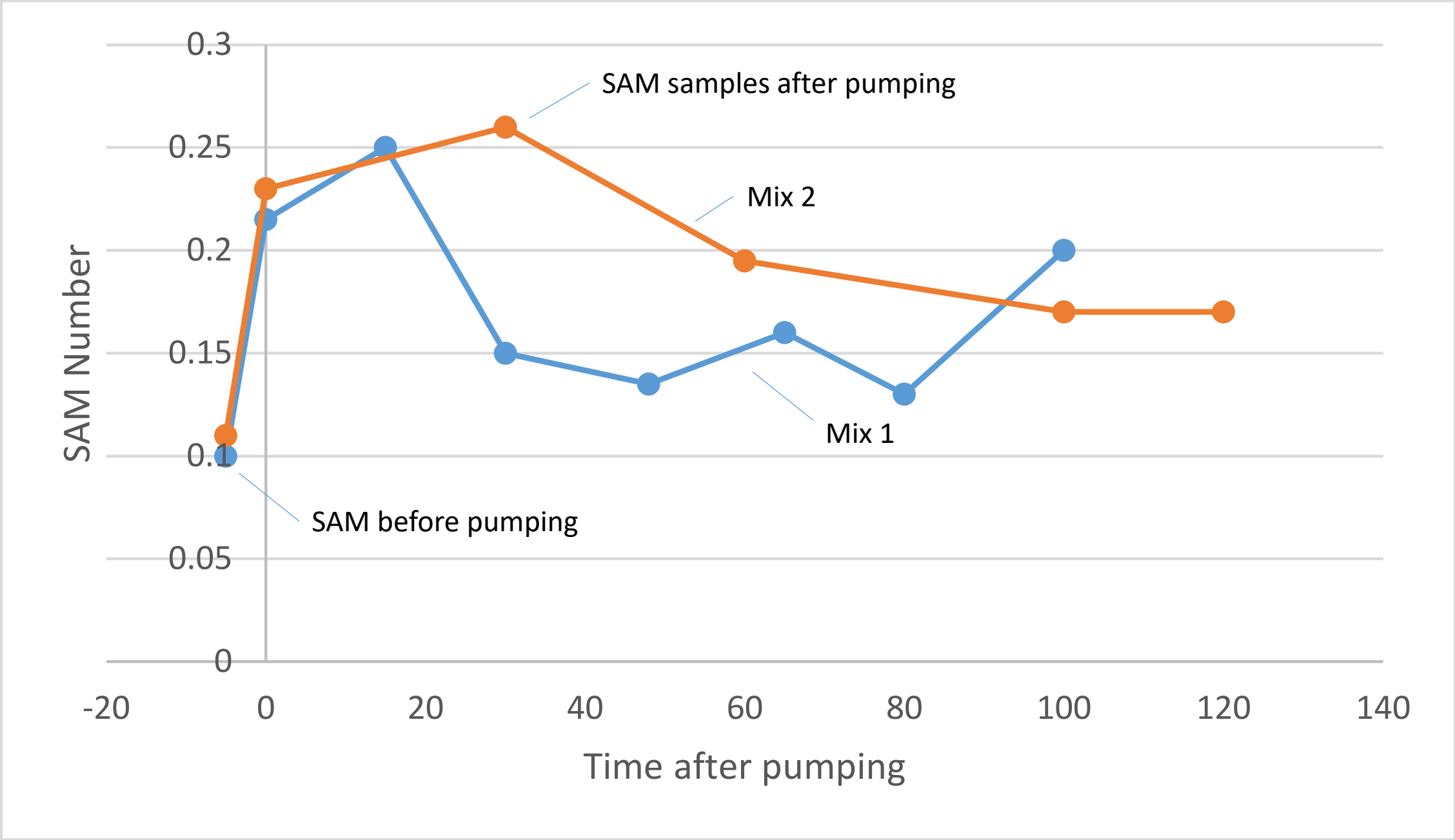

SAM After Pumping
SAM Before Pumping
Previous Work
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Durability Factor
-
0.10
0.20
0.30
0.40
0.50
0.60
SAM Number
Failure (D.F)
SAM...

Discussion

- The air content did not always decrease on the field samples but the SAM Number was still observed to change.
- We are seeing similar things in the lab and the field.

SAM over time

- In order to learn more we decided to do a pump mixture in the lab and then measure the change in the SAM Number over time.


0.3
0.25
0.2
0.15
0.1
0.05
0
SAM Number
-20
0
20
40
60
80
100
120
140
Time after pumping
SAM samples after pumping
Mix 2
Mix 1
SAM before pumping

What might be happening???

- The pressures from pumping cause the small bubbles to <u>temporarily</u> dissolve

- Good performance in the petrographic analysis, freeze-thaw testing, and reducing SAM Number over time suggests that the **dissolved air comes back before the concrete hardens**.

- When the air comes back it seems to be well dispersed and provides a similar spacing factor to what went into the pump.

What does this mean?

- Air Content and SAM testing after pumping may not be representative of the hardened concrete.

- One should be hesitant to reject concrete for low air or high SAM Number after pumping.

- It appears that sampling the concrete prior to pumping is a good indicator to the air void system in the hardened concrete.

Conclusion

- The SAM was an invaluable tool to give insights into the performance of air before and after a concrete pump.

- Pumping was observed to modify the air content and SAM Number in both the lab and the field testing.

- Based on the hardened air void analysis, freeze thaw testing, and changing SAM Number over time, the air seems to return to the concrete with similar volume and spacing as was in the concrete before pumping.

Disclaimer

- Pumping and air is one of the black arts of concrete.
- These results were based on 16 lab and 18 field mixtures with a limited set of admixtures.
- However, the results are consistent and the recommendations are not based on a single measurement.

I need your help!!!

- I want to prove this is happening on a wide range of concrete.
- I need you to use the SAM to investigate concrete before pumping and make a hardened sample of concrete.
- I need you to then investigate the concrete with the SAM after pumping and take a hardened sample.

I need your help!!!

- Please run the SAM within 10 min of discharge from the pump.
- Please record as much information about the mixture, pump setup, and pump details as possible.

What should happen

- The hardened air void analysis before and after pumping should have similar values.

- The majority of the air content and SAM Numbers should be different before and after the pump.

- This will be very valuable data and can give us more insight into what is happening.

Questions?

www.tylerley.com

Please subscribe to my concrete YouTube channel!

Go here!

A Clue!!!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Hardened Air Content