Fresh Properties of Blended Cements

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Lifetouch

Not all people are the same and so we shouldn’t expect them to behave the same.

Not all **cements** are the same and so we shouldn’t expect them to behave the same.

Limestone Cement

Currently, 70% of the domestic cement market

Controversy over the performance

Some states report issues, and others do not.

Two part discussion

Part 1 – Fresh properties

Part 2 – Curing

Project is finished in June

Two part discussion

Part 1 – Fresh properties

Part 2 – Curing

Project is finished in June

What is the goal?

Data!

Establish tools to quantify performance.

About me

Texas DOT

Zachry Construction

Work with contractors on troubleshooting and mixture designs

Professor at Oklahoma State University, 18 y

Award winning teacher and researcher

PhD, PE

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Structural Cracking in Reinforced Concrete

Tyler Ley, PE, PhD

> 124K subscribers
> 13 M views

Structural Cracking in Reinforced Concrete

Tyler Ley, PE, PhD

www.youtube.com/tylerley

Acknowledgements

American Society of Concrete Contractors

Cement Producers and the ACA for some great discussion.

Overview

16 - 1L cements

1 – I/II cement

One plant made both a Type I/II and 1L

The project ends in June.

What tests are we running on the cement?

- XRF
- XRD
- Limestone content
- Blaine
- Particle Size Analysis
  - Liquid and Dry

What concrete tests are we running?

- Slump
- Unit weight
- Air
- Strength (7, 28 days)
- Rheometer
- Calorimeter
- Set time
- Blead
- Phoenix (w/cm in fresh concrete)
- Float

What concrete tests are we running?

- Slump
- Unit weight
- Air
- Strength (7, 28 days)
- Rheometer
- Calorimeter
- Set time
- Blead
- **Phoenix (w/cm in fresh concrete)**
- **Float**

Phoenix - ASTM C 1953

Measures the w/cm of fresh concrete in 15 minutes with 0.01 w/cm accuracy.

Used by MnDOT to accept concrete on a major paving job.

Iowa, Kansas, Oklahoma, Wisconsin, FHWA MCTC

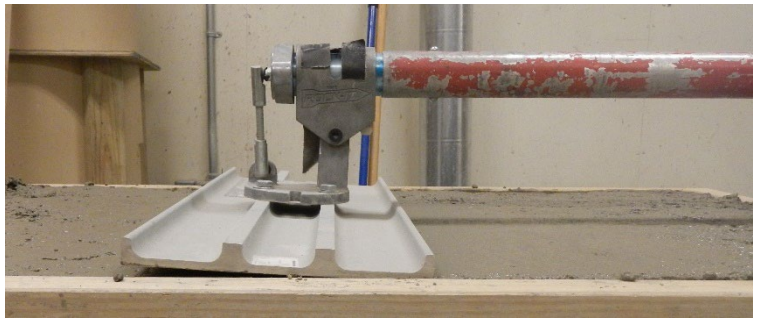
UNC Charlotte, Univ Arkansas + 10 more organizations

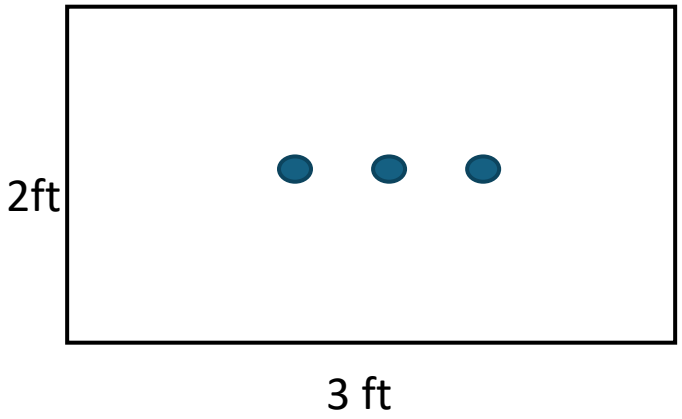
The Float Test

Evaluates the surface finish of a mixture.

Steps:

1. Place concrete in 3’ x 2’ x 3” forms and strike concrete
2. Create 3 known 1” diameter and 1” deep holes
3. Move bull-float at a fixed angle over surface at a constant speed
4. Measure number of passes to:
   -close the 3 holes
   -create a smooth finish





1. Place and Level Concrete

2. Create Three Holes

Place Template

Create Holes

3. Float Surface

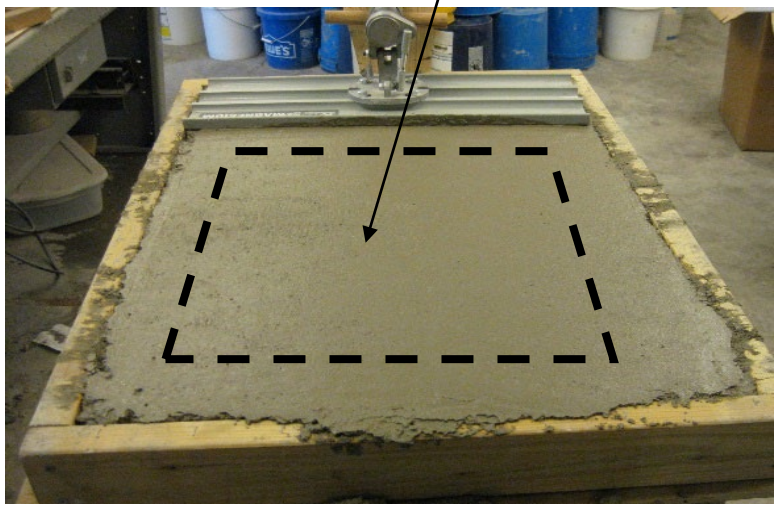
- The sides of the form are marked and a metronome is used to help the operator move at a constant rate.

The float is trimmed to only ride on the concrete

The yolk keeps the angle constant

First Pass with Bull Float

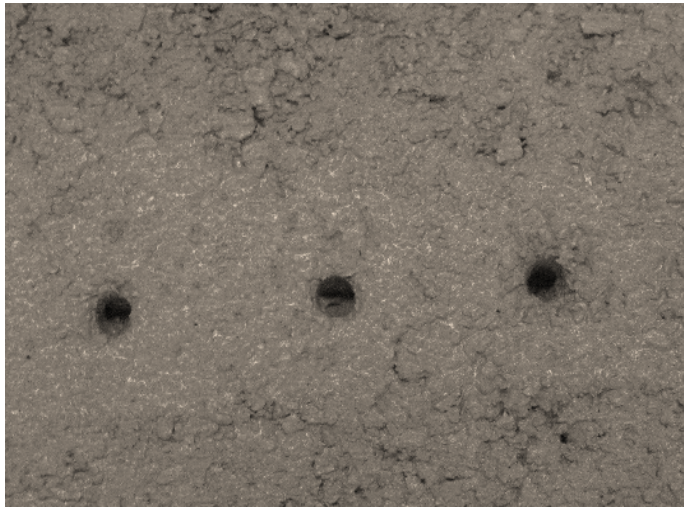
Evaluate only this area



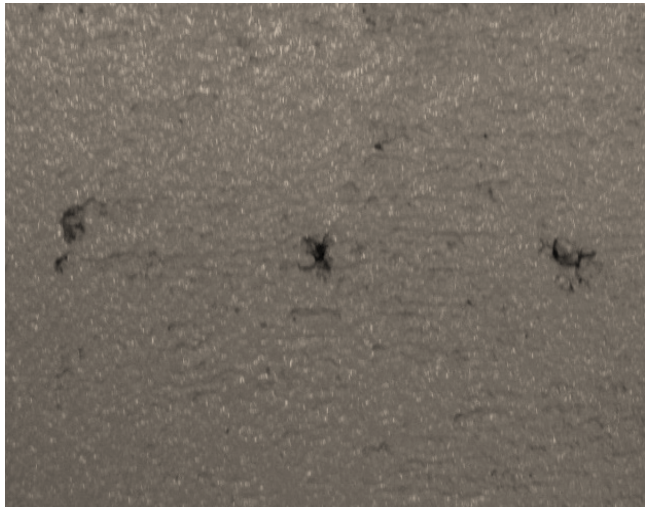
Last Pass with Bull Float

Example of Holes Closing

0 Passes



2 Passes



4 Passes

	
4	**3**
Over 50% of area was textured	30 to 50% of area was textured
	
2	**1**
10 to 30% of area was textured	Less than 10% of area was textured

	
4	**3**
Over 50% of area was textured	30 to 50% of area was textured
	
2	**1**
10 to 30% of area was textured	Less than 10% of area was textured

Discussion

The float test is a tool that you can use to quantitatively compare the performance of different mixtures.

We have used the float test with fibers, sand content, manufactured sands, etc.

It has been very valuable.

www.tylerley.com/float

Concrete mixture design

0.45 w/cm
6.5 sacks (no SCMs)
Dolomitic Limestone
Natural Sand

Sieved to get a constant gradation
Water checked with the Phoenix

Mid Range WR

How do we evaluate them?

Make a mixture and measure the initial slump with no water reducer (water slump)

Add water reducer to get a slump between 3” and 4”

Run tests

Keep in Mind

Not all cements are the same and so we do not expect them to perform the same.

A statistical significance test was used to determine the best correlations.

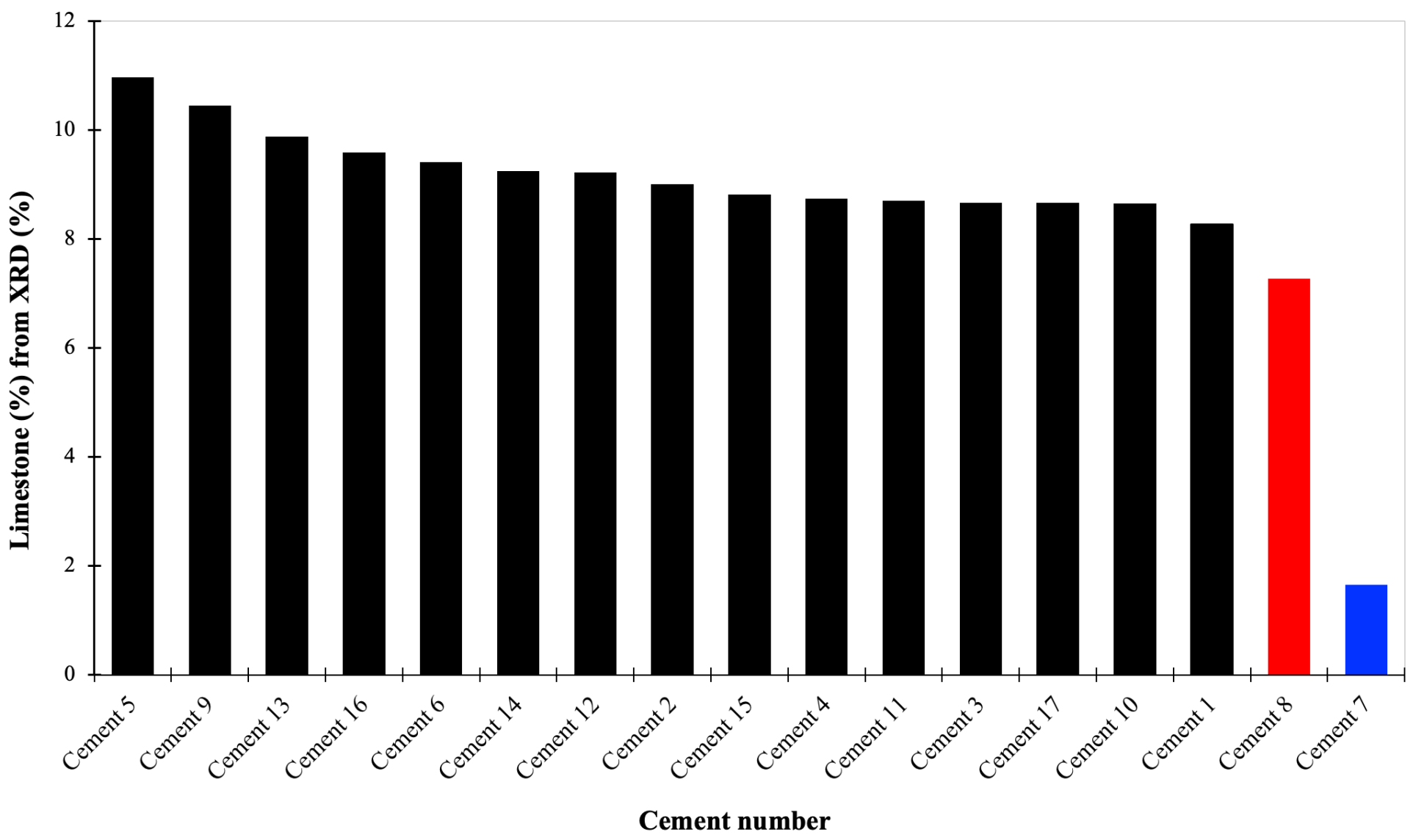
Only the best correlations are shown others will be discussed in the report.

Keep in Mind

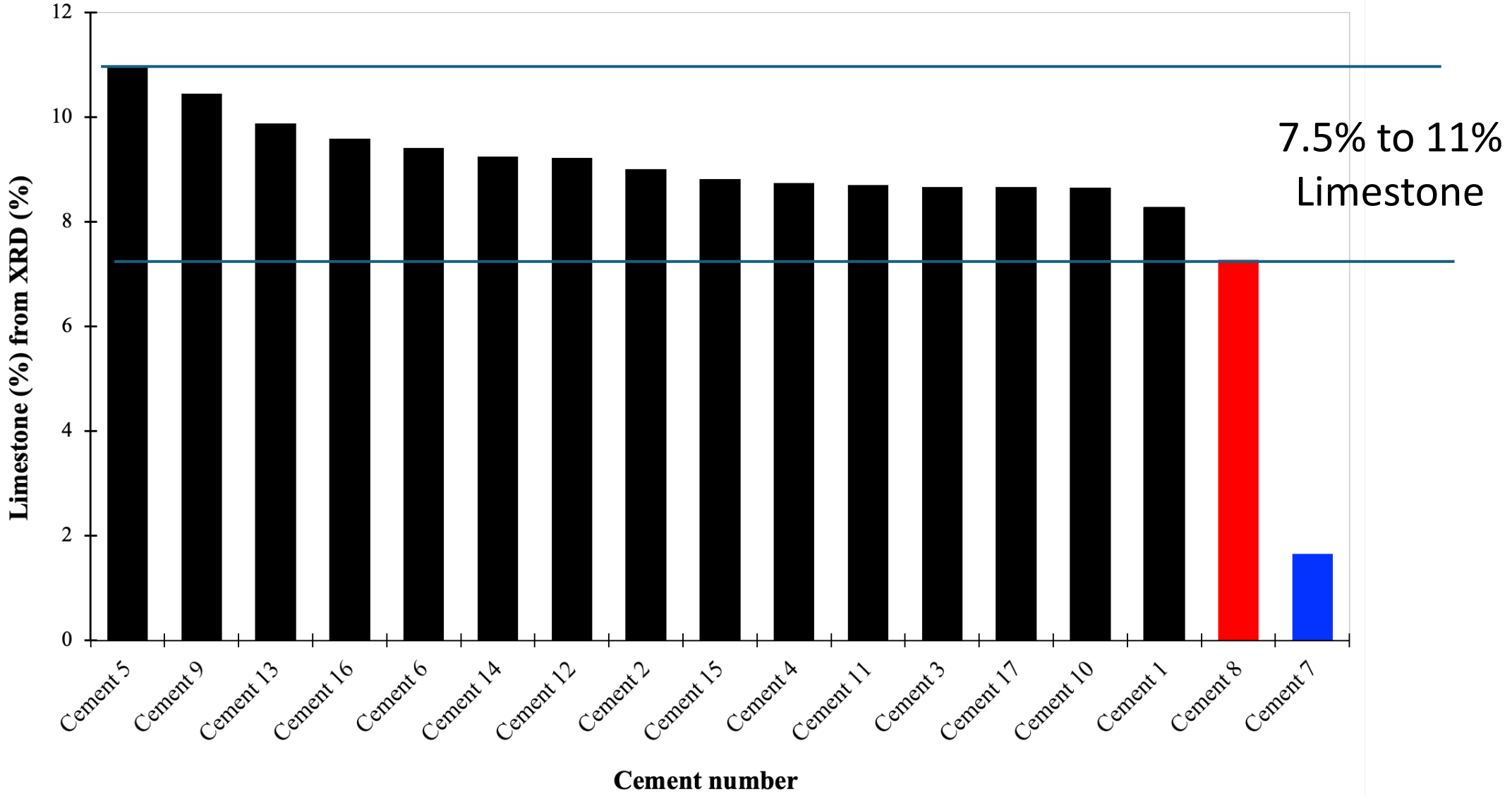
One plant produced both a Type I and a Type IL.

Type I/II – Blue

Type IL - Red



Red – Type IL
Blue – Type I/II
at same plant



Red – Type IL
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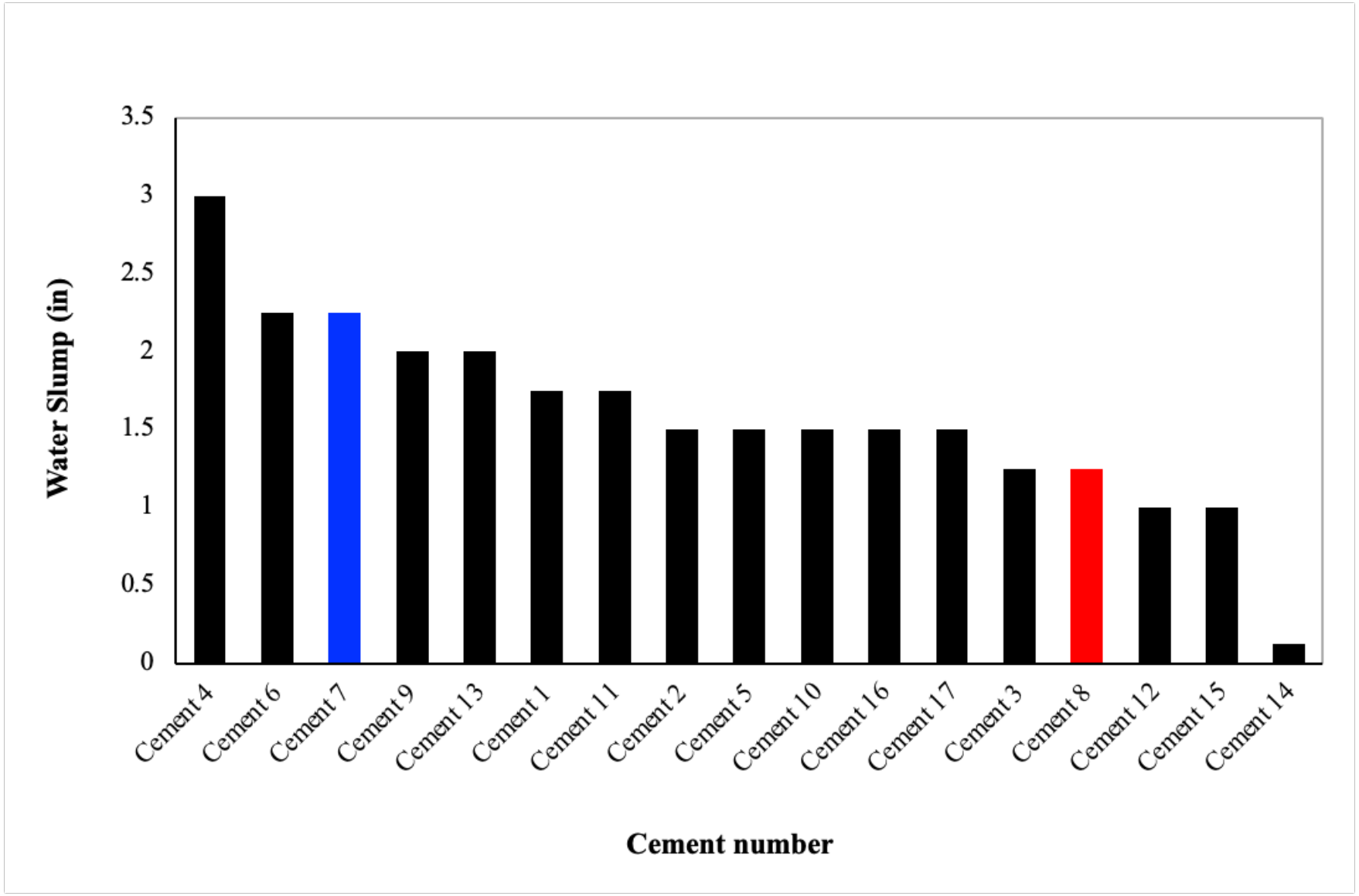
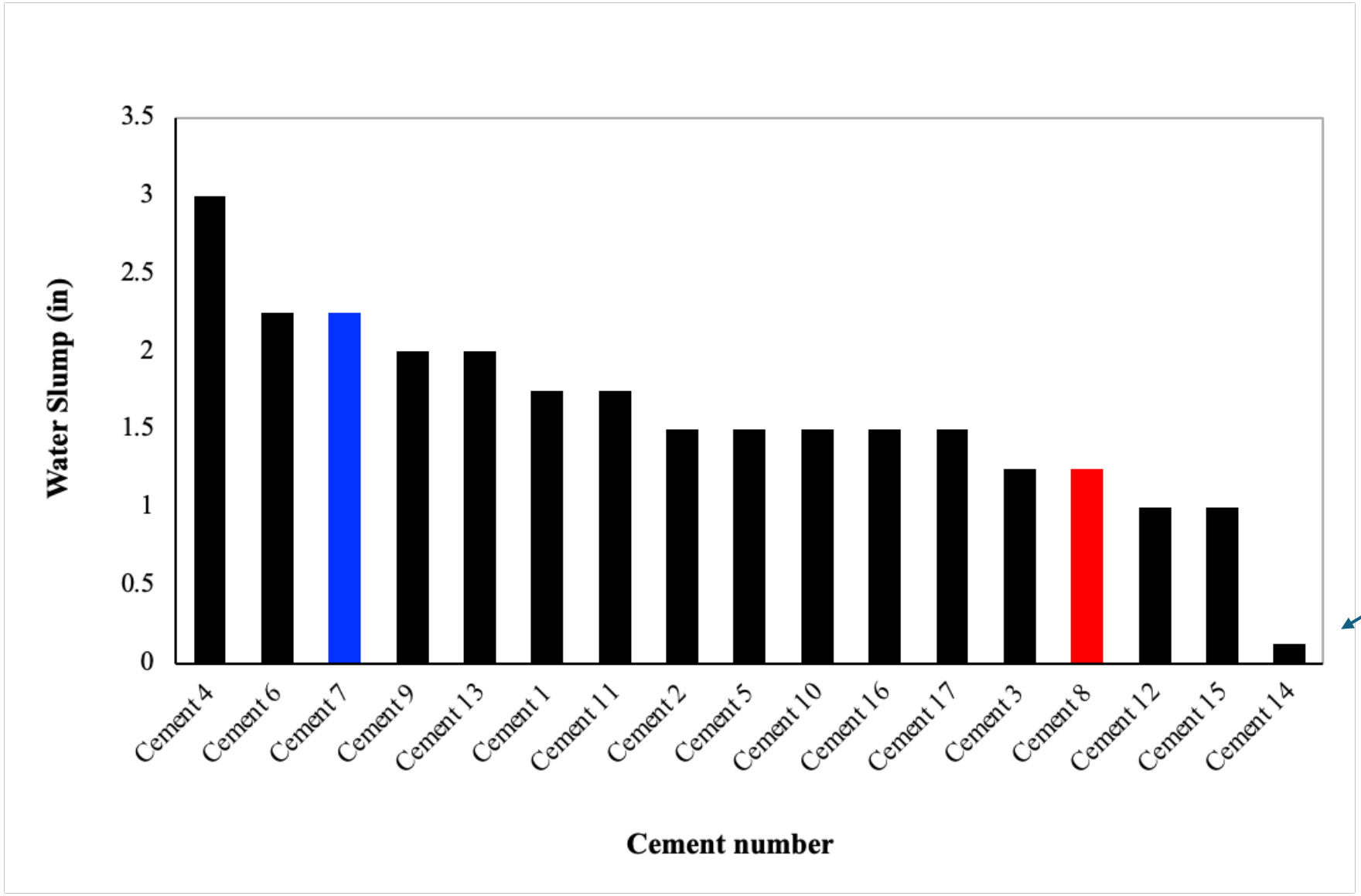
at same plant

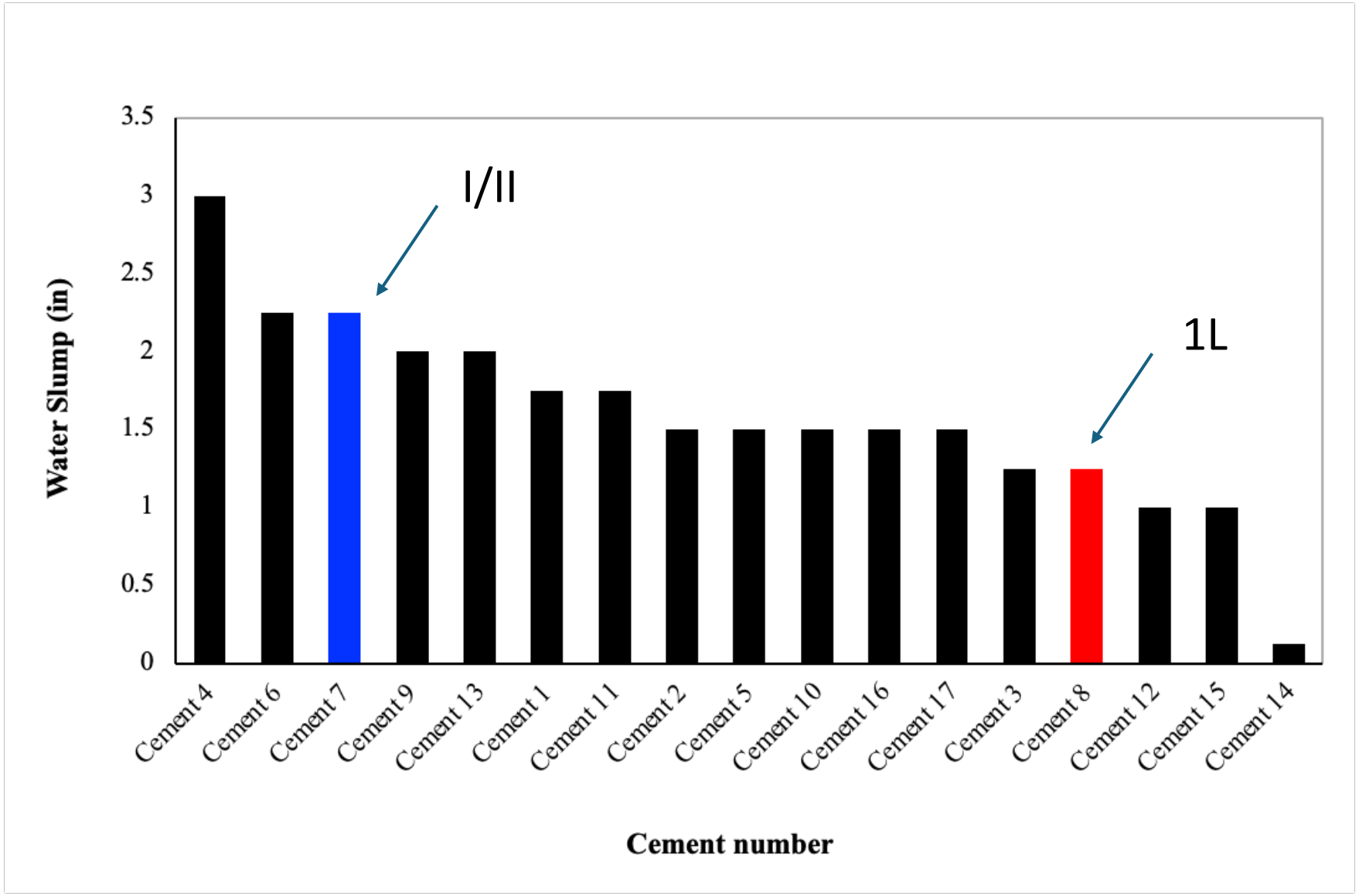


Red – Type IL
Blue – Type I/II
at same plant

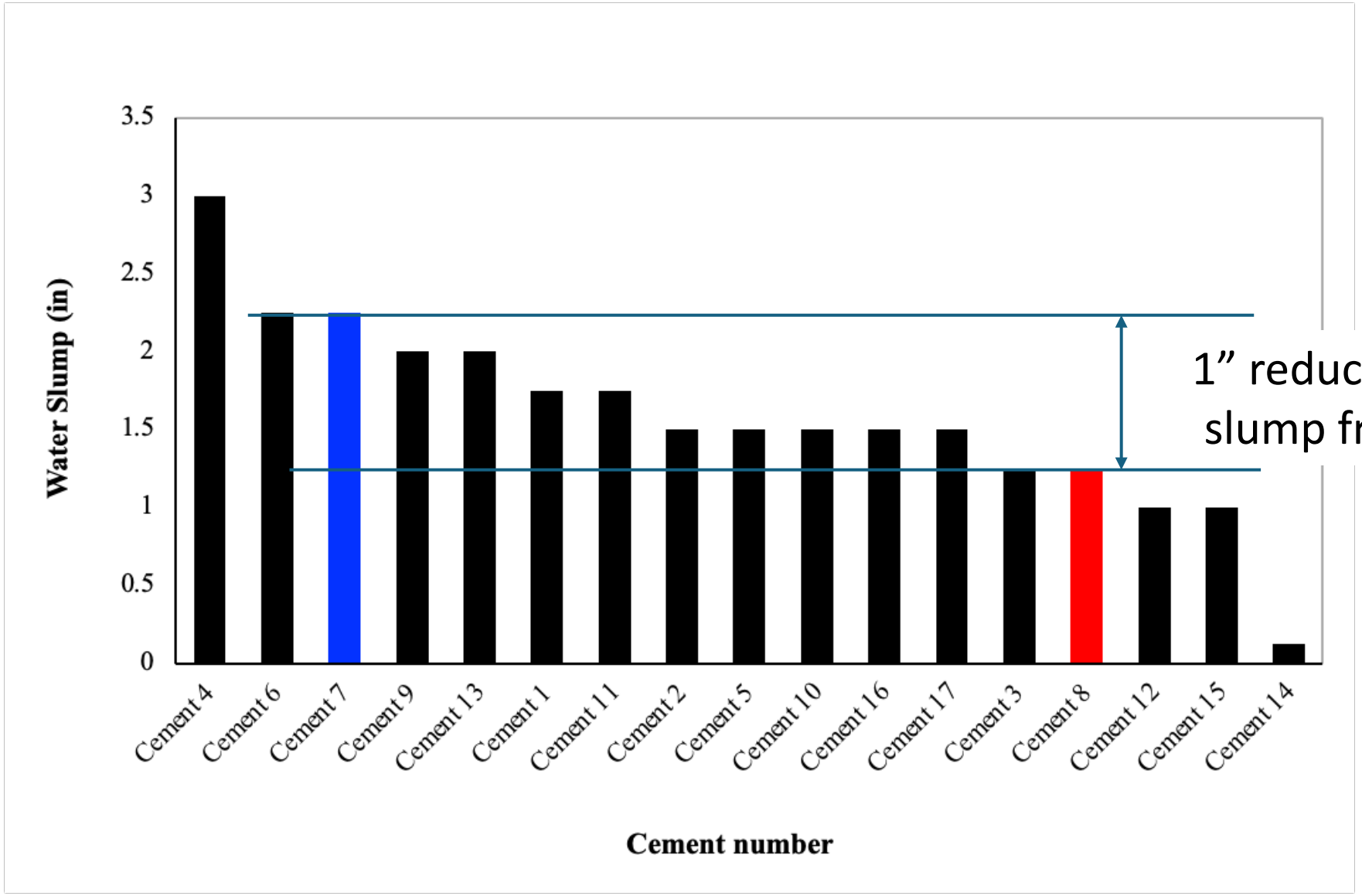


Flash Set

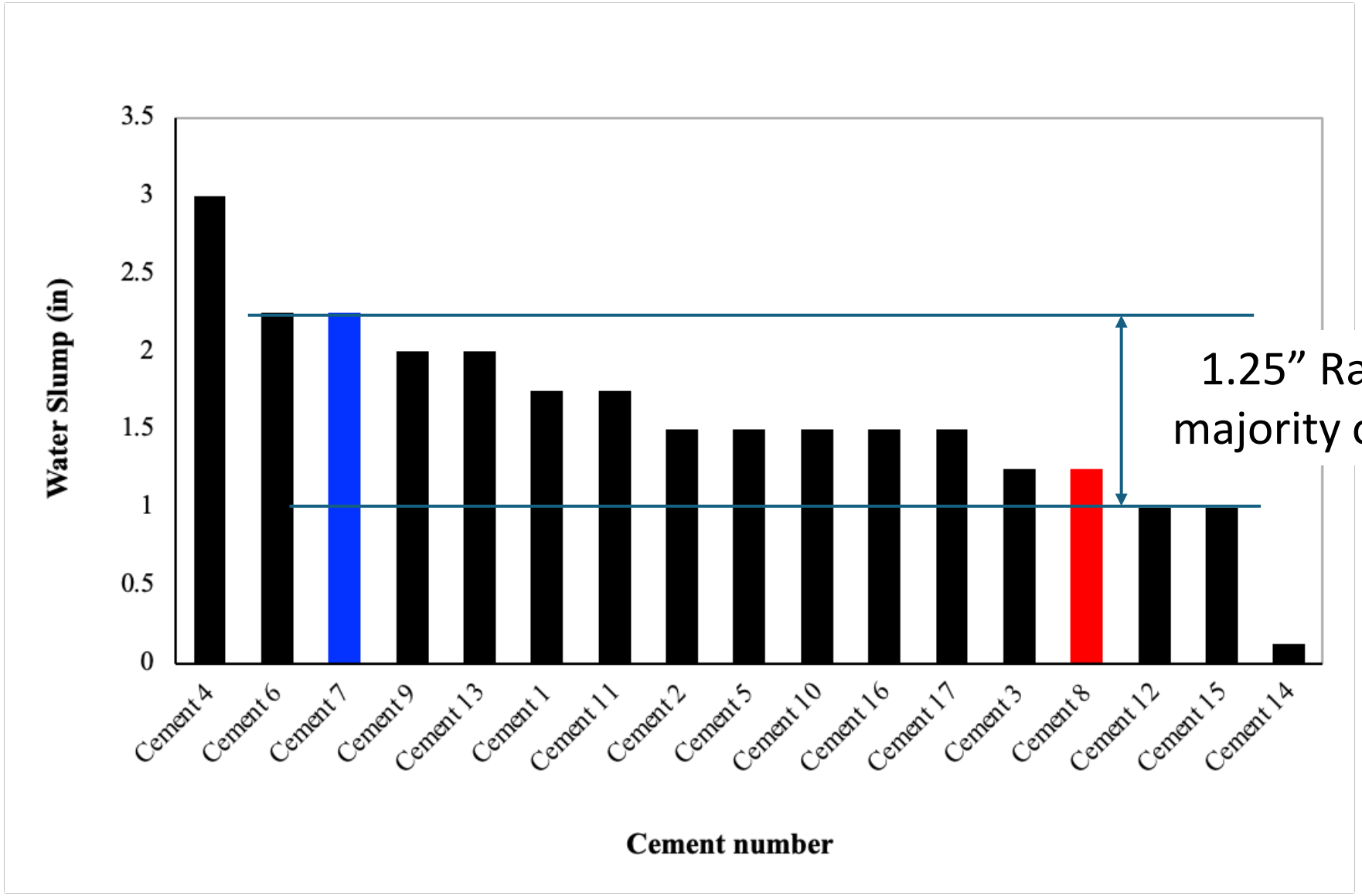
Red – Type IL
Blue – Type I/II at same plant



Red – Type IL
Blue – Type I/II
at same plant

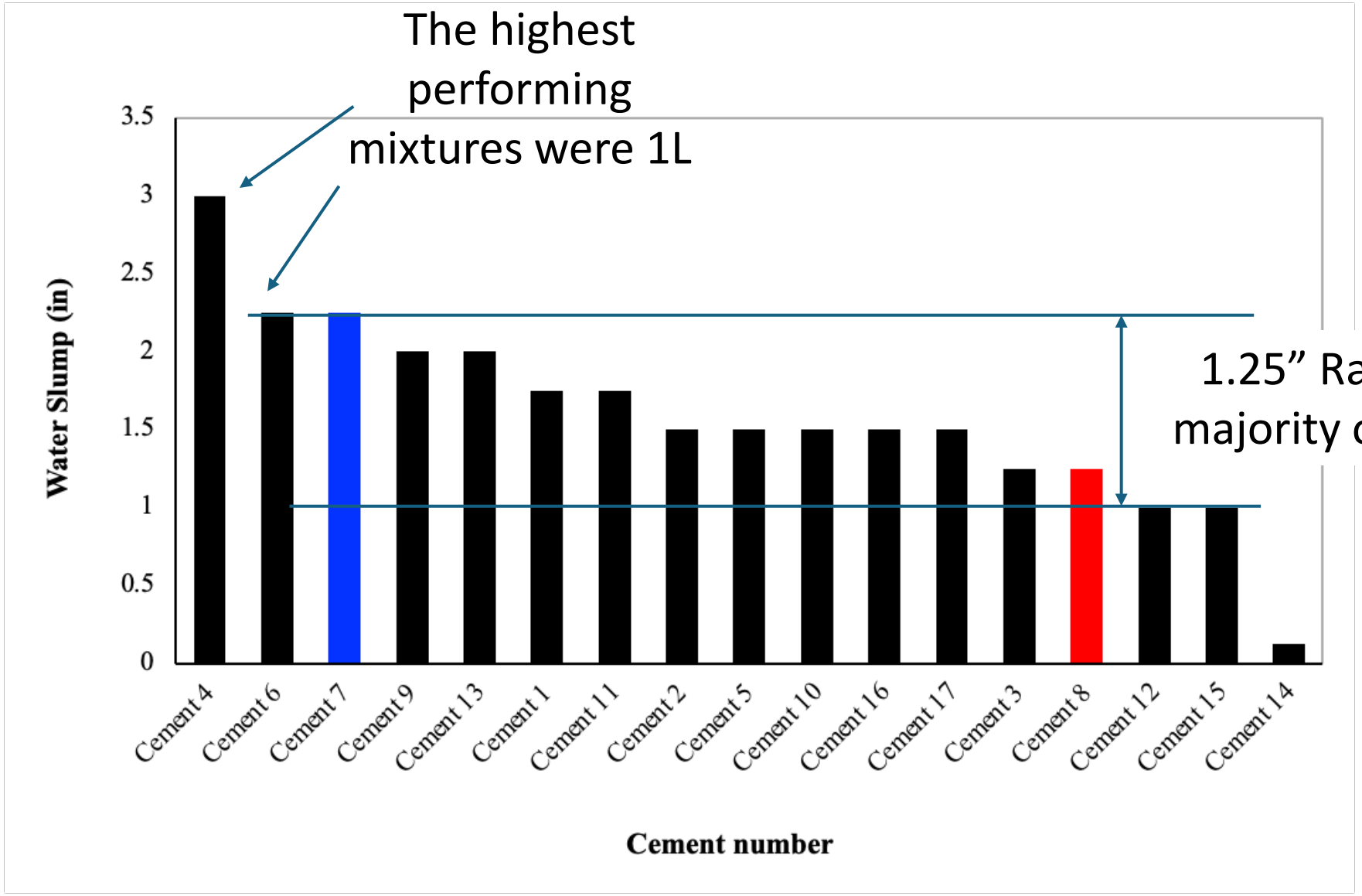


Red – Type IL
Blue – Type I/II at same plant



1.25” Range over majority of the data

Red – Type IL
Blue – Type I/II at same plant



Red – Type IL
Blue – Type I/II at same plant

Discussion

- There was a 1” reduction in slump for the Type IL compared to the Type I/II from the same plant.

- The cement with the lowest water demand is a Type IL cement

Discussion

- There was a 1” reduction in slump for the Type IL compared to the Type I/II from the same plant.

Is this predicted by the fineness of the cement?

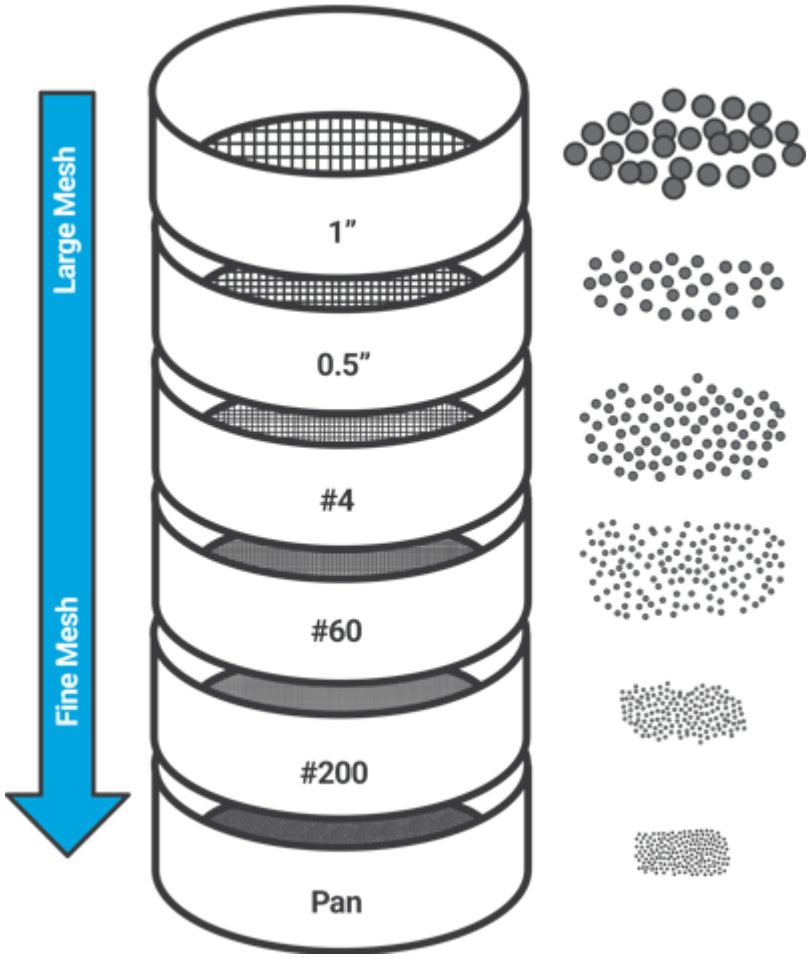
How do you measure fineness?

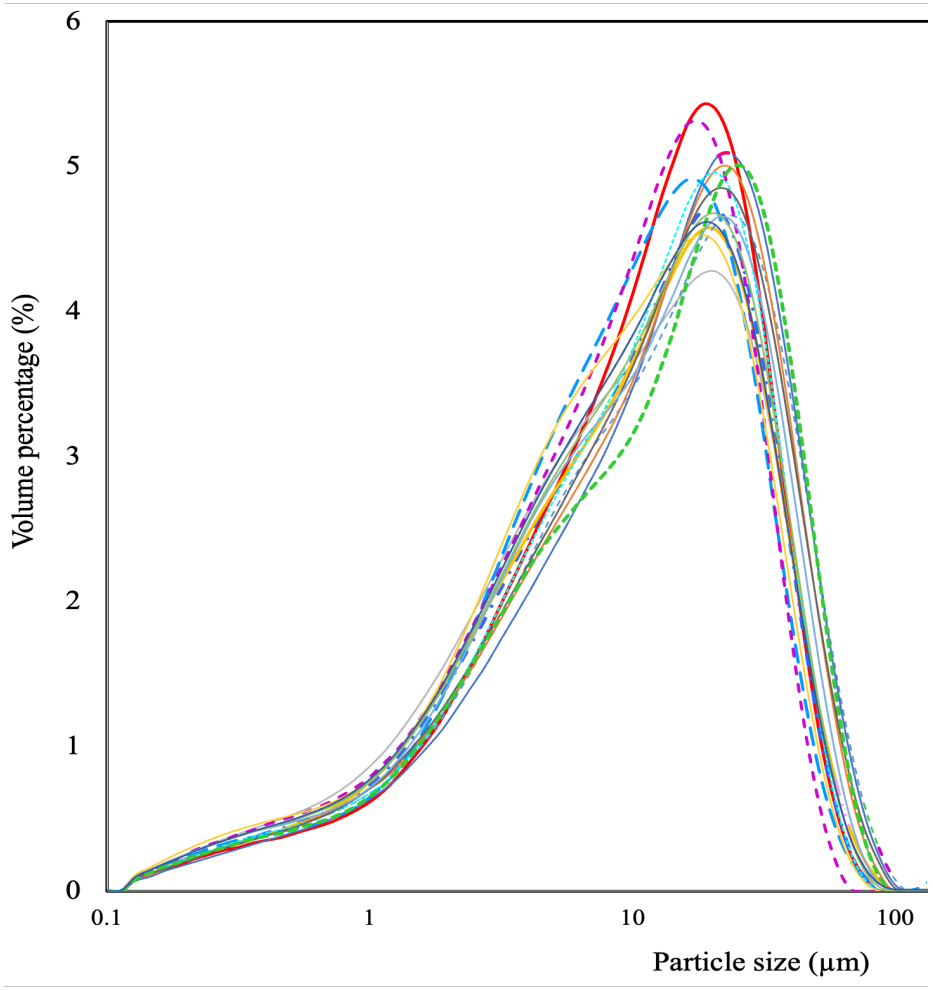
- Blaine
- Particle Size Distribution – PSD Wet
- Particle Size Distribution – PSD Dry

Blaine

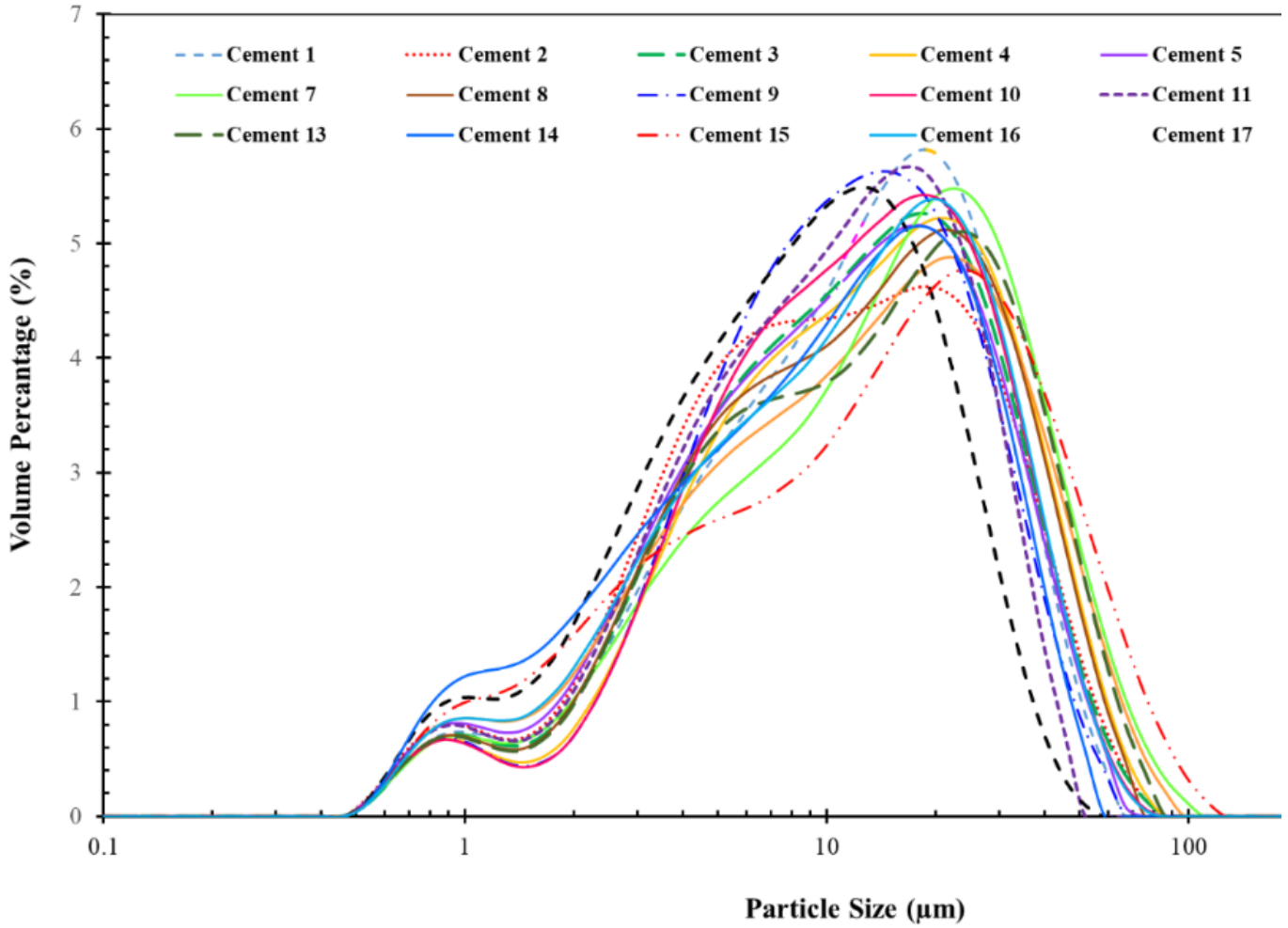
est. 1943

Laser diffraction – Particle size distribution




Volume percentage (%)
Particle size (μm)
0
1
2
3
4
5
6
0.1
1
10
100

Dry

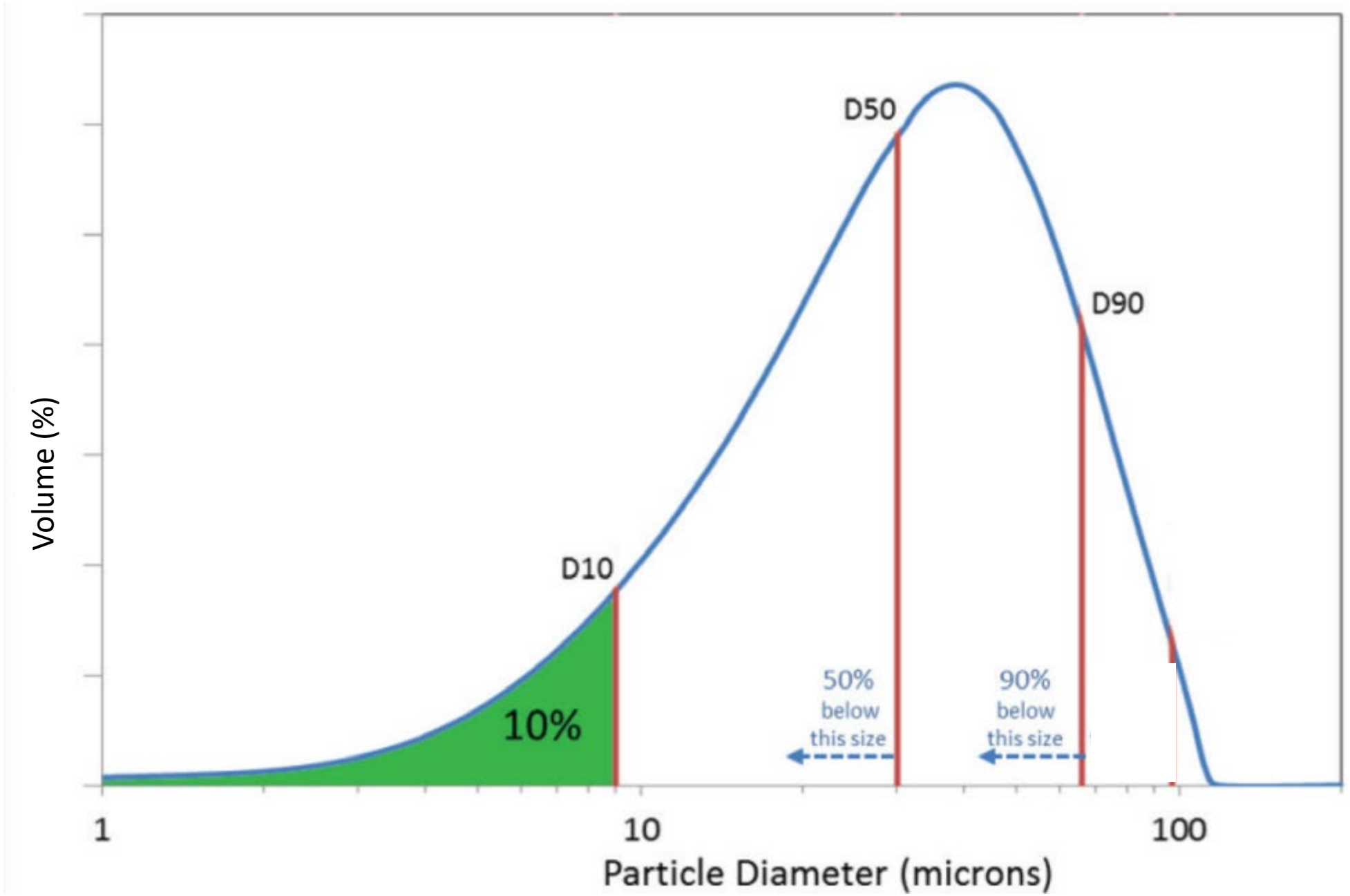

Cement 1
Cement 2
Cement 3
Cement 4
Cement 5
Cement 7
Cement 8
Cement 9
Cement 10
Cement 11
Cement 13
Cement 14
Cement 15
Cement 16
Cement 17
Volume Percantage (%)
Particle Size (μm)
0
1
2
3
4
5
6
7
0.1
1
10
100

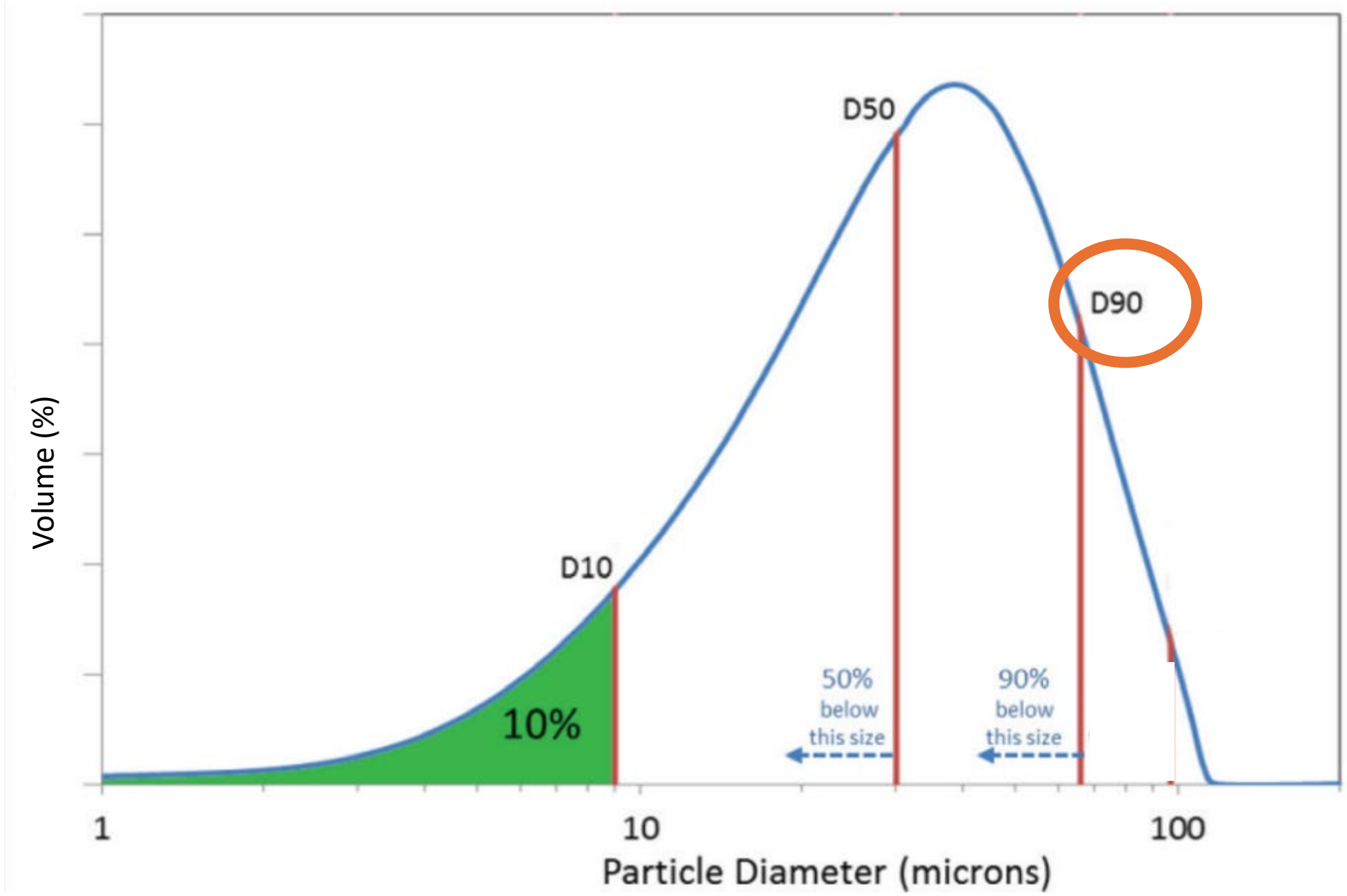
Wet

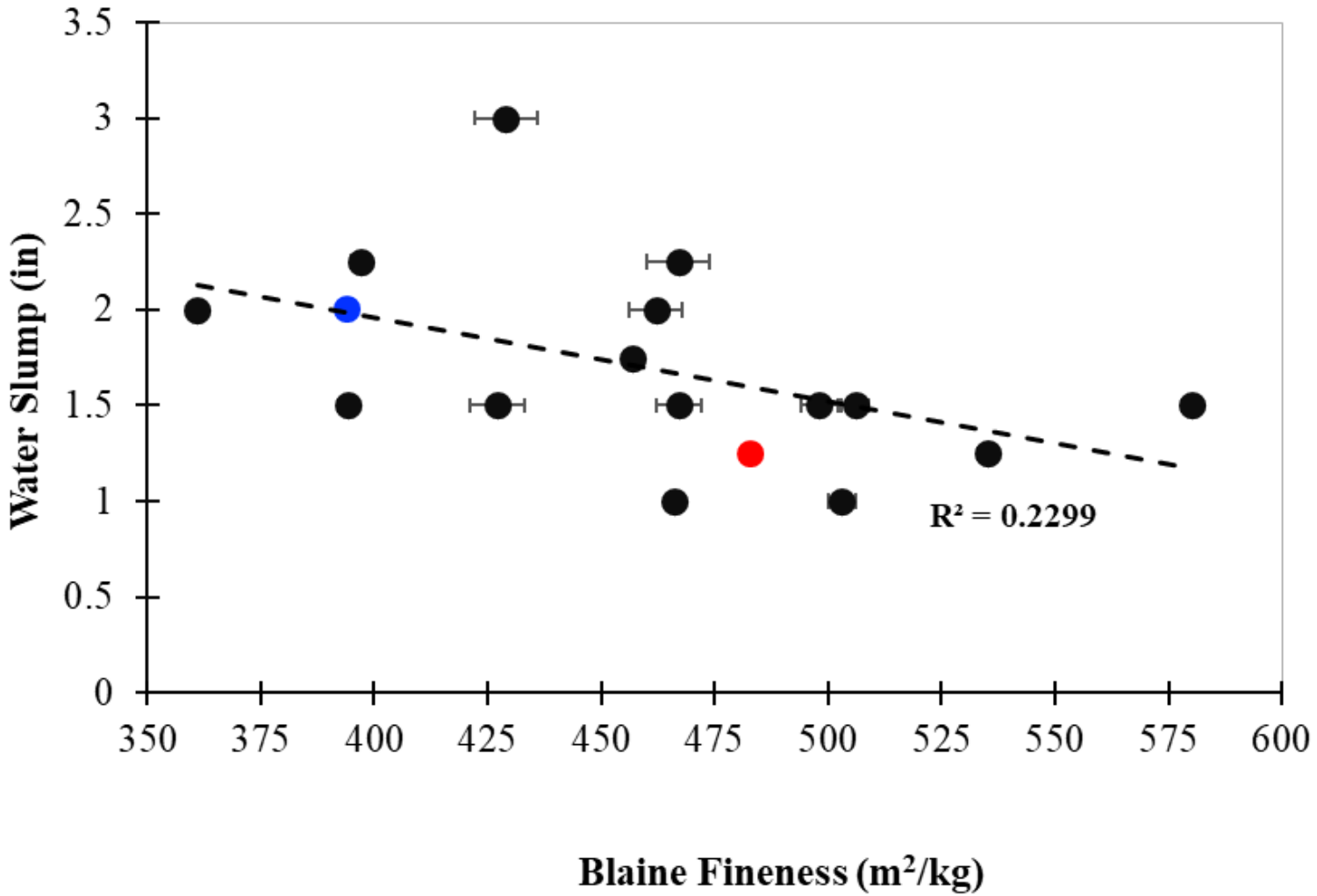
Specific surface area

Assume all the particles are spheres

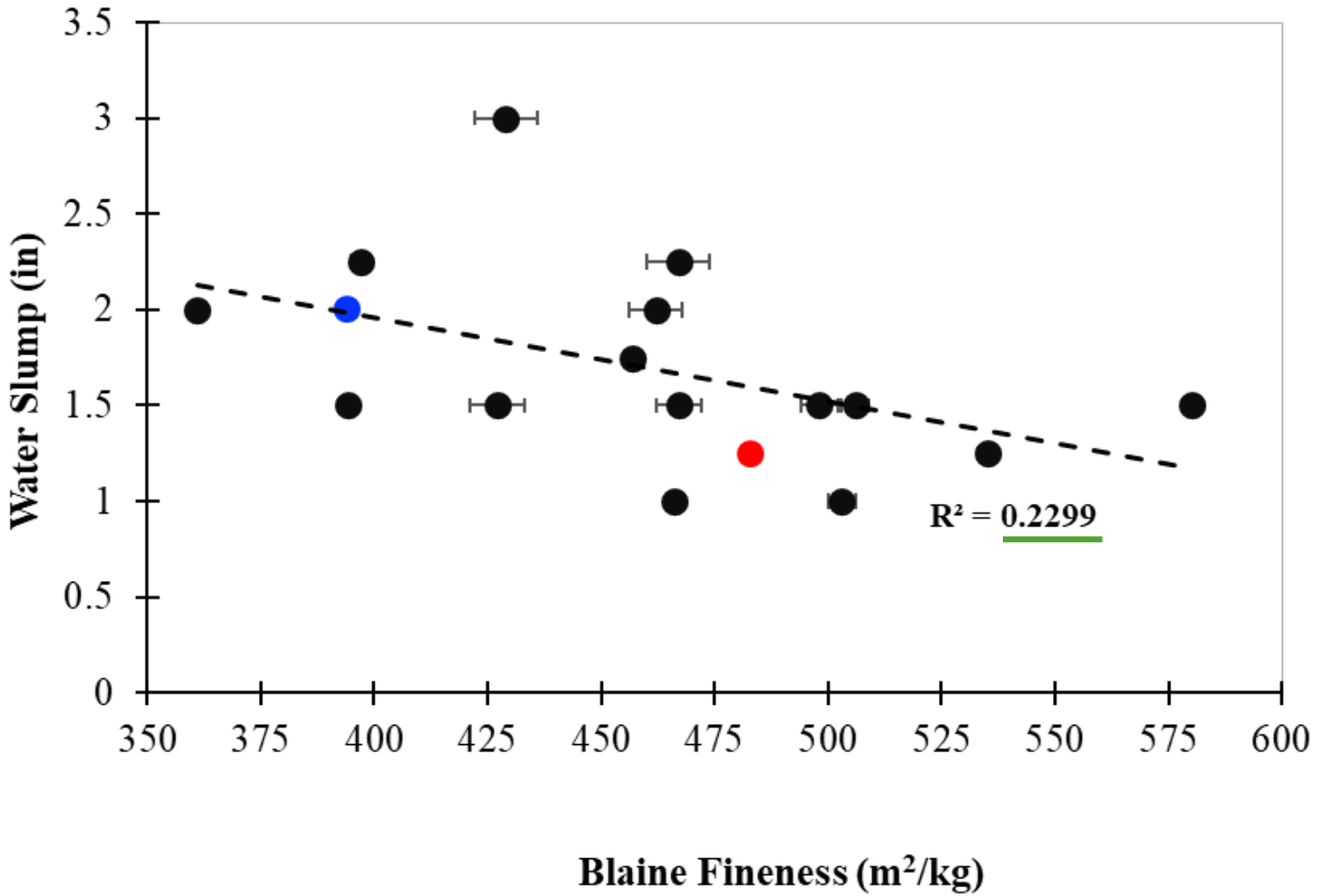
Specific Surface Area = Σ (Area / Volume)


D50
D90
D10
10%
50%
below
this size
90%
below
this size
Volume (%)
1
10
100
Particle Diameter (microns)


D50
D90
D10
10%
50%
below
this size
90%
below
this size
Volume (%)
1
10
100
Particle Diameter (microns)



Red – Type IL
Blue – Type I/II
at same plant



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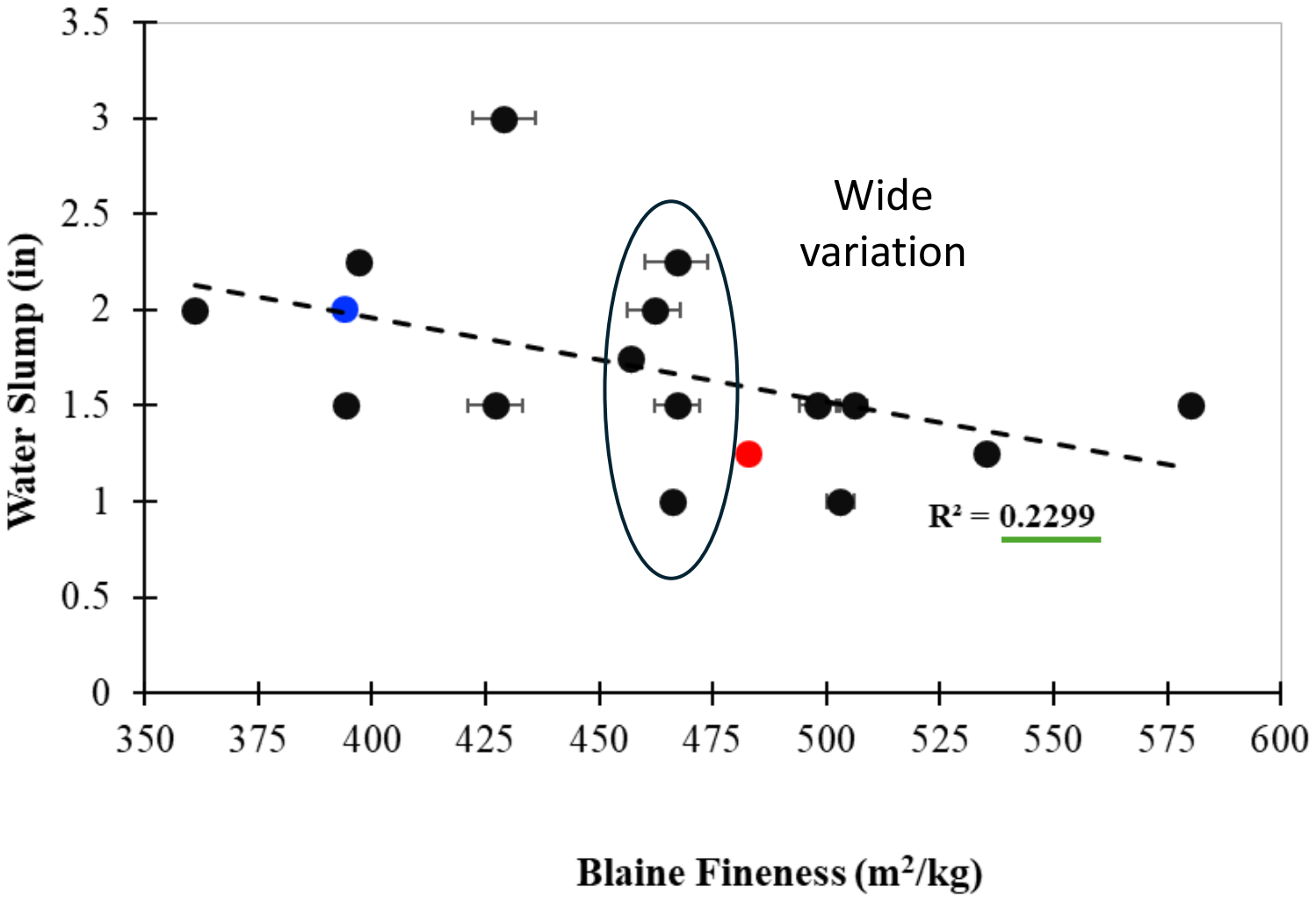

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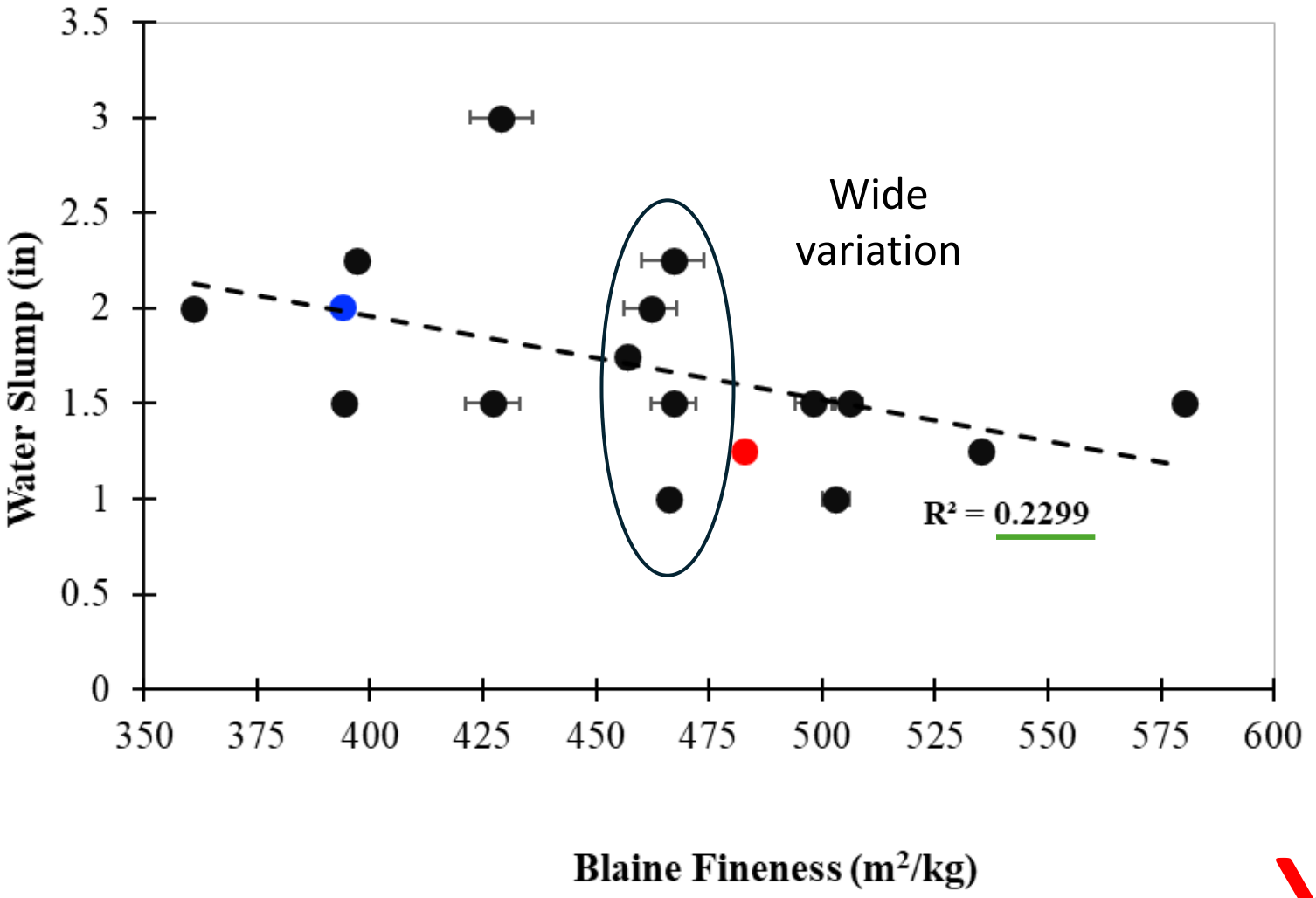
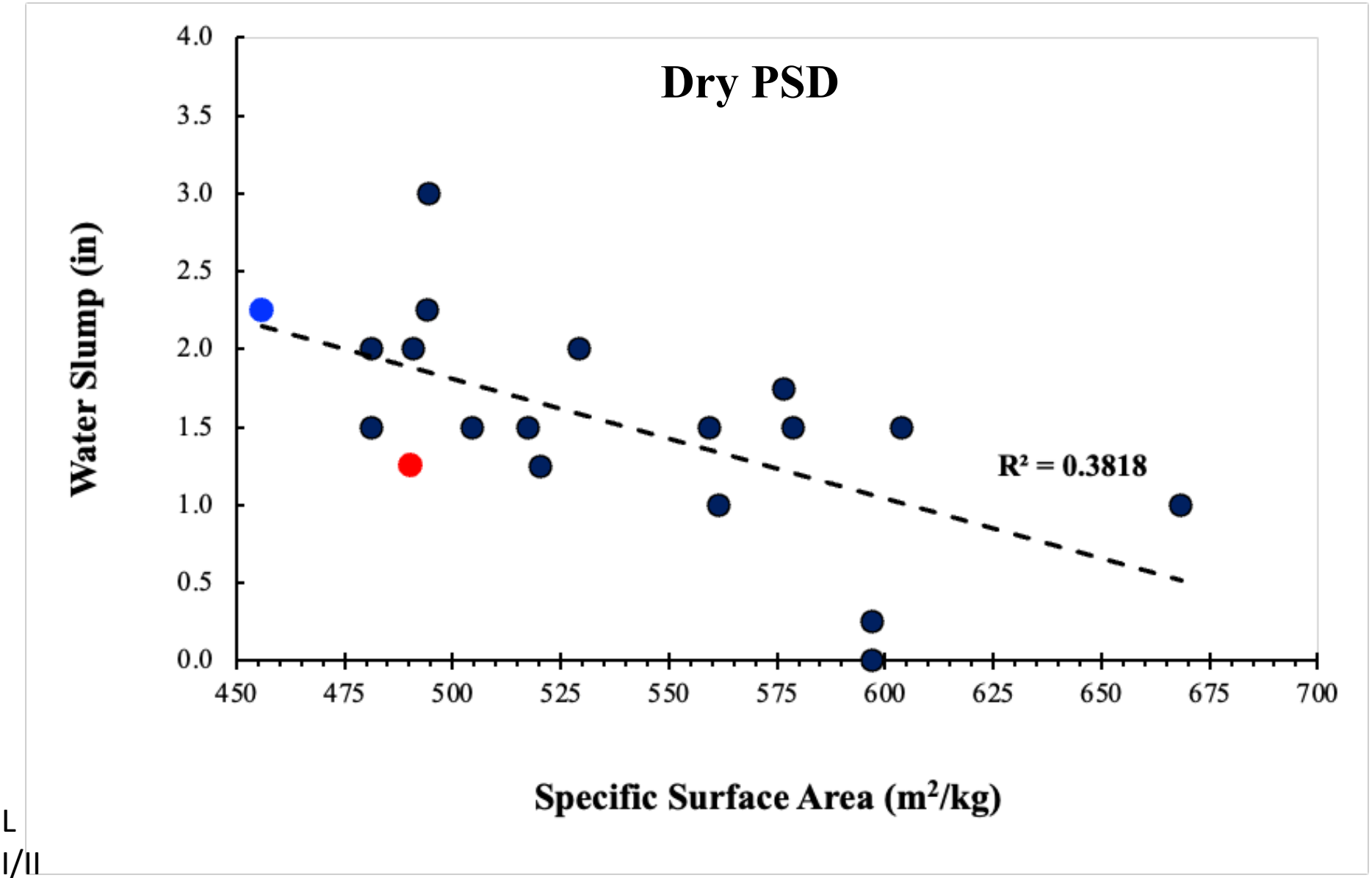
at same plant

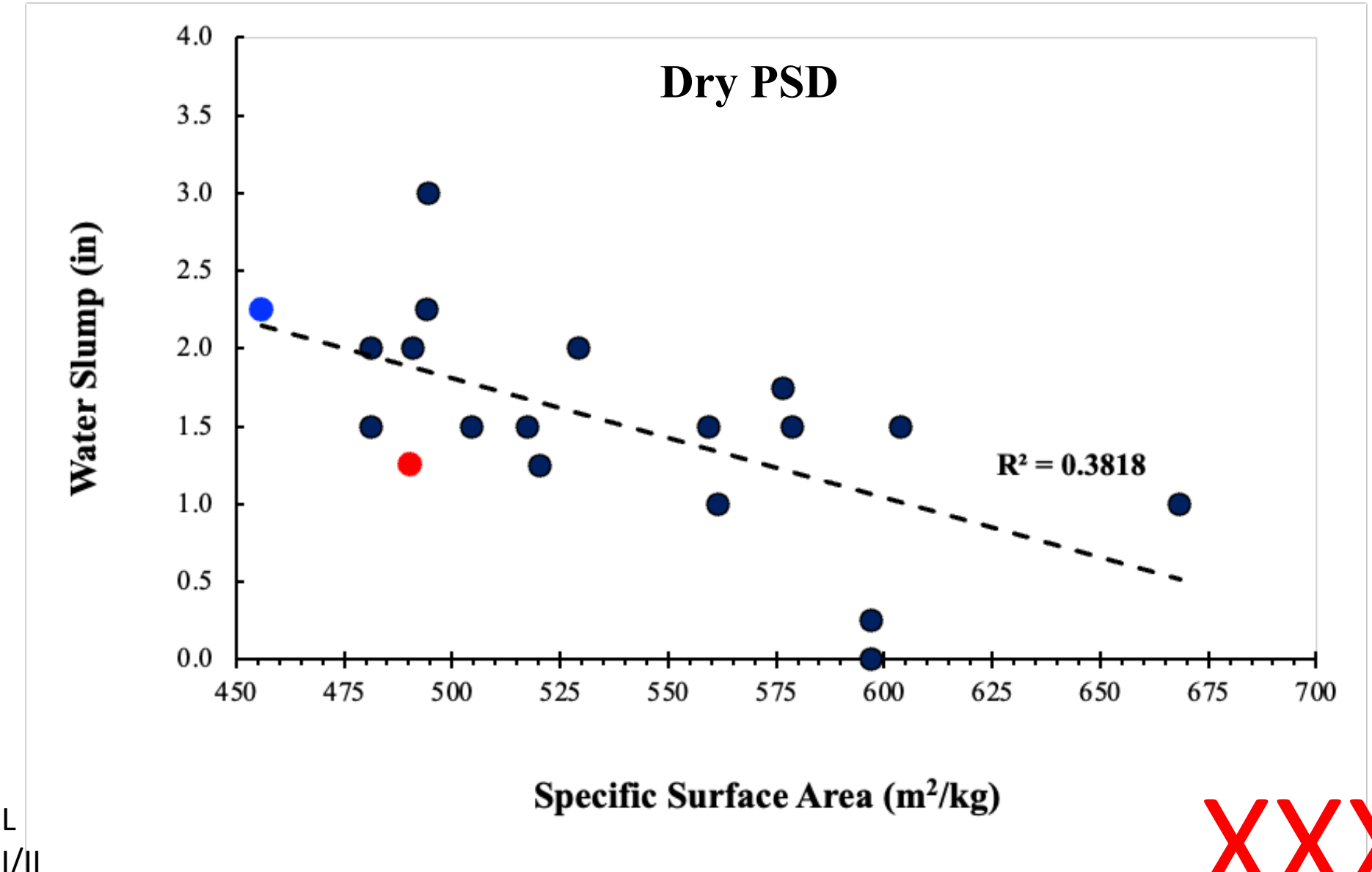


Red – Type IL
Blue – Type I/II
at same plant

XXX

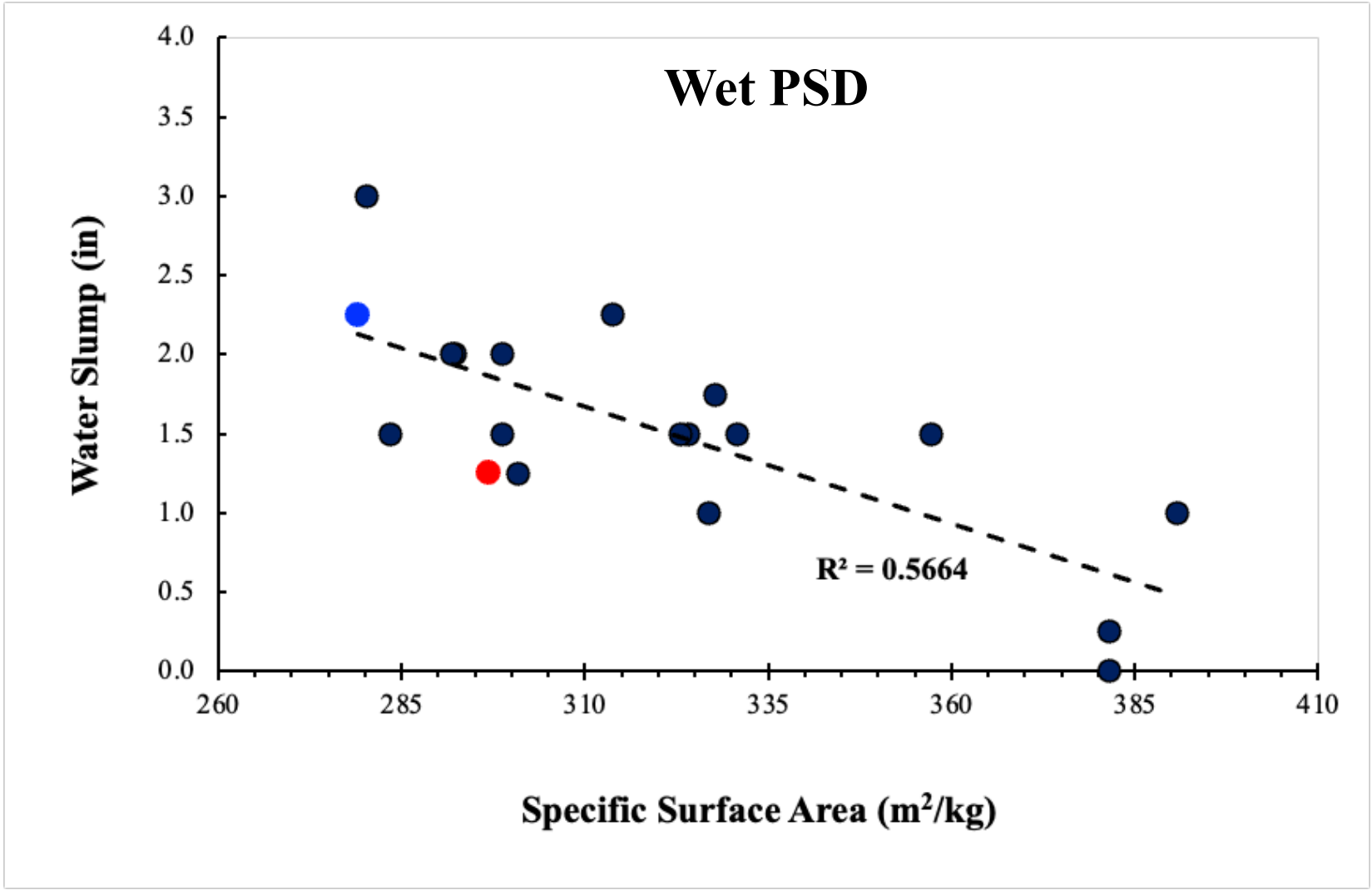


Red – Type IL
Blue – Type I/II
at same plant



Red – Type IL
Blue – Type I/II
at same plant

XXX



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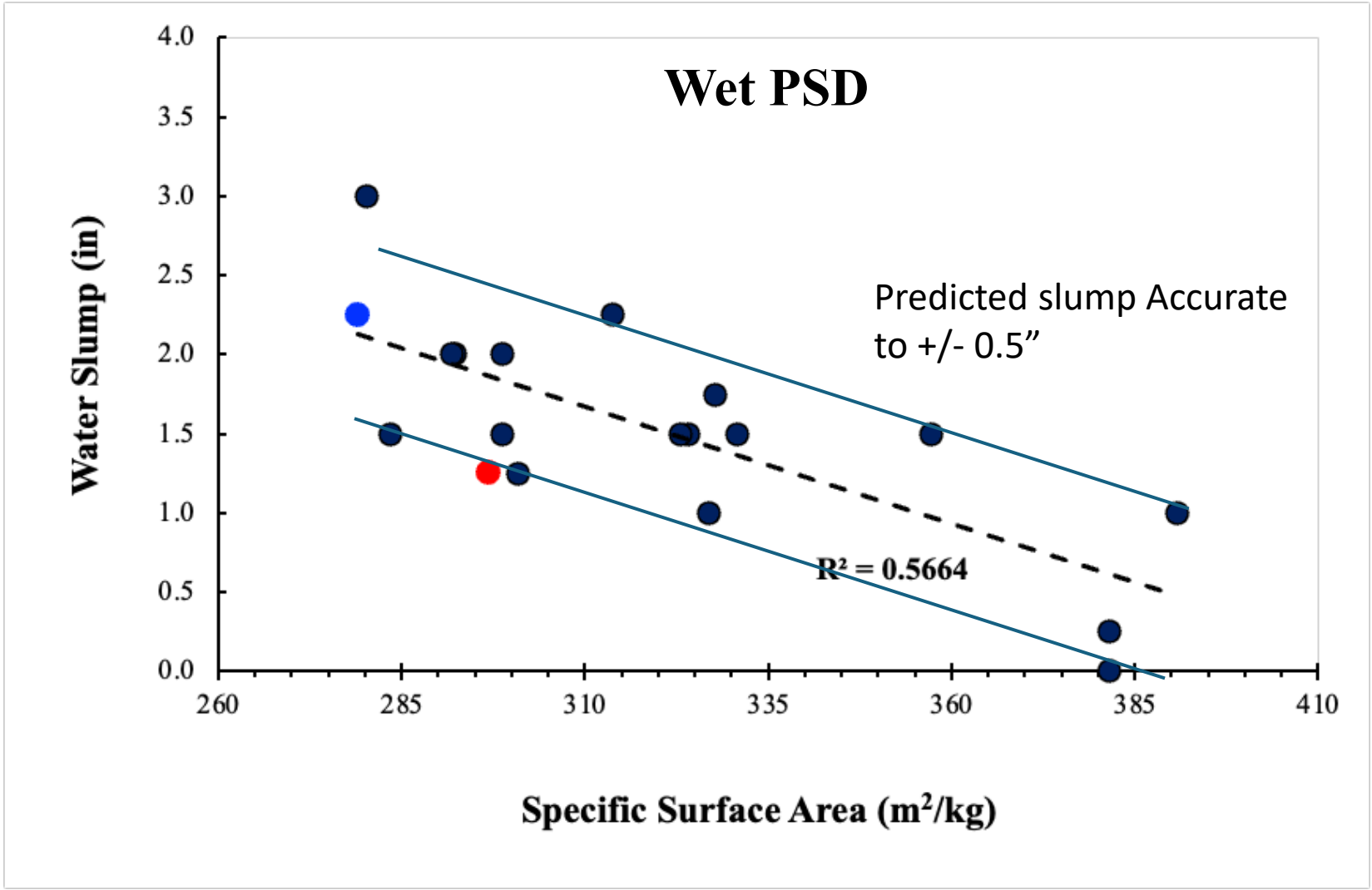
Blue – Type I/II
at same plant



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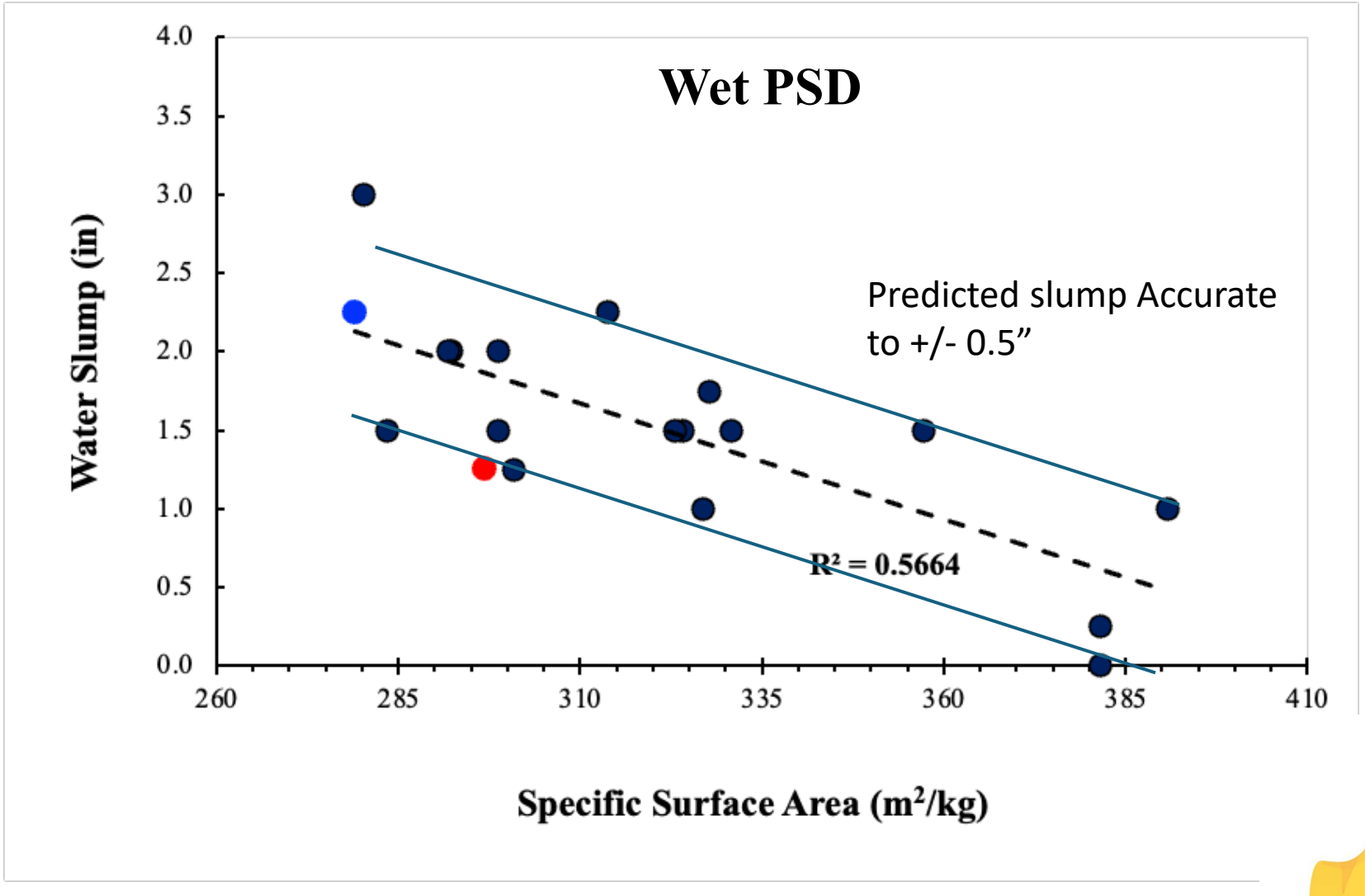
Blue – Type I/II at same plant



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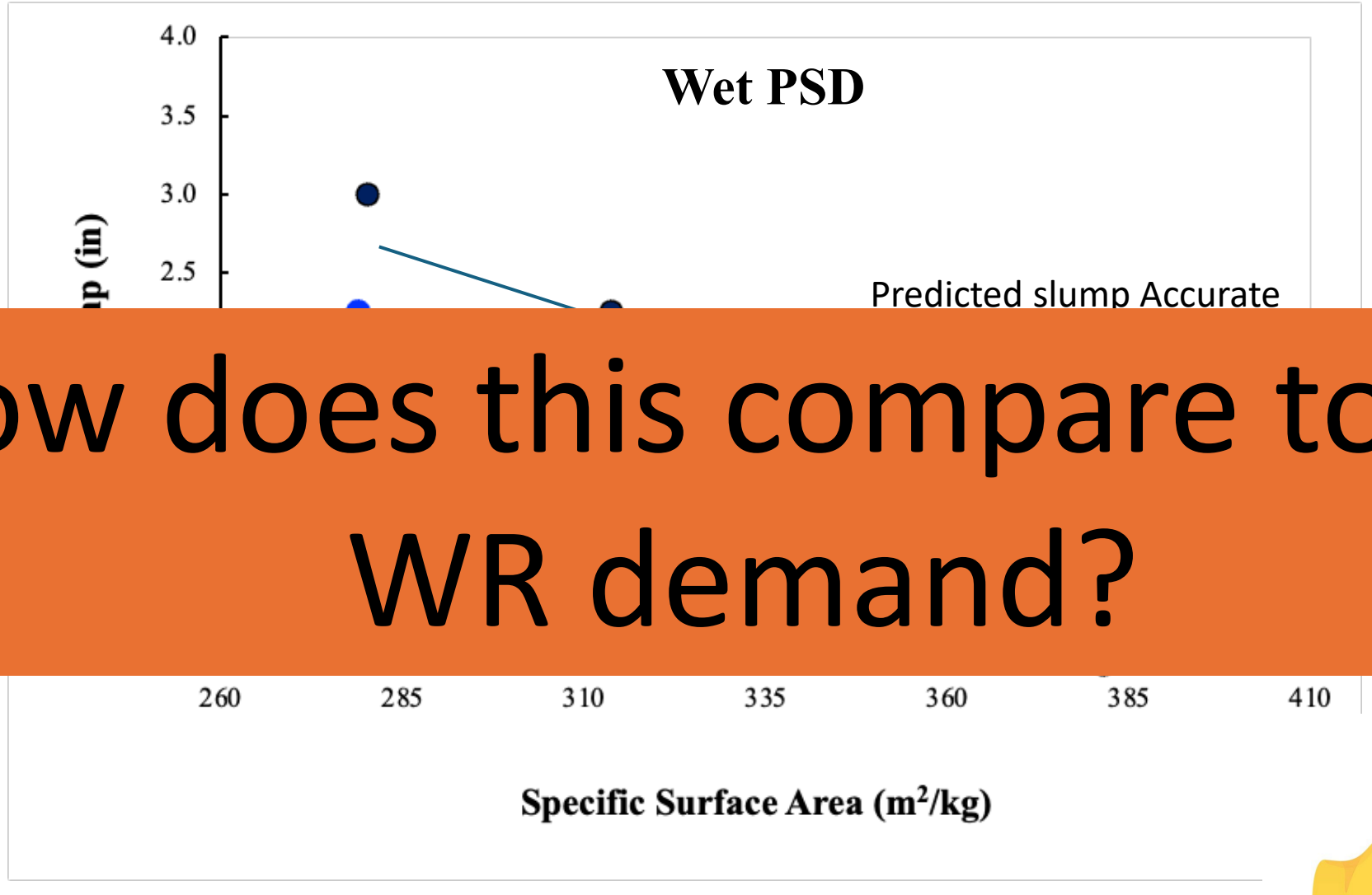
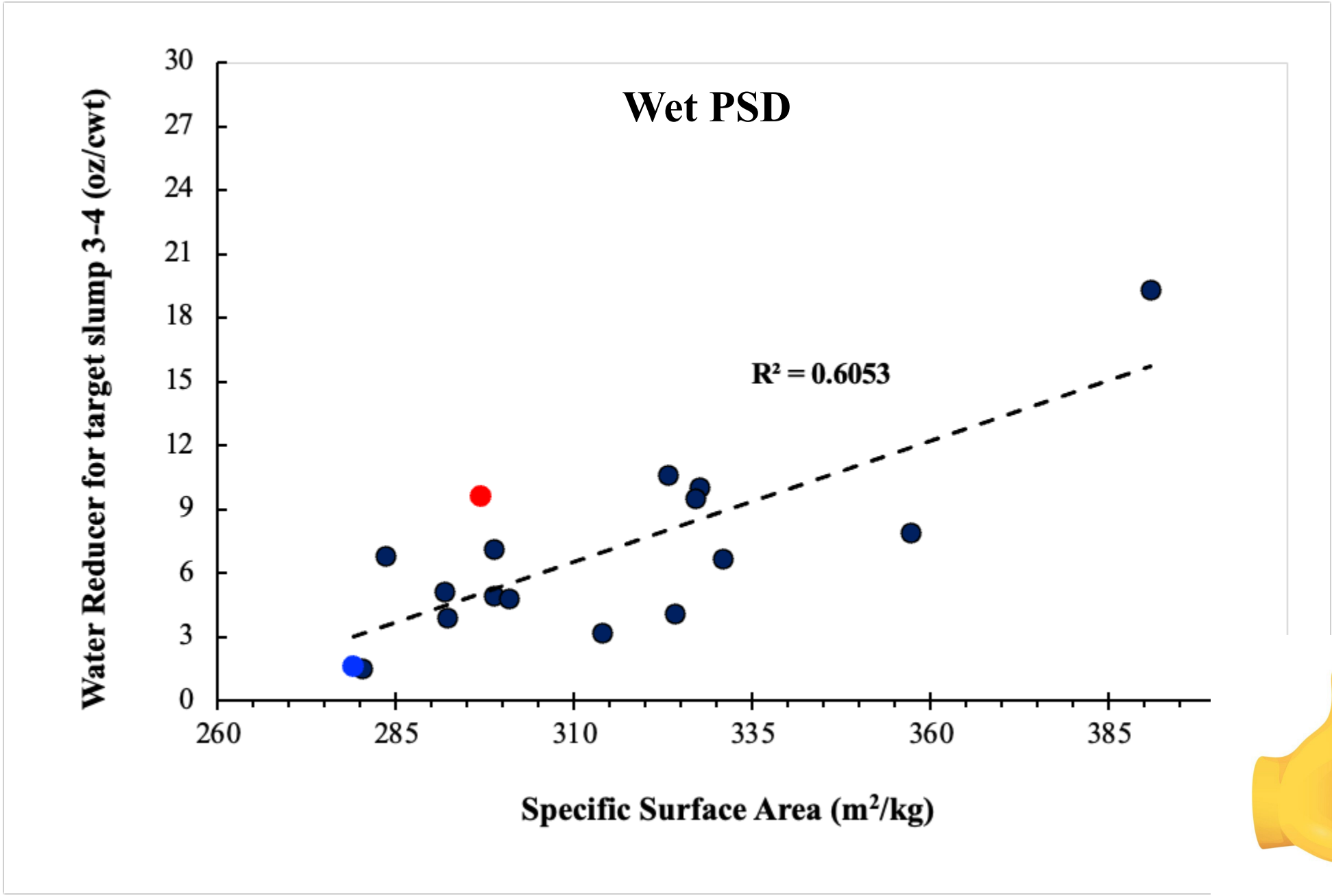
at same plant



How does this compare to the WR demand?

Red – Type IL
Blue – Type I/II
at same plant


Wet PSD
Water Reducer for target slump 3-4 (oz/cwt)
30
27
24
21
18
15
12
9
6
3
0
260
285
310
335
360
385
R² = 0.6053
Specific Surface Area (m²/kg)

Discussion

- Blaine is not a useful predictor of water demand for the cements investigated.
- The wet PSD provides more insight into performance than the dry PSD.
- The wet PSD specific surface area showed the best correlation to water slump with +/- 0.5” accuracy and to the water reducer demand.

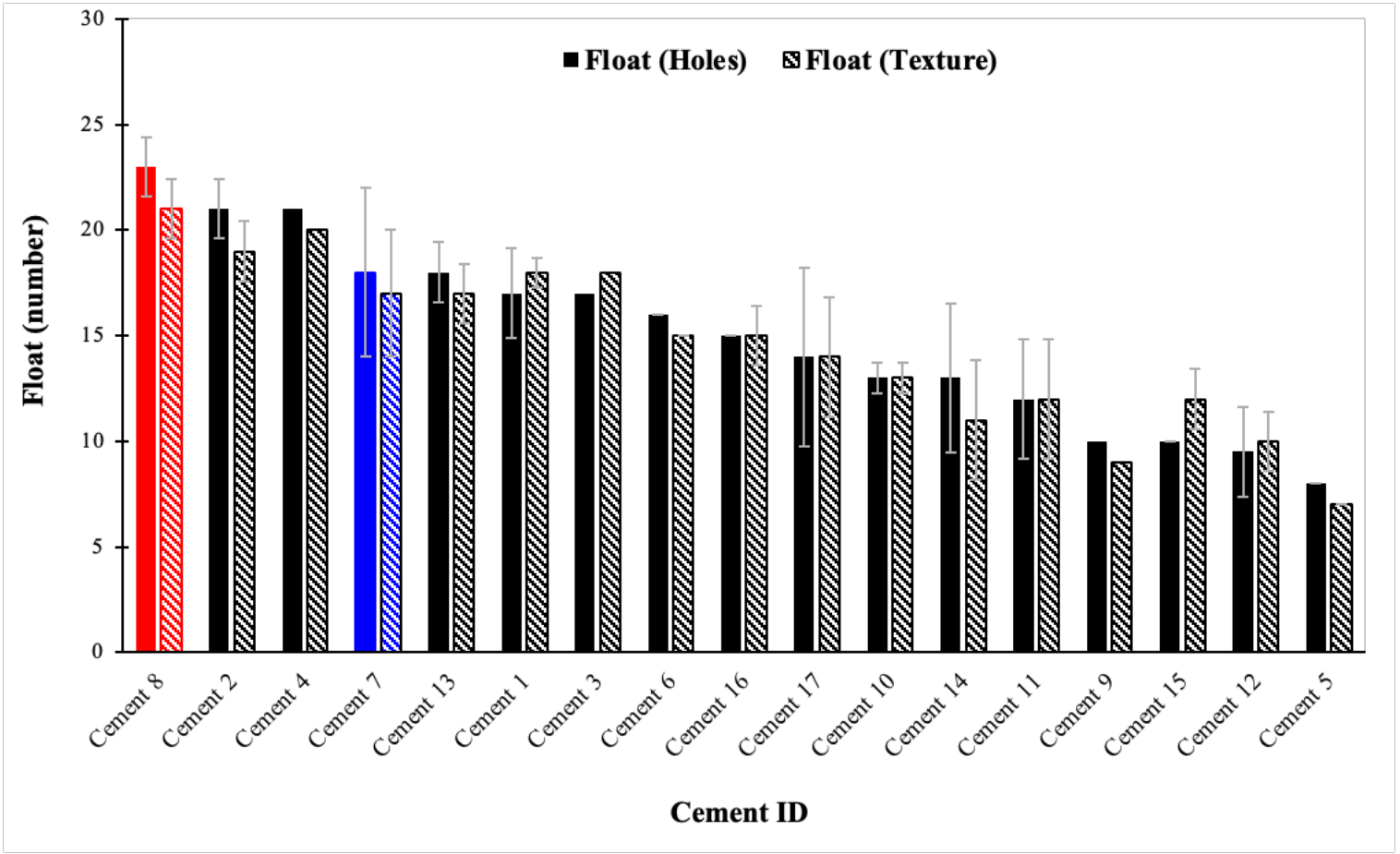
Discussion

- Blaine is not a useful predictor of water demand for the cements investigated

How do they finish?

the dry PSD.

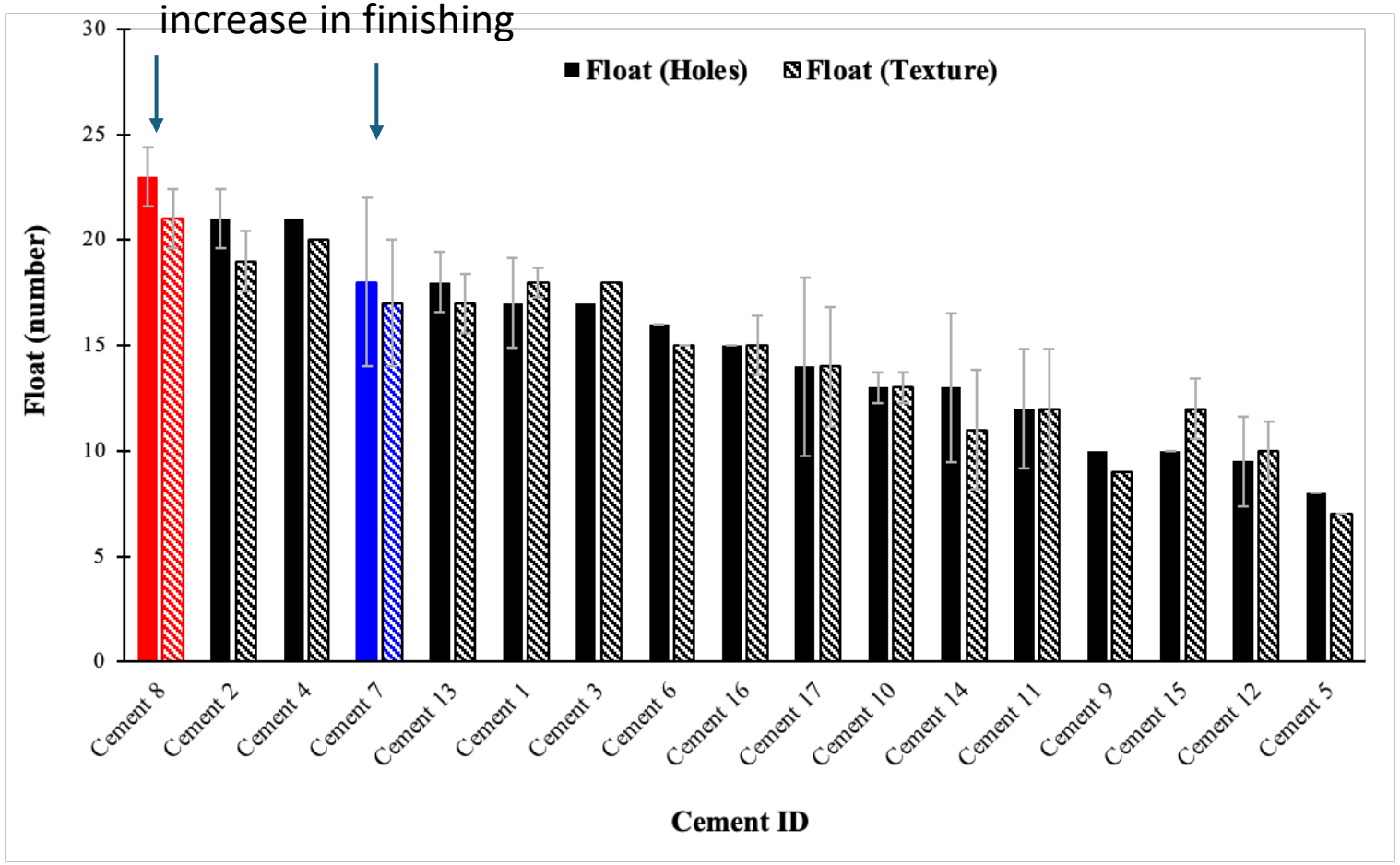
- The wet PSD spec… the best correlation to wat…ccuracy and to the water reducer der…



Red – Type IL
Blue – Type I/II
at same plant

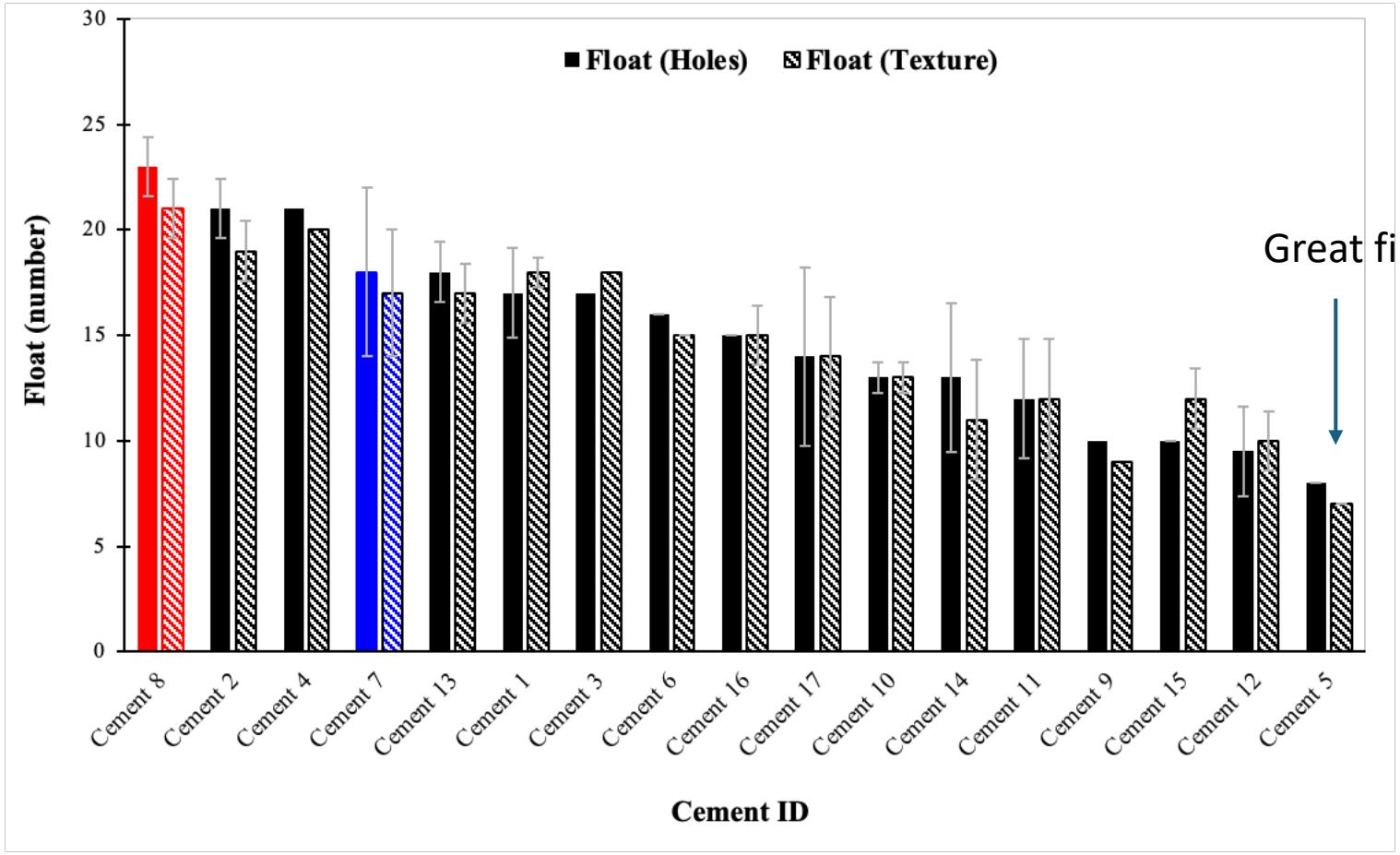
All mixes have a slump between 3” and 4”

Type IL required 20% increase in finishing



Red – Type IL
Blue – Type I/II at same plant

All mixes have a slump between 3” and 4”

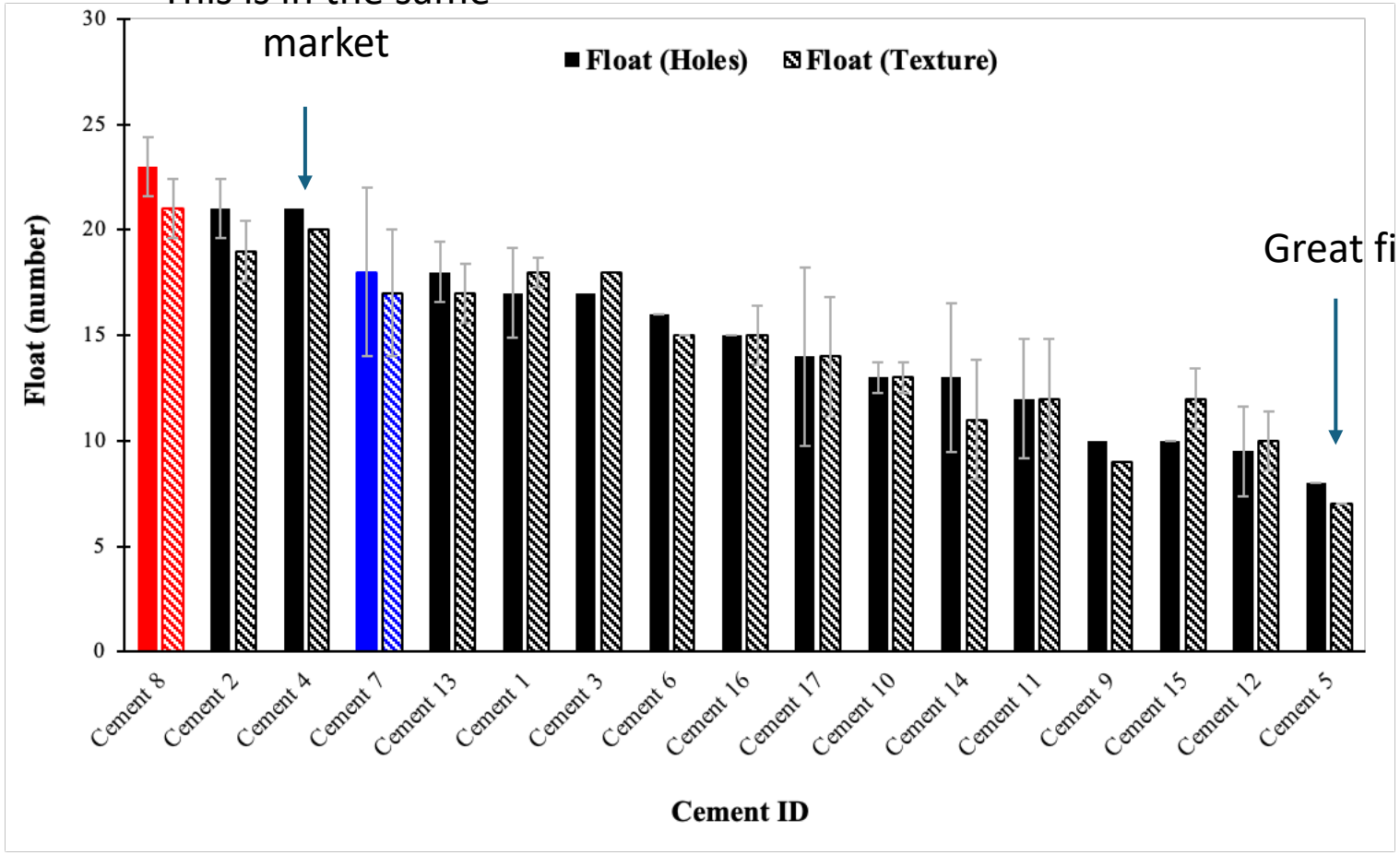


Great finishing 1L

Red – Type IL
Blue – Type I/II
at same plant

All mixes have a slump between 3” and 4”

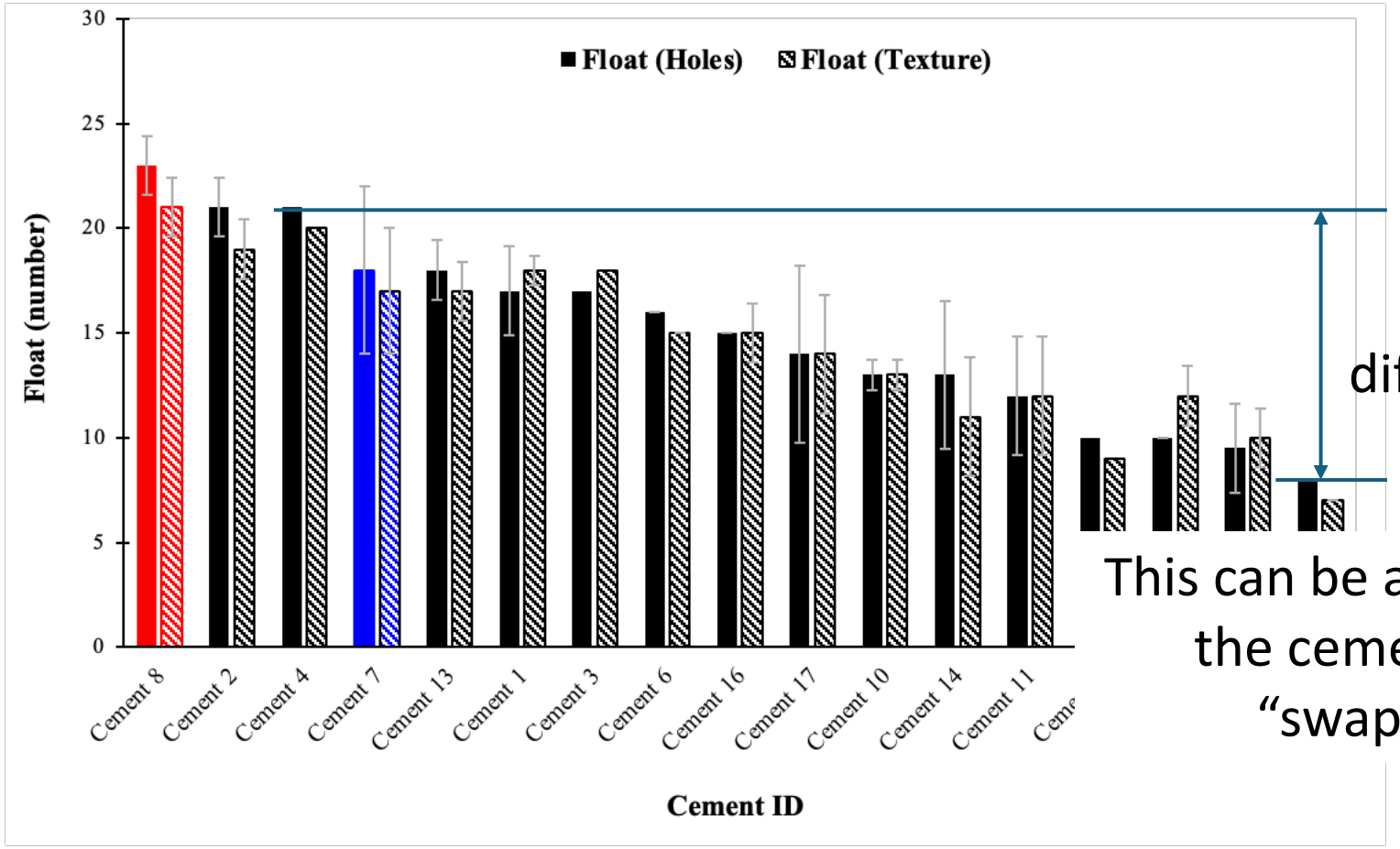
This is in the same market



Great finishing 1L

Red – Type IL
Blue – Type I/II
at same plant

All mixes have a slump between 3” and 4”



3X difference

This can be a problem if the cements are "swapped"

Red – Type IL
Blue – Type I/II
at same plant

All mixes have a slump between 3" and 4"

Discussion

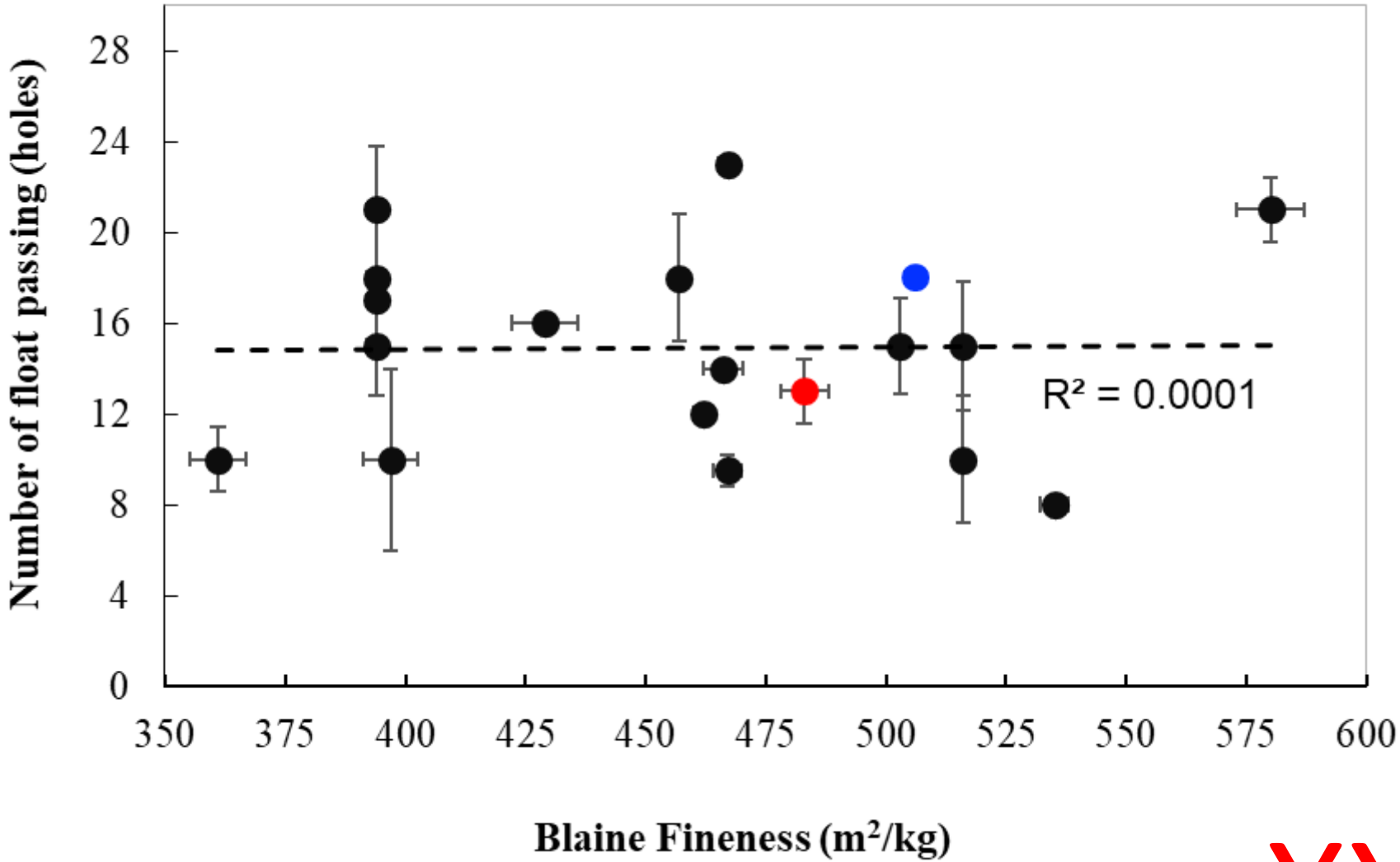
- The Type IL from the same plant as the I/II required 20% more passes in the float test.
- Some Type IL cements had great finishing performance.
- There can be a wide range of finishing performance in the same market.

Discussion

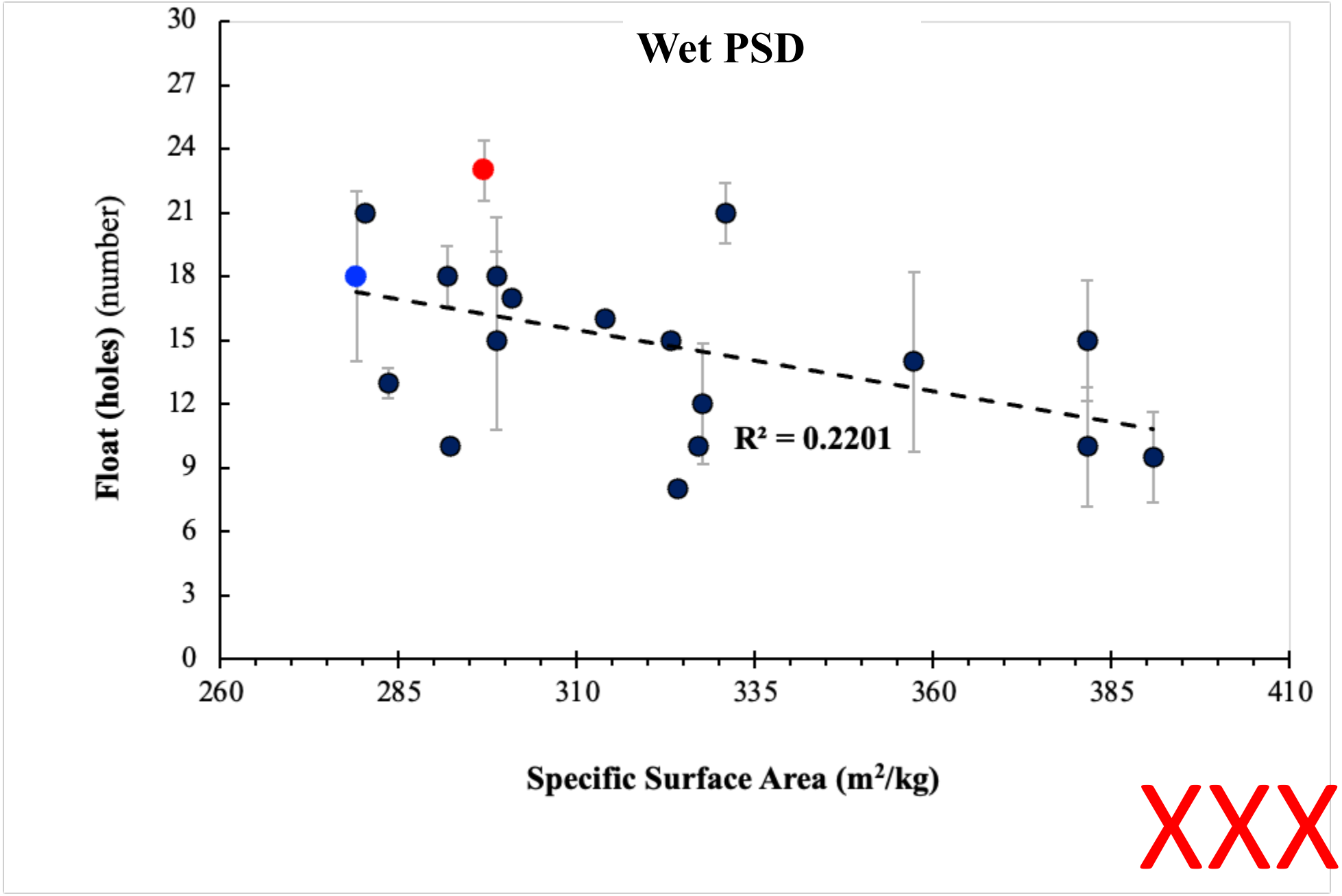
- The Type IL from the same plant as the I/II required 20% more passes in the float test

Does fineness predict this?

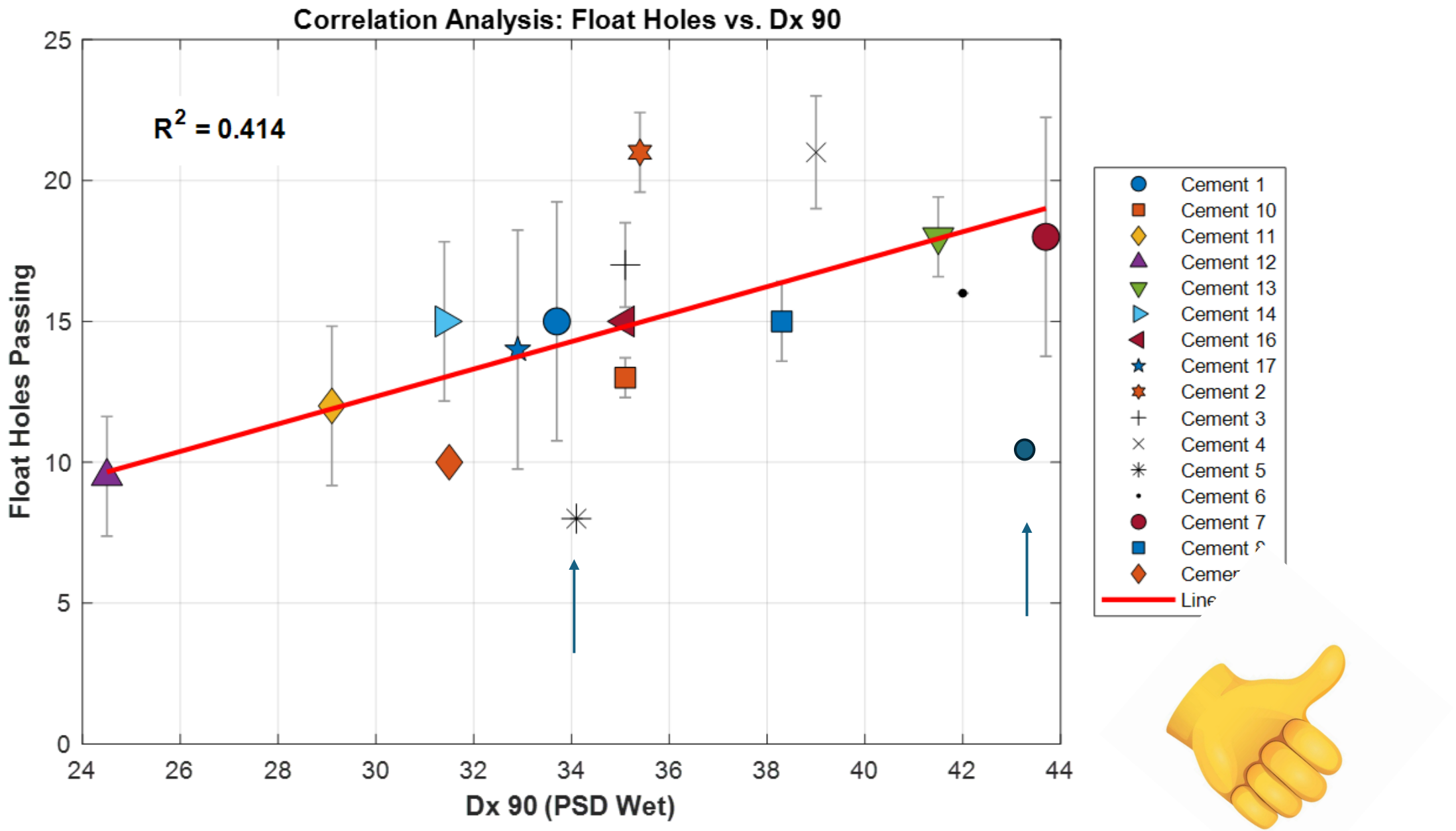
- There can be a wide range of finishing performance in the same market.


Number of float passing (holes)
28
24
20
16
12
8
4
0
350
375
400
425
450
475
500
525
550
575
600
R² = 0.0001
Blaine Fineness (m²/kg)

XXX


Wet PSD
Float (holes) (number)
30
27
24
21
18
15
12
9
6
3
0
260
285
310
335
360
385
410
R² = 0.2201
Specific Surface Area (m²/kg)

XXX


Correlation Analysis: Float Holes vs. Dx 90
R^2 = 0.414
Float Holes Passing
Dx 90 (PSD Wet)
0
5
10
15
20
25
24
26
28
30
32
34
36
38
40
42
44
Cement 1
Cement 10
Cement 11
Cement 12
Cement 13
Cement 14
Cement 16
Cement 17
Cement 2
Cement 3
Cement 4
Cement 5
Cement 6
Cement 7
Cement 8
Cemer
Line

Discussion

- Blaine does not predict performance in the float test.

- The Wet PSD D90 seems to correlate best with the performance in the float test. We are working on better correlations.

Discussion

- Blaine does not predict performance in the float test.

OK! Let’s wrap this up!!!

What have we learned?

What have we learned?

Different cements have different performances.

What have we learned?

Based on **one** plant where a Type 1L and I/II are produced, the Type 1L has a higher water demand and increased effort to finish the surface.

The **wet PSD** would have predicted this.

What have we learned?

Slump/WR demand – Wet PSD Specific Surface Area

Float – Wet PSD D90

Blaine is not helpful

What have we learned?

There are some Type 1L cements with outstanding finishing and water demand.

The amount of limestone in the cement is not an indicator of performance. Use the Wet PSD.

Do I think our industry should move to wet PSD?

I think it shows promise and Blaine is misleading.

Dry PSD machines can be upgraded to do wet.

You can still use dry PSD for production checks and just do spot checks with the wet PSD.

Why is wet PSD not widely used?

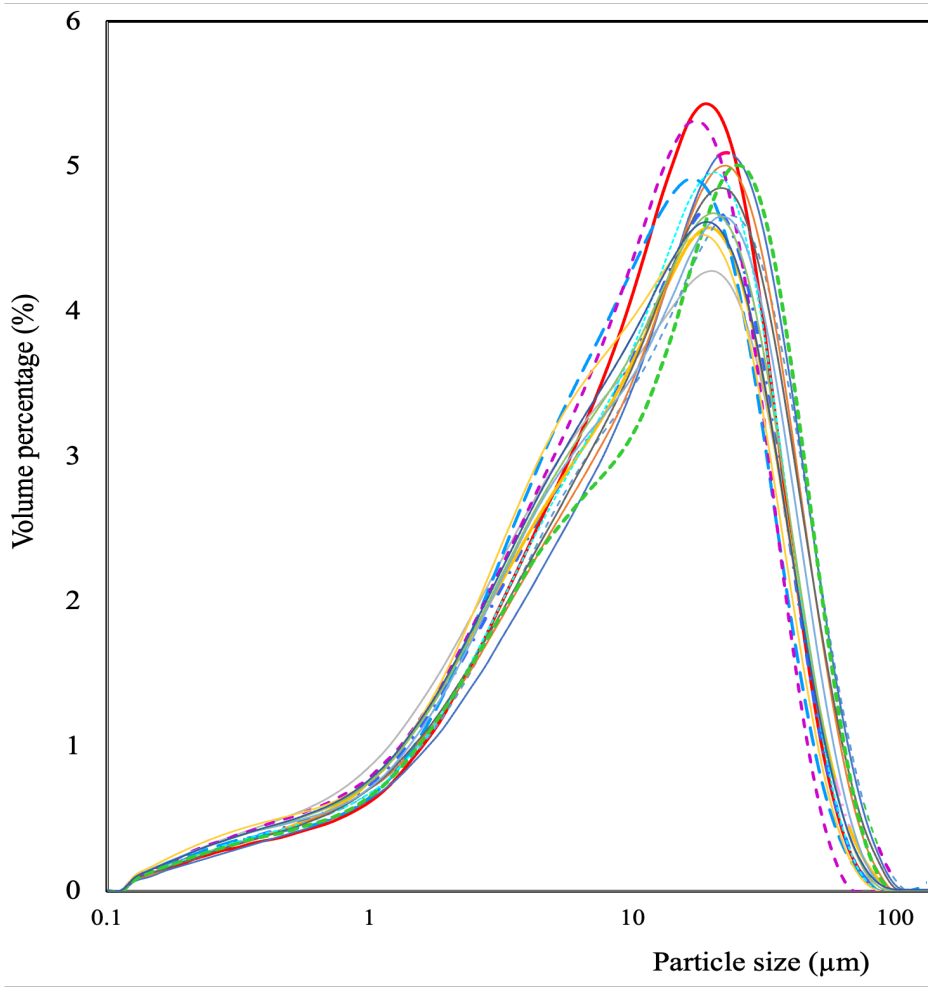
It takes longer and is more expensive than dry PSD.

It requires alcohol to disperse the cement and this increases costs and the alcohol must be disposed of properly.

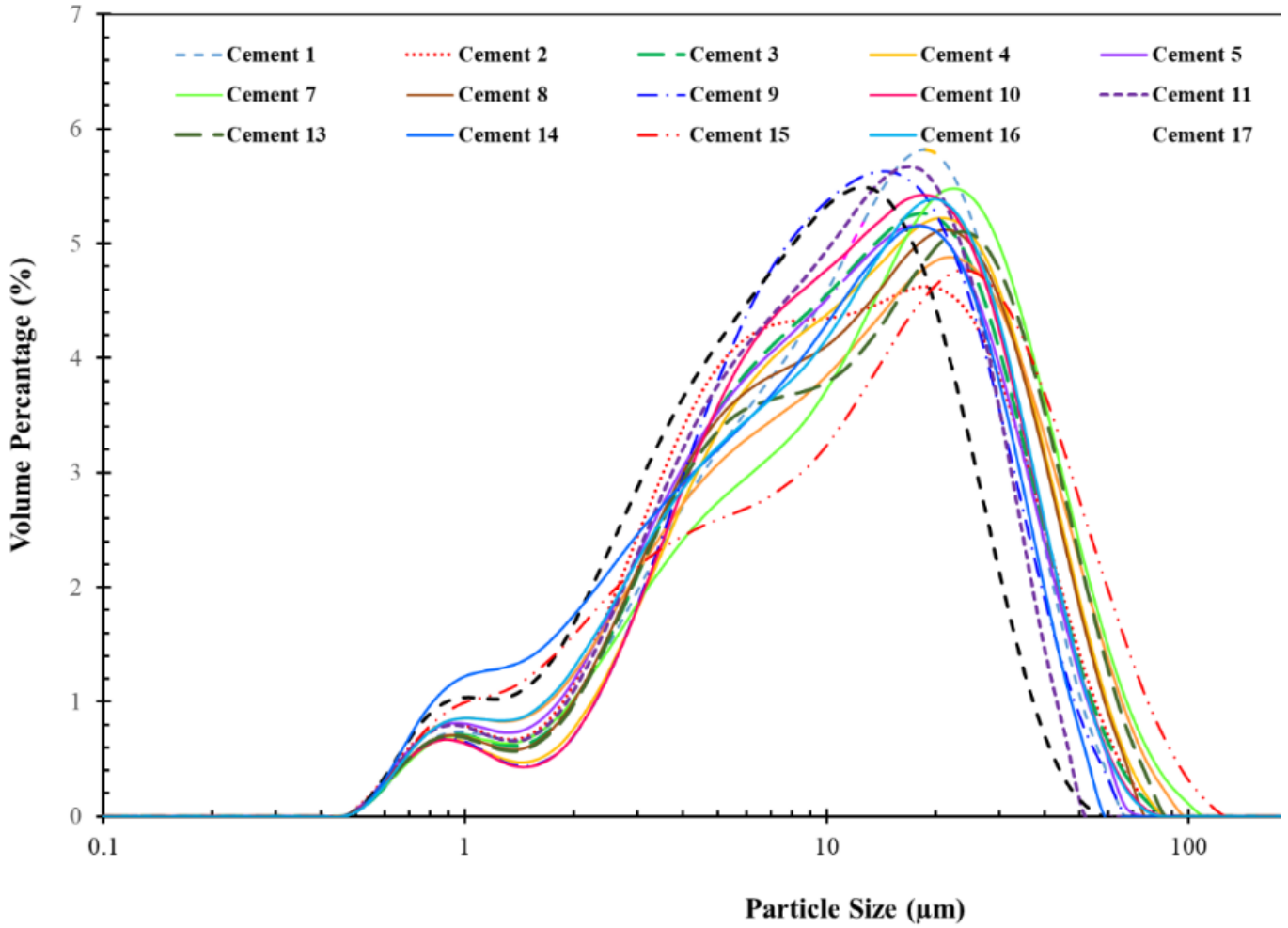
Why is wet PSD better than dry?

Cement particles stick together and the dry PSD is not able to separate them.

The wet PSD uses sonication in the alcohol to improve the dispersion.


Volume percentage (%)
Particle size (μm)
0
1
2
3
4
5
6
0.1
1
10
100

Dry


Cement 1
Cement 2
Cement 3
Cement 4
Cement 5
Cement 7
Cement 8
Cement 9
Cement 10
Cement 11
Cement 13
Cement 14
Cement 15
Cement 16
Cement 17
Volume Percantage (%)
Particle Size (μm)
0
1
2
3
4
5
6
7
0.1
1
10
100

Wet

What can cement companies do?

Tweak your processes to decrease your wet PSD specific surface area and your D90.

Blaine is not helpful, and I think it is misleading and hurting you.

What can ready mix producers do?

Use a standard mix to check your water slump and finishability performance with the float test with new deliveries of materials.

Talk to your cement producers about measuring and reporting the wet PSD.

What can owners do?

Require trial batching that measures what matters most to you.

Bridge deck/sidewalk – Slump and Float Test

Pavement – Box Test

Require a mock up or test pour

Why don’t we do this in transportation?

What can contractors do?

Push the owner for a mock up.

Do one anyway on projects that matter where you simulate the delivery, haul time, and finishing.

Tell the ready mix what you want.

What other work is needed?

17 cements is good but more would is needed.

We need to test more plants that do both Type IL and I/II.

We need to compare different wet PSD machines to see how they compare.

What other work is needed?

We need to look at bleed at a much deeper level.

I think our bleed measurement methods need to change.

More work is needed to determine why certain cements perform the way they do.

What other work is needed?

Would you be willing to fund research to do this?

More work is needed to determine why certain cements perform the way they do.

Two part discussion

Part 1 – Fresh properties

Part 2 – Curing

Project is finished in June

Two part discussion

Part 1 – Fresh properties

Part 2 – Curing ← **This afternoon!**

Project is finished in June

www.concretefreaks.com

Structural Cracking in Reinforced Concrete

www.youtube.com/tylerley

Tyler Ley, PE, PhD

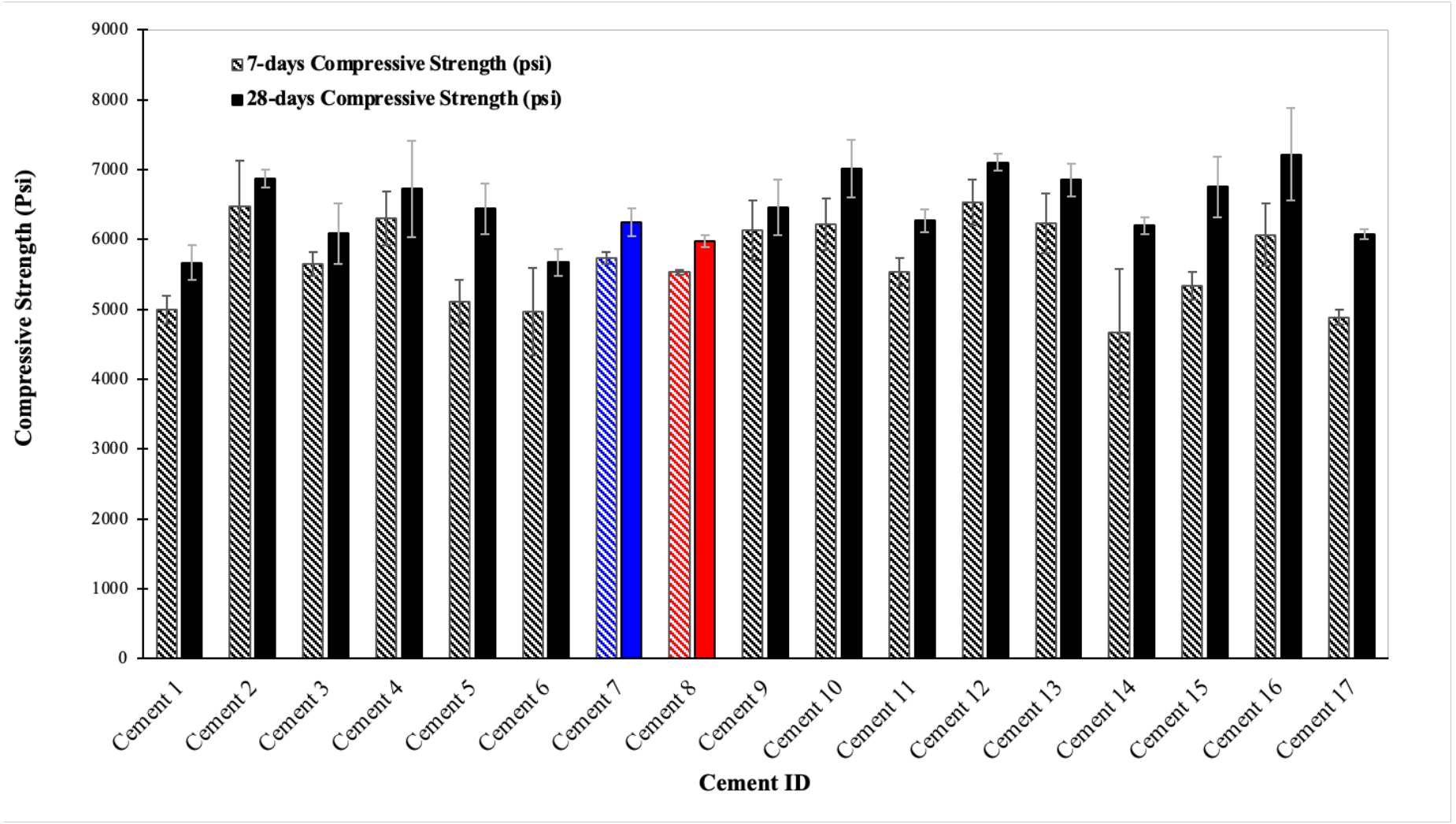
Questions?

Tyler.ley@okstate.edu

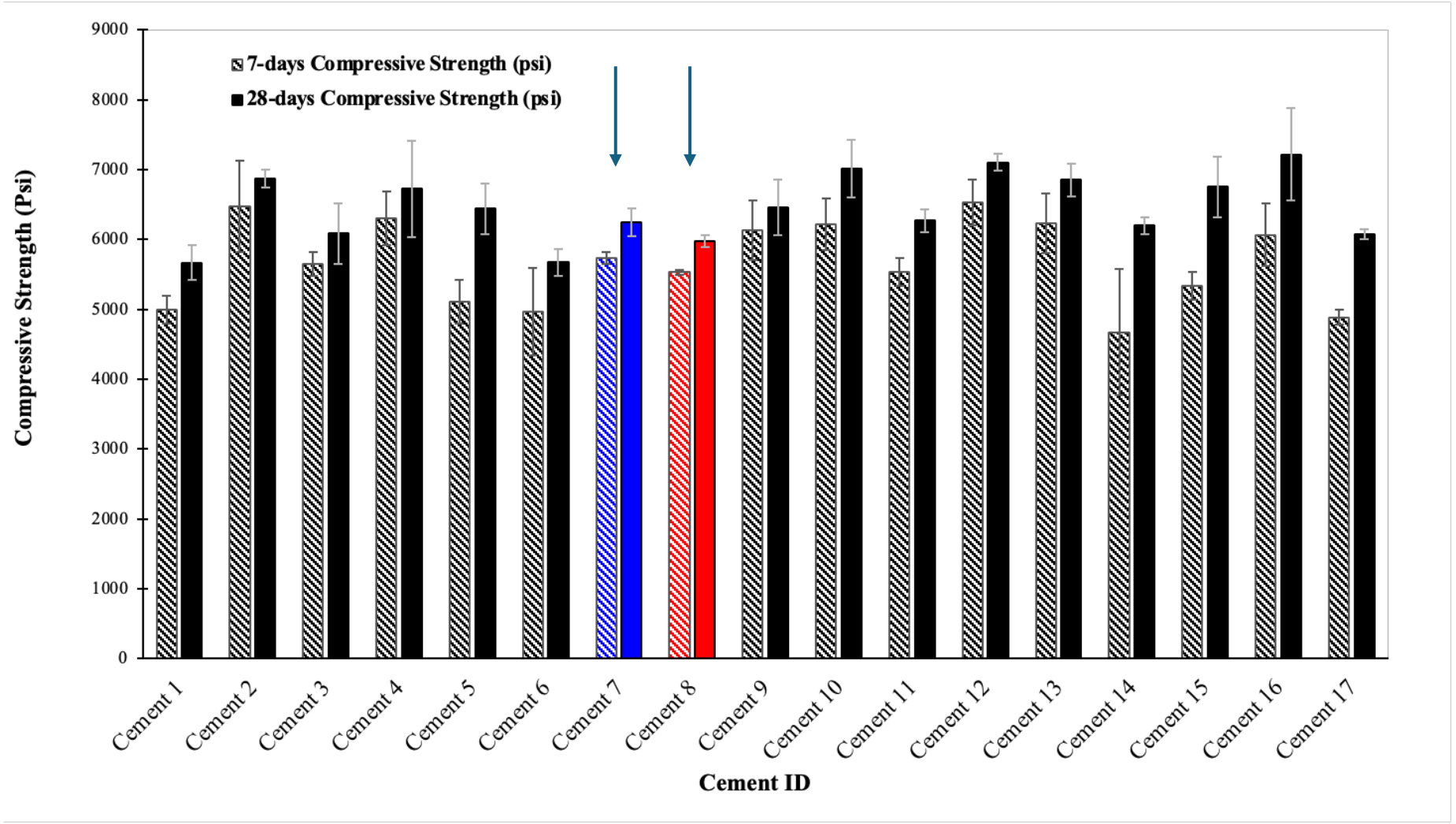
Discussion

- Blaine does not predict performance in the float test.

How do the strengths compare?

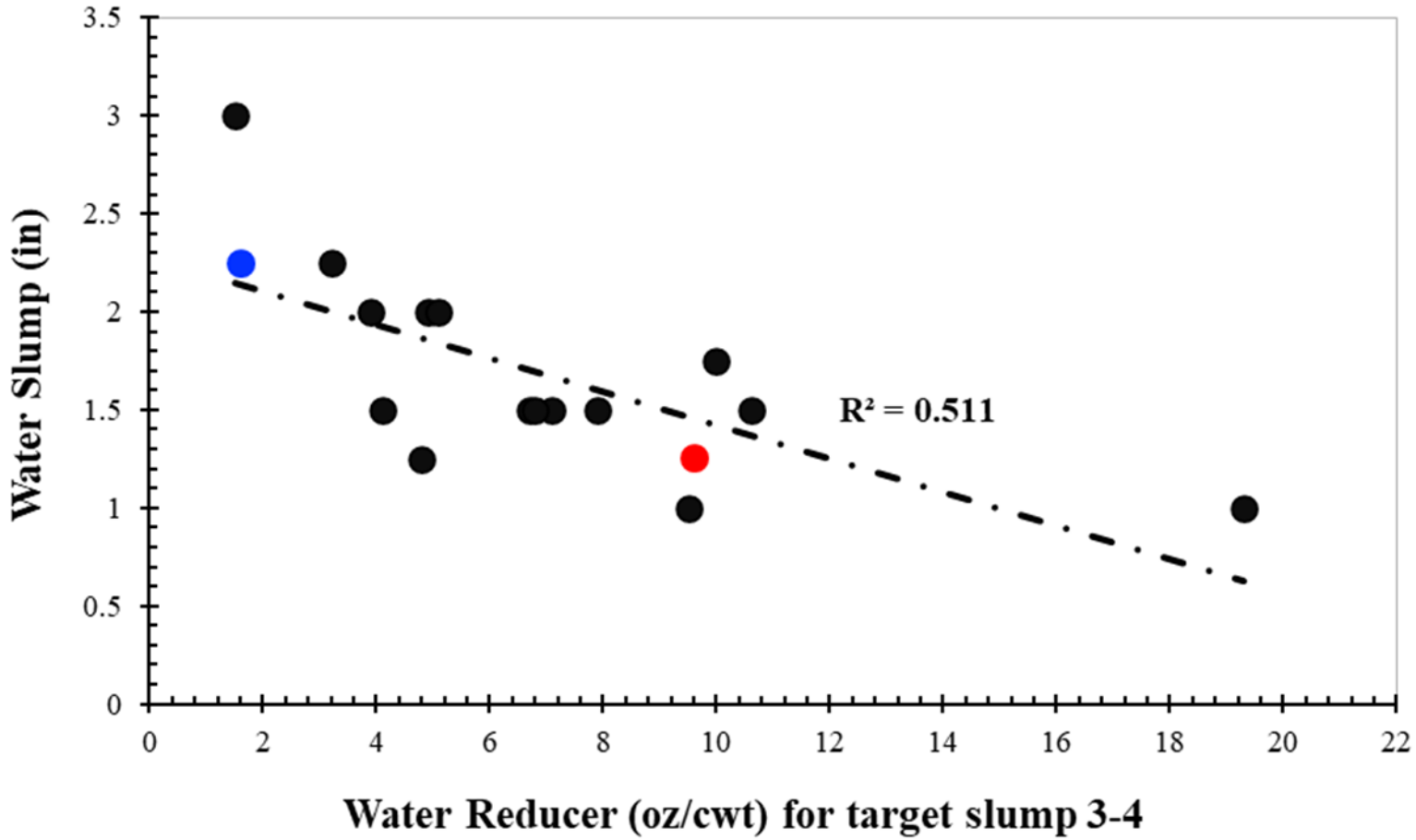


7-day strength – 4800 to 6500 psi
28-day strength – 5500 to 7300 psi

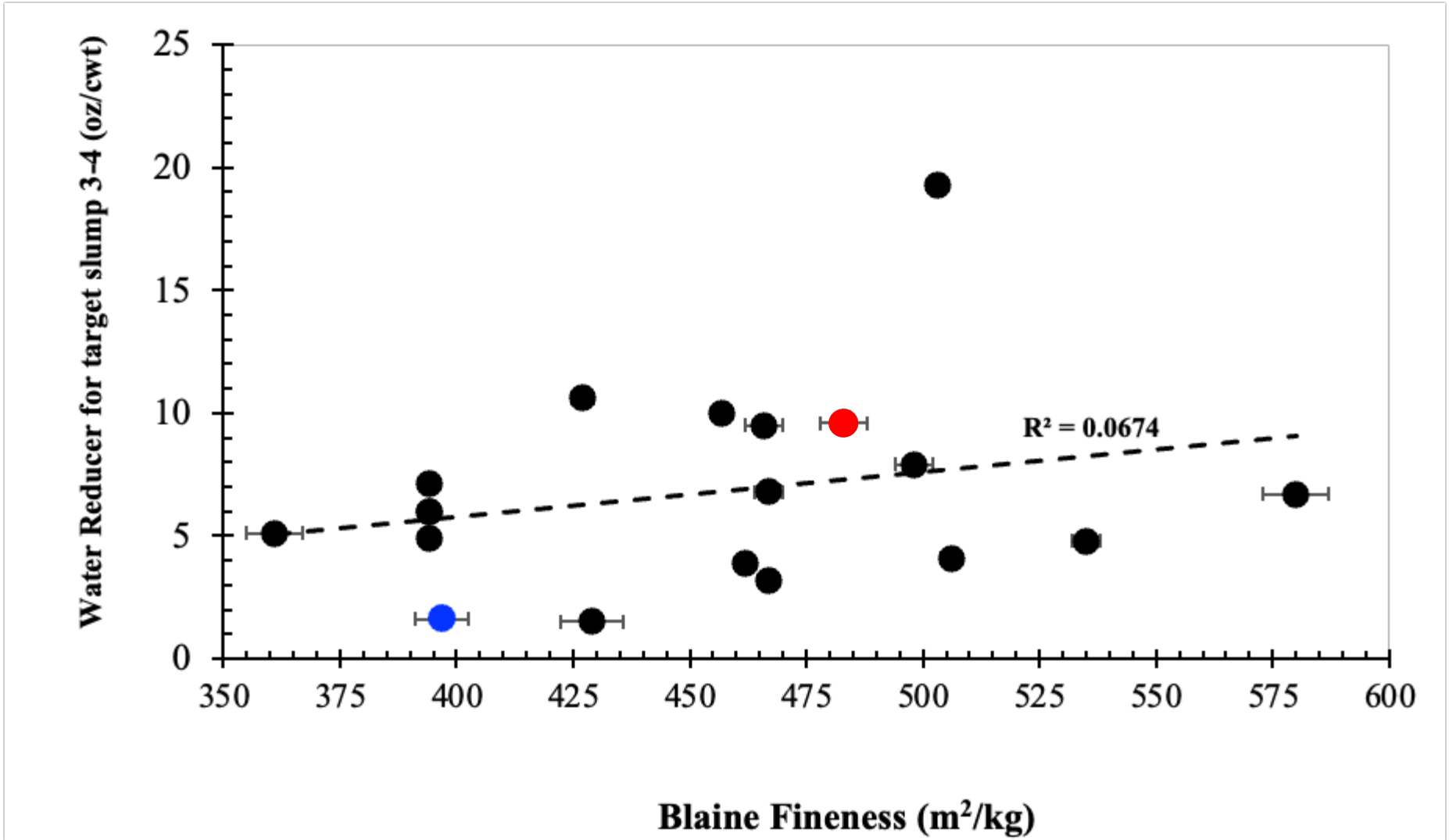


7-day strength – 4800 to 6500 psi
28-day strength – 5500 to 7300 psi


1-800-547-4296
SAFE-T-STRAP



Red – Type IL
Blue – Type I/II
at same plant

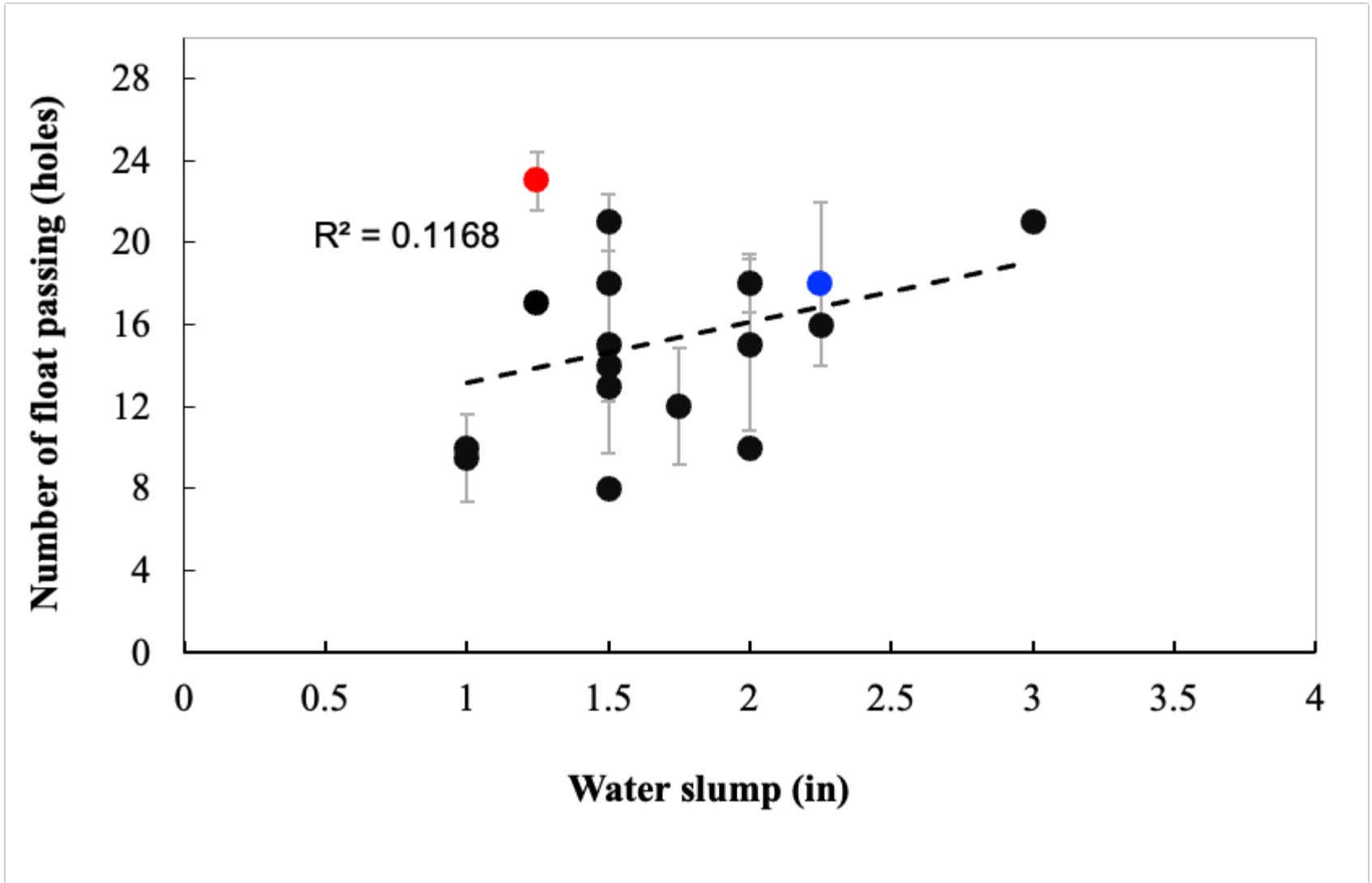


Red – Type IL
Blue – Type I/II
at same plant

Discussion

- The water reducer demand is closely related to the water slump but not the Blaine.

- Admixture performance is a function of the fineness, C3A, and alkalinity of the cement.

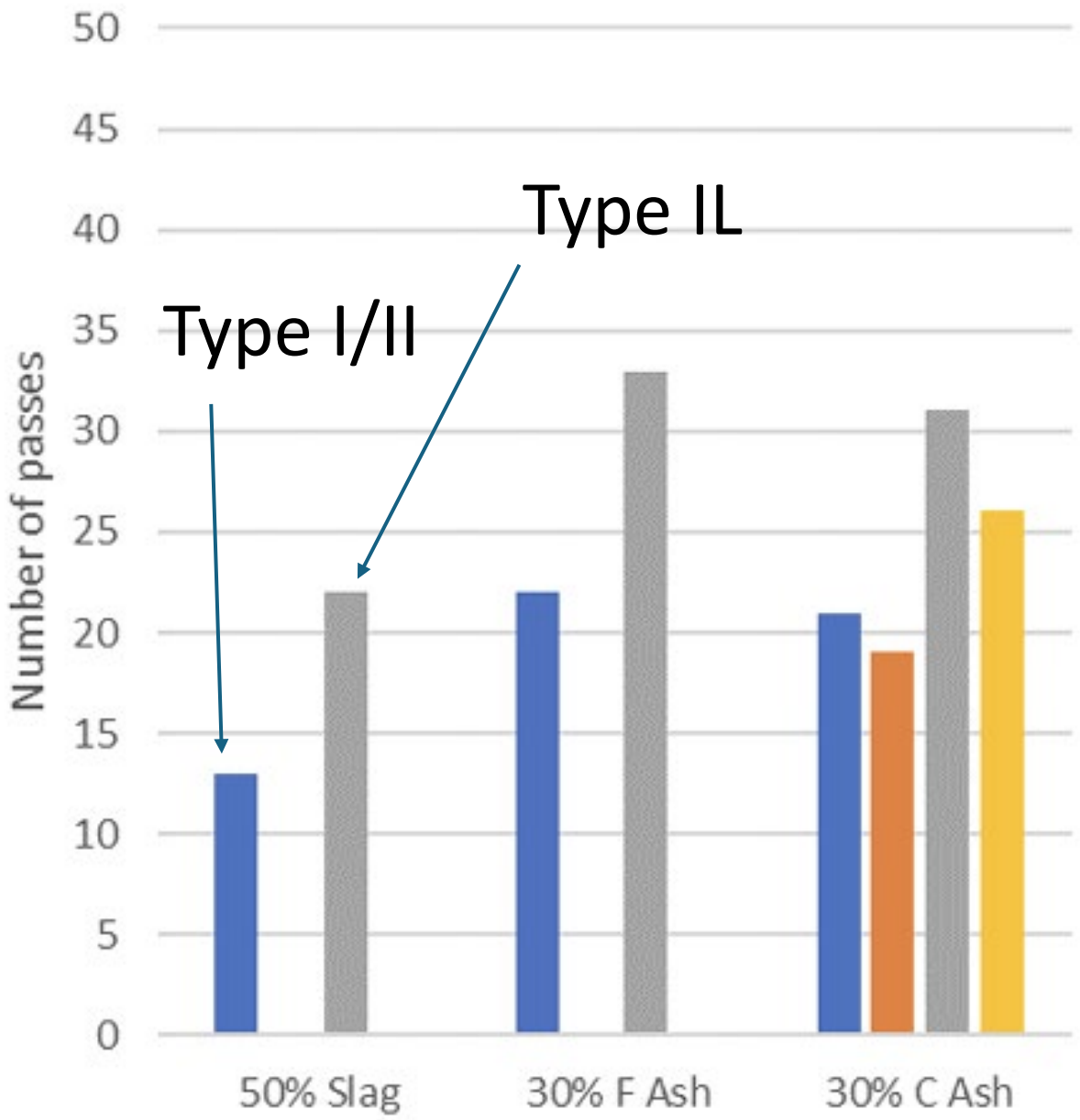

Number of float passing (holes)
28
24
20
16
12
8
4
0
R² = 0.1168
0
0.5
1
1.5
2
2.5
3
3.5
4
Water slump (in)

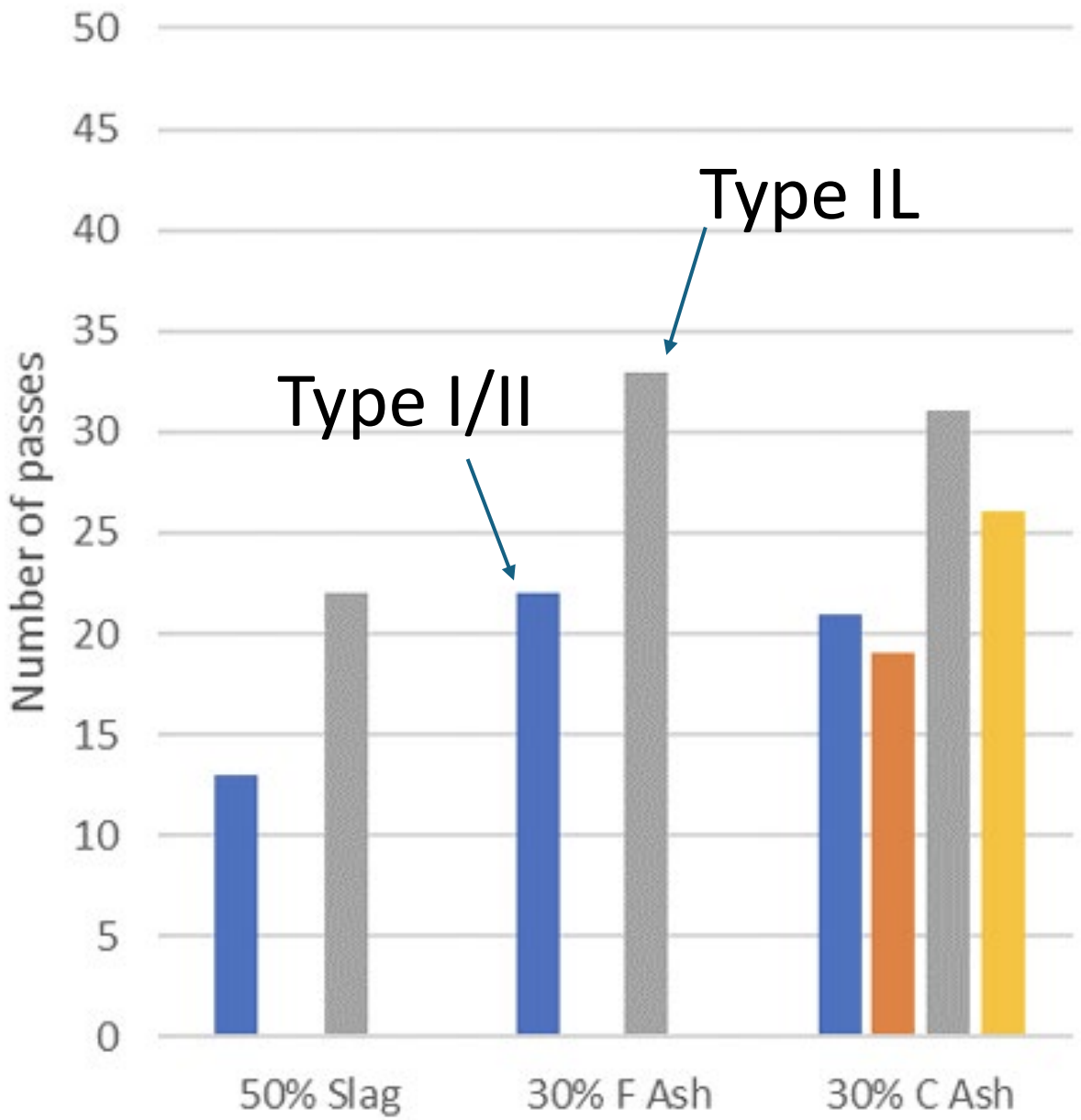
Cemex Testing

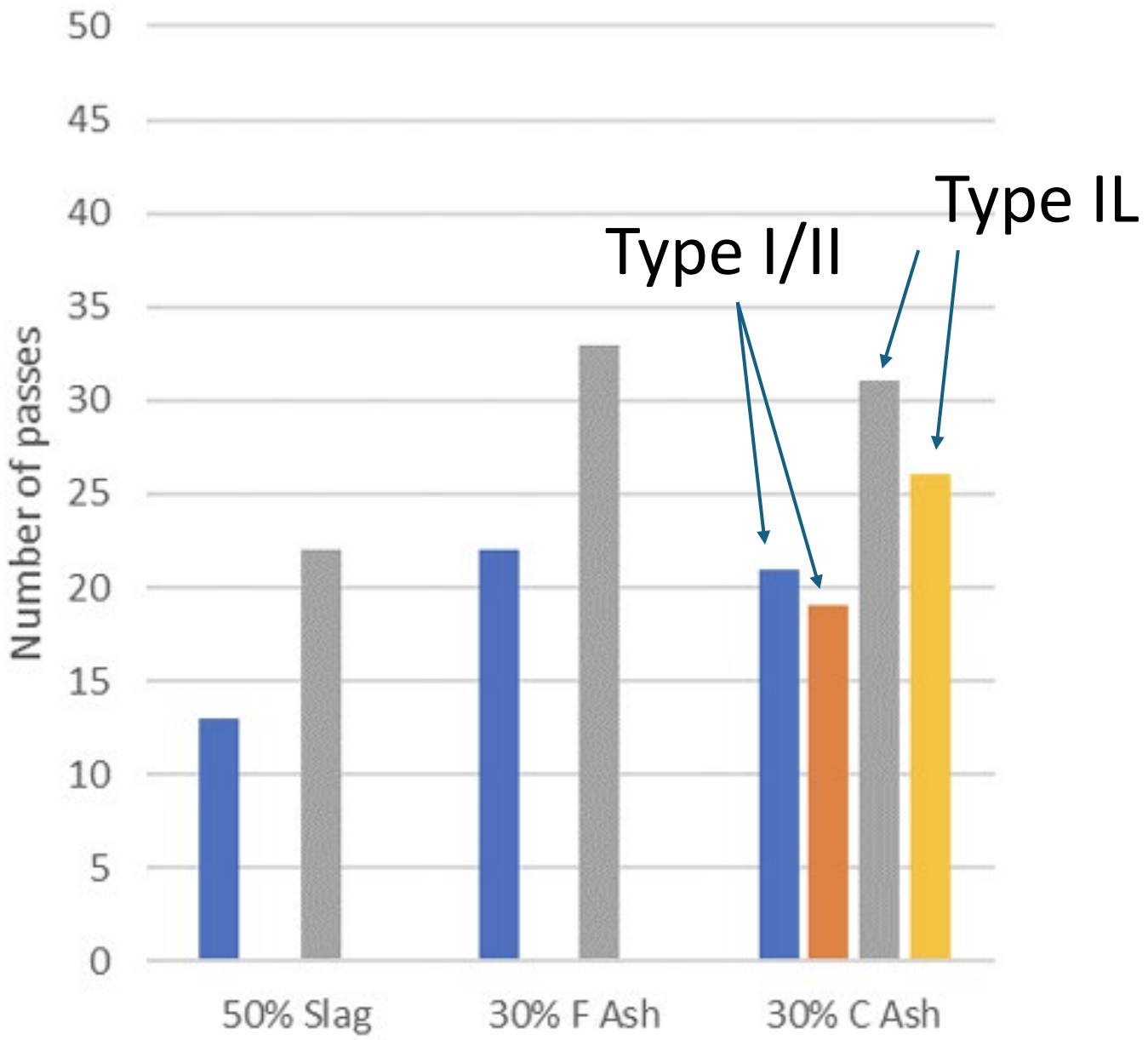
- Used the same mixture design between all trials.
- Slump was adjusted to be 2” +/- ½”
- The float test was used to compare:
  - 2 – Type I/II cements
  - 2 – Type IL cements


CAUTION
SAFETY GLASSES
REQUIRED

26 Passes


Type IL
Type I/II
Number of passes
50
45
40
35
30
25
20
15
10
5
0
50% Slag
30% F Ash
30% C Ash


Type IL
Type I/II
Number of passes
50
45
40
35
30
25
20
15
10
5
0
50% Slag
30% F Ash
30% C Ash


Type I/II
Type IL
Number of passes
50
45
40
35
30
25
20
15
10
5
0
50% Slag
30% F Ash
30% C Ash

Discussion

- The Type IL cements took more passes to finish the surface.

- This means that it will take more effort to finish the surface in the field.

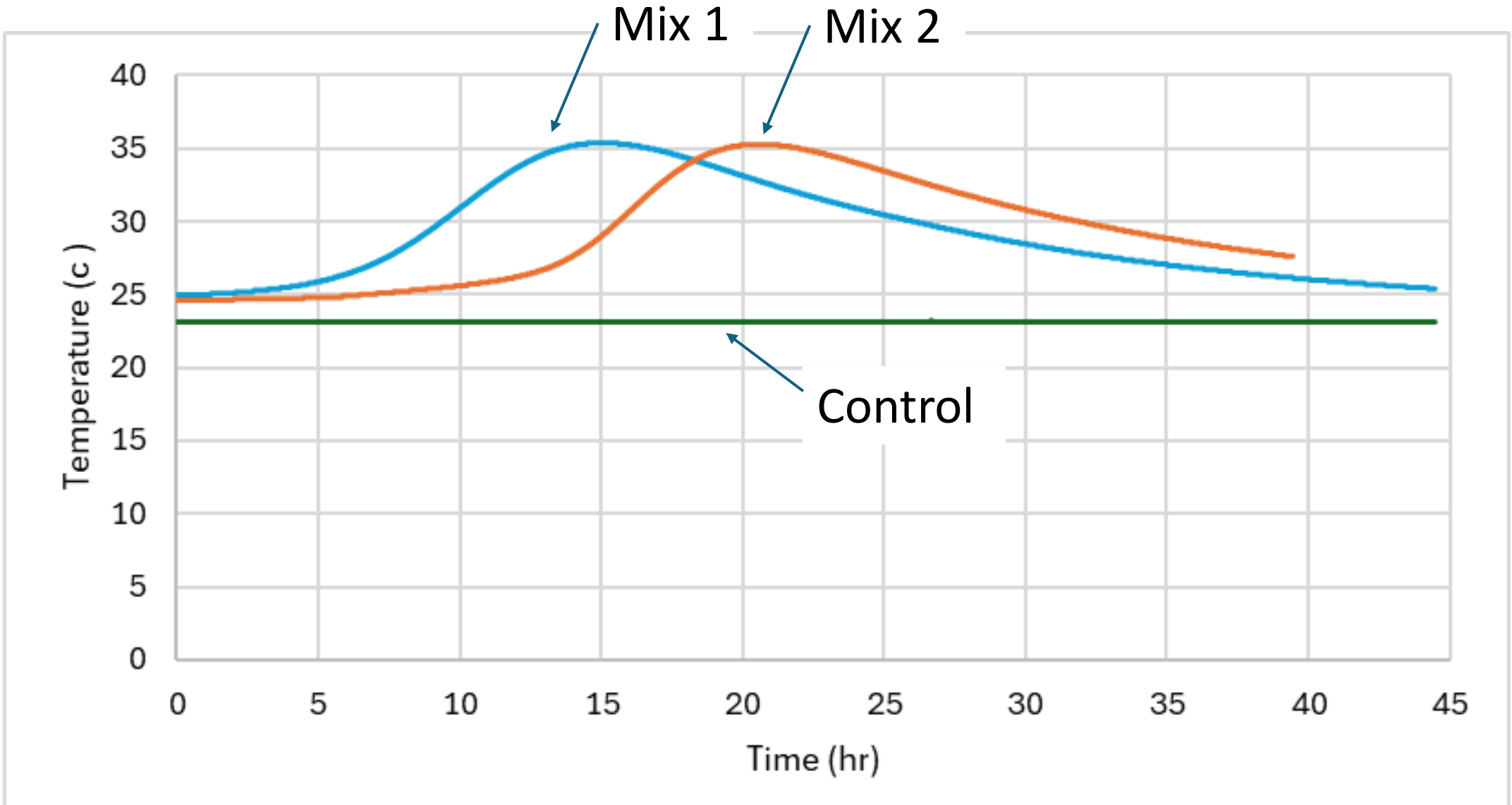
Semi-Adiabatic Calorimeter

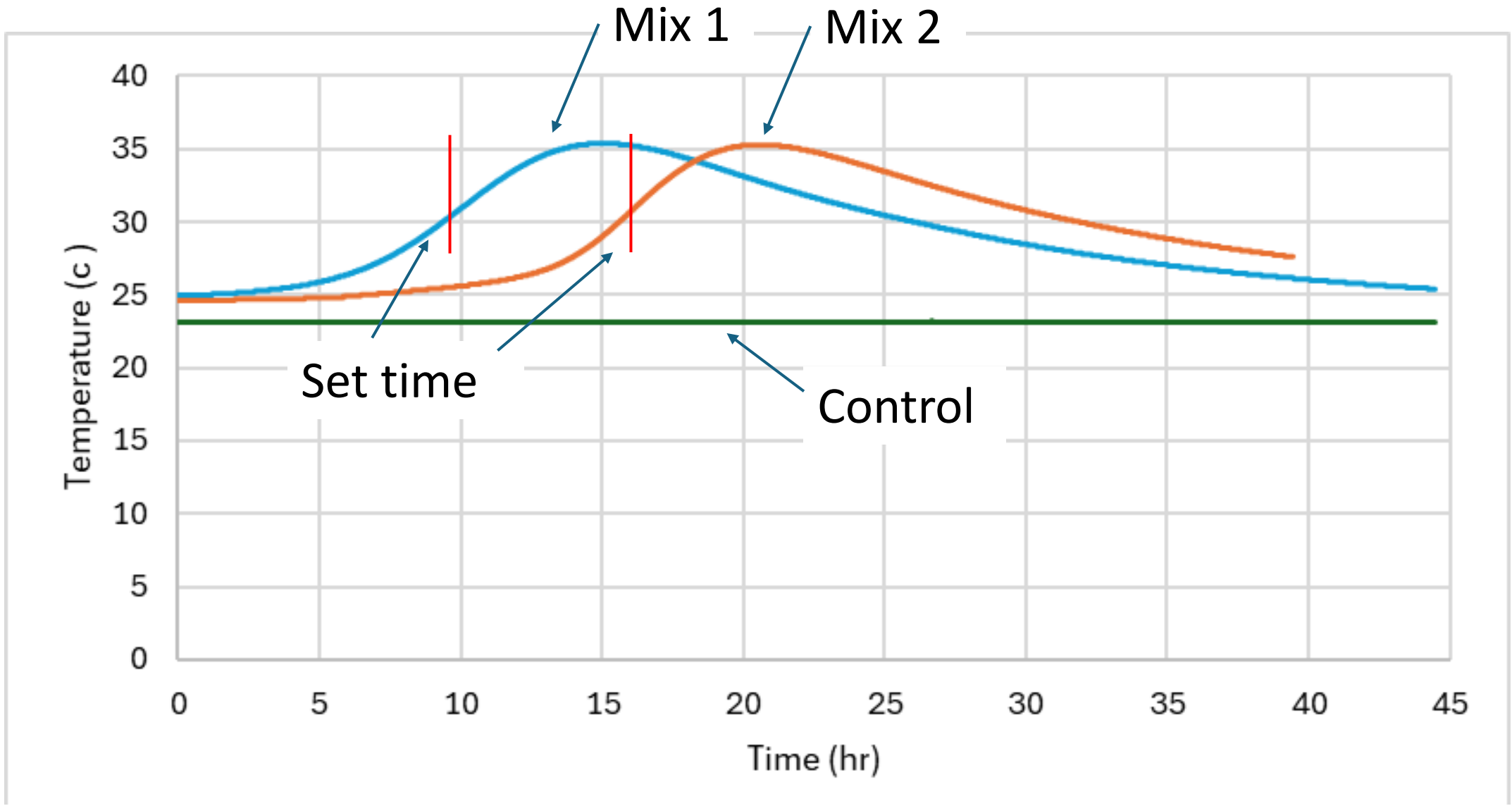
Make concrete

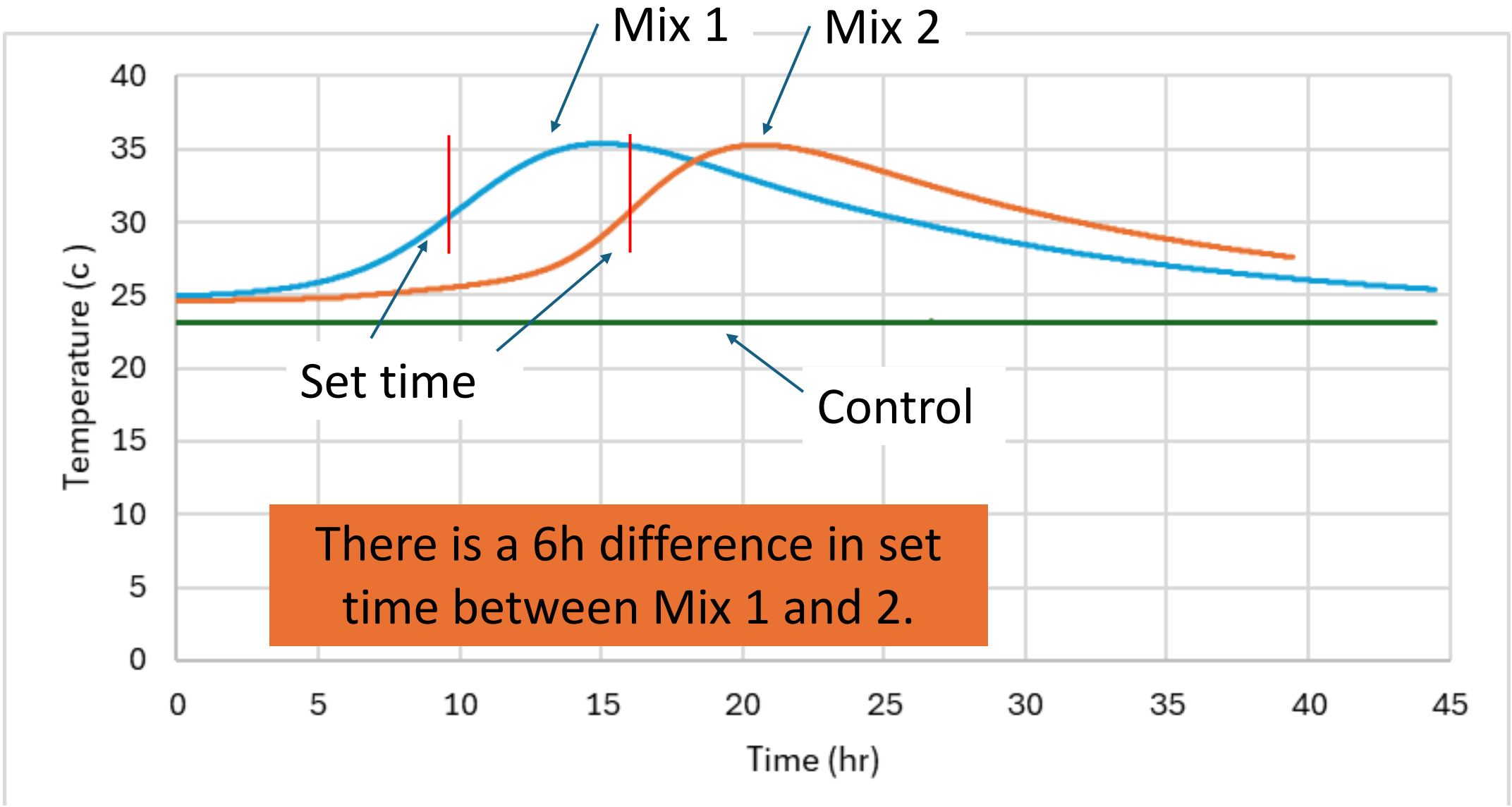
Fill cylinder

Place cylinder in the box

This measures the heat given off during hydration.


Mix 1
Mix 2
Control
Temperature (c)
Time (hr)
0
5
10
15
20
25
30
35
40
45


Mix 1
Mix 2
Set time
Control
Temperature (c)
Time (hr)
0
5
10
15
20
25
30
35
40
45

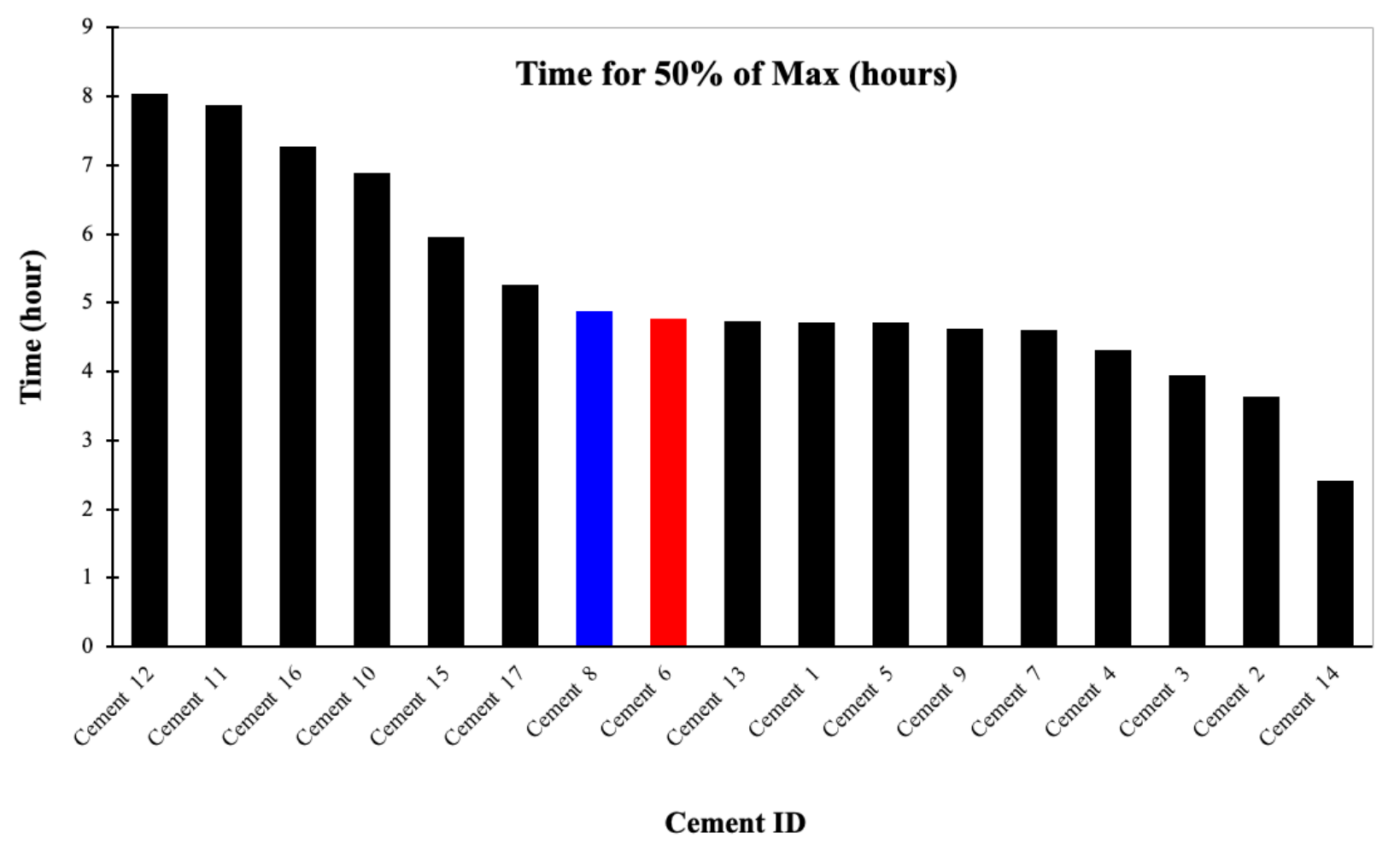

Mix 1
Mix 2
Set time
Control
There is a 6h difference in set time between Mix 1 and 2.
Temperature (c)
Time (hr)
0
5
10
15
20
25
30
35
40
45

Discussion

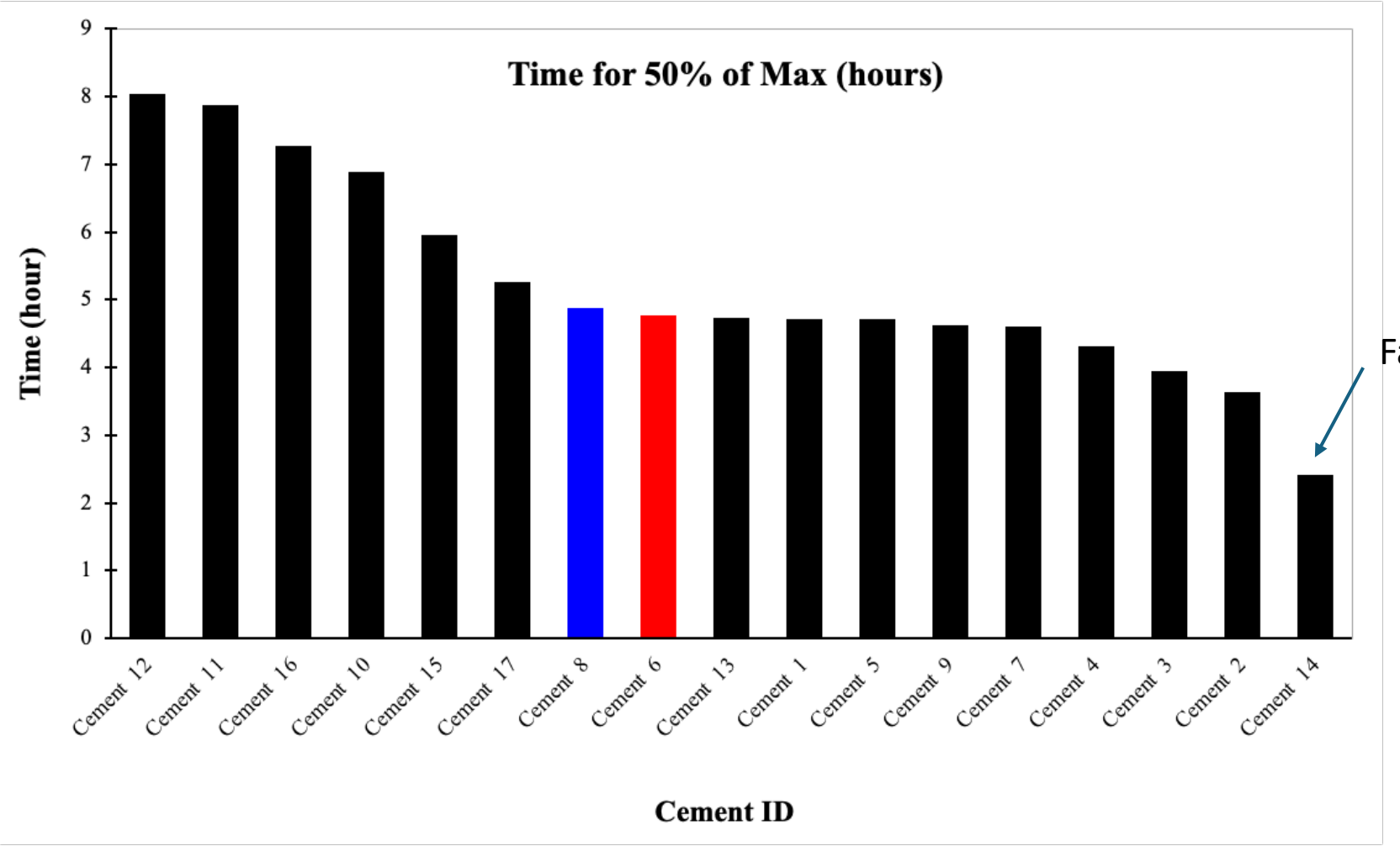
- Calorimetry testing can help you estimate relative set time and strength gain.

- This is useful tool to trouble shoot mixtures and look for consistency of materials.

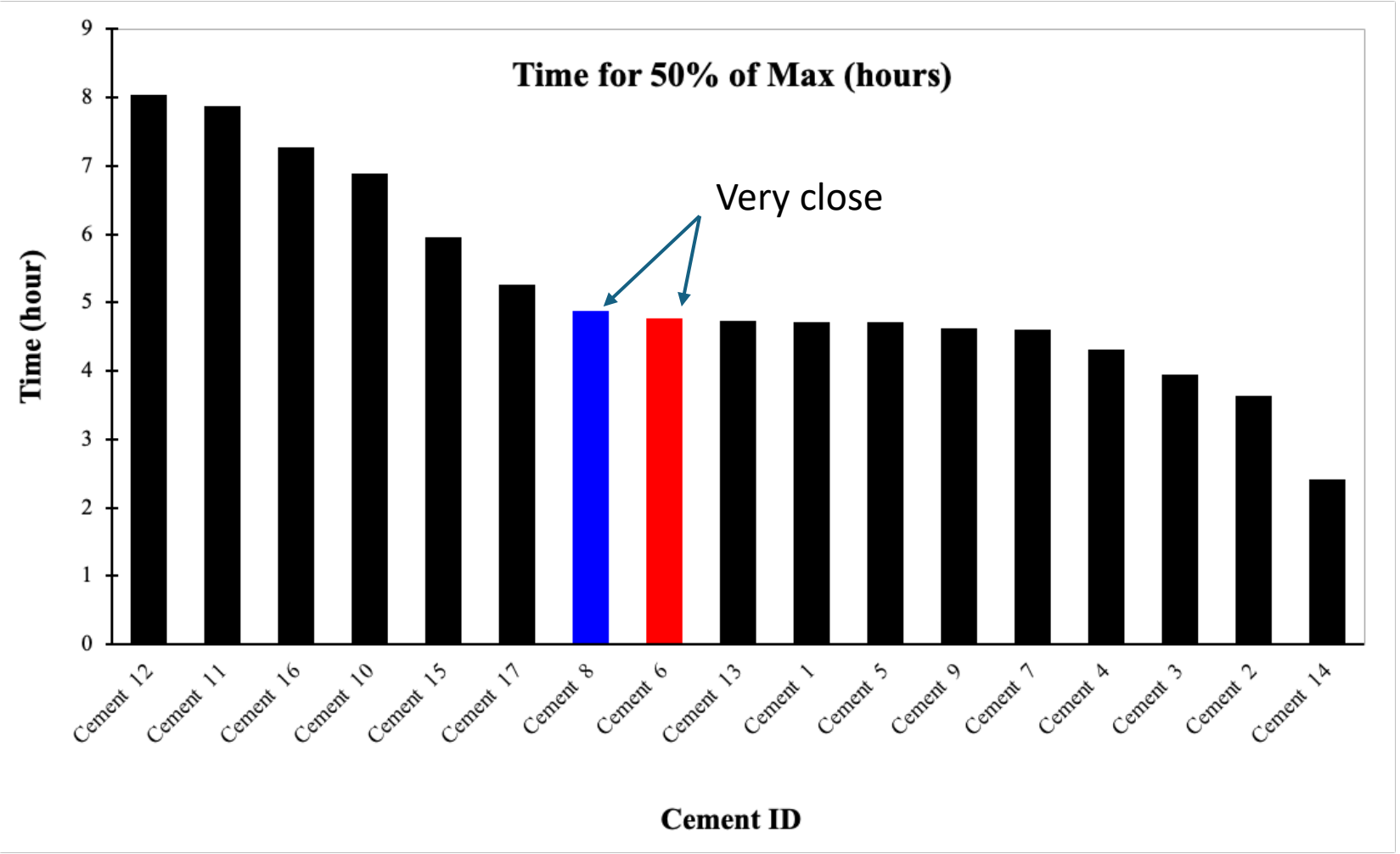
Estimate of final set from Calorimetry



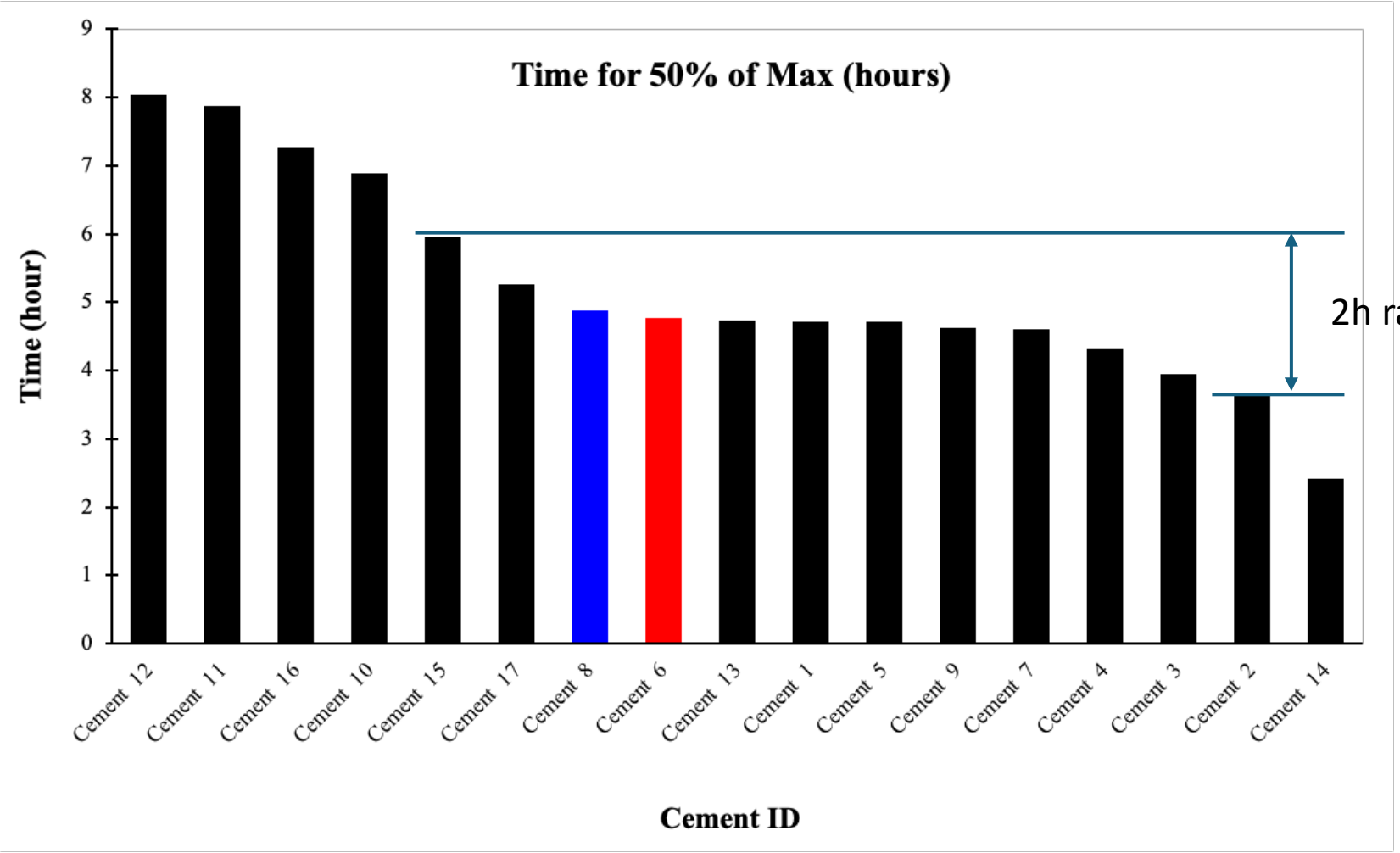
Estimate of final set from Calorimetry



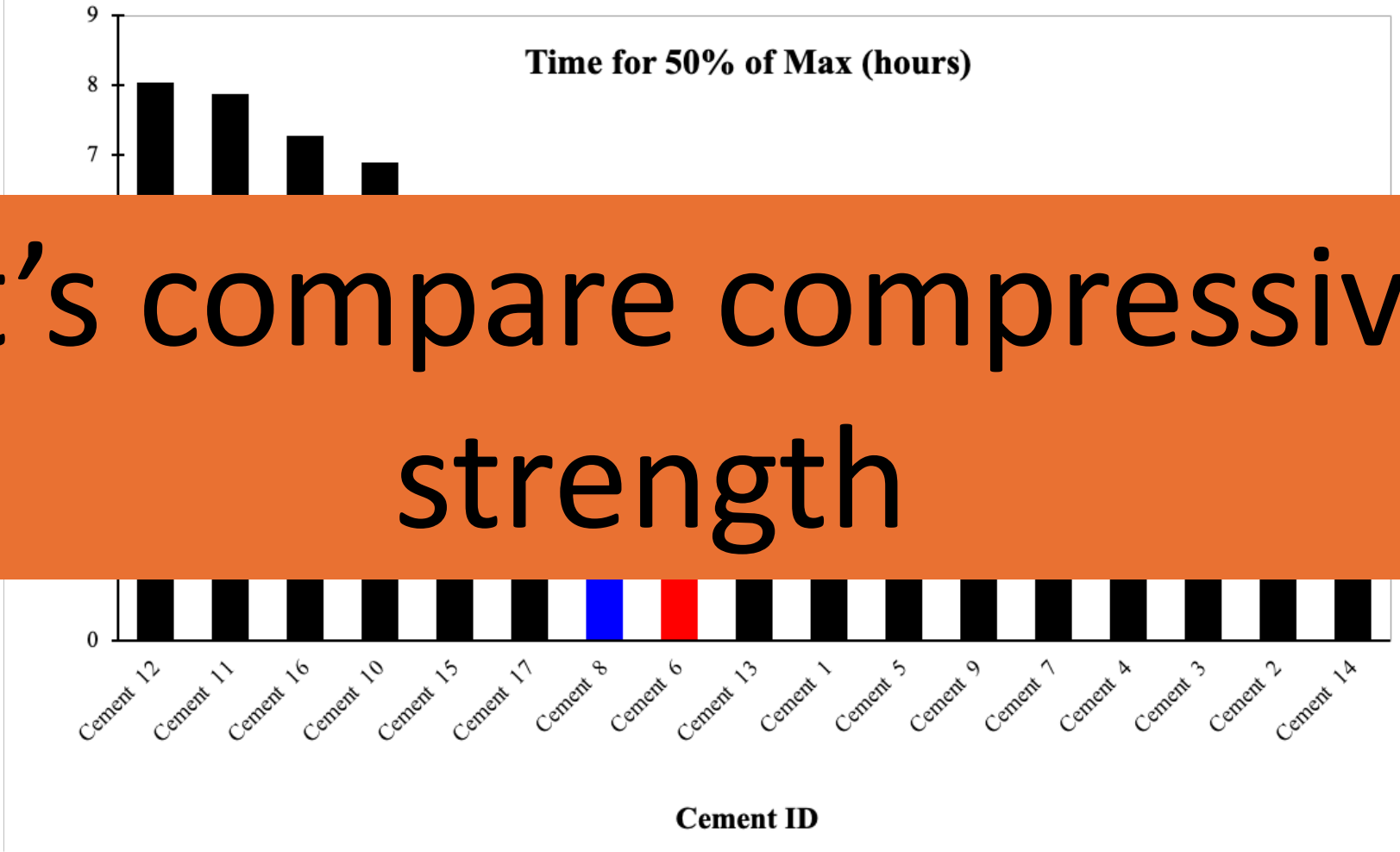
Estimate of final set from Calorimetry



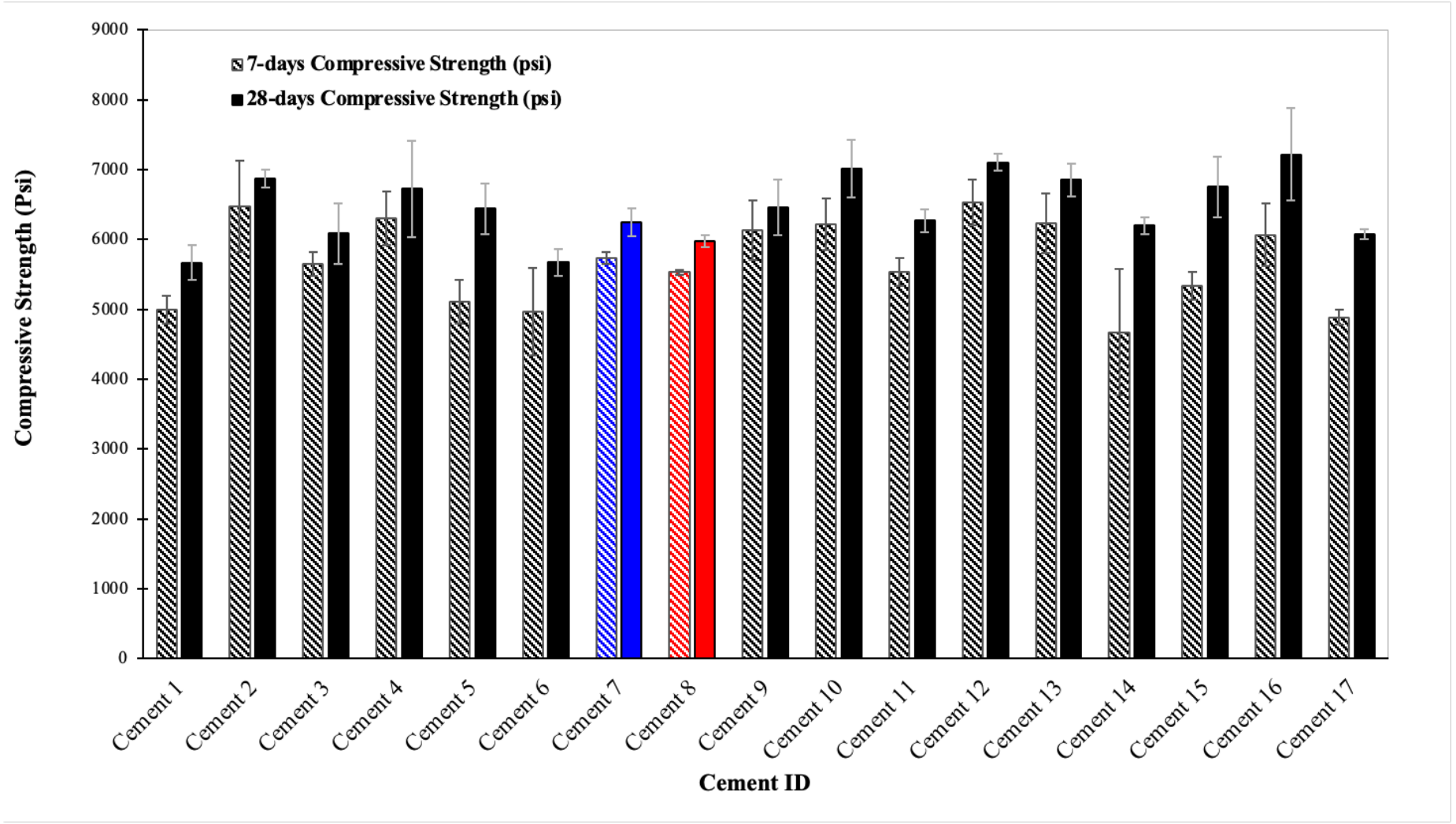
Estimate of final set from Calorimetry



Estimate of final set from Calorimetry



Let’s compare compressive strength



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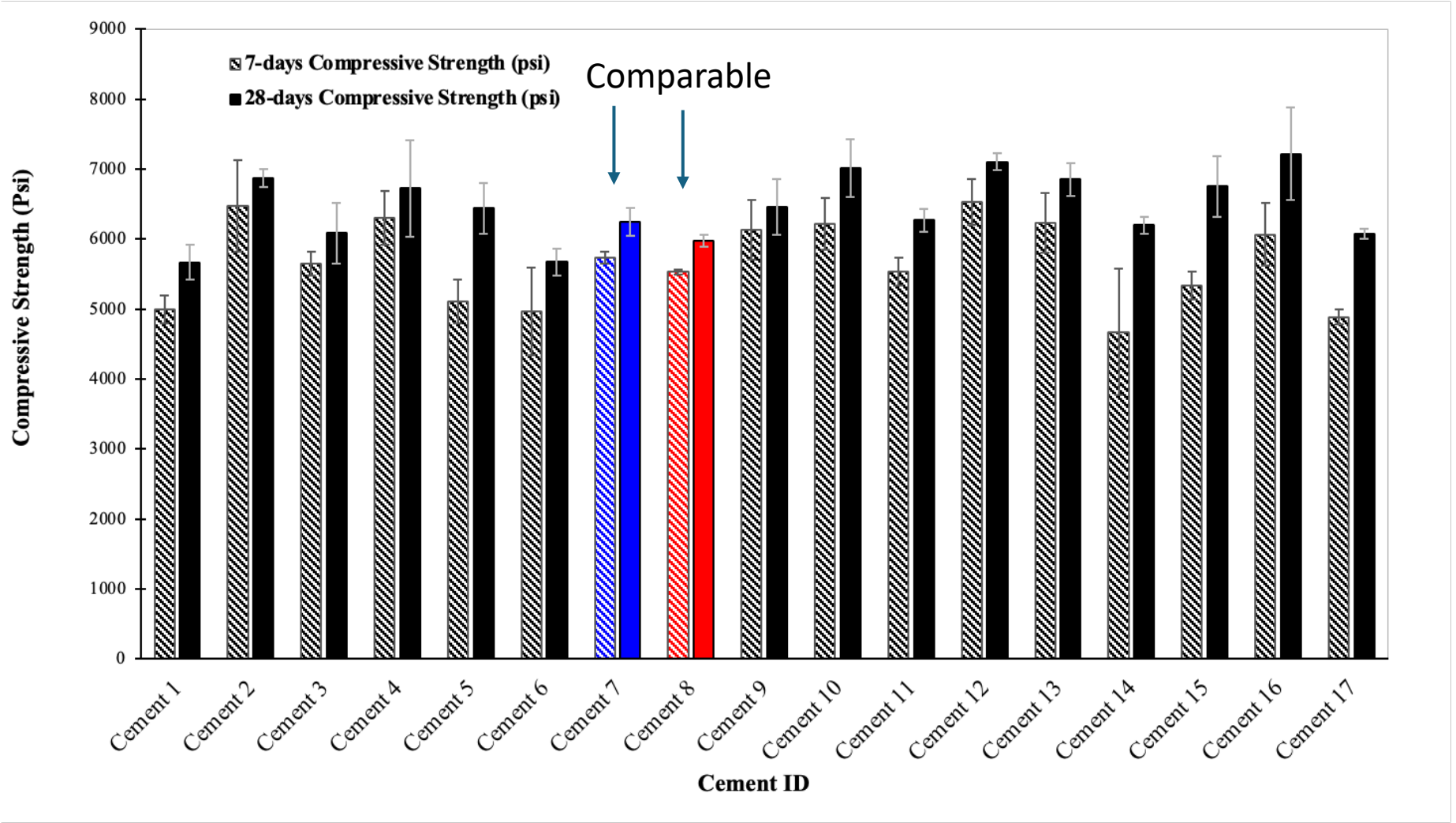
28-day strength – 5500 to 7300 psi



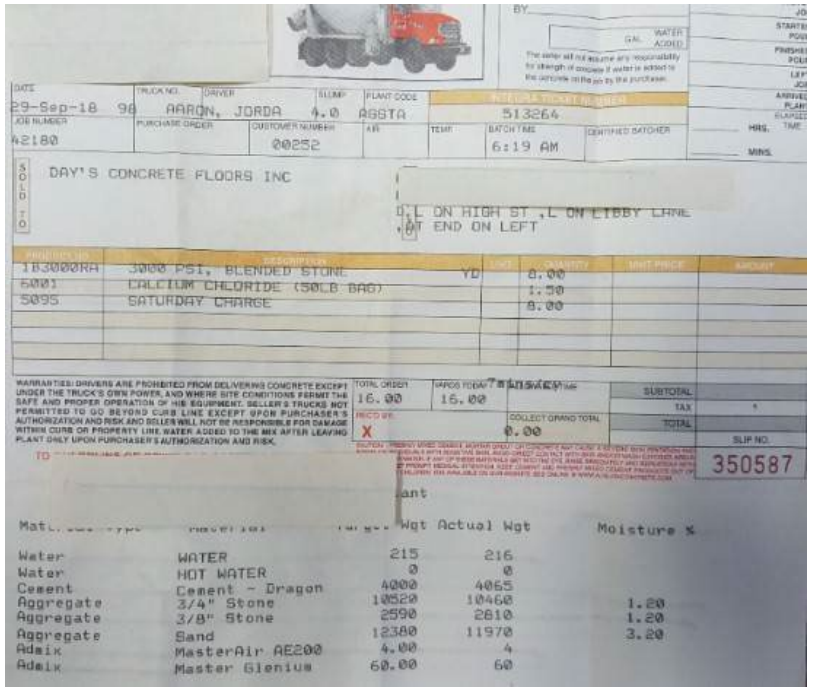
7-day strength – 4800 to 6500 psi
28-day strength – 5500 to 7300 psi

Discussion

There is little difference in the heat given off and the compressive strength at 7 and 28 d for the companion Type I/II and Type 1L cements

The calorimetry estimated final set is comparable for most of the cements.

Items needed…



DAY'S CONCRETE FLOORS INC

29-Sep-18	98	AARON, JORDA	4.0	AGGTA
42180		00252		513264

6:19 AM

183000RA	3000 PSI, BLENDED STONE	YD	8.00	
5001	CALCIUM CHLORIDE (50LB BAG)		1.50	
5095	SATURDAY CHARGE		9.00	

TOTAL ORDER	16.00	PREV DELIVERED	16.00	
COLLECT GRAND TOTAL	0.00			

SLIP NO. 350587

		Wgt	Actual Wgt	Moisture %
Water	WATER	215	216	
Water	HOT WATER	0	0	
Cement	Cement - Dragon	4000	4065	
Aggregate	3/4" Stone	10520	10460	1.20
Aggregate	3/8" Stone	2590	2810	1.20
Aggregate	Sand	12380	11970	3.20
Admix	MasterAir AE200	4.00	4	
Admix	Master Glenium	60.00	60	

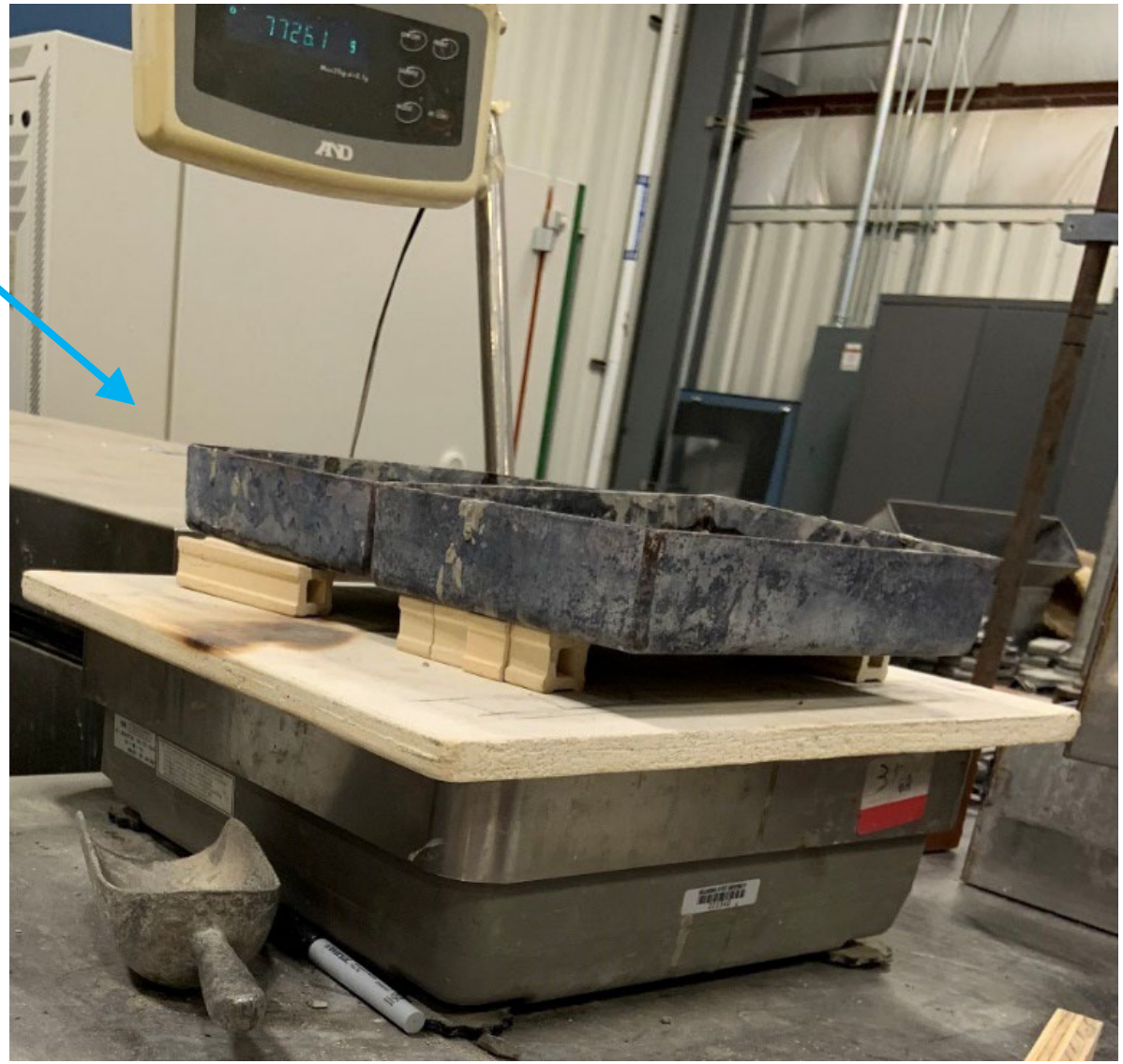
Batch and agg info

Pan on scale

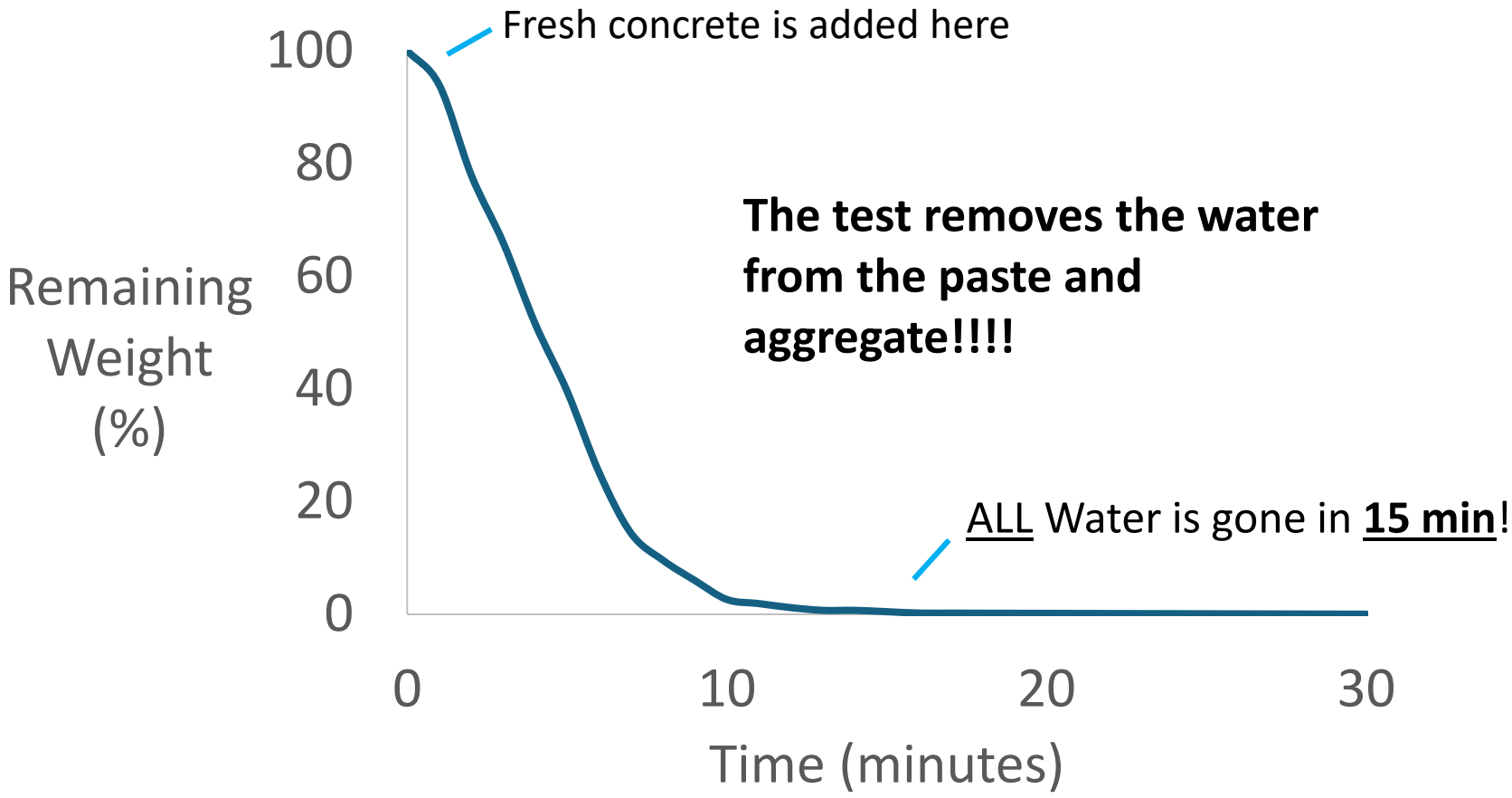
Awesome kiln!!!

1500 °F (816 C) max temp

Dry concrete



Change in weight over time



Discussion

Measure the unit weight of the concrete

Use a spreadsheet or an app to calculate the water to cement ratio of the concrete mixture.

See ASTM C 1953 for more details.