

Measuring the Water Content in Fresh Concrete



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Acknowledgements

FHWA Mobile Concrete Trailer

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Jim Grove

John Anderson



Acknowledgements

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Walt Peters

Background

Why is this important?

Current methods

The Phoenix!

Why is the w/cm important?

- As you increase water in a mix then you increase the spacing between the cement grains.
- This dilutes the mixture.



Why is the w/cm important?

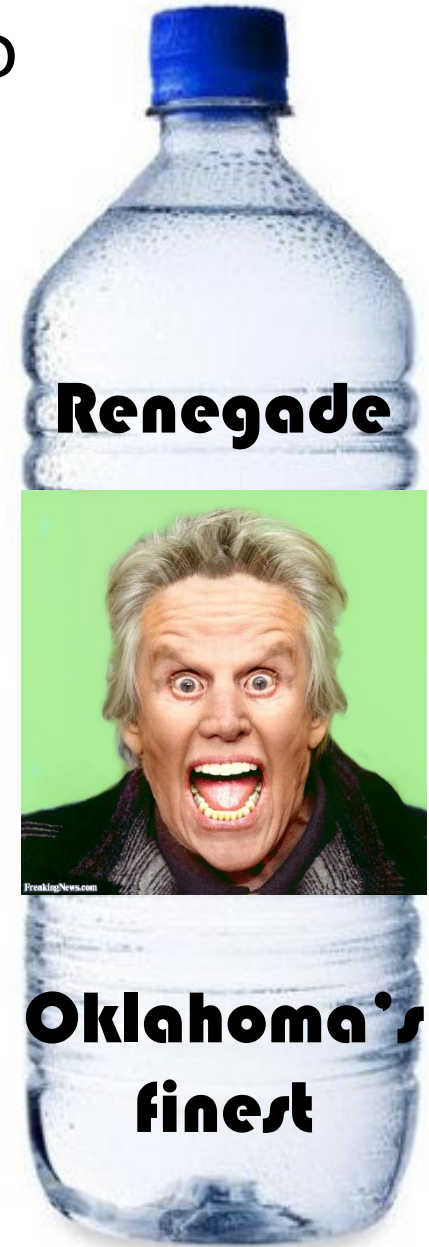
- Determines your strength and permeability.
- Consistency
- **We need a reliable field test to measure this.**

Why is the water content off?

- Incorrect aggregate moisture content
- Batch plant tolerance
- Wrong amount is added
- **Renegade Water!**

What is Renegade Water?

What is Renegade Water?



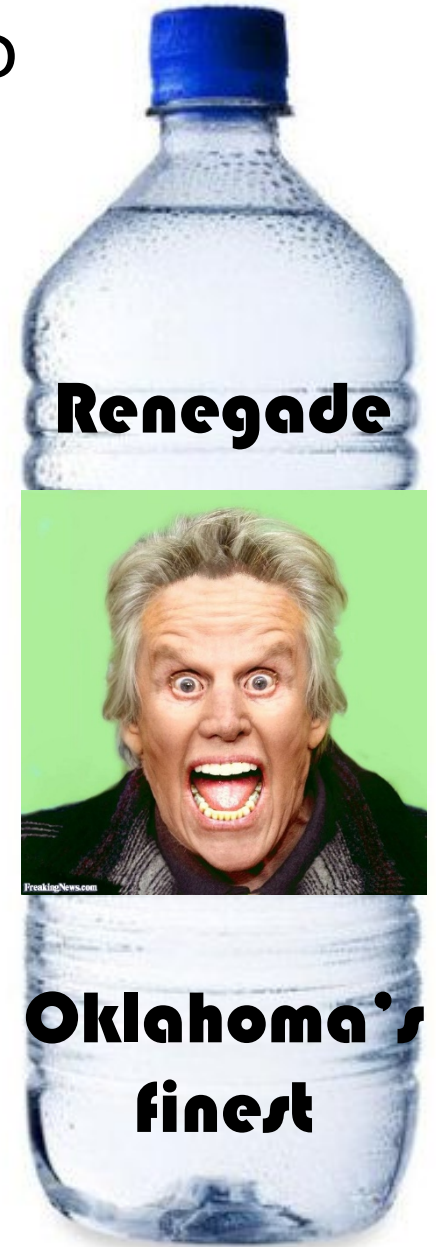
Renegade

**Oklahoma's
finest**

What is Renegade Water?

Water not recorded on the batch ticket -

- In the drum from previous mix
- Added to concrete in transit or on site
- etc



Microwave Oven – AASHTO T 318

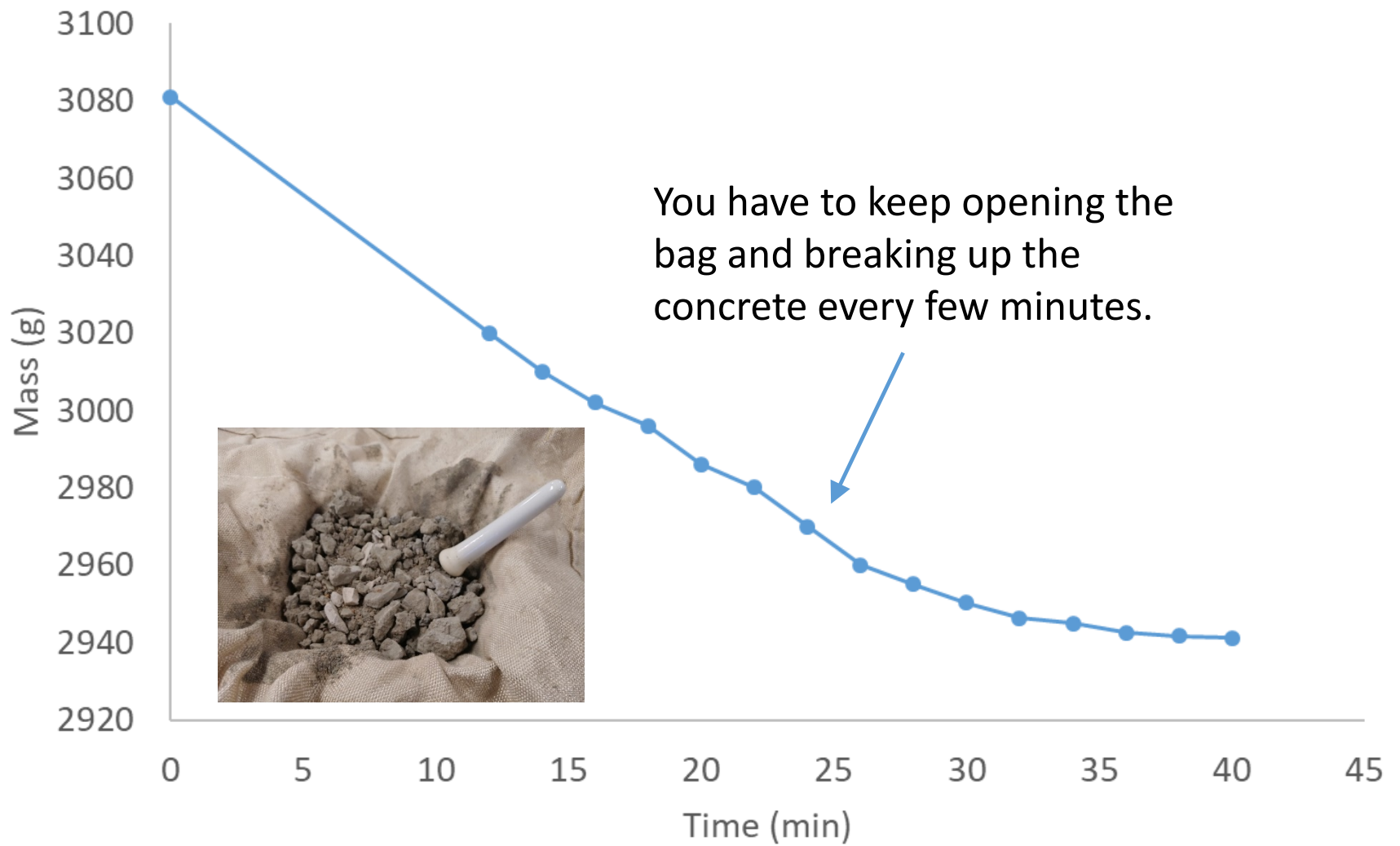
- Collect 1500 g of concrete
- Weigh sample
- Evaporate water
- Weigh sample
- Compare to cement content in the mix and determine w/cm
- Sounds simple, right?



Challenges with microwave oven test

- ≈ 40 min in length
- Labor intensive
- Results are variable (± 0.05 w/cm)





Challenges with microwave oven test

- Results are variable ± 0.05 w/cm

Amount required
in the test

1500 g
 $\approx 1/3$ of 4x8
cylinder



4x8 cylinder

How can we improve the microwave oven method?

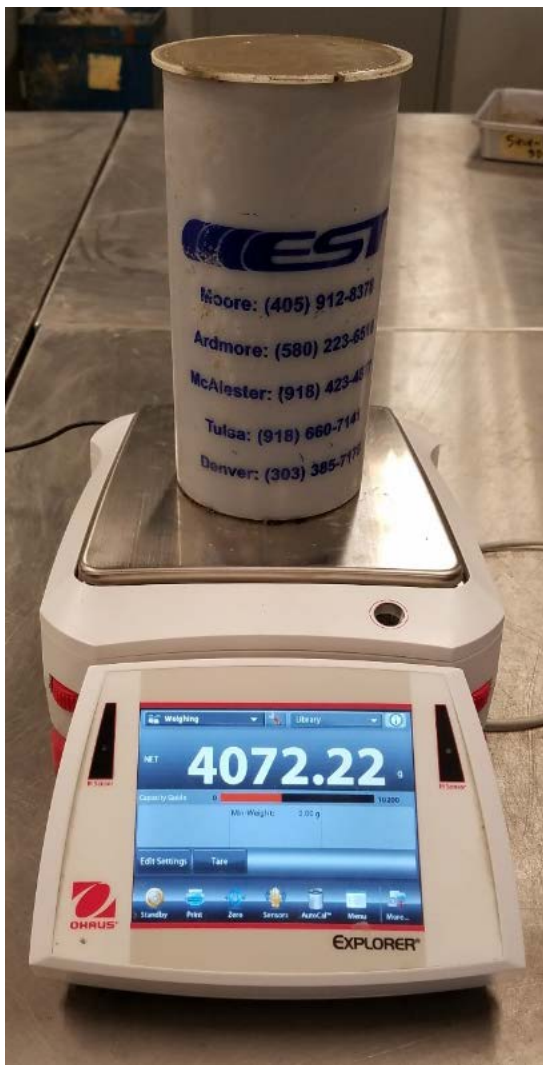
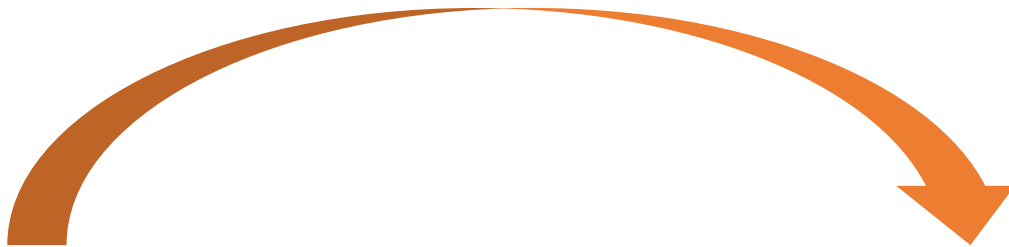
- Increase sample size
- Remove technician labor
- Decrease time
- Use the batch ticket

Steps

- Record batch ticket and aggregate properties
- Make and weigh 4x8 cylinder
- Dump cylinder into pan and weigh
- Start test
- Come back when finished
- Weigh pan

We call this test “The Phoenix”!!!



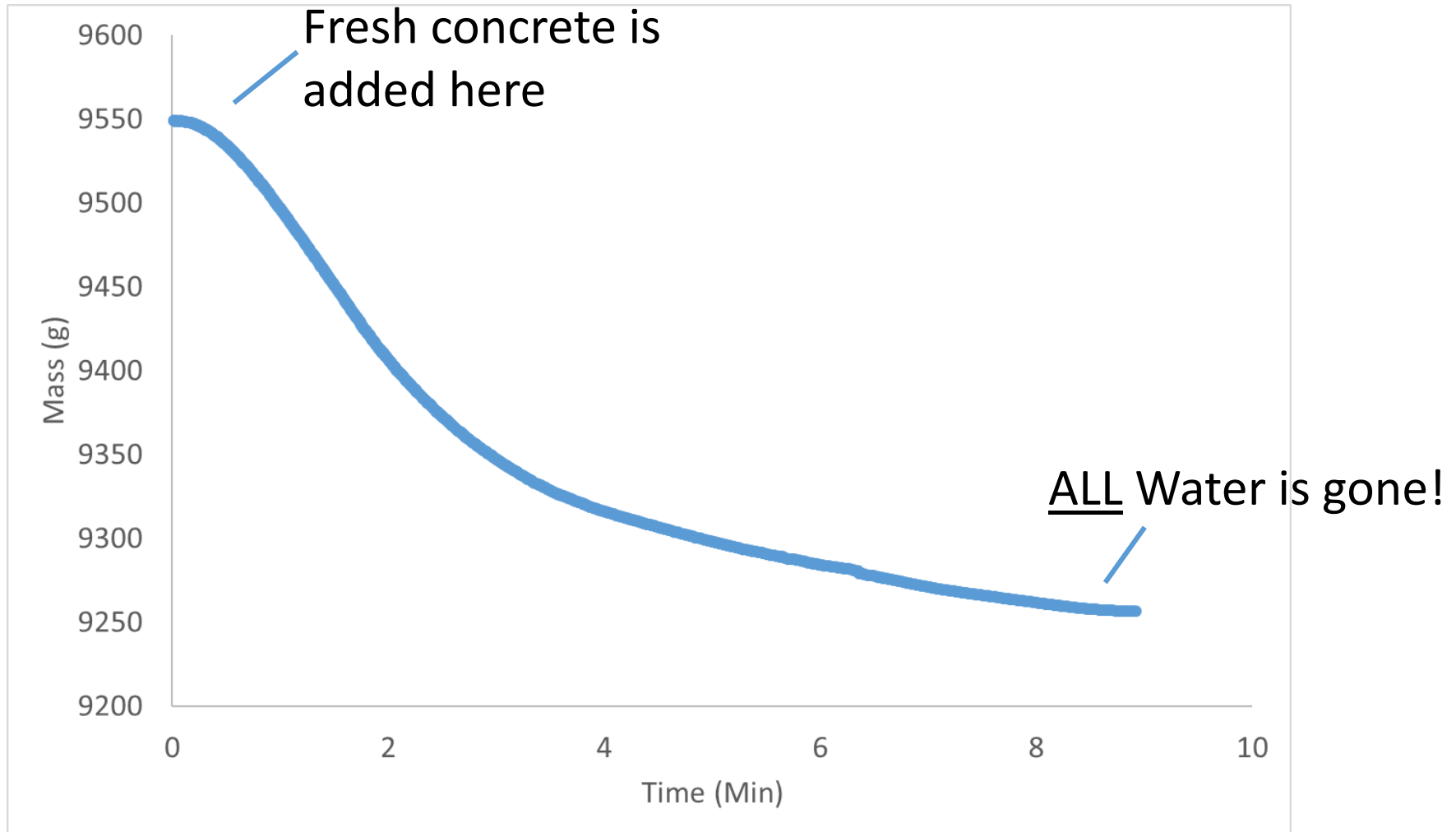




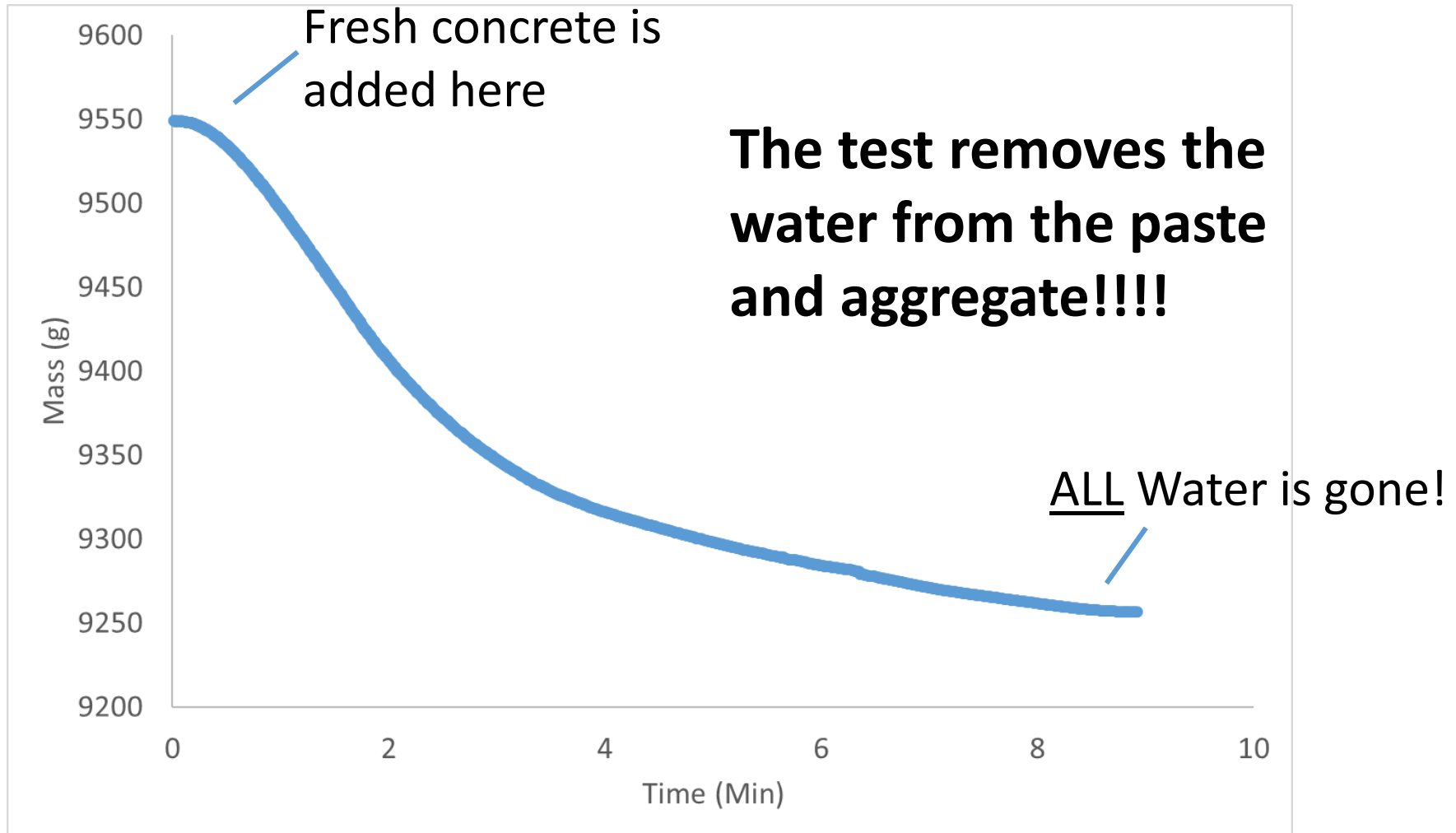


Dry concrete

Change in mass over time



Change in mass over time



The Phoenix removes all the water!!!

- If we know the absorption capacity of the aggregate then we can remove this from the total water content and get the w/cm
- This assumes that during mixing the moisture content of the aggregate will become SSD

How do you get w/cm?

- The change in mass before and after cooking = amount of water in the cylinder
- Calculate how much water will be in aggregate after reaching SSD and remove that from the total water

How do you get w/cm?

- Use the batch ticket information to find the amount of binder within the cylinder
- Make a correction based on the measured cylinder unit weight versus the theoretical unit weight to correct for air

There is an app for that!!!

The screenshot shows a mobile application interface with an orange header bar. The header contains a back arrow, the text "Set Entries", and system status icons (time 5:40, settings, battery, signal, and Wi-Fi). Below the header, the app is divided into two main sections. The first section, titled "Batch Weights", contains input fields for "Batch Size CY" (value: 4), "Cement (lb)", "Coarse Agg 1 (lb)", "Fine Agg 1 (lb)", and two fields for "Water" (gal and lb). The second section, titled "Aggregate and Cementitious Properties", contains input fields for "Coarse Agg 1 Abs (%)" (value: .6), "Coarse Agg 1 SpG" (value: 2.8), and "Fine Agg 1 Abs (%)". A circular orange button with a floppy disk icon is positioned to the right of the "Fine Agg 1 Abs (%)" field. The bottom of the screen shows a black Android navigation bar with back, home, and recent apps buttons.

5:40 ⚙️ 🔋 📶 🔒

← Set Entries

Batch Weights

Batch Size CY

4

Cement (lb)

Coarse Agg 1 (lb)

Fine Agg 1 (lb)

Water (gal) Water (lb)

Aggregate and Cementitious Properties

Coarse Agg 1 Abs (%)

.6

Coarse Agg 1 SpG

2.8

Fine Agg 1 Abs (%)

6

How can we test it?

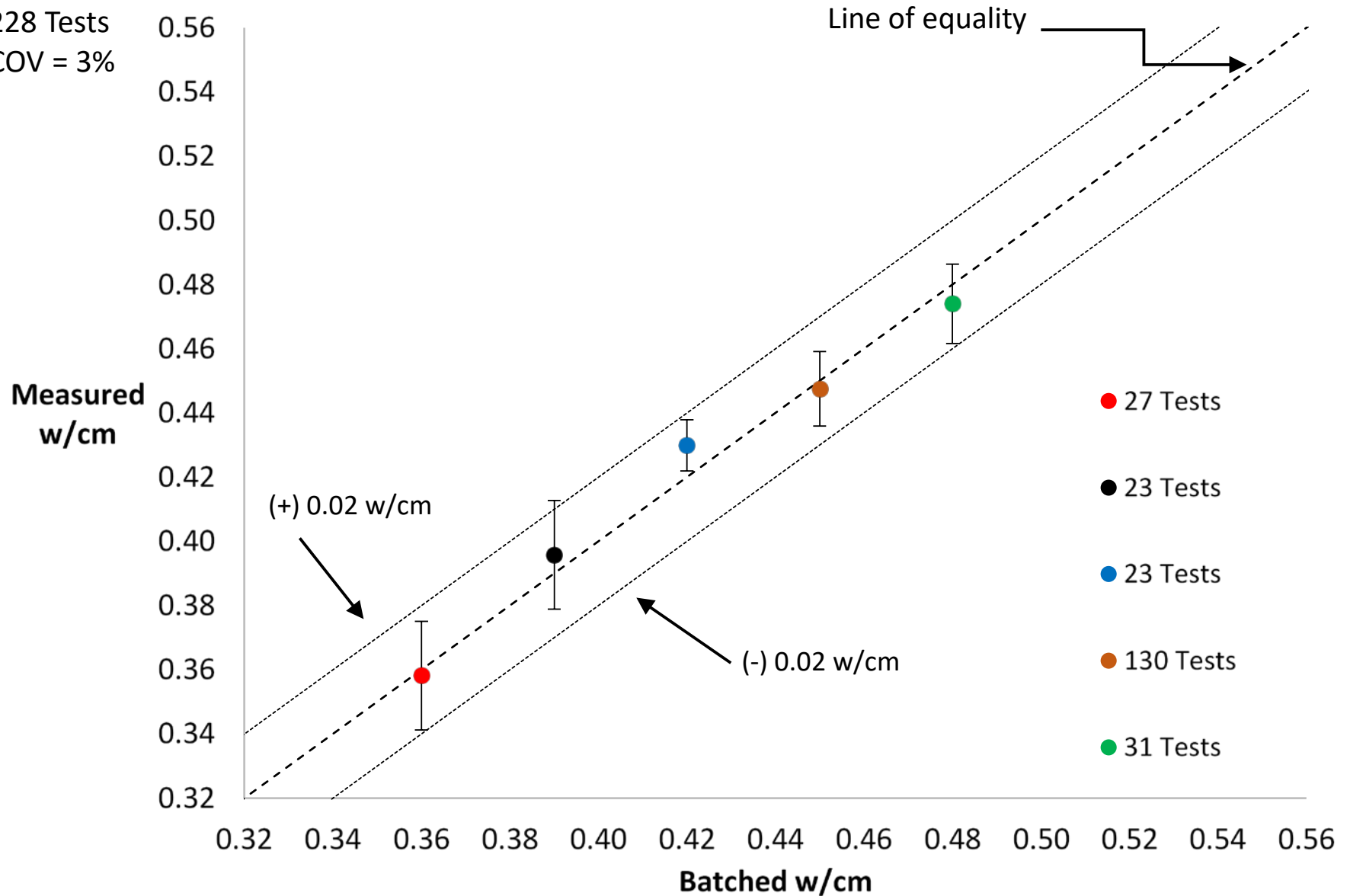
- Make mixtures in the lab where we carefully control the moisture contents and batch weights.
- We should know the w/cm very accurately.
- Measure the w/cm with the Phoenix and compare.

Mix Information

- 9 Sources of Coarse Aggregate
 - Granites, River Rock, and Limestones
- 3 Sources of Fine Aggregate
 - Natural sands and Manufactured sand
- Specific Gravities: 2.42-2.75
- Absorptions (%): 0.46-4.69
- Five different w/cm
- Different paste contents

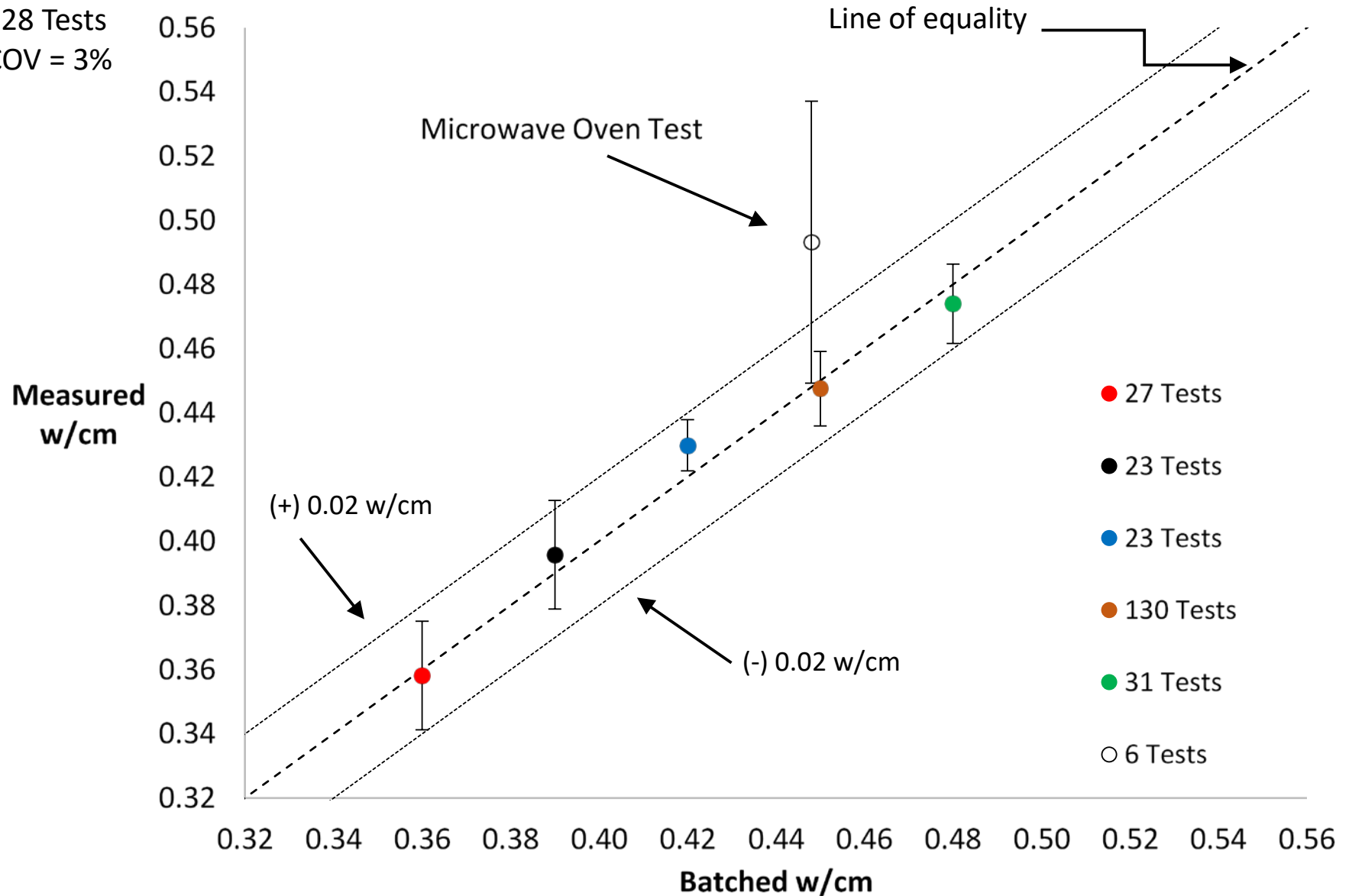
Lab Data

9 Coarse Agg
3 Fine Agg
5 Different w/cm
228 Tests
COV = 3%

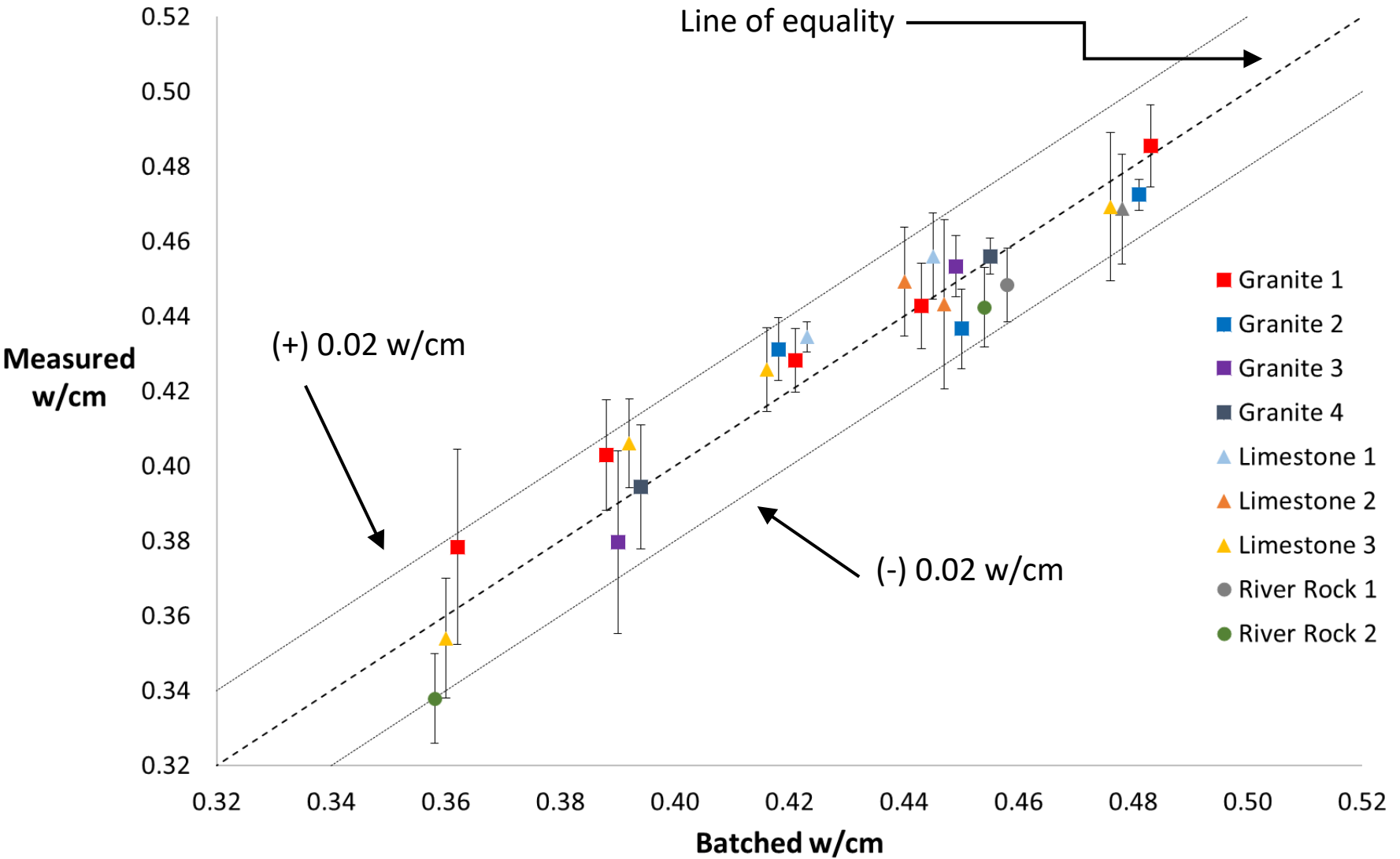


Lab Data

9 Coarse Agg
3 Fine Agg
5 Different w/cm
228 Tests
COV = 3%



Lab Data



Aggregate Type	Size	SpG	Abs (%)	State
Granite 1	Coarse	2.75	0.46	OK
Granite 2	Coarse	2.75	0.51	GA
Granite 3	Coarse	2.59	1.06	MN
Granite 4	Coarse	2.66	0.66	MN
Limestone 1	Coarse	2.42	4.69	IA
Limestone 2	Coarse	2.67	0.70	OK
Limestone 3	Coarse	2.67	0.64	OK
River Rock 1	Coarse	2.67	1.52	MN
River Rock 2	Coarse	2.68	0.81	MN
Natural Sand 1	Fine	2.62	0.64	OK
Natural Sand 2	Fine	2.61	0.20	OK
Man Sand	Fine	2.76	1.05	OK

Discussion

- All lab mixes are within ± 0.02 w/cm with most of them within ± 0.01 w/cm.
- The COV is $< 3\%$!!!
- What about the field?



WARNING
Do NOT operate until you have
read the safety precautions
on the side of this unit.

SENTINEL
smartTOUCH



By Barlett Instruments Company
www.barlett.com

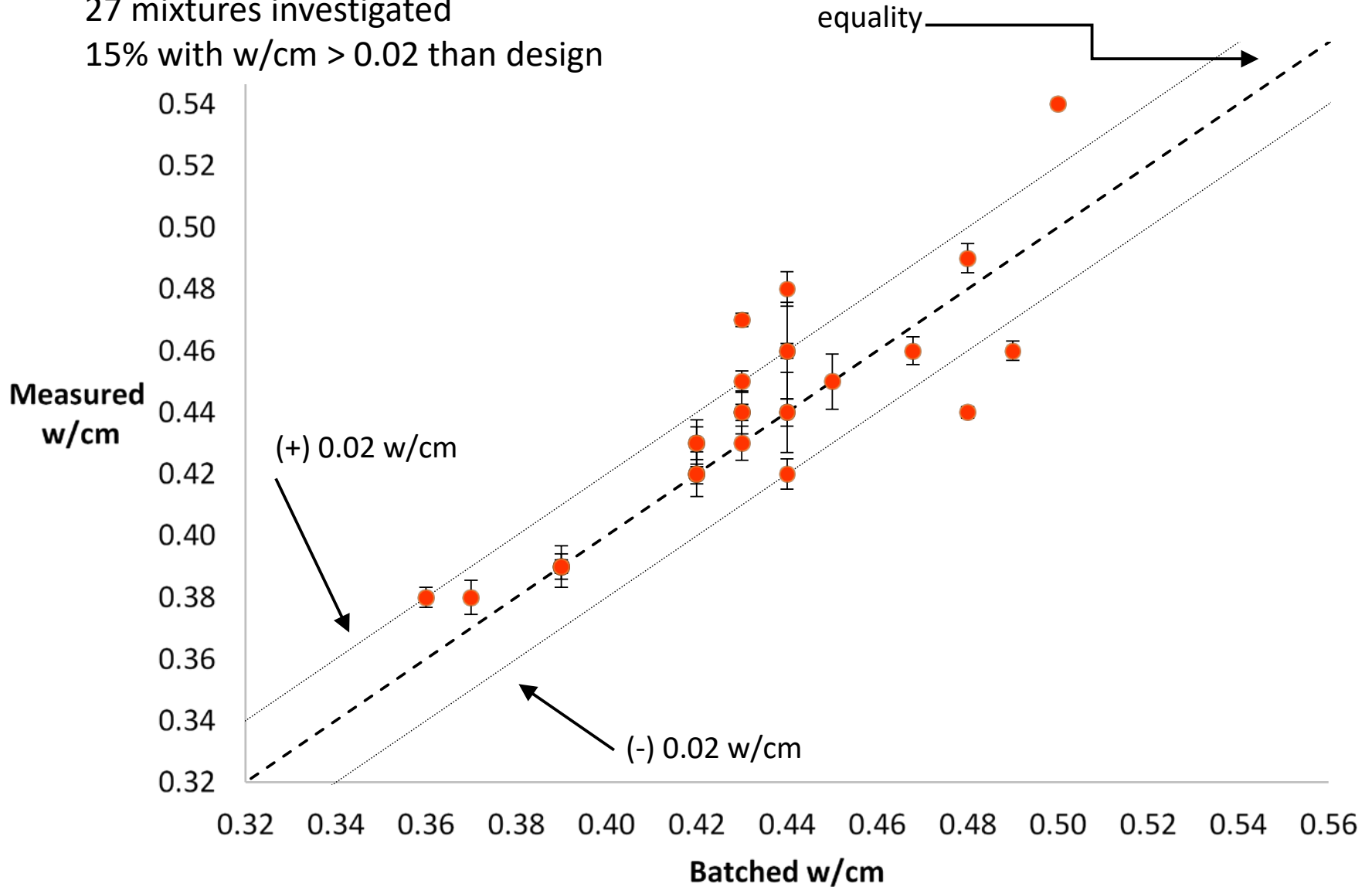
How can we test in the field?

- Use the batch ticket information to determine design w/cm
- Measure w/cm with the Phoenix
- All testing was done at the batch plant
- Four different projects 27 different mixtures
- Paving, bridge decks, substructure

Field Data

27 mixtures investigated

15% with $w/cm > 0.02$ than design



Discussion

- The Phoenix data looks promising
- 15% of mixtures had a $w/cm > 0.02$ than what was reported on the batch ticket.
- All testing was done at the batch plant.
- The producers knew we were coming.

How can the Phoenix help you?

- Tells you the water content at any point in the construction process < 12 min.
- Helps you produce very consistent concrete.
- Moisture corrections or absorption capacity for aggregates in < 3 min.
- Bench mark that a plant is operating correctly
- Training tool for operators

I need your help!!!

- I need people willing to try a Phoenix in the field and collect data and provide feedback.
- **Would AASHTO COMP be willing to support a new test method?**

Contact me if you are interested in
taking a ride on the Phoenix!!!



Conclusion

- Beware Renegade Water!!!
- Test methods are needed to measure the water content of fresh concrete
- The Phoenix is a new test method with ± 0.01 w/cm accuracy and COV = 3% for over 228 lab tests.

Questions???

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Sample Size Comparison

- 3 mixes
 - 0.45 w/cm; No admixes, 6.5 sacks
 - Tested UW with 4 different size cylinders
 - 3 cylinders for each size

Table 1. Multiple size volumes tested for three, 0.45 w/cm mixtures.

Number Of Samples	Sample Volume (ft ³)	Average Density (lb/ft ³)	Standard Deviation (lb/ ft ³)	Average Measured w/cm	Standard Deviation
9	0.02	150.6	3.2	0.42	0.022
9	0.03	150.5	1.4	0.44	0.021
9	0.06	151.6	0.3	0.45	0.010
9	0.07	151.6	0.5	0.45	0.010
9	0.20	151.0	0.7	0.44	0.011
9	0.25	151.3	0.5		

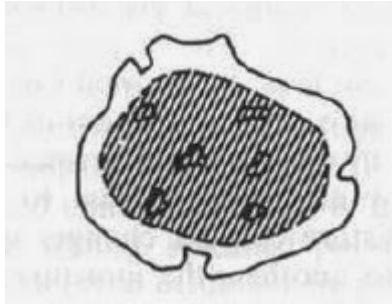
Have you ever been penalized for low strength?

- Low strengths is typically caused by poor cylinder handling.
- Our industry puts so much emphasis on strength because it is easy to measure.
- If you can verify air and w/cm on site then the strength will come.

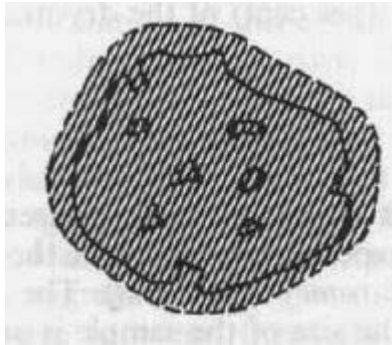
How many ways can extra water get in our mix?

1. Moisture contents of aggregate
2. Batching tolerances
3. Water in drum during batching
4. Batching Tolerances
5. Added during transit or on site

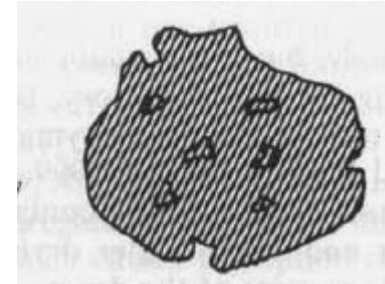
< SSD



> SSD



Aggregates in
stockpiles can
have a variety
of moisture
contents

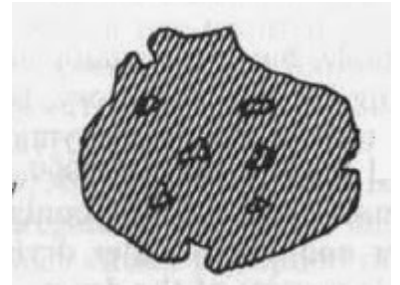
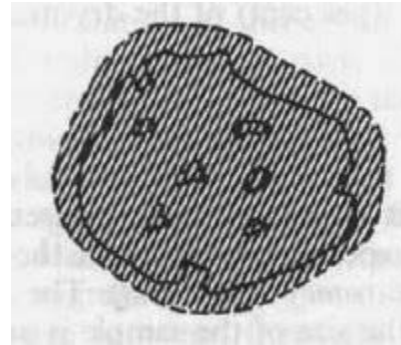
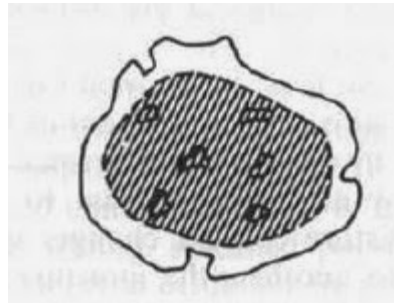
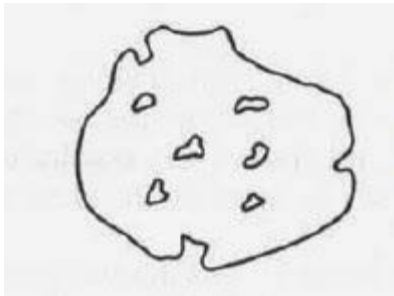


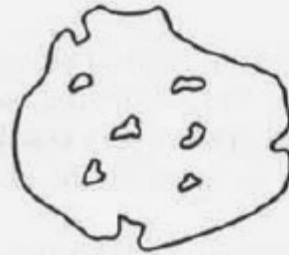
= SSD

Aggregates after
mixing and hauling

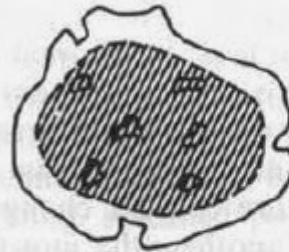
The Phoenix removes all the water!!!

- This means we need to know how much water is in the aggregate so that we can subtract that from the total water to find what is in the paste.

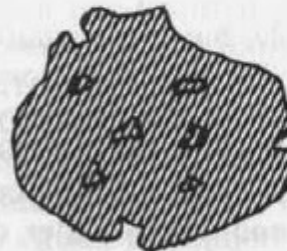




**Bone-dry
or
oven dry**



Air dry

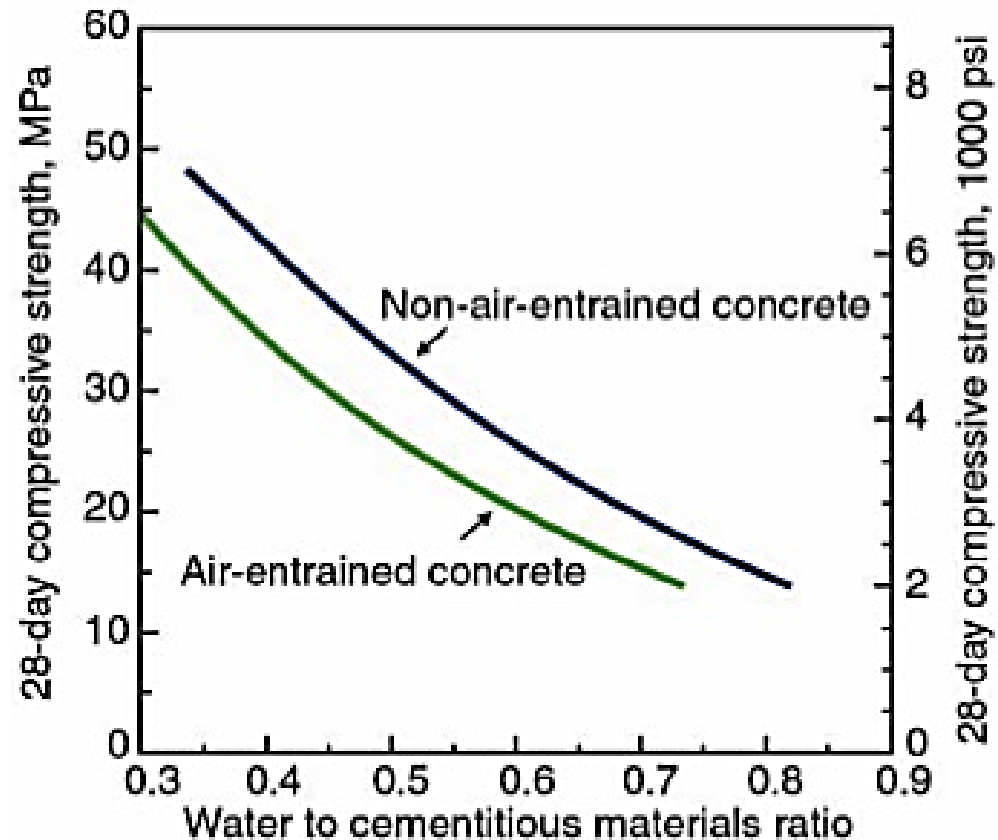


**Saturated
and
surface-dry
(SSD)**



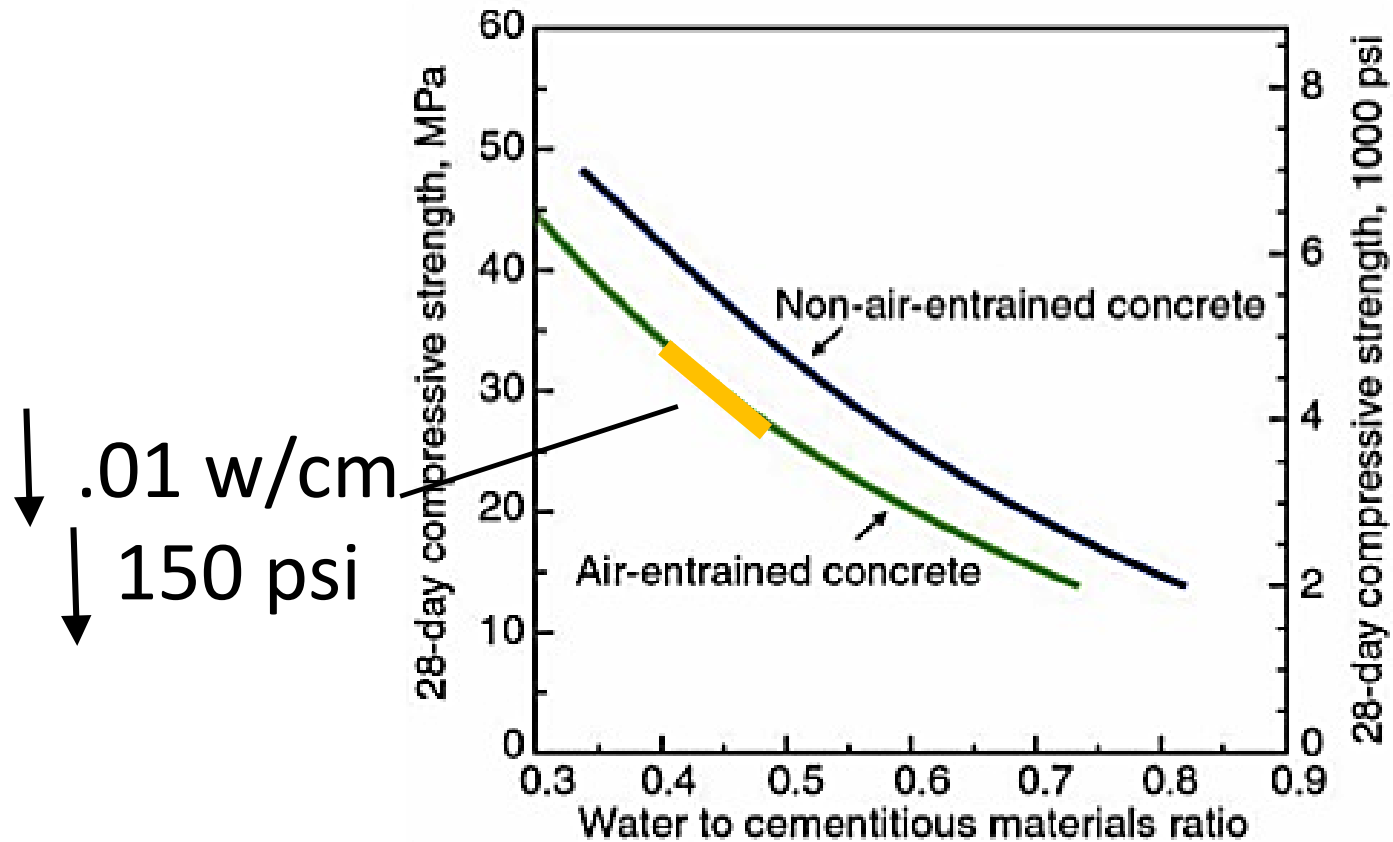
Moist

How much does this really impact strength?



ACI 211

How much does this really impact strength?



ACI 211

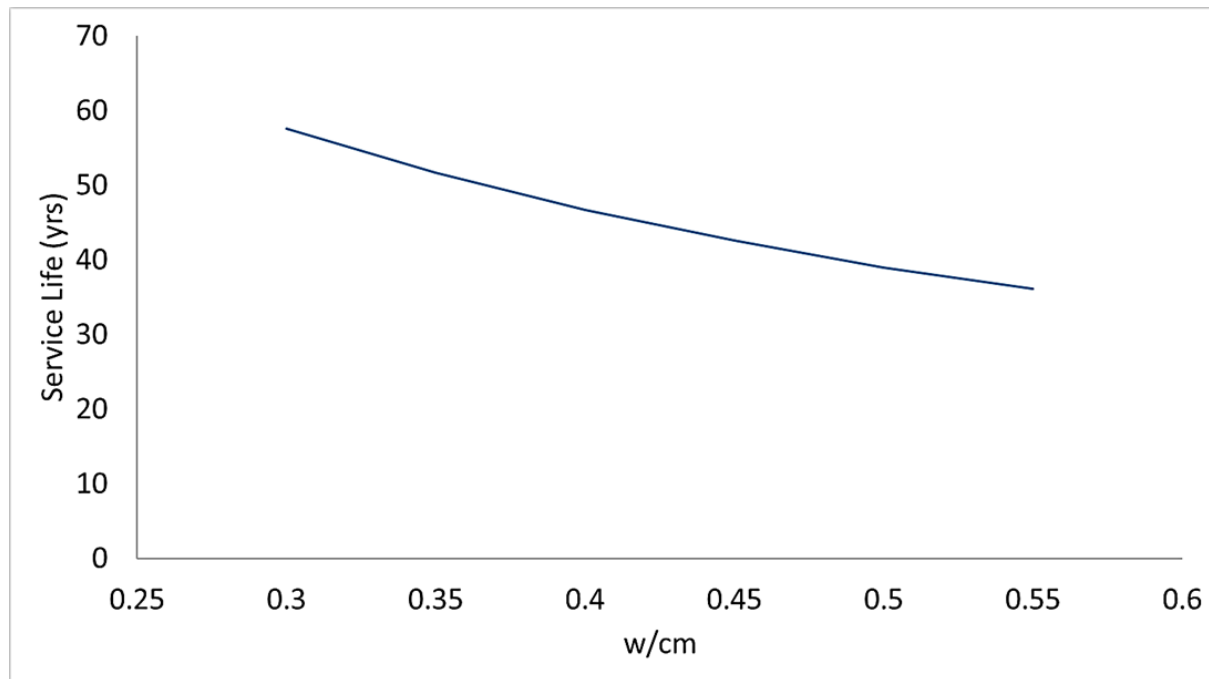
How much does this really impact durability?

Fluid penetration is important for most durability mechanisms.

Let's focus on corrosion and use Life365 software to model this.

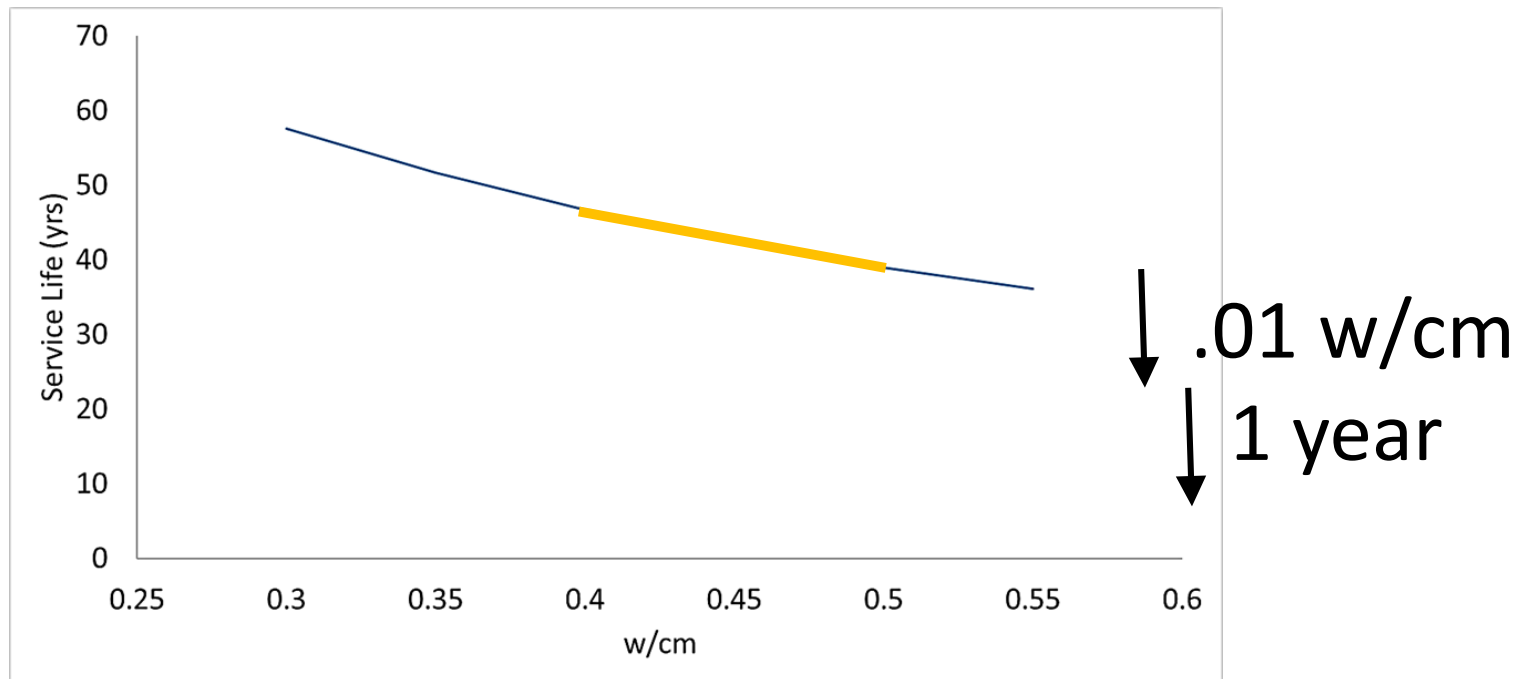
Be careful with service life models!

How much does this really impact durability?



Bridge Deck in Oklahoma
2" of cover

How much does this really impact durability?



Bridge Deck in Oklahoma
2" of cover

What about consistency?

Water plays a key role in the consistency of your concrete.

1 gallon/yard = 1" slump

How much extra water matters?

For 8 cubic yards of a 6 sack mix



= +0.01 w/cm
-150 psi
-1 yr service life
+1" slump

Is there a way to measure this?

- Slump
- Minnesota DOT Method
- Electrical Methods
- Microwave Oven

Does the slump tell me how much water is in my mix?

Slump is a measure of consistency

Mixtures can be rejected because the slump is too high

Does this mean the water is off?

The water content is constant but the aggregate gradation is not

Deficient Fine Sand



High Intermediate



Just right...



Excessive fine sand



High Coarse



Minnesota DOT Method

- Moisture content of aggregates at plant are tested
- Dump trucks are used for placement
- No water in the truck before concrete
- No water added in route or onsite
- The batched w/cm doesn't change
- **This only works for paving mixtures**

Electrical Methods

- An electrical signal current is sent between at least two probes
- The movement of electrons through the concrete is characterized
- Correlate this to w/cm



Challenges

The following items impact the measurement:

- Aggregate size
- Aggregate volume
- Temperature
- Admixture type and dosage
- Paste content
- SCM volume
- Values change over time
- Water content

Challenges

The following items impact the measurement:

- Aggregate size
- Aggregate volume
- Temperature
- Admixture type and dosage
- Paste content
- SCM volume
- Values change over time
- Water content



Only one of these have
to do with water!!!!

Discussion

- The industry needs a test that can measure the water content in fresh concrete.
- The existing tests give us some information but they all have a major flaw.
- The microwave oven test shows the most potential.

Rejecting because of Slump

- Max slump spec = 7” for a pier “to control w/cm”
- Concrete was rejected but w/cm was measured on site to be within specified range

Truck Number	Average Measured w/cm	Specified w/cm	Slump (in)	Specified Slump (in)
Truck 6	0.47	0.25-0.48	9.00	7.00
Truck 7	0.42	0.25-0.48	8.00	7.00