# Bridge Deck Curing Systems

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# Questions?

- Visit:

Pollev.com/tylerley390

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Then text your question

# Disclaimer

- This work has investigated a limited range of materials for a limited range of applications.
- If you do not like the results then I suggest you publish your own measurements.

# Acknowledgements


- Oklahoma Department of Transportation
- Kenny Seward
- Matt Romero
- Walt Peters

- Dave Suchorski, Ash Grove
- Peter Taylor, CP Tech Center
- Todd Hanson, Iowa DOT

# Outline

- Background
- Experiments
- A New Method of Wet Curing
- Conclusion

# What do we want from our bridges?

- Performance over the expected lifespan
- Minimal repairs
- Reasonable cost and construction time

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- Performance over the expected lifespan
- Minimal repairs
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Economic Durability!

# Why is curing important?

If you don’t cure then your concrete may be compromised.

Curing helps the concrete reach its potential

# Why do we cure concrete?

1. Reduce evaporation
2. Promote hydration to form a dense microstructure
3. Minimize temperature gradients

# Why don’t we get better curing?

1. People don’t understand how important it is

2. We need to pay for it and verify if we get it

3. We need to make it easier

# Why is wet curing challenging?

1. Wet curing requires significant labor
2. If placed too early wet burlap can scar the surface and reduce cover
3. We don’t do a good job of keeping the burlap wet
4. Challenging to inspect
5. Expensive

# What is the cost of curing?

| | $/sf* | Percentage of Oklahoma bridge cost/sf ** |
|---|---|---|
| Burlap wet cure | 0.42 | 0.47% |
| Premium curing compound | 0.17 | 0.19% |
| Common curing compound | 0.06 | 0.07% |

* from an Oklahoma contractor

** Using $89/sf from 2013 NHS

# What have people done about it?

In Oklahoma, contractors have proposed using a lithium silicate curing compound in place of wet cure.

This material is applied after the water has evaporated from the surface. This may take 30 minutes to an hour after strike off.

# OSU Testing

We developed a testing protocol to evaluate how curing impacts the concrete microstructure.

Cast concrete and cure with different methods

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

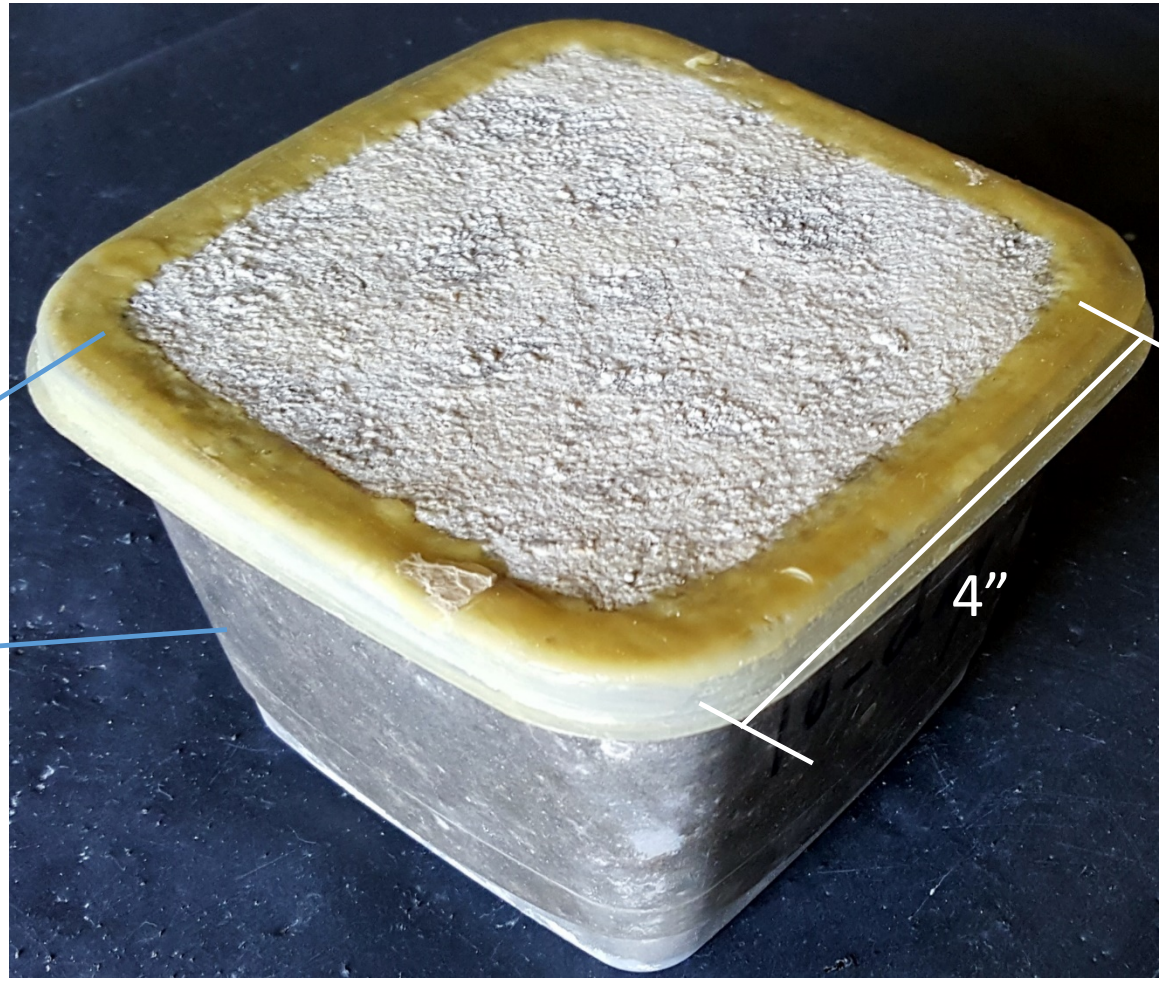
# How did we cure them?

- No curing
- Wet curing for 1, 3, 7, 10, 14 days with wet burlap covered in plastic
- Lithium silicate curing compound
- Poly Alpha Methyl Styrene (PAMS) curing compound

- Curing compounds were applied in two layers with a total coverage of 200 sf/gal
- Lithium silicate representatives and ODOT were present for the testing

wax

plastic container



# OSU Testing

If the concrete is well cured then:

1. It will be hard for the concrete to lose moisture.
2. The concrete will be resistant to water uptake.
3. The concrete will be resistant to chloride penetration.

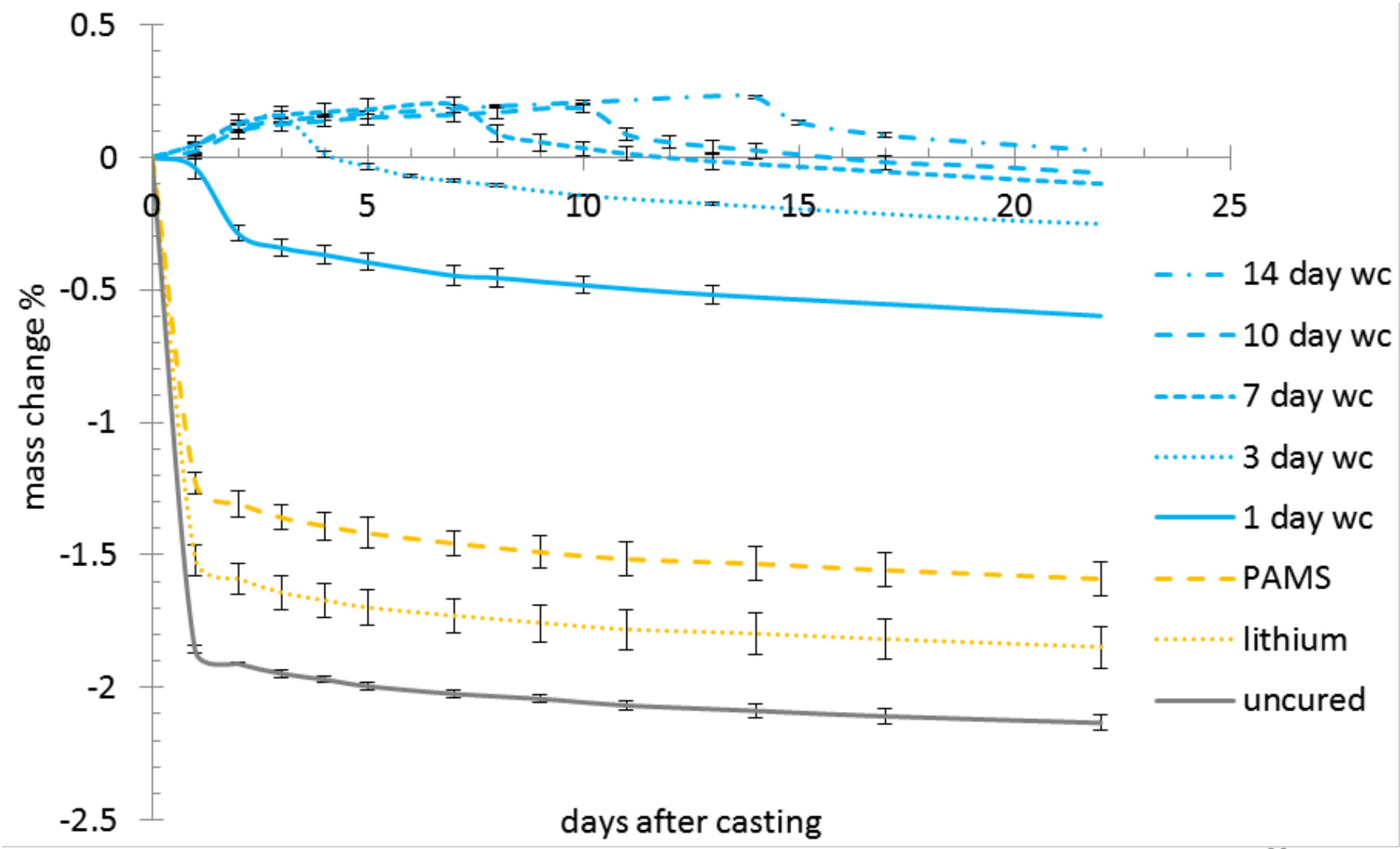
# What did we do?

| Step | Test | Details |
|---|---|---|
| 1 | drying | Mass change in 40% RH and 73°F for 22 days |
| 2 | water uptake | Mass change in lime water for 5 days |
| 3 | chloride penetration | Mass change in 5% NaCl for 35 days<br>Chloride profile |

# Step 1 – Dry the sample

Measure mass change in 40% RH and 73$^{o}$F for 22 days

# 1. Mass change in 40% RH and 73°F for 22 days



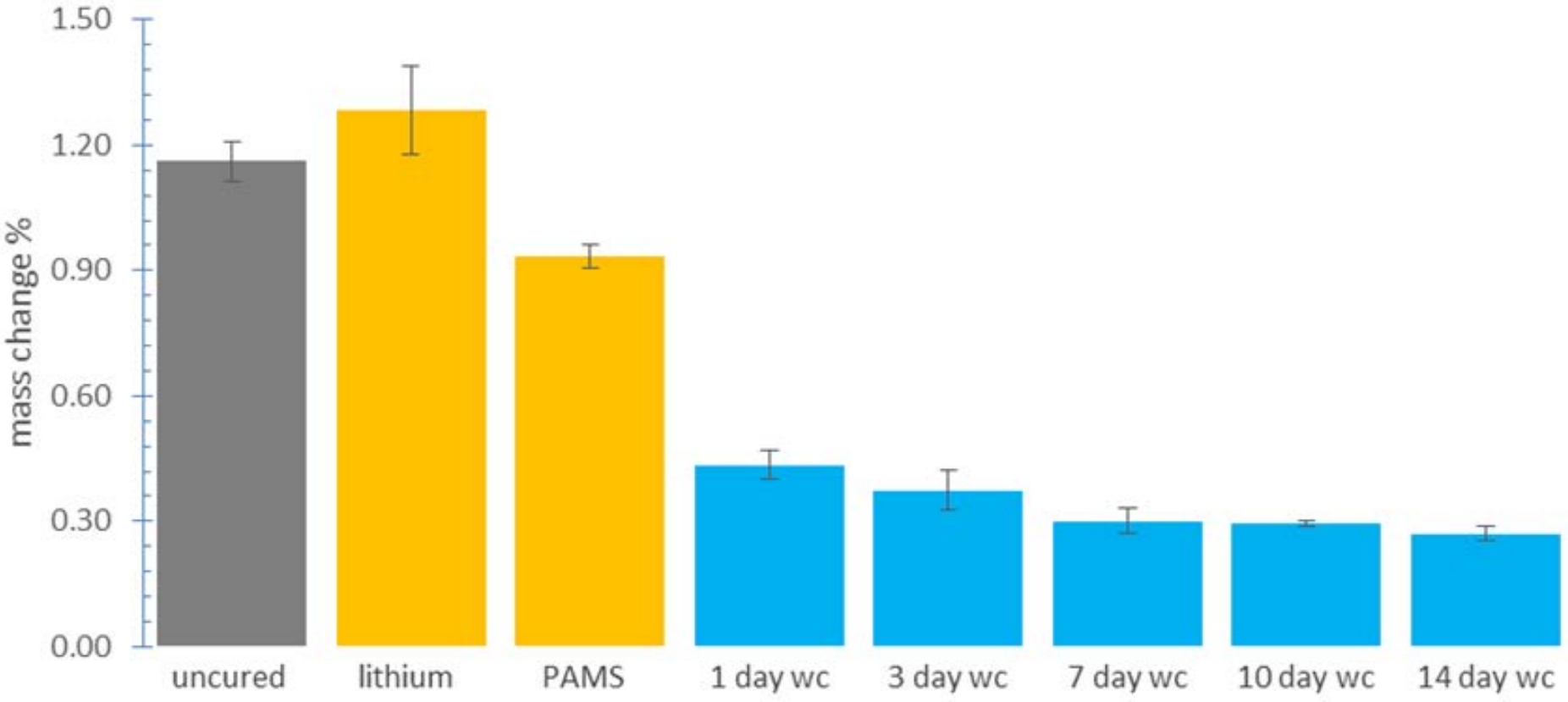
# Discussion

- The samples are losing water as they dry.
- The better the curing the less mass was lost.
- Lithium silicate reduced mass loss by 12% and the PAMS by 38% when compared to not curing.
- After 7 days of wet curing there was a low mass loss.
- There was little difference between 7, 10, and 14 days of wet curing for these conditions and materials.

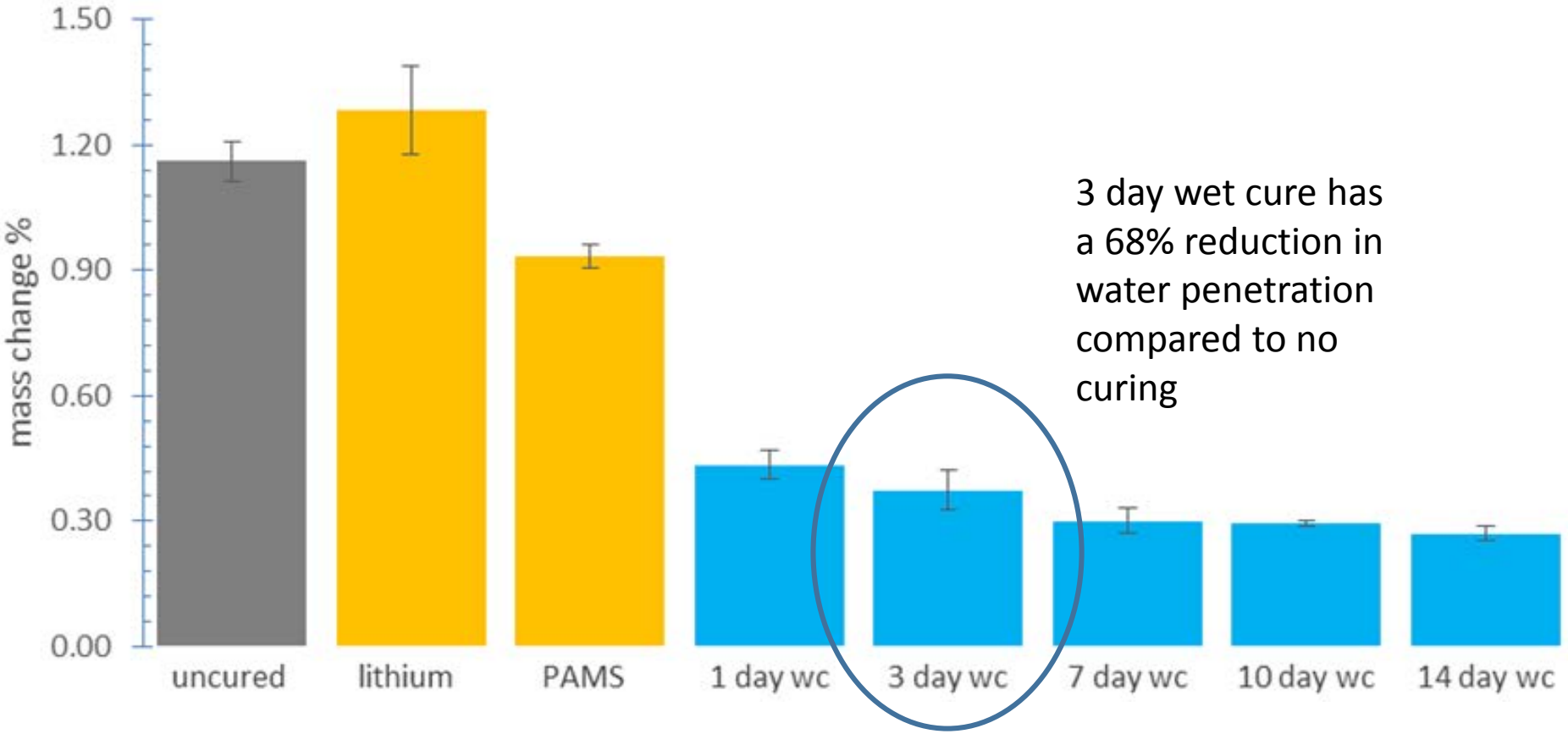
# Step 2 – Place concrete in lime water

Measure mass change in lime water for 5 days

# 2. Mass change in lime water for 5 days



# 2. Mass change in lime water for 5 days

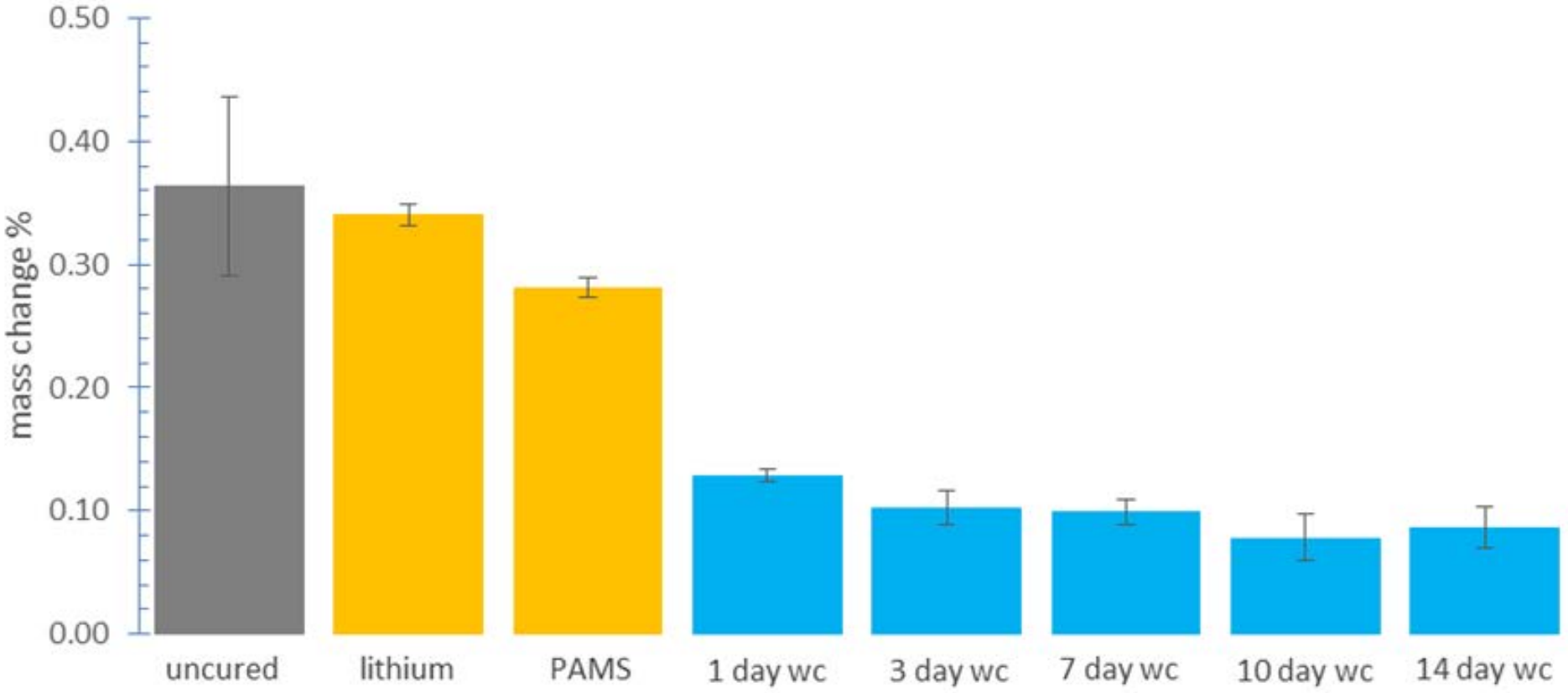



3 day wet cure has a 68% reduction in water penetration compared to no curing

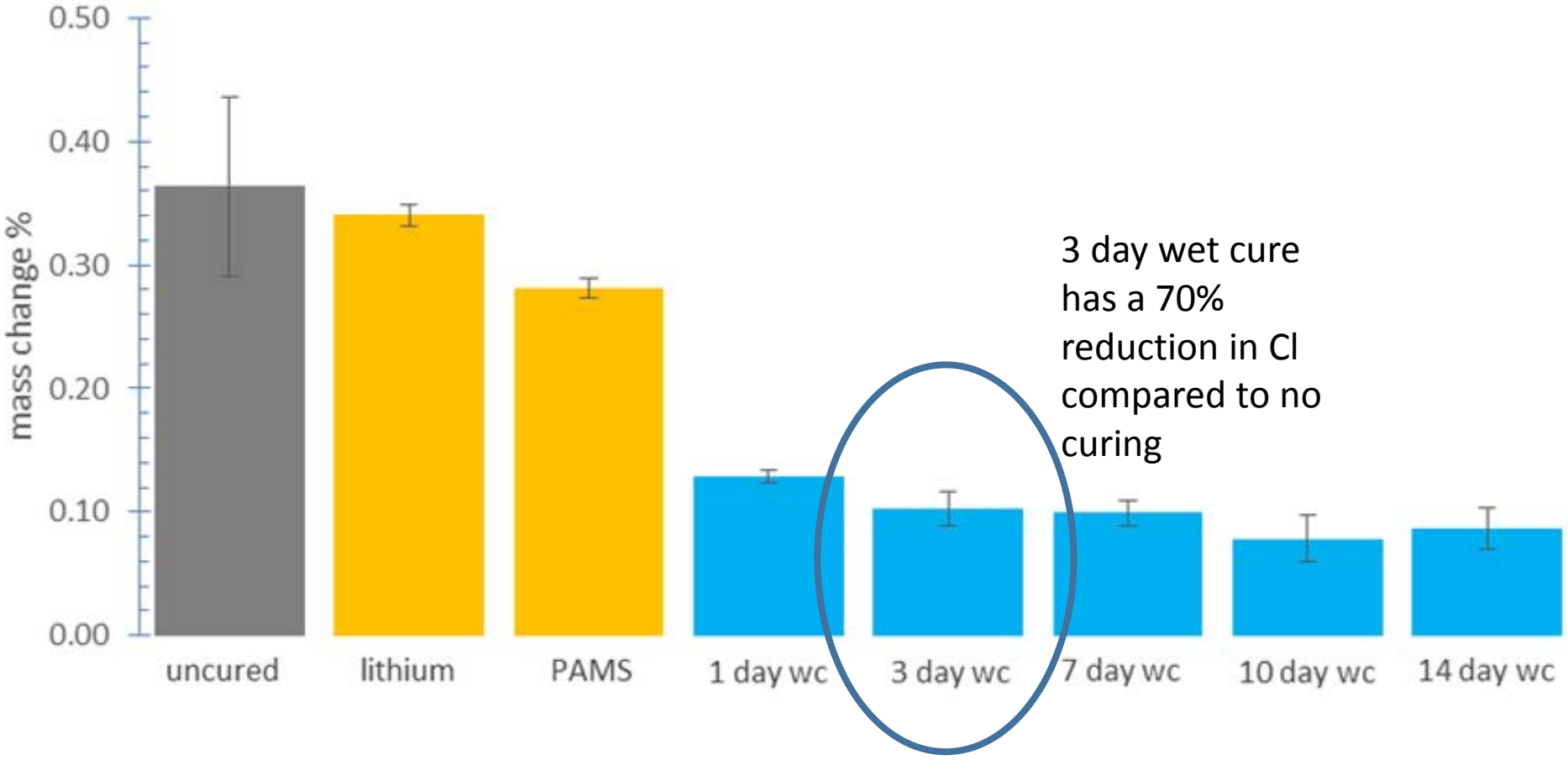
# Step 3 – Place concrete in NaCl solution

Measure mass change in NaCl solution for 35 days

# 3. Mass change in 5% NaCl for 35 days



# 3. Mass change in 5% NaCl for 35 days




3 day wet cure has a 70% reduction in Cl compared to no curing

# Discussion

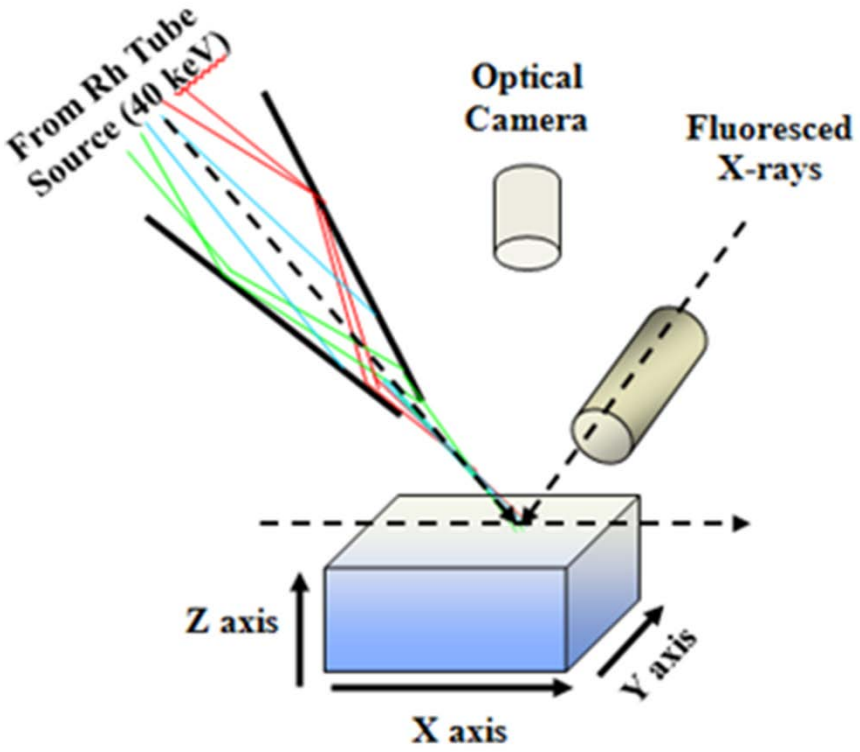
- Concrete with a tighter microstructure will gain less mass when wetting
- The trends are similar for initial water uptake and long term chloride penetration
- Lithium silicates performed similarly to not curing
- PAMS reduced fluid uptake by 25% when compared to not curing
- Wet curing for 3 days reduced fluid uptake by ~ 70%
- Very little difference between the fluid penetration for 3, 7, 10, and 14 days of wet curing

# Chloride Profiles

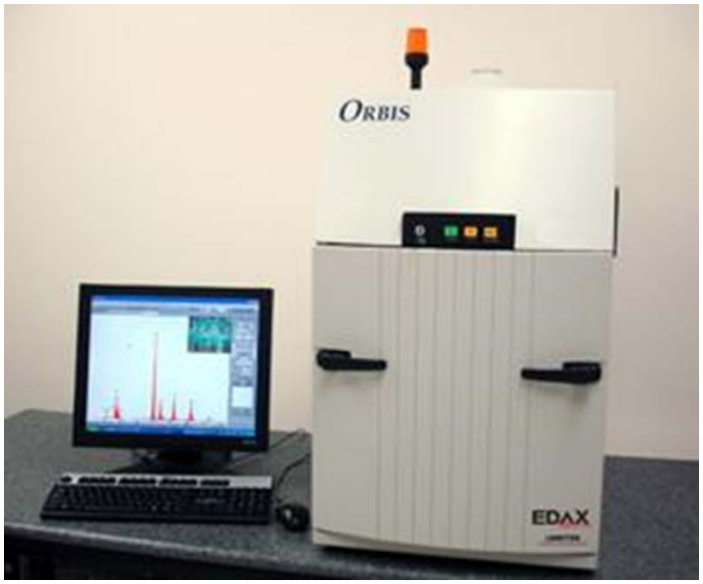
- Next we cut the samples and investigated the surface with a XRF microscope
- This is similar to a bulk XRF instrument but it has extra focusing system so that we can map the surface.

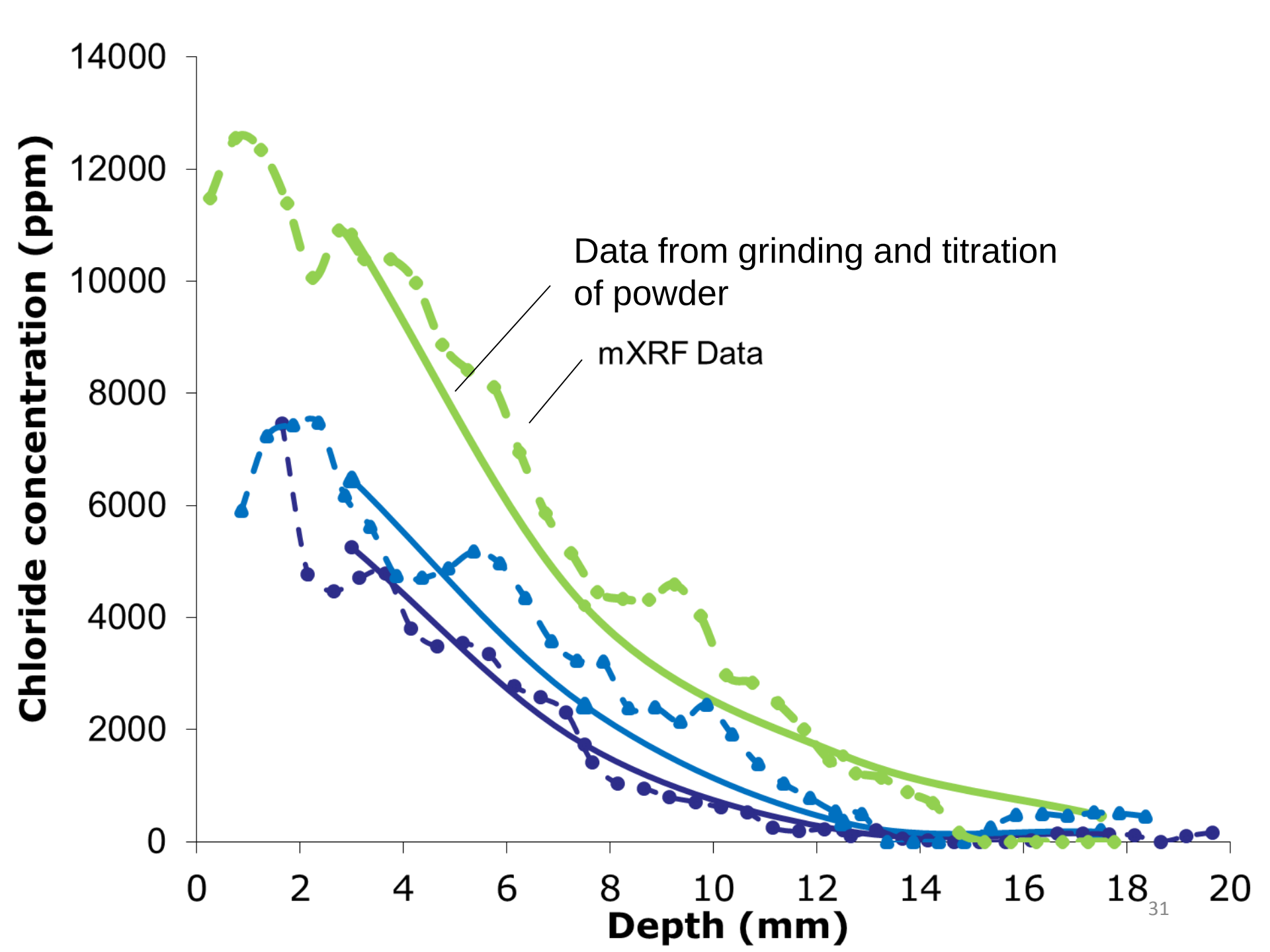
# µXRF technique description

- Uses an X-ray optic to focus a stationary beam of X-rays onto a sample
- The interaction of the X-rays with the electrons emits a secondary fluoresced X-ray
- Every element emits a unique signal
- Uses a polycapillary optic to focus X-rays to a size of approximately 50 µm in diameter

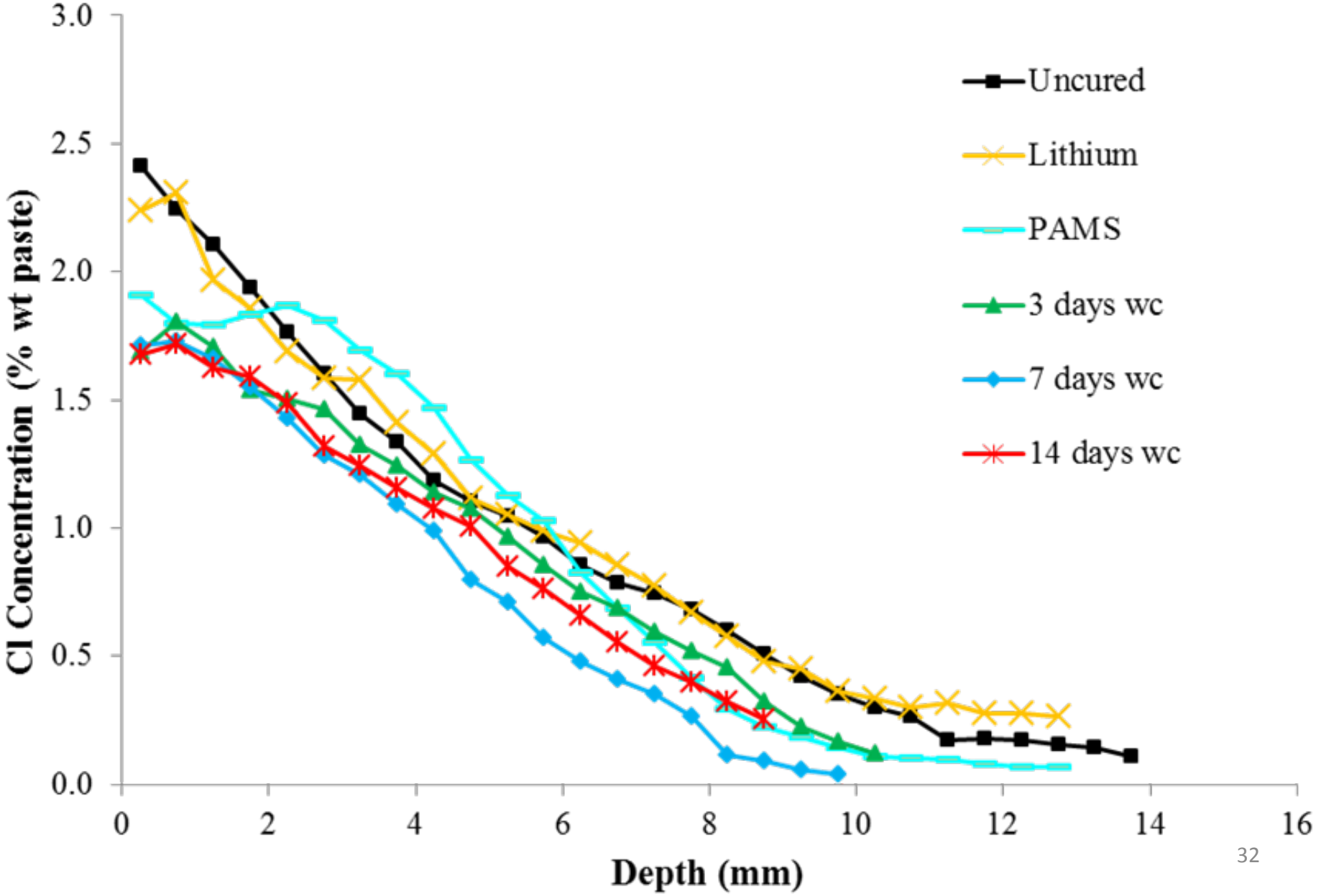



**Orbis by EDAX**




Chloride concentration (ppm)
14000
12000
10000
8000
6000
4000
2000
0
0
2
4
6
8
10
12
14
16
18
20
Depth (mm)
Data from grinding and titration of powder
mXRF Data

# 4. Chloride profile



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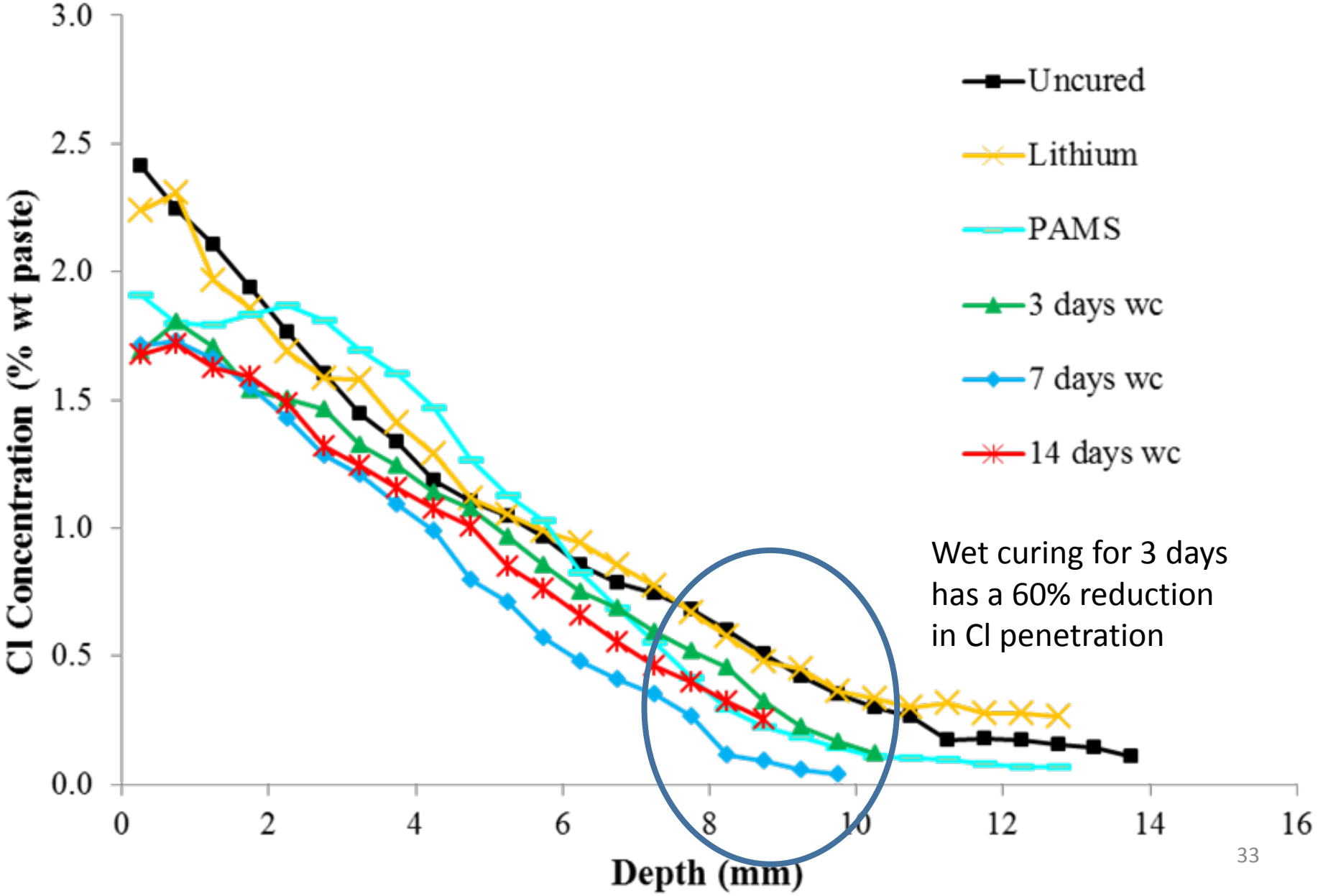

# Discussion

- The chloride penetration data had similar trends as the fluid uptake.
- No cure and lithium silicate performed similarly
- Wet curing performed better than the curing compounds
- There was about a 60% reduction in the chloride ingress for the 3 day wet cured sample compared to the sample that was not cured.
- *This suggests that by wet curing your concrete you approximately double your lifespan compared to not curing.*

# What is the cost of curing?

| | $/sf* | Percentage of Oklahoma bridge cost/sf ** |
|---|---|---|
| Burlap wet cure | 0.42 | 0.47% |
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***For ~ .5% of your cost you are doubling the lifespan of your bridge deck***

# Discussion

- The mass change from drying, moisture absorption, and chloride diffusion showed similar trends
- Lithium silicate and no curing had  similar performance
- PAMS showed improved performance but not as good as wet cure
- Curing for 7 days had slightly better performance than 3 days.
- You can approximately double the lifespan of your bridge deck against chloride ingress with wet curing for 3 days over not curing

# Can we do this better?

- We have been using burlap to cure concrete for over 70 years.

- We need new tools to help us improve our curing while also simplifying our construction.

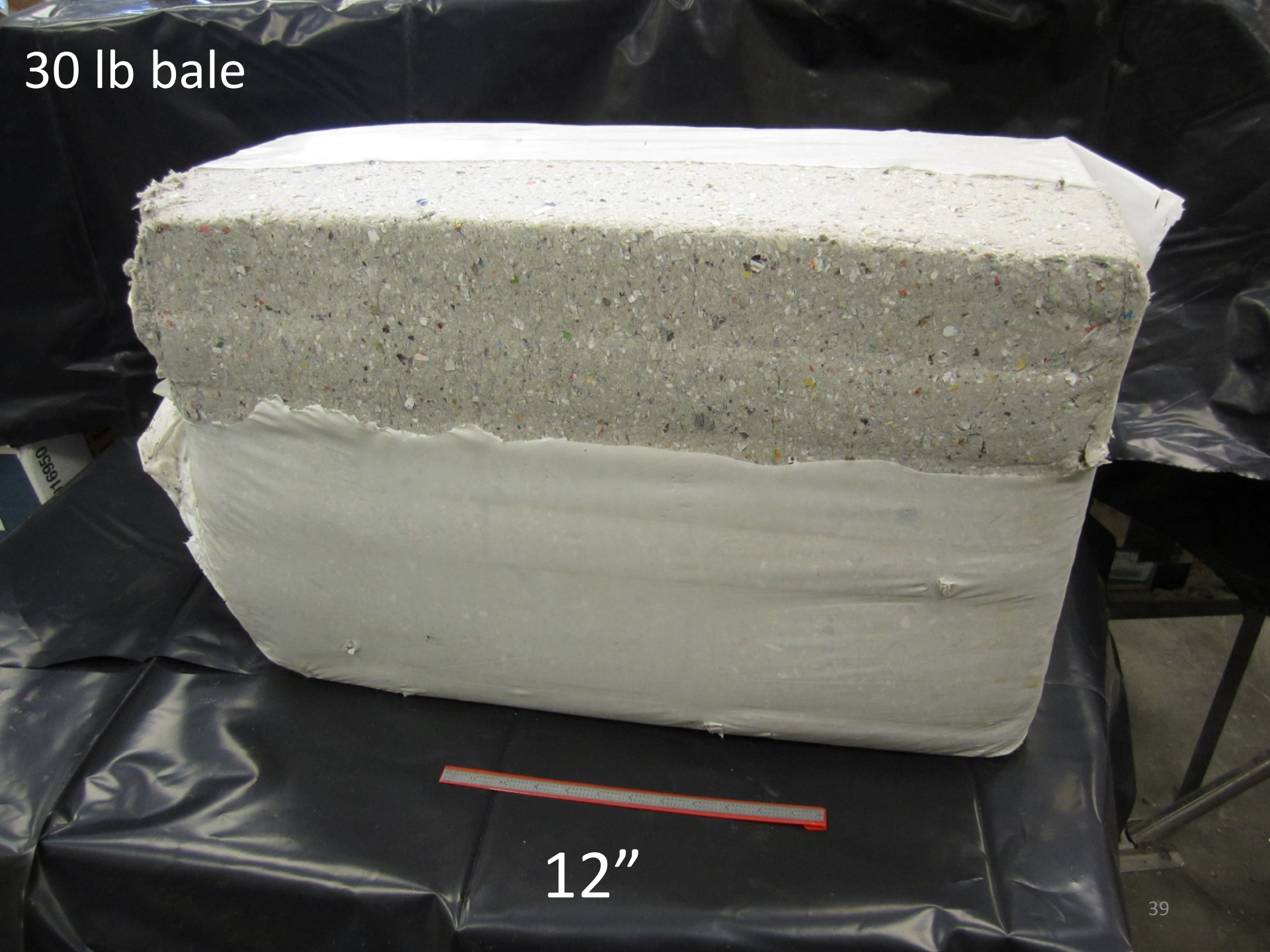
# *PulpCure*

PulpCure is recycled paper, water, and herbs and spices developed at Oklahoma State University.

It is a spray on wet blanket.

It is non toxic, environmentally friendly, biodegradable, and can be reused!

# 30 lb bale



# *How Does It Work?*

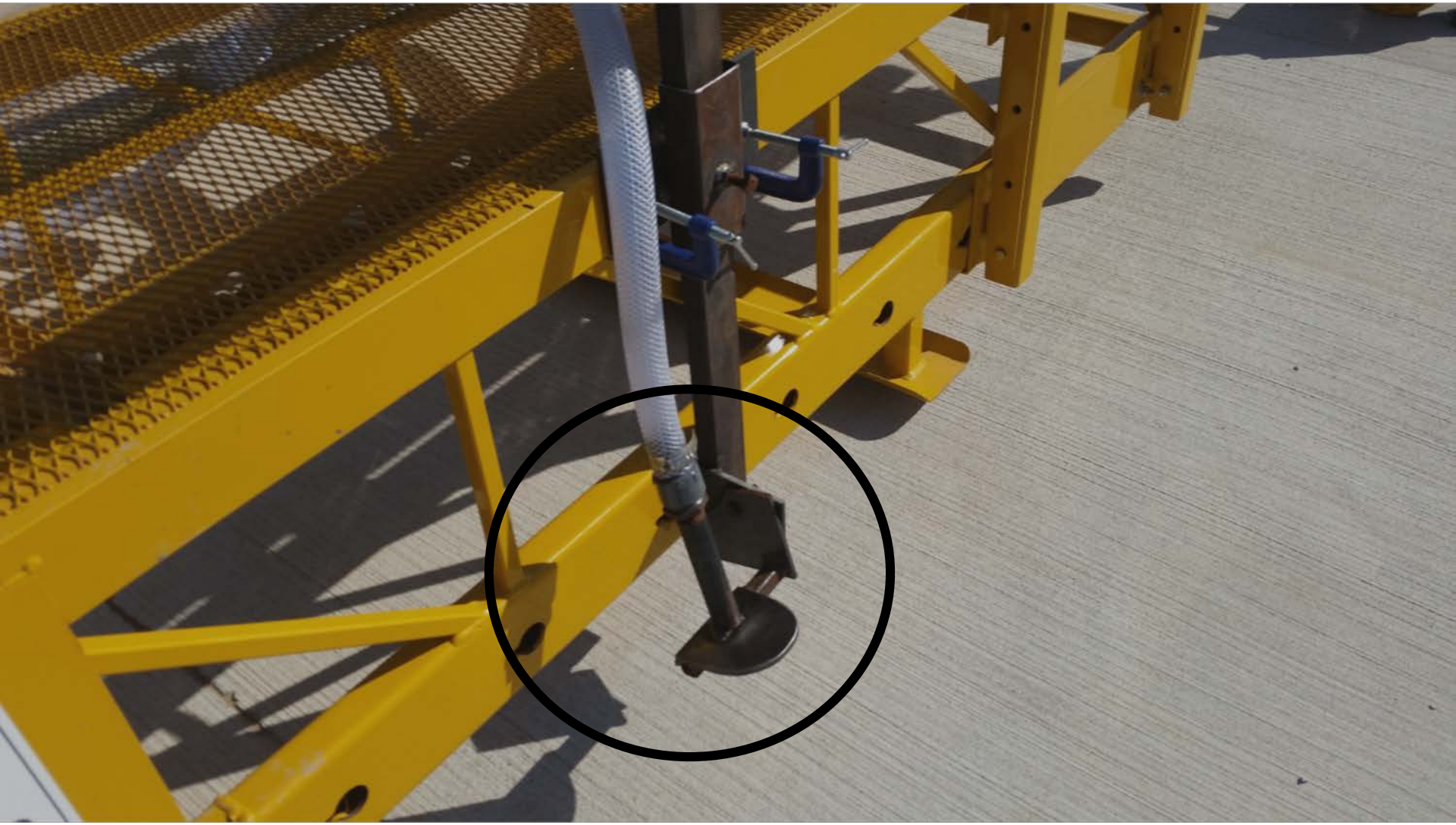
You mix the product with water and then apply it

For some applications this is done with a machine and for others it can be done by hand

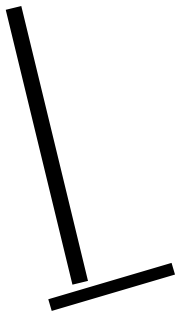
If you use the material in combination with plastic it will hold moisture for months.

Remove with shovels, street broom, water pressure, or bobcat with a modified shovel

550 gallon applicator

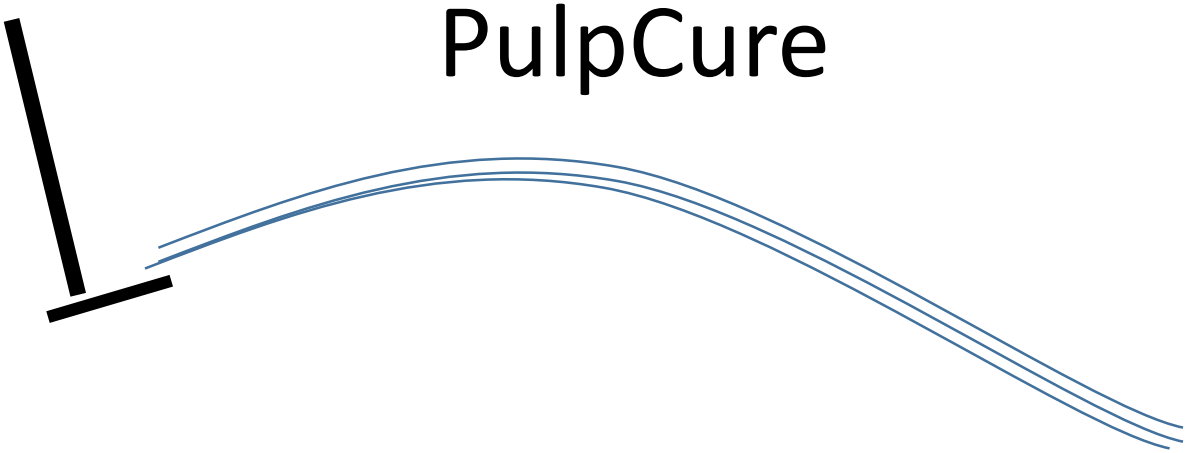


Nozzle

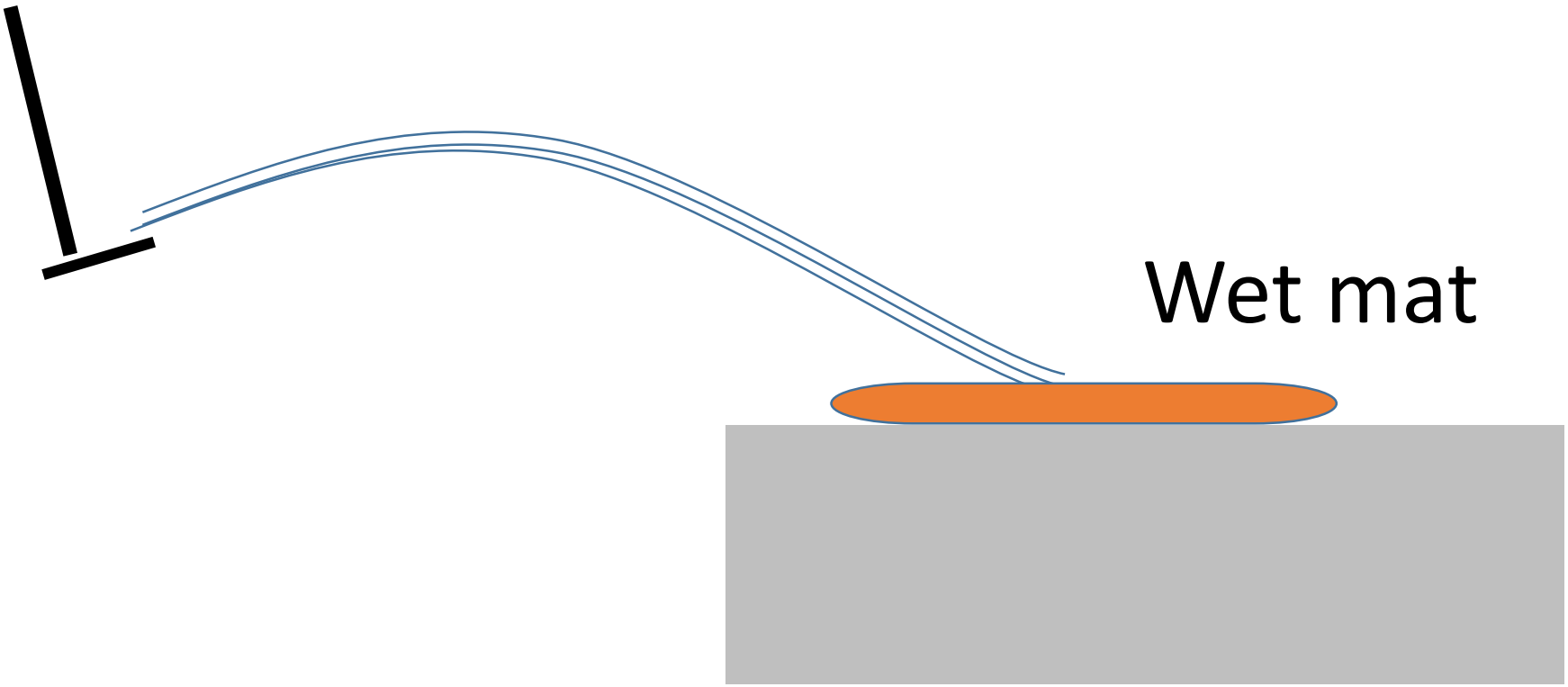


Concrete

PulpCure



Low angle of impact


Wet mat

Watch this video

Google: Youtube pulpcure

https://www.youtube.com/watch?v=oDzPqMqUy7E

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# Why is wet curing challenging?

1. Wet curing requires significant labor
2. If placed too early wet burlap can scar the surface and reduce cover
3. We don’t do a good job of keeping the burlap wet
4. Challenging to inspect
5. Expensive

# What are the benefits?

- Contractors have estimated that curing with PulpCure will cost 30% less than curing with wet burlap
- There are significant savings in labor and water
- Since PulpCure can be placed so rapidly it can minimize plastic shrinkage cracking without harming the surface

# What are the benefits?

- It can cut out interim curing steps like evaporation retarder and curing compounds
- Curing is done at the surface where it is needed
- No additional water is needed after application
- Easy to apply and inspect
- The material can be re-used
- It is orange!!!

# What are the drawbacks?

- You need a one time investment for specialized equipment ($18K)
- Little local experience with mixing and application

- Change is scary!

Sisal Fiber Mats, 1930s

Pictures from Todd Hansen, Iowa DOT

Sisal Fiber Mats, 1930s

Pictures from Todd Hansen, Iowa DOT

# Summary

- PulpCure is a recycled material that can be used to rapidly and economically wet cure with less labor
- It has been used successfully on two bridges in Oklahoma.
- When used at ½” thickness with plastic it will hold water a LONG time with no extra water added
- It is easy to remove when wet
- We are planning on using it on more bridges this spring.

# Why is this important?

- Curing is important for our concrete!
- Wet curing creates an improved microstructure over not curing or curing compounds investigated.
- PulpCure makes it easier and cheaper to wet cure
- This is a new tool that has the potential to improve how we do business

# Where should this be used?

- Bridge decks
- Substructure under joints
- Repair patches
- Thin overlays
- Sidewalks
- Driveways
- Anyplace where your concrete would benefit from a wet cure!

# Summary

- Lithium silicate curing compound did not perform as well as wet curing or PAMS in drying, water sorption, or chloride penetration
- PAMS showed improved performance over lithium silicate but not as good performance as wet curing
- There was little difference between wet curing for 7, 10, and 14 days for with 20% Class C fly ash replacement at the conditions tested
- ½” of PulpCure with plastic has been used successfully as a replacement for wet curing on two bridges in Oklahoma and they are performing well in the field

# Questions?

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