



Tyler Ley, PE, PhD

Professor at Oklahoma State University for 13 y

Work experience with a contractor, DOT, and a consultant.

Research focus – Constructability, Durability, and Novel Test methods

YouTube Channel > 6M views and > 60K subscribers

CONCRETE FREAK!!!!

Fast-Setting Patching Materials



Tyler Ley, PhD, PE

Acknowledgements

National Concrete Consortium – Pooled Fund Study
Steve Tritsch

FHWA – EAR - Novel Alternative Cement Binders for
Highway Structures and Pavements

Georgia Tech (lead) – K.E. Kurtis, L.E. Burris, and P. Alapati

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Tourney Consulting Group (TCG) – N.R. Berke

US Army ERDC – R.D. Moser

Acknowledgements

My daughter Isabel



Who is your favorite super hero???

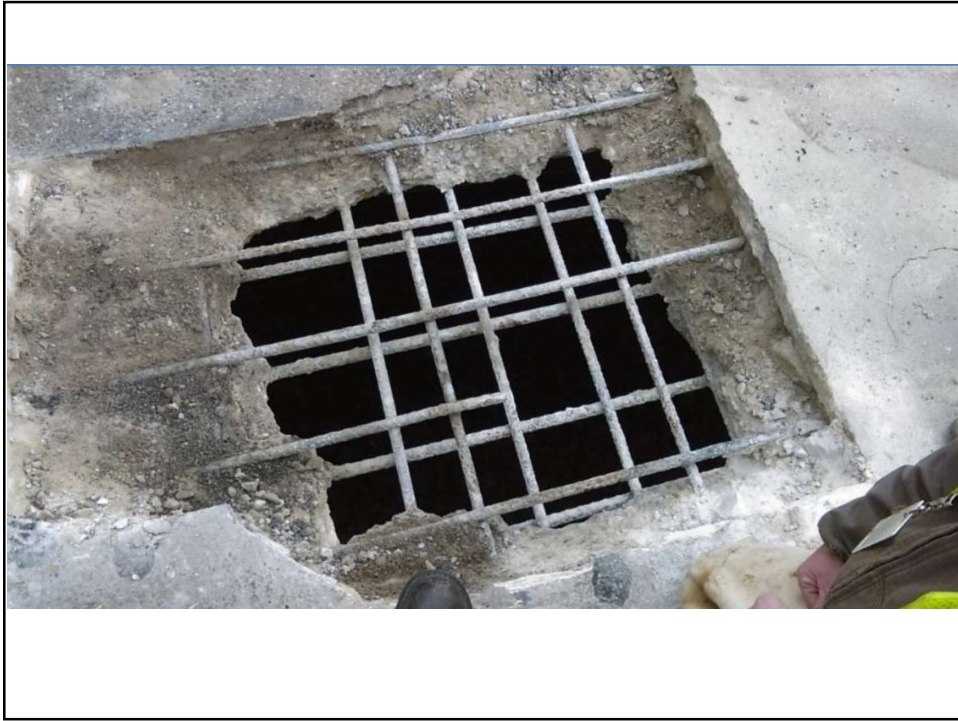


Overview of Synthesis Document

- Four Keys to choosing patching materials
- How do the patching materials work
- Mixing, placement, curing, grinding
- Comparison of patching material performance for strength and durability from literature
- Case studies with a focus on long term durability.
- Common testing protocols and specification

Why is this talk important?







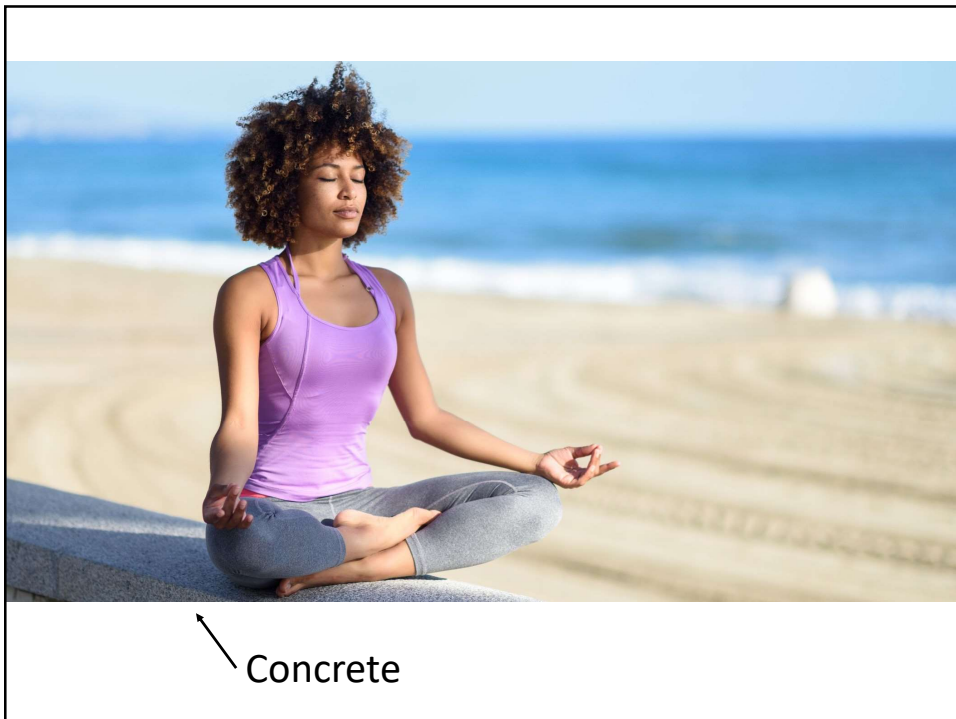
I need the strongest, fastest, most durable concrete on the planet!!!!



Ohio DOT Research Report 134816

“In this project, the lowest cost repair material performed nearly as well as the highest price materials that cost more than 20 times as much.”

Delatte et al., 2016



How do we know which repair material to choose???

Rapid OPC

Latex modified

UHPC

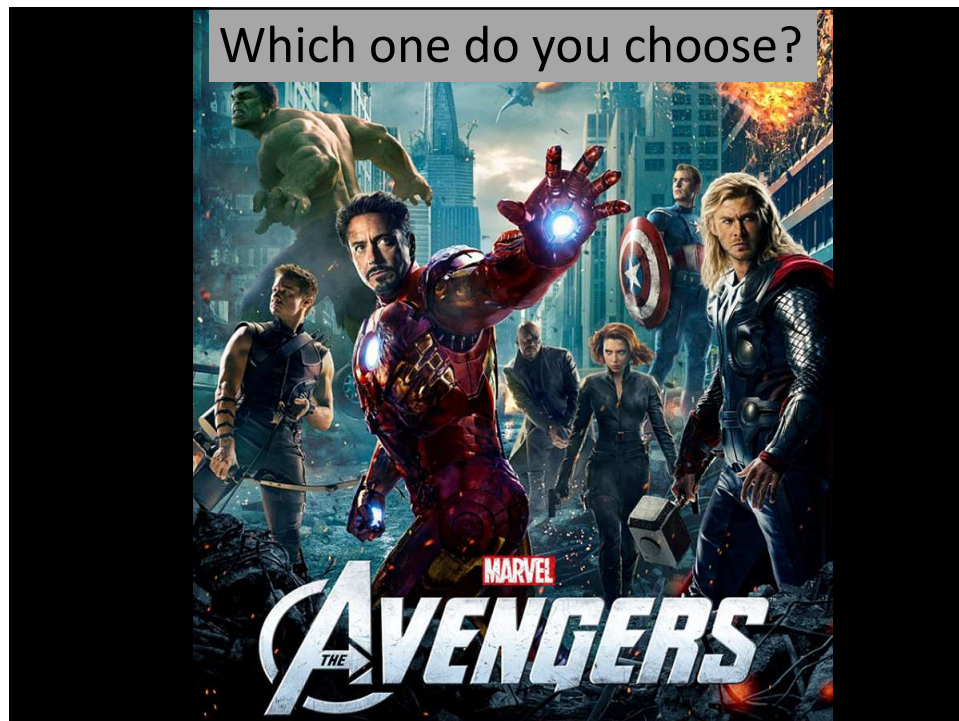
Geopolymer

Mag Phosphate

Polyester Concrete

Calcium sulfoaluminate (CSA)

Calcium aluminate (CAC)



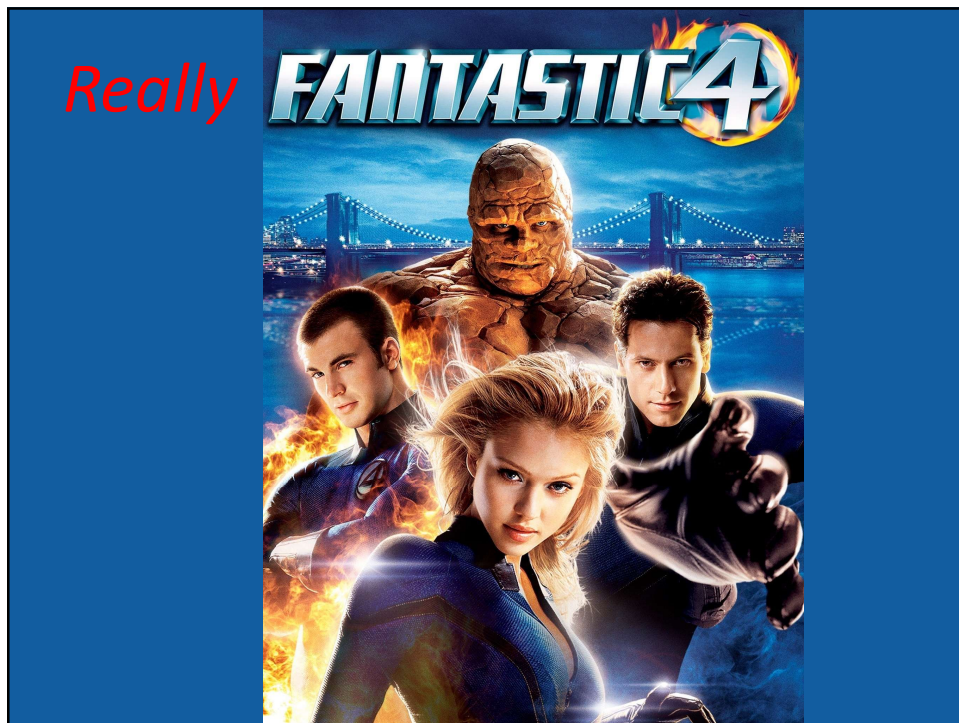
Ask better questions and you
will get better answers!

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Ask better questions and you
will get better answers!

There are four key questions
with all repairs.



The *Really* Fantastic Four Questions

1. How fast do you *really* need it open?
2. What strength do you *really* need?
3. Is reinforcing steel *really* close to the surface?
4. How long do you *really* need it to last?

How fast do you *really* need it open?

The longer you can delay opening the more chance you are giving the material to gain strength.

This also reduces the pressure on the contractors.

Less pressure = more quality = longer life

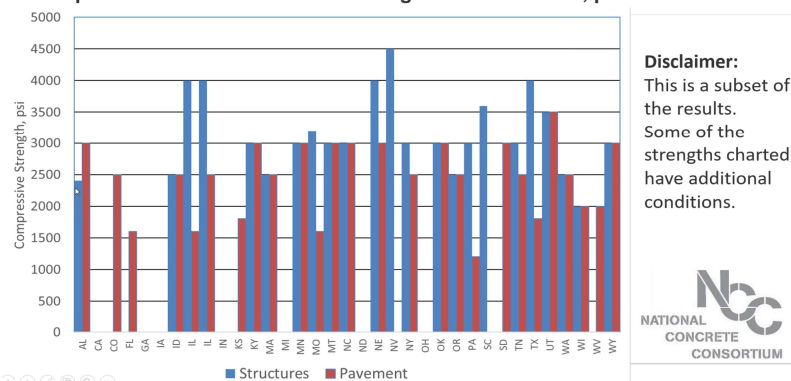
What strength do you *really* need?

- The lower the strength you need the easier it is to make it happen.
- Reducing f'c by 500 psi can make a **big** difference.
- Most of our repairs are over designed

Super Maria!!!!



Q13: What strength does your Agency require patches to achieve before they are open to traffic? If different for bridges and structures, please indicate.



Compressive Strength for Opening

Structures 2000 – 4500 psi

Wisconsin

Pavements 1250 – 3500 psi

Pennsylvania

It was a trick question!!!!

Your opening strength should be a function of the stresses in the patch.



See early opening doc from Delatte, Weiss, Taylor

The correct answer is it depends...
Who gets extra credit?

California, Georgia, Iowa, Indiana,
Michigan, North Dakota, Ohio

Is reinforcing steel *really* close to
the surface?

Bridge structures often have rebar close to the
surface.

You want your patching material to protect that
steel.

Did you know portland cement naturally protects rebar from corroding?

Portland cement produces calcium hydroxide and this raises the pH of the pore solution.

pH > 13



Rebar will corrode in air!

But not in ↑ pH concrete



How do you measure pH?

Place a pH indicator on concrete. The most common one is phenolphthalein.

pH 8 – 12

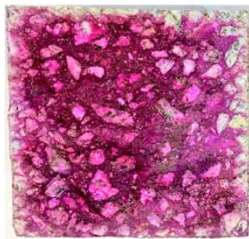


fuscia

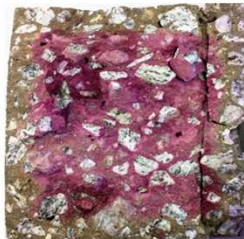
pH < 8



clear



OPC

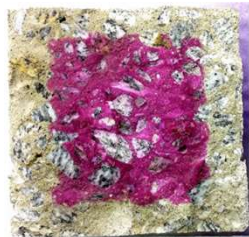


CAC2

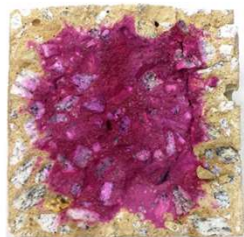


CACT

4" x 4"



CSA2

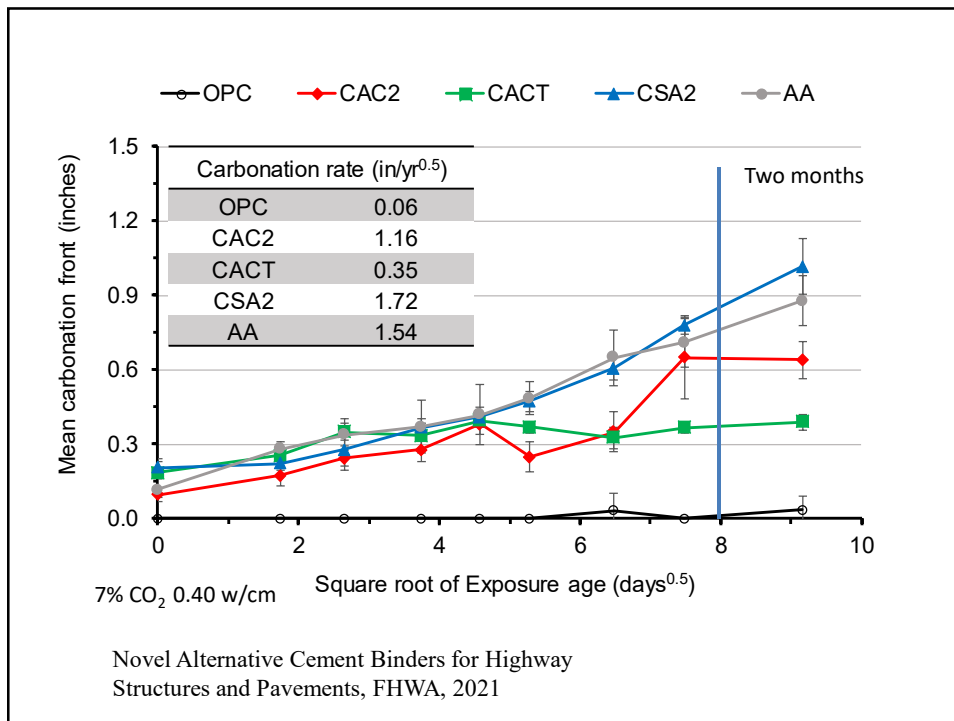
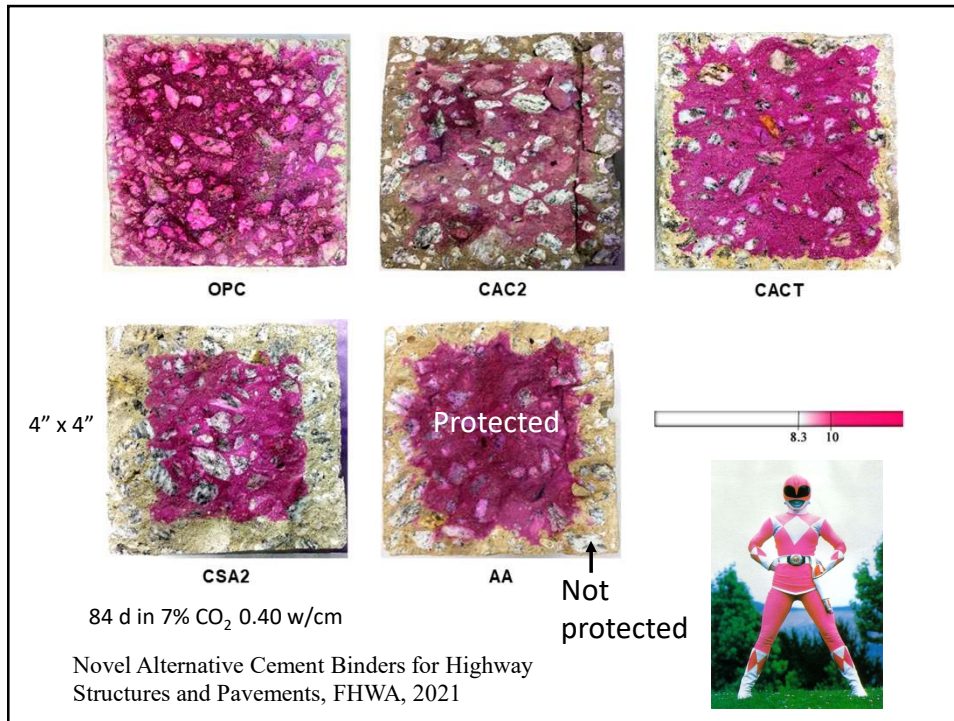


AA



84 d in 7% CO₂ 0.40 w/cm

Novel Alternative Cement Binders for Highway Structures and Pavements, FHWA, 2021



Most repair materials have issues with this.

This means that if you have rebar 2" from the surface and the repair material is a low pH then the rebar will start corroding within the structure in < 2y!!!!

The corrosion will cause cracks in your patching material and section loss in your rebar.

How do repair materials compare?

Good for carbonation

(**Good** for bridges)

Rapid OPC (non chloride!)

UHPC

Polyester Concrete

Latex modified

Bad for carbonation

CAC

Geopolymer

Mag phosphate

CSA



Carbonation:
The eventual **KILLER** of concrete
Tyler Ley, PE, PhD

www.youtube.com/tylerley

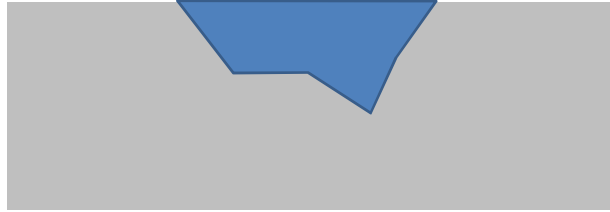
How long do you *really* need it to last?

As long as possible!!!!

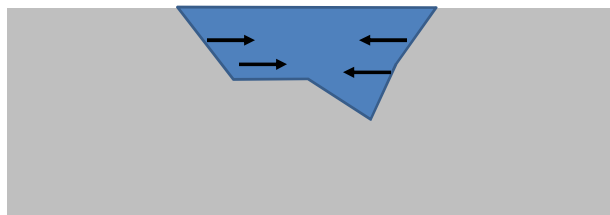
State report says 10 – 15 years.

Some last +20 y. (I think this is very doable.)

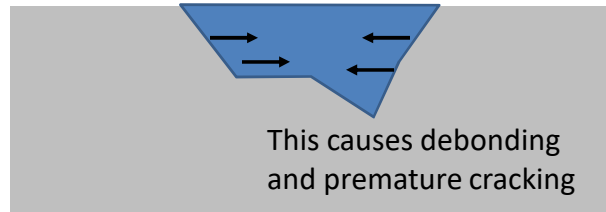
One of the keys is shrinkage!

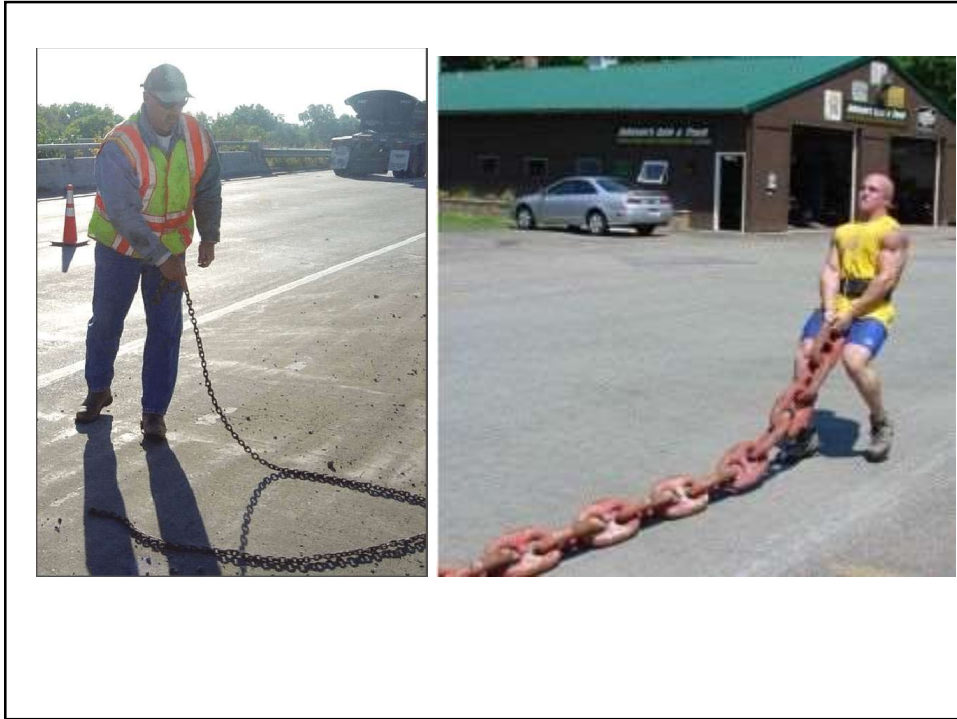


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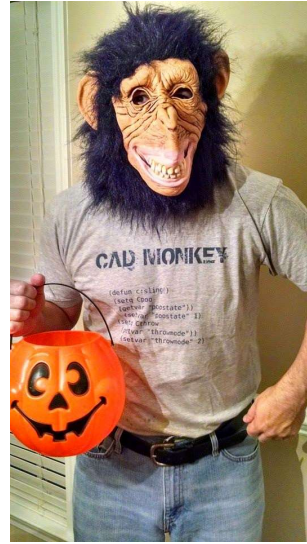


Shrinkage Basics

Watch out for the CAD Monkey!

Shrinkage Basics

Watch out for the CAD Monkey!



Chemical
Autogenous
Drying

Shrinkage Basics

type of shrinkage	timing	cause
<u>C</u> hemical	hours	free water consumed by hydration
<u>A</u> utogenous	days	hydration taking water from pores
<u>D</u> rying	months	water leaving pores from drying

Mixture designs

Concrete mixtures with a $w/cm = 0.40$ and a 4" to 6" slump with 2 h to 4 h initial set time were developed.

These were used for drying shrinkage testing.

An equivalent paste from these mixtures were used for the other tests.

Shrinkage Testing

Chemical shrinkage
 ASTM C1608
 (Dilatometry method)



Autogenous shrinkage
 ASTM C1698
 (Corrugated tube method)

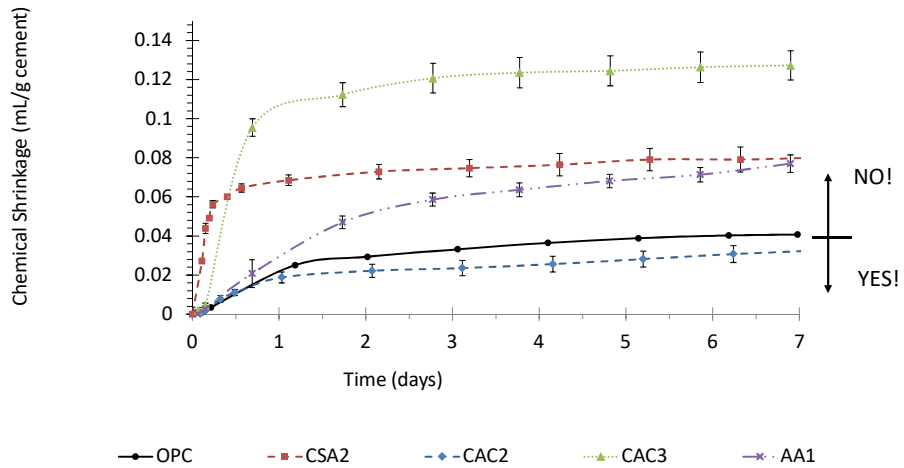


Drying shrinkage
 ASTM C157 (Linear drying shrinkage)

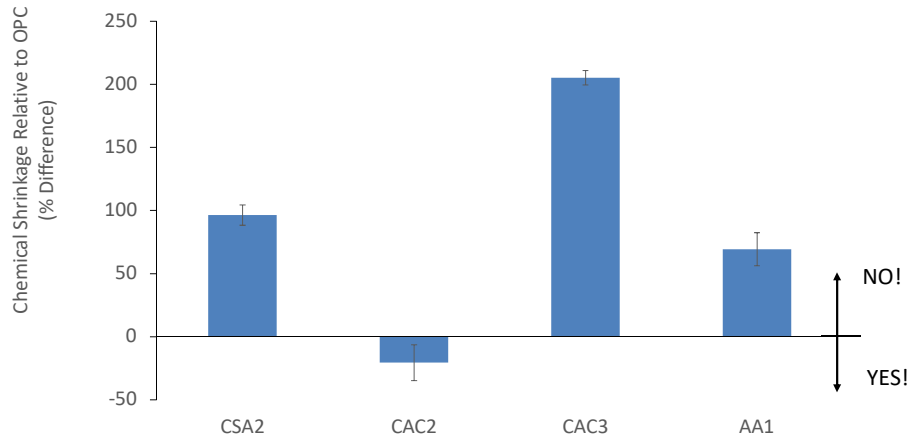


Photo credit: pitt.edu PMML

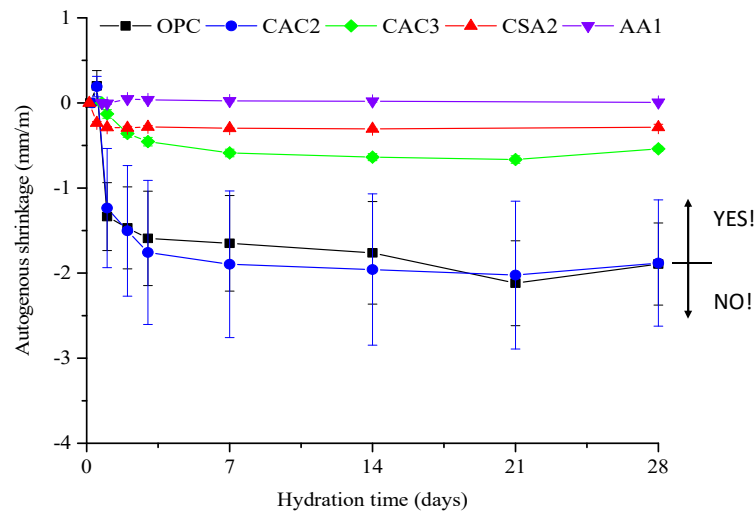
Chemical Shrinkage Results

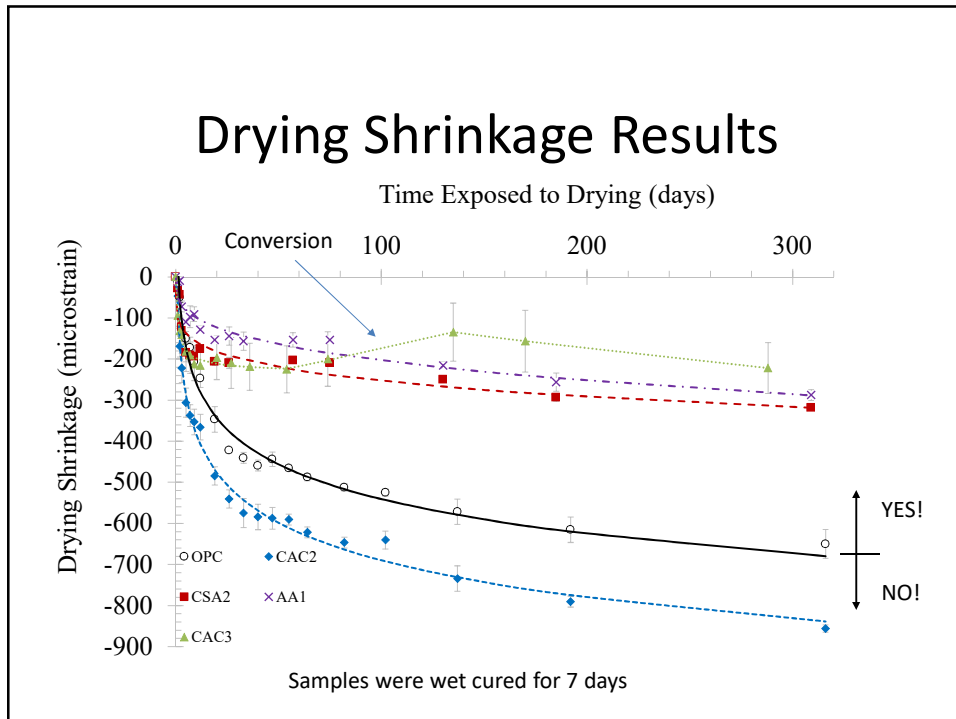
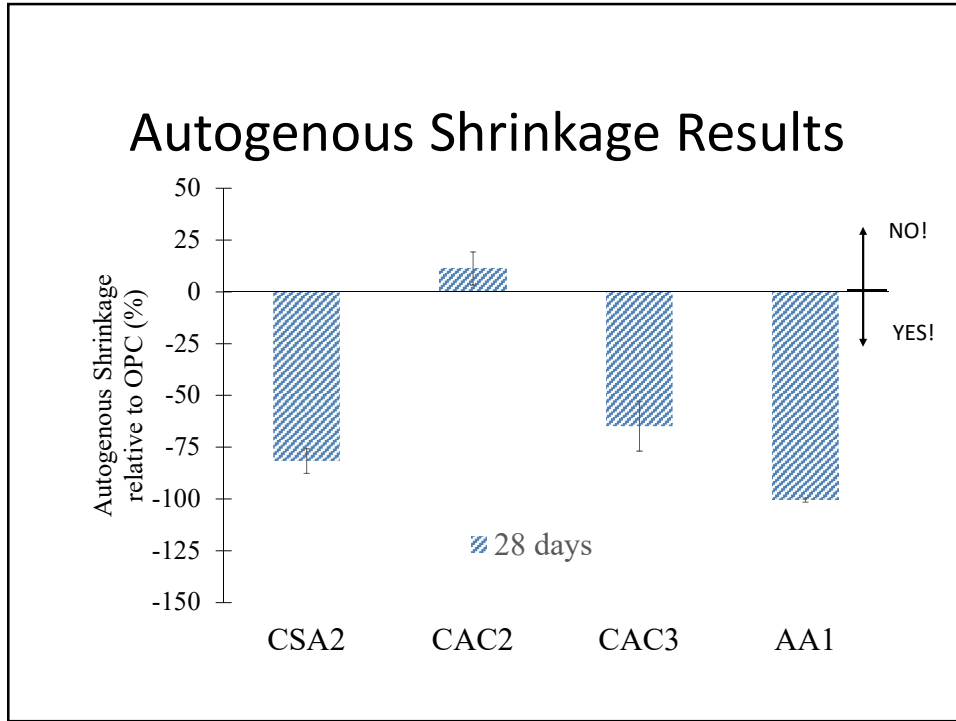


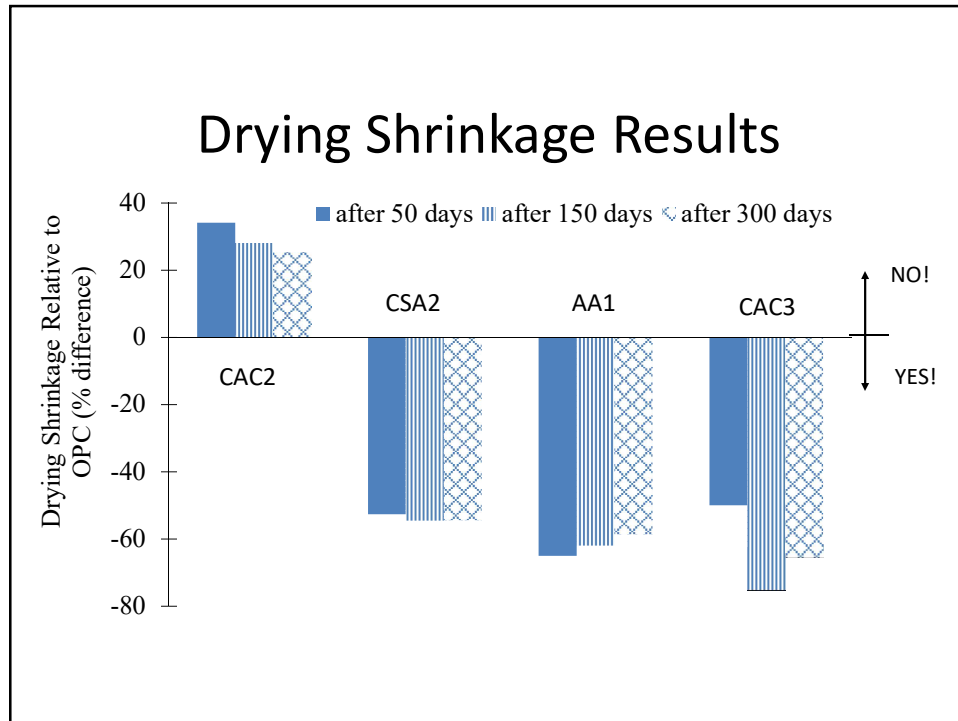
Chemical Shrinkage Results



Autogenous Shrinkage Results







How does it compare to OPC??

Shrinkage:	Chemical	Autogenous	Drying
CSA	✗	✓	✓
CAC blend	=	=	✗
CAC	✗	✓	✓
AA	✗	✓	✓

What does this mean?

- The Geopolymer, CSA, and CAC showed a lower amount of autogenous and drying shrinkage than OPC.
- Less strain should mean less cracking and/or curling and warping

What does this mean?

- These repair materials have an increase in chemical shrinkage in comparison to OPC.
- Based on limited concrete and paste testing no detectable damage occurred at $w/cm = 0.40$.
- Lower w/cm mixtures should be investigated.



Shrinkage in Reinforced Concrete

Tyler Ley, PE, PhD

www.youtube.com/tylerley

Can repair materials really resist freeze thaw, ASR, sulfate attack, corrosion?

Can repair materials really resist
freeze thaw, ASR, sulfate attack,
corrosion?

YES!!!

(If they are designed right!)

Novel Alternative Cement Binders for Highway
Structures and Pavements, FHWA, 2021

Conclusion

- Start with the really fantastic four questions to help improve your rapid patching designs.
- Beware of products with low pH if you are protecting rebar.
- Minimizing shrinkage is helpful and most patching materials are better at this than OPC.

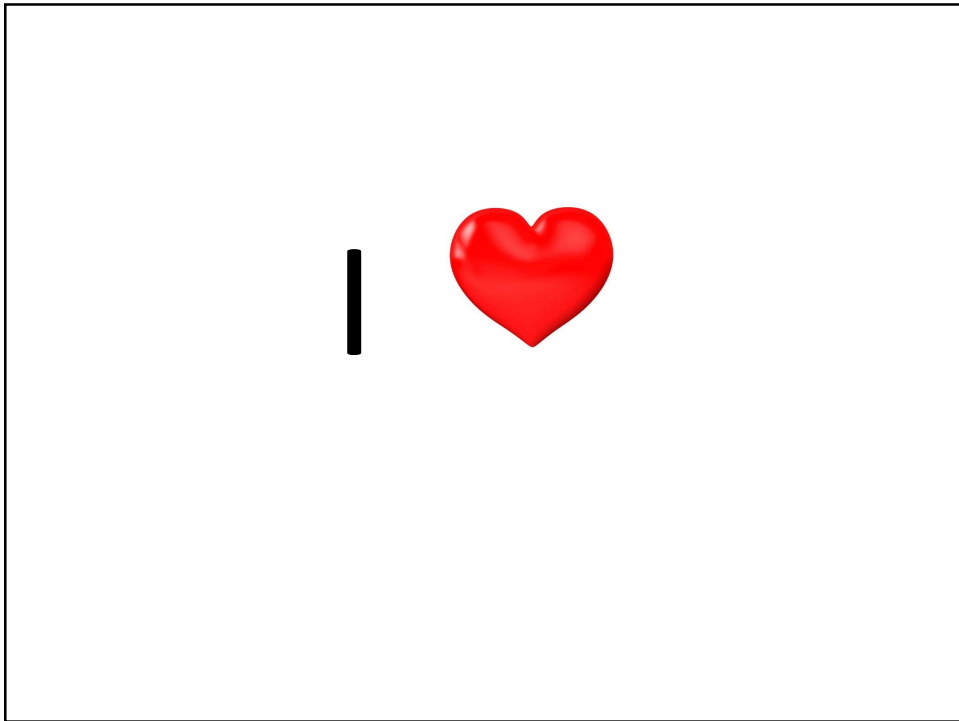
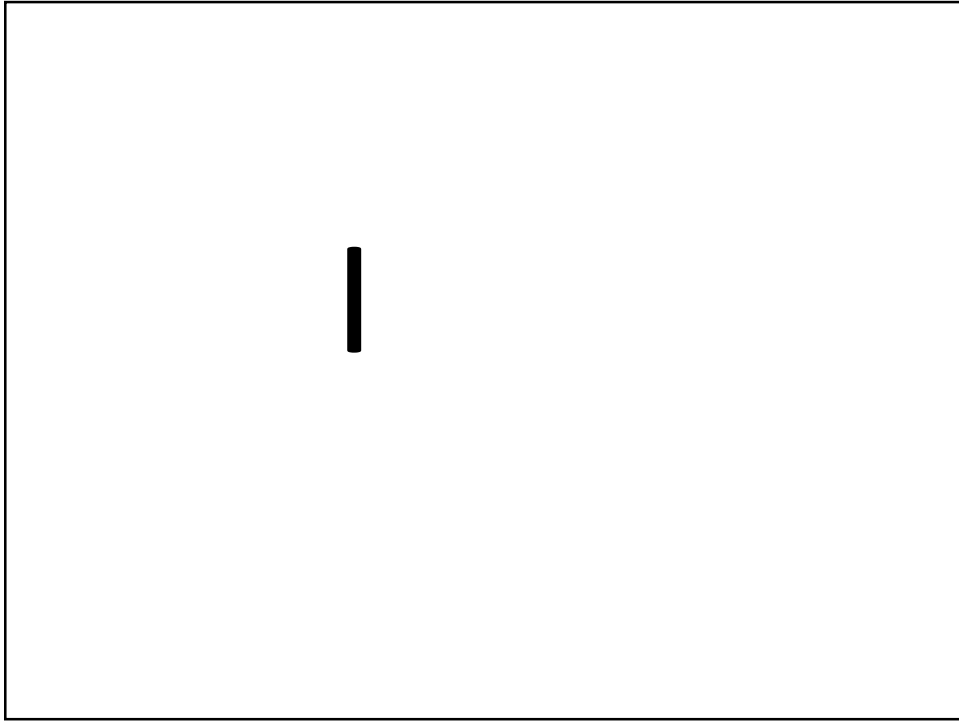
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Questions???

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Concrete