

Shelf life of prepackaged Post-Tensioning Grouts

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Outline

- ◆ Introduction to PT grout
- ◆ FDOT - Project Objective(s) and Scope
- ◆ What we know about cement hydration?
- ◆ Prehydration - cause and effect on cement
- ◆ Shelf life - Test method(s) for Age and Exposure Conditions in addition to MITT for soft grout
- ◆ Preliminary Results
- ◆ Research direction going forward

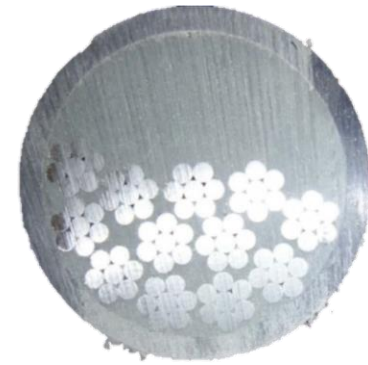
PT Grout

◆ Purpose

- ✓ Transfer PT force
- ✓ Strand Protection

◆ Issues

- ✓ Soft grout (unhardened)
- ✓ High Chloride Levels
- ✓ Voids
- ✓ Bleed water
- ✓ Segregation



Soft Grout

Unhydrated material with putty consistency



At 24 hour set



PT Grout Research Goals



◆ Project Objective

- ✓ Explore the cause of bleed and segregation on plain and commercial PT grout

◆ Scope

- ✓ Effect of age, heat, humidity and pre-hydration on cement and admixtures
- ✓ Sensitivity of admixtures and SCM to age
- ✓ Properties of expired grout
- ✓ Packaging, storage, transport
- ✓ Field test(s) for evaluating Shelf-Life

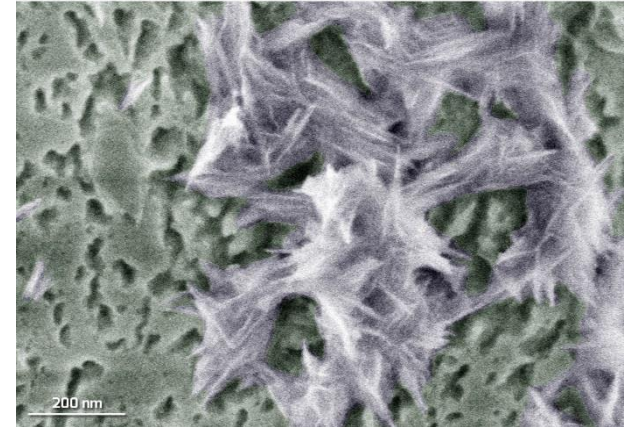
Hydration of Portland Cement



mix with water

Anhydrous cement:
 C_3S , C_2S , C_3A , C_4AF

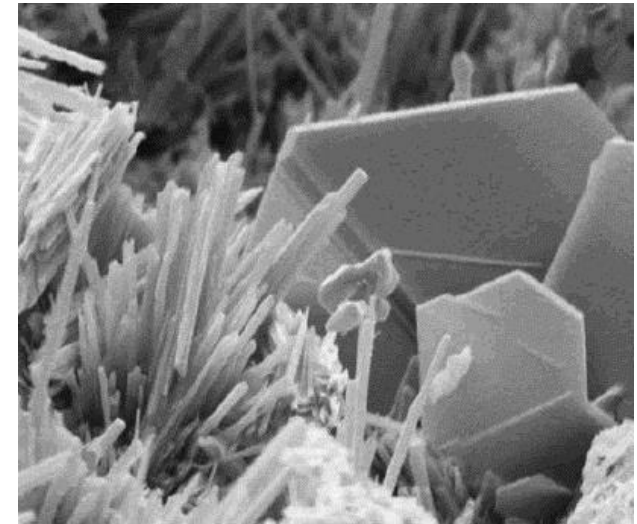
Formation of needle like C-S-H on the surface of etch-pitted triclinc C_3S after 5hr hydration w/c=0.4 © cementlab.com



Calcium silicate hydrate ($C_3S_2H_3$)

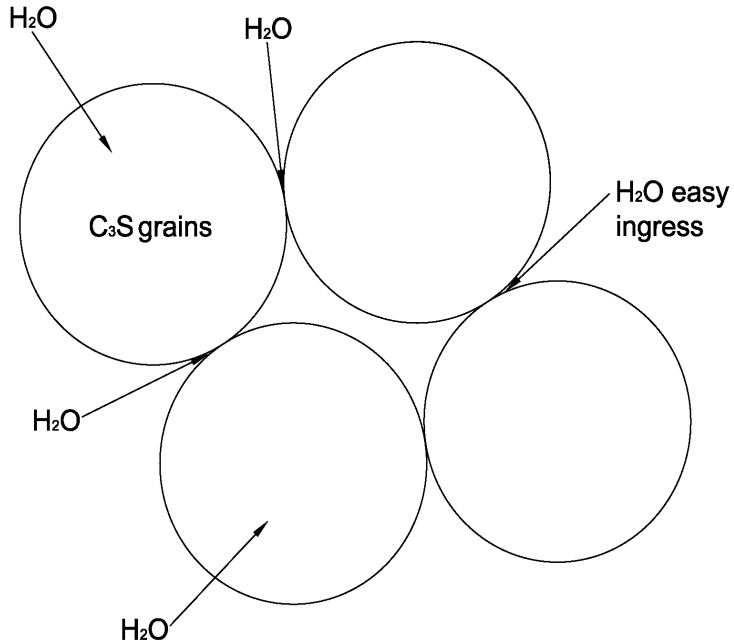


Calcium hydroxide (CH)

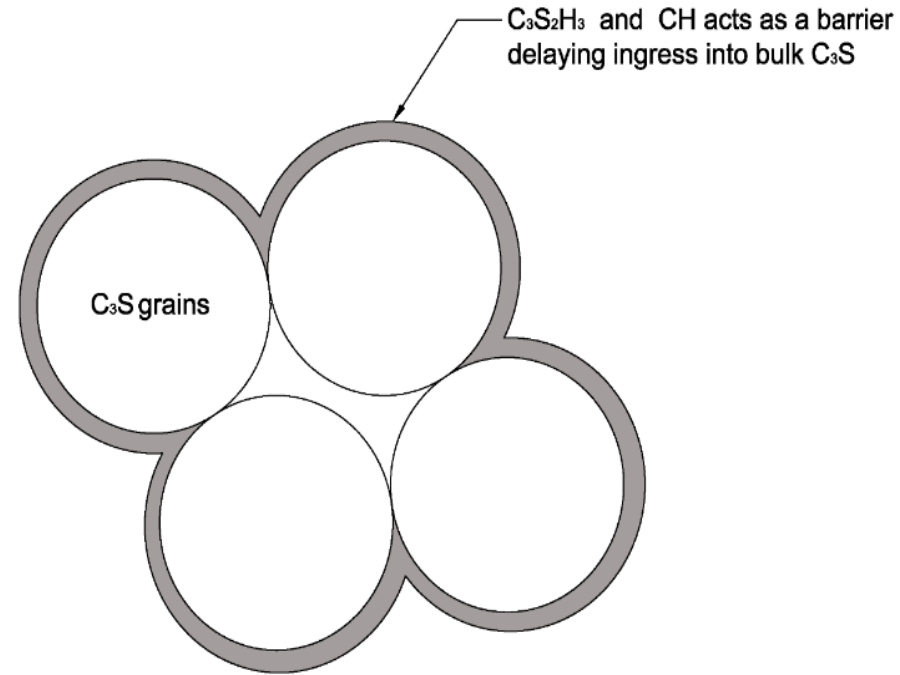


Ettringite

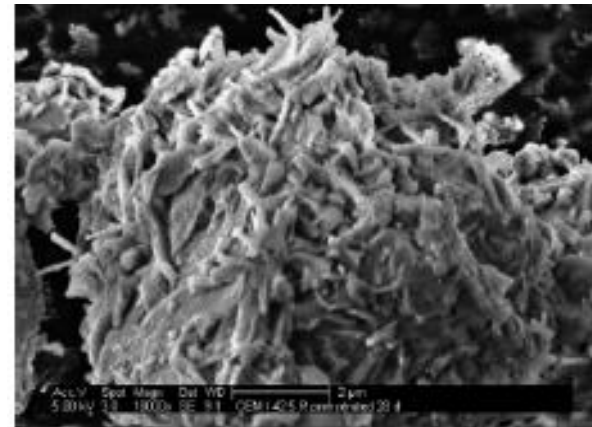
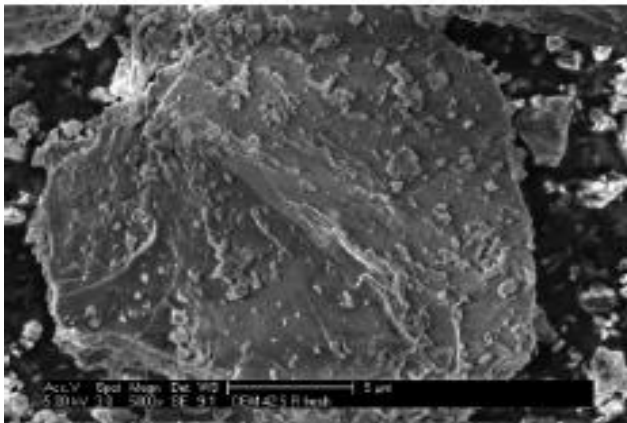
Prehydration of Portland Cement?



Fresh cement



Pre-hydrated cement



(Winnefeld) Empa, Swiss Federal Laboratories for Materials Testing and Research, Dübendorf/Switzerland

Effect of Prehydration

- ◆ Environment heat and humidity
 - ✓ Cement sensitivity to RH% varied by microstructure

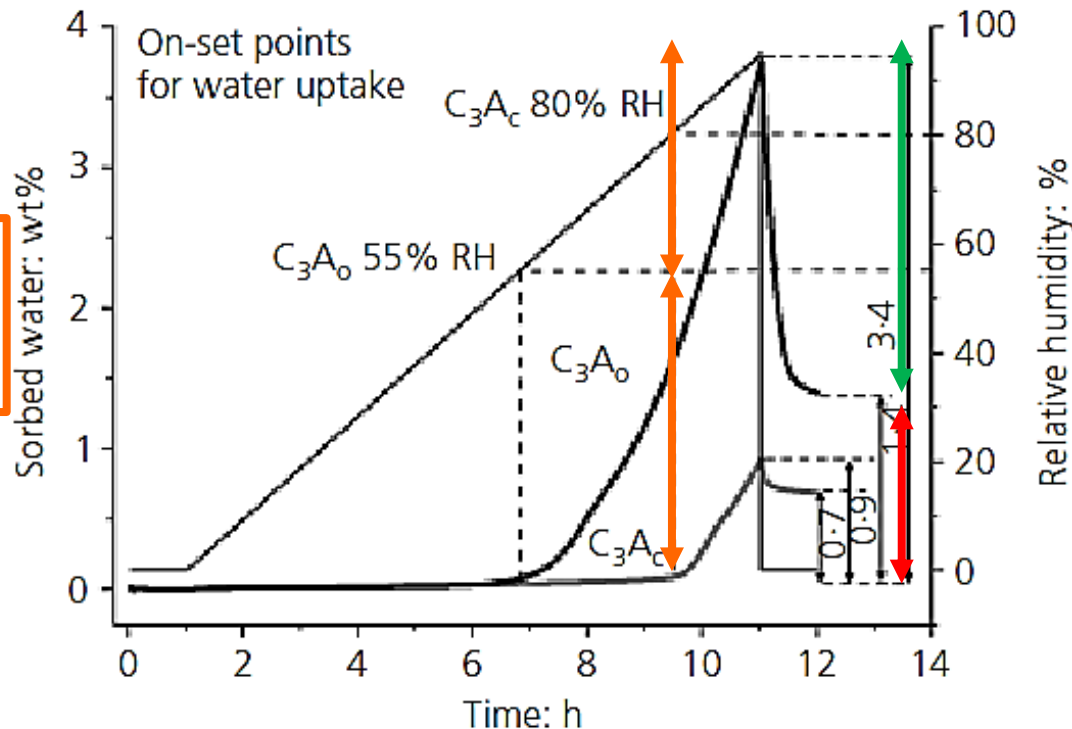


Figure 3. Water vapour sorption isotherms of cubic and orthorhombic C_3A , determined on a sorption balance at 20°C using ramp mode and measured over a period of 11 h

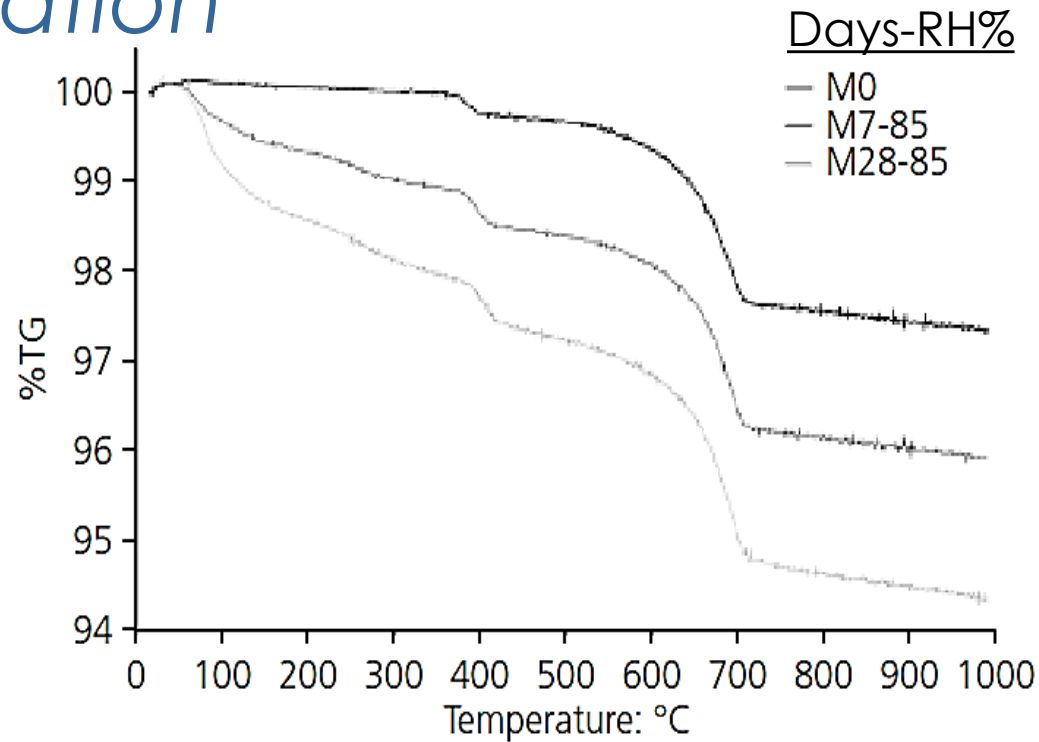
Cement Pre-hydration

◆ Cause

- ✓ Storage conditions
- ✓ Age
- ✓ Temperatures $>65^{\circ}\text{F}$
- ✓ RH $>55\%$

◆ Effects on Grout

- ✓ Bleed Water
- ✓ Segregation
- ✓ Delayed set
- ✓ Soft grout formation



Research Approach

- ◆ Exposure (age, relative humidity and temperature)
- ◆ Soft grout
 - ✓ Modified Inclined Tube Test (MITT)
- ◆ Particle size
 - ✓ Particle Size Analyzer (PSA)
 - ✓ Blaine Fineness (BF)
 - ✓ Thermogravimetric analysis (TGA)
 - ✓ Loss of Ignition (LOI)
- ◆ Determine if grout has expired
 - ✓ This will examine packaging and exposure



Exposure

- ◆ Effect of age and environment on prepackaged PT Grout

Expiration Ratio: $\frac{\text{age of bagged material at mixing}}{\text{shelf life}}$



Laboratory: 65°F, 50-75% RH

Field: Covered outdoor in Gainesville, FL

Walk-In Chamber: 95°F, ~88 % RH

Closet Chamber: 95°F, 95% RH

Soft Grout Results – Field/Laboratory

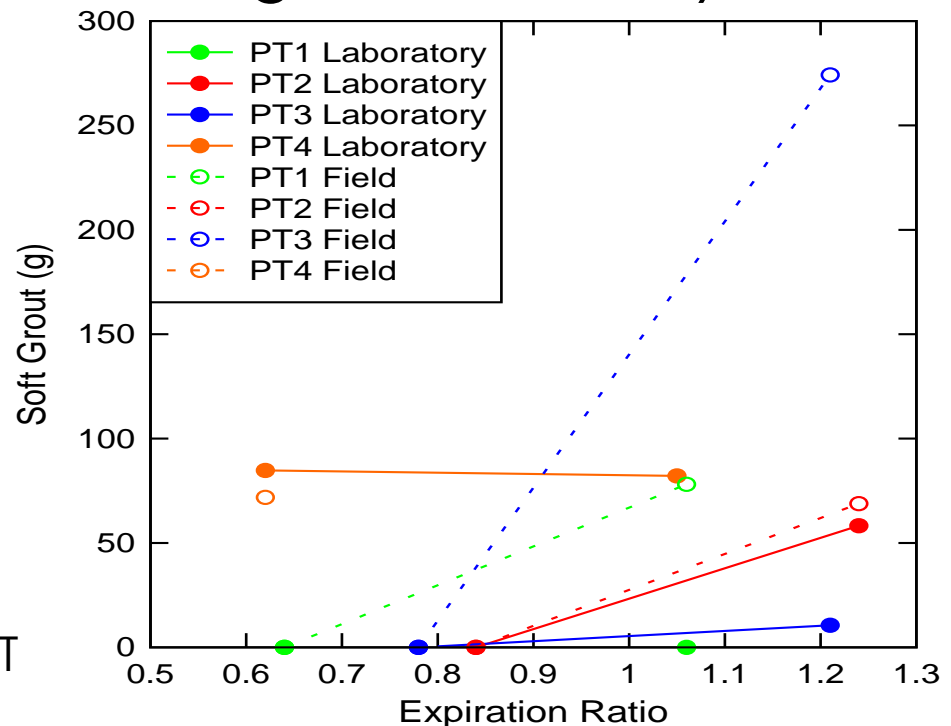
- ◆ No grouts, except PT4, formed soft grout in *Laboratory* conditions at $R_{exp} < 1.0$,
- ◆ All grouts, except PT1, eventually formed soft grout in both conditions at $R_{exp} > 1.0$
- ◆ Soft grout production: Field storage $>$ *Laboratory* storage



Bleed found in MITT

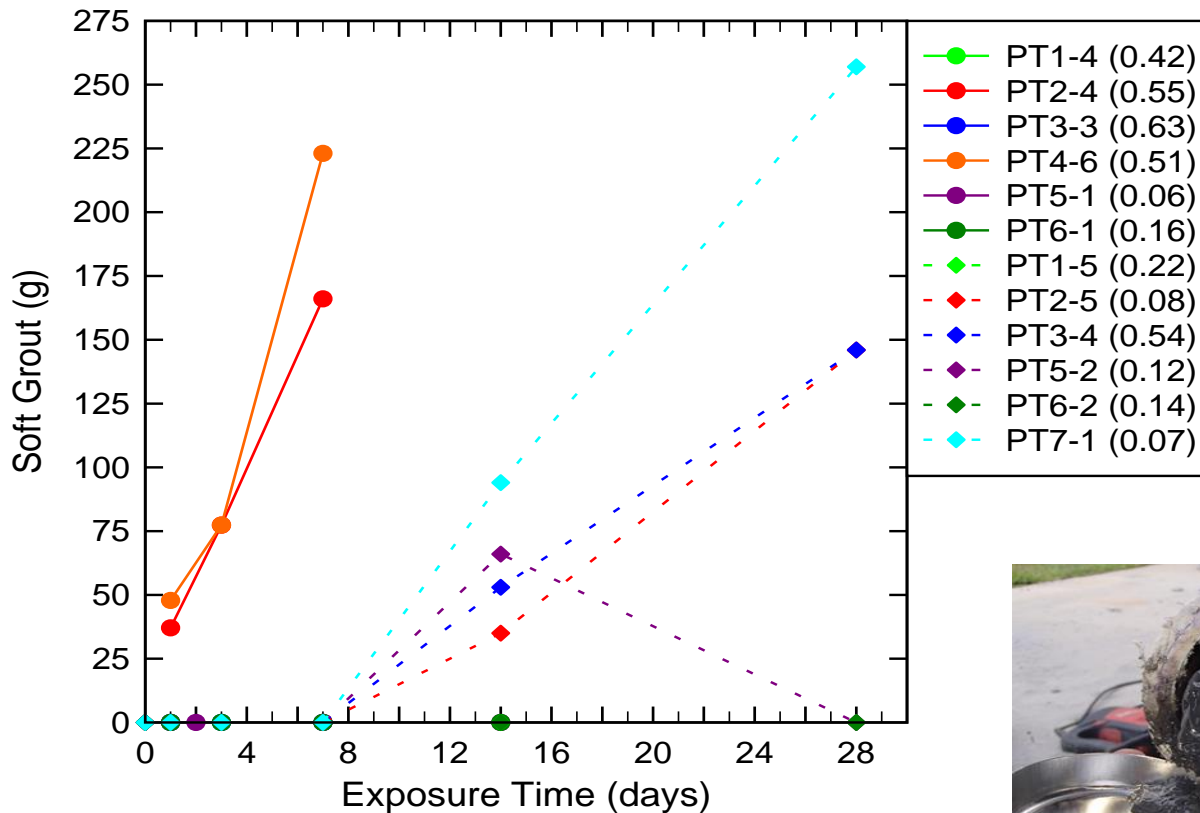


Soft grout found in MITT



Soft Grout Results – Extreme

- ◆ Soft grout formed under *Extreme* conditions
- ◆ PT5, PT7 not set at 24 hours →



Delayed set



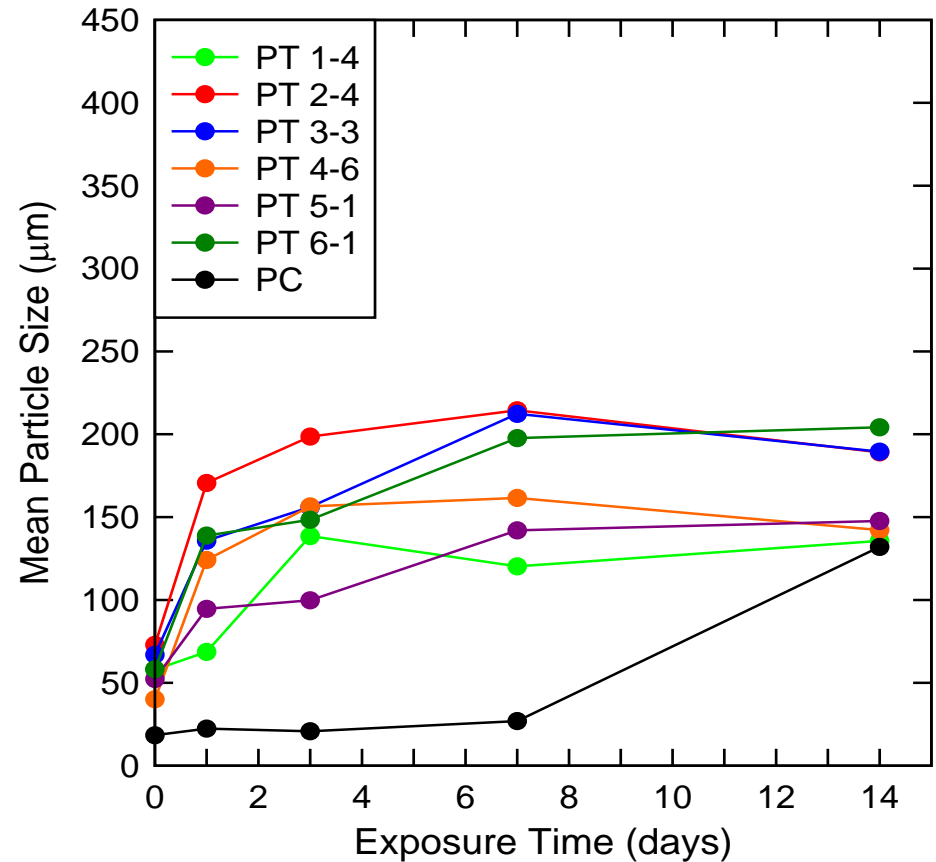
Severe pre-hydration



Soft grout found in MITT

Particle size - PSA

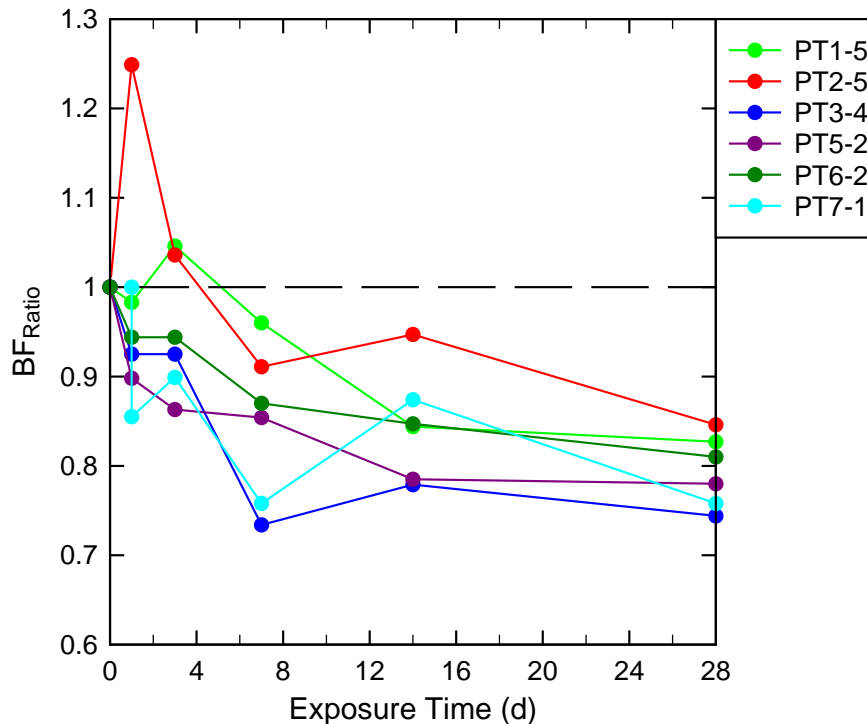
- ◆ Mean particle size increased over time for all grouts exposed to *Extreme* conditions (95°F, 88-95% RH)



Particle Size - Blaine Fineness

◆ Blaine Fineness Test

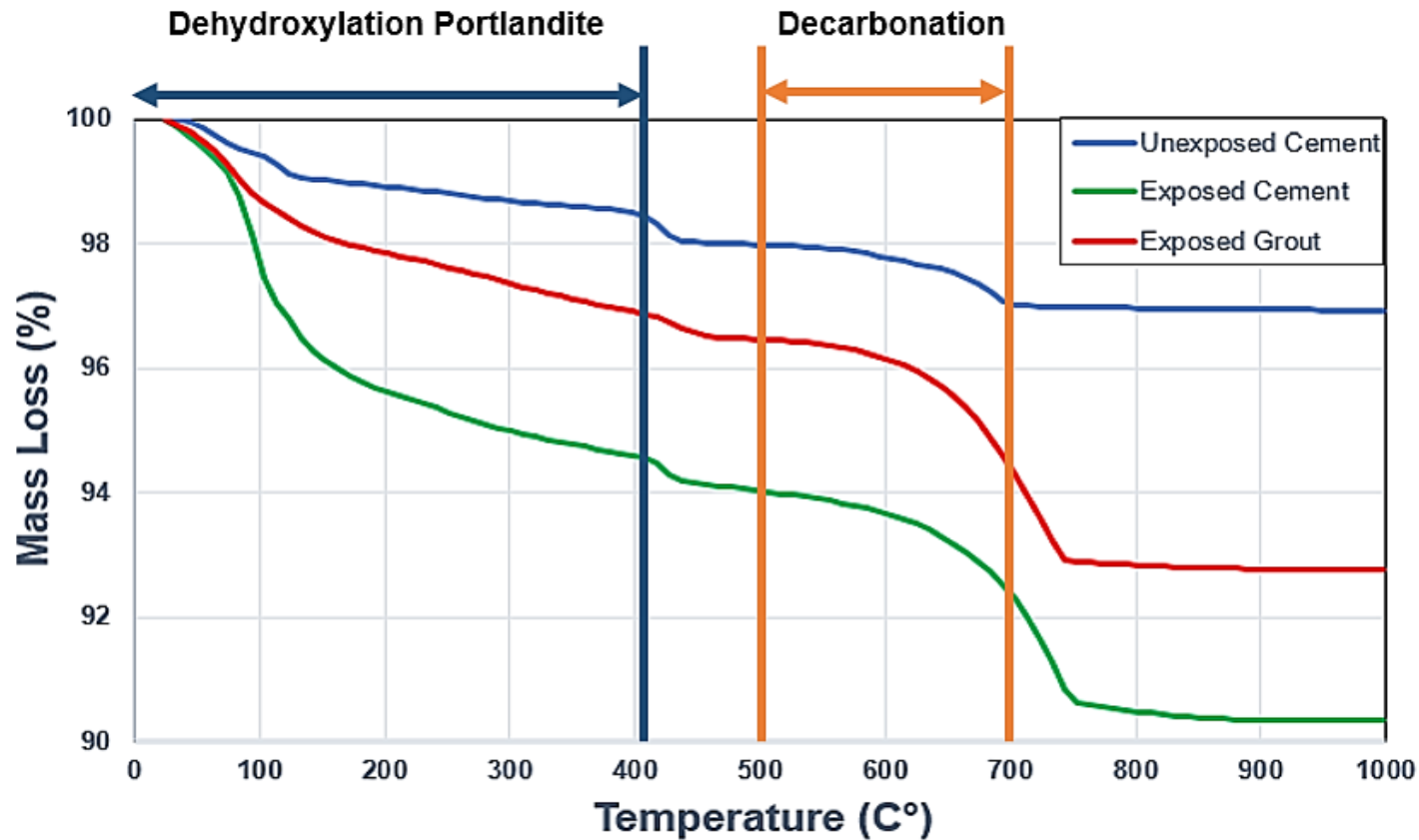
- ✓ BF_{ratio} decreased over time for all grouts exposed to *Extreme* conditions (95°F, 88-95% RH).



$$BF_{ratio} = 1.0 - \frac{\text{grout blaine time with no exposure} - \text{grout blaine time}}{\text{grout blaine time with no exposure}}$$

Particle size – LOI/TGA

- ◆ Particle mass loss increased over time for all grouts exposed to Extreme conditions (95°F, 88-95% RH)



Packaging Effectiveness

- ◆ Packaging dimensions and layer schemes were very similar across all manufacturers investigated.
- ◆ The degree of perforation and the methods used to close the corners of the bags varied from one manufacturer to another.



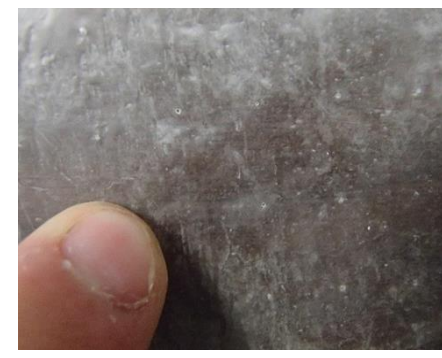
PT3 Layering



PT7 Layering



PT3 perforation



PT7 micro-perforation



PT3 closing corner

Findings to Date

- ◆ High temperature and relative humidity increased soft grout.
- ◆ Prolonged storage increased soft grout at all storage conditions
- ◆ Mean particle size and particle size distribution increases over time (95 °F, 95% RH)
- ◆ Mass gain is exponential with exposure time

Possible test(s) for Shelf Life Evaluation

- ◆ Blaine Fineness
 - ✓ Particle surface area change with Age and storage condition
- ◆ LOI/TGA
 - ✓ Oven heating cement material to determine mass loss due to pre-hydration
- ◆ DSR
 - ✓ Measure fluidity
- ◆ Direction for ensuring quality packaging and storage practices



Summary

- ◆ Grout mass change is a result of storage conditions
- ◆ Packaging effects of perforation and bag closing influence grout protection
- ◆ Loss of Ignition and Thermogravimetric analysis are areas to explore
- ◆ Field testing on cements robustness

Thank you

