# 2016 PTI Convention
# Long Beach, California

Technical Session 3

PT Bridges II

1976-2016 40 years pti POST-TENSIONING INSTITUTE™

# *Effect of Exposure to Humidity and Temperature on the Fresh Properties of Cementitious Post-Tensioning Grout*


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# FDOT Project BDV31-977-31

## Objective

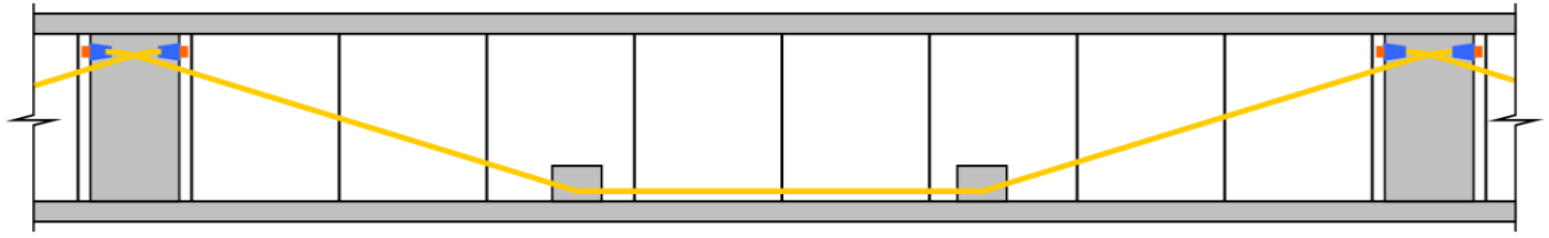
- Explore the cause of bleed and segregation on plain and commercial PT grout

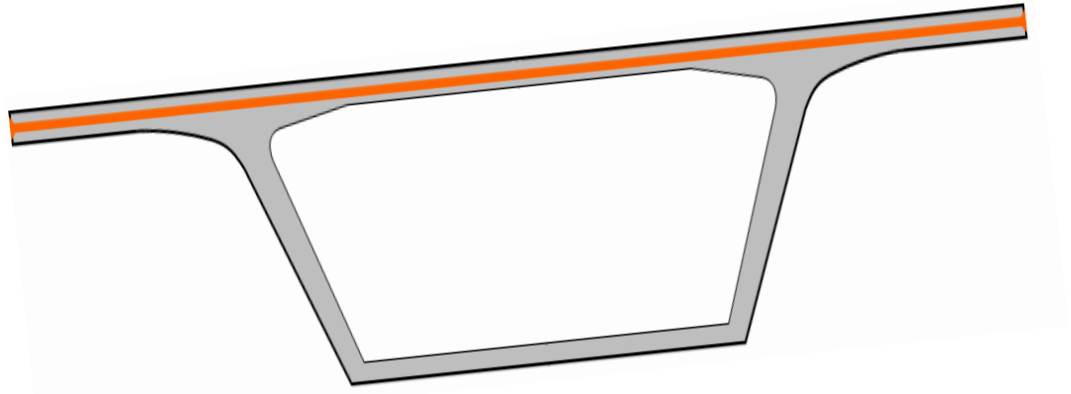
## Scope

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

# *Problem:*

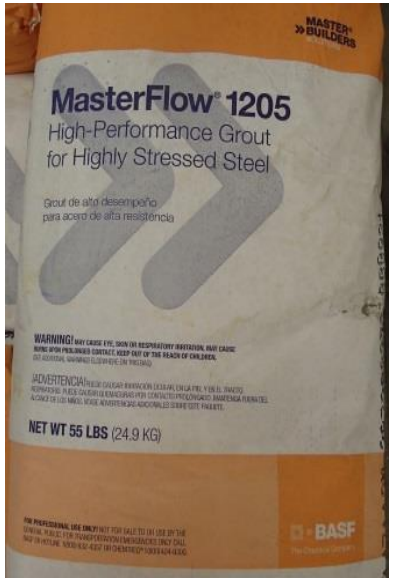
- What effect does heat and humidity have on bagged materials?
- Connection between shelf life and soft grout?





# PT Grout Constituents

- Portland Cement
- SCM
  - ✓ Fly ash
  - ✓ Slag
  - ✓ Silica fume
- Admixtures

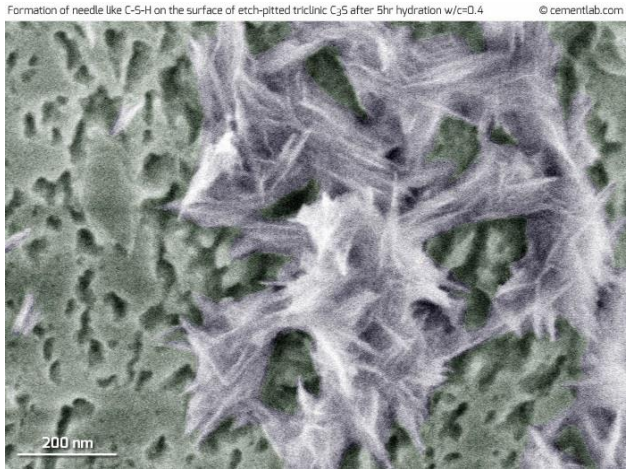





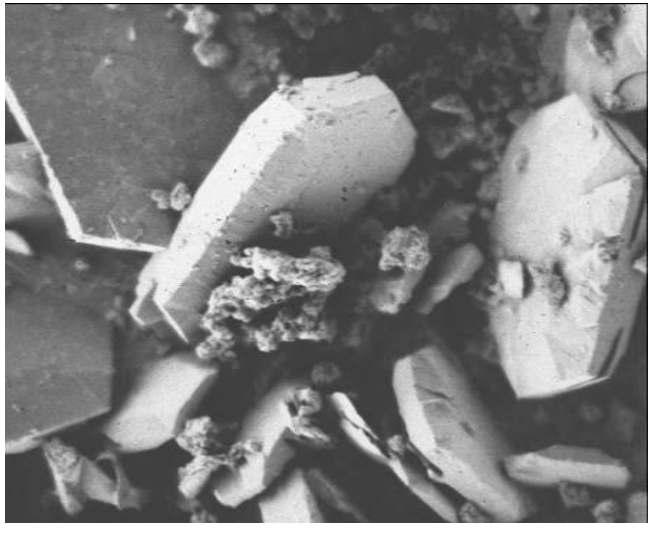
# *Hydration of Portland Cement*

Anhydrous cement:
$C_3S$, $C_2S$, $C_3A$, $C_4AF$

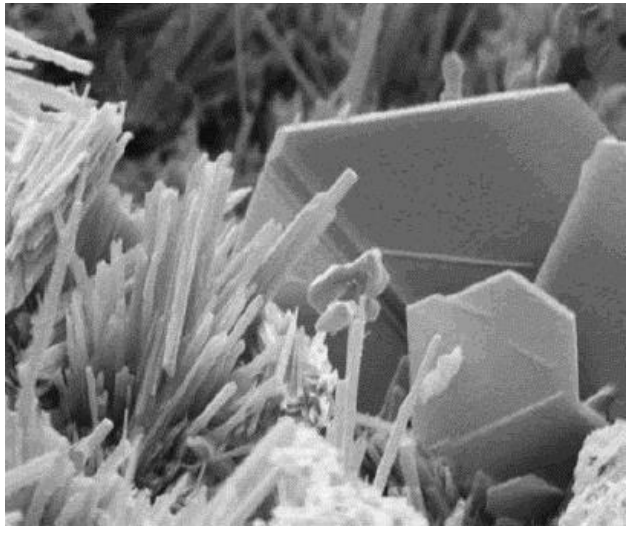
mix with water




Calcium silicate hydrate($C_3S_2H_3$)

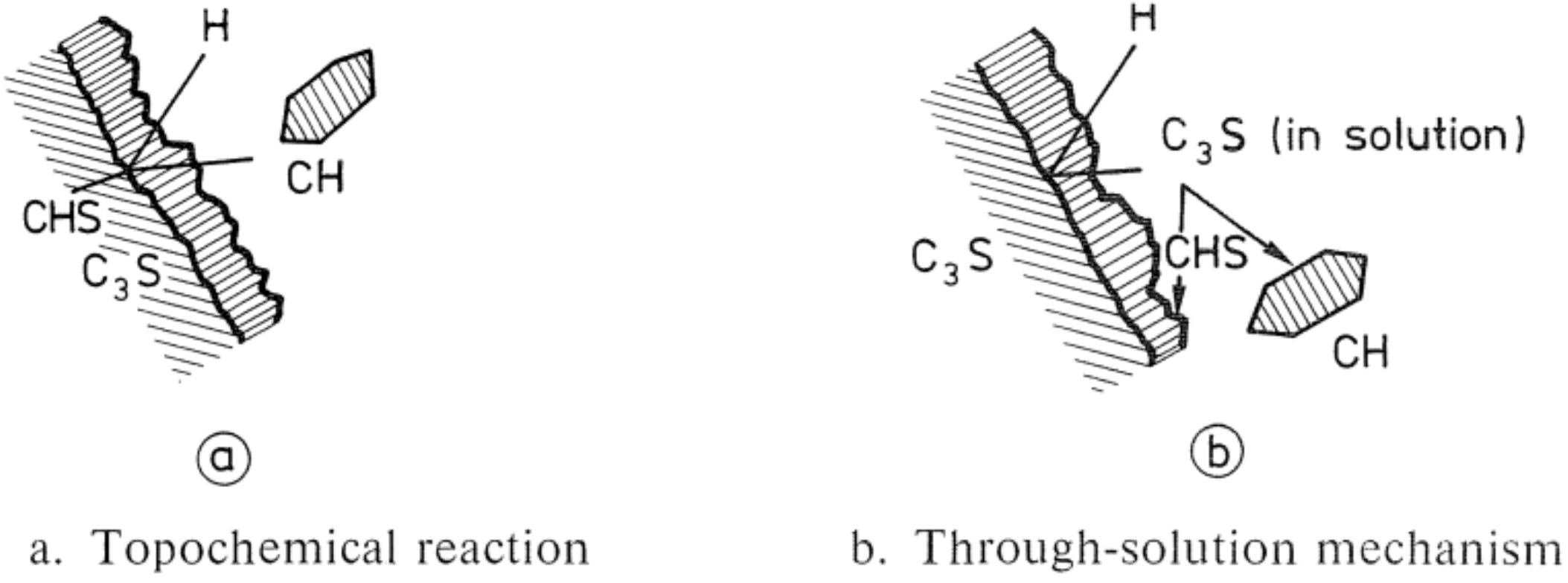


Calcium hydroxide($CH$)



Ettringite

# Hydration Reaction




a. Topochemical reaction

b. Through-solution mechanism

Breugel, K. van. 1992. Numerical Simulation of Hydration and Microstructural Development in Hardened Cement-Based Materials. Delft: Delft University of Technology.

# Hydration products and moisture retention

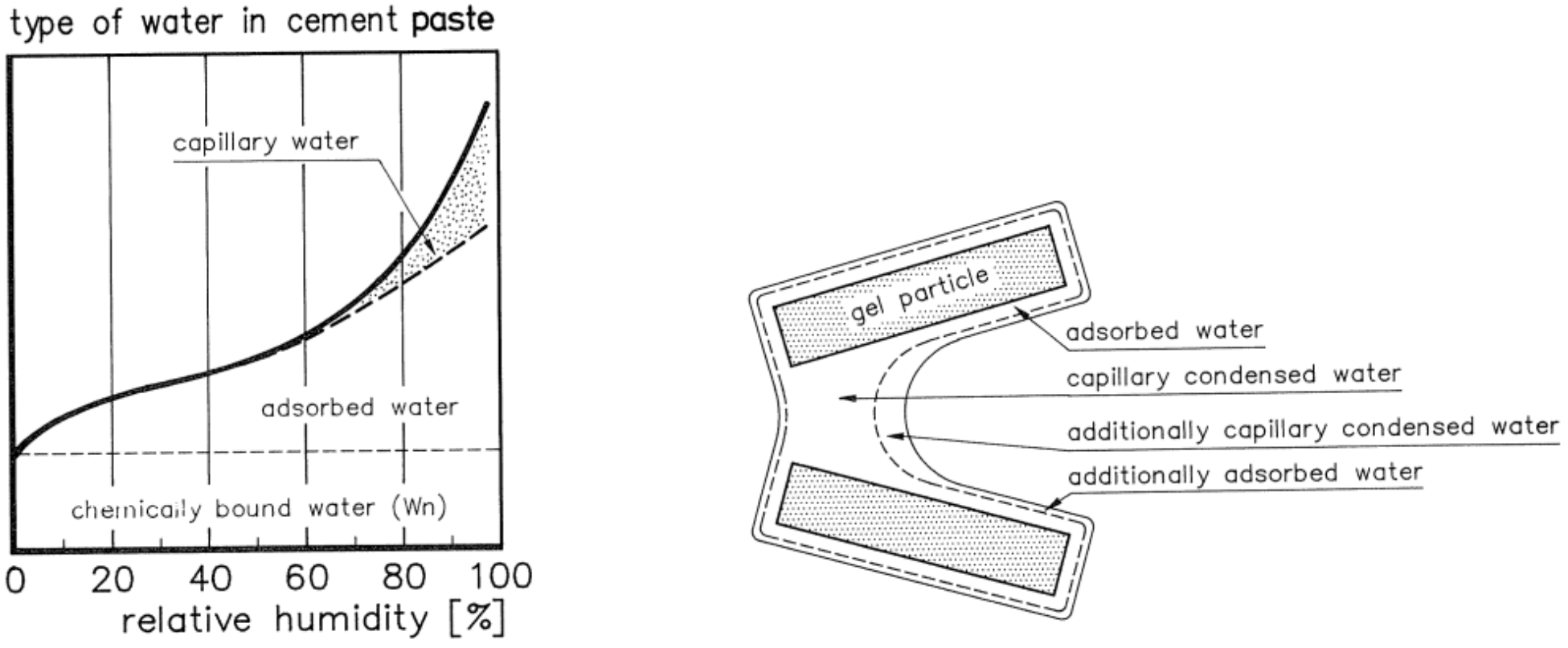
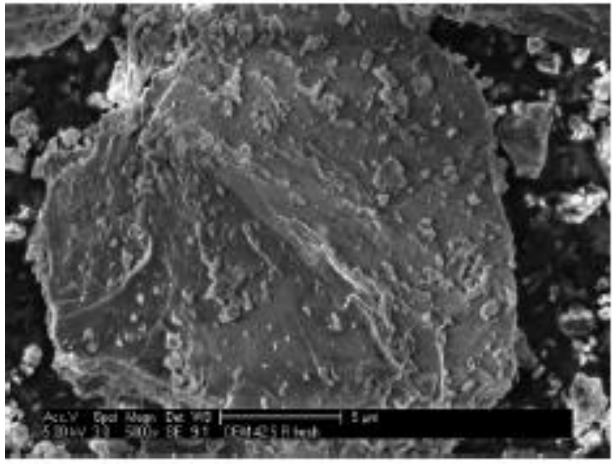



Fig. 2.4 Distribution of water in cement paste as a function of the relative humidity.
a. Diagrammatical representation of types of water in cement paste
b. Representation of adsorption isotherm including capillary condensation (after [26])

Breugel, K. van. 1992. Numerical Simulation of Hydration and Microstructural Development in Hardened Cement-Based Materials. Delft: Delft University of Technology.

# Particle Characteristics



Whittaker, M. D.-M. (2013). *The effect of prehydration on the engineering properties of CEM I Portland.* Advances in Cement Research.

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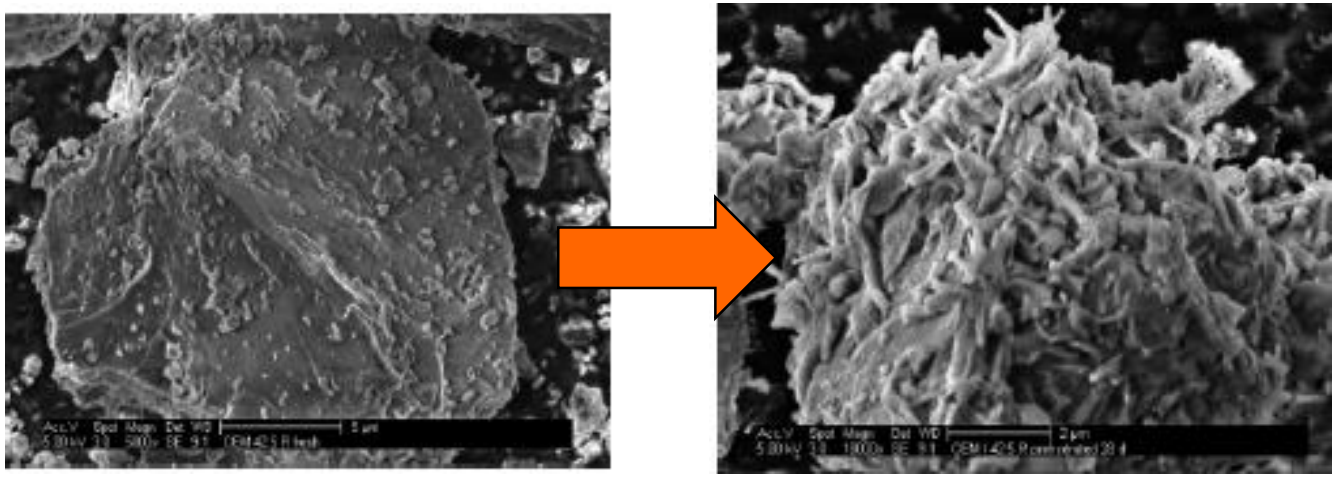

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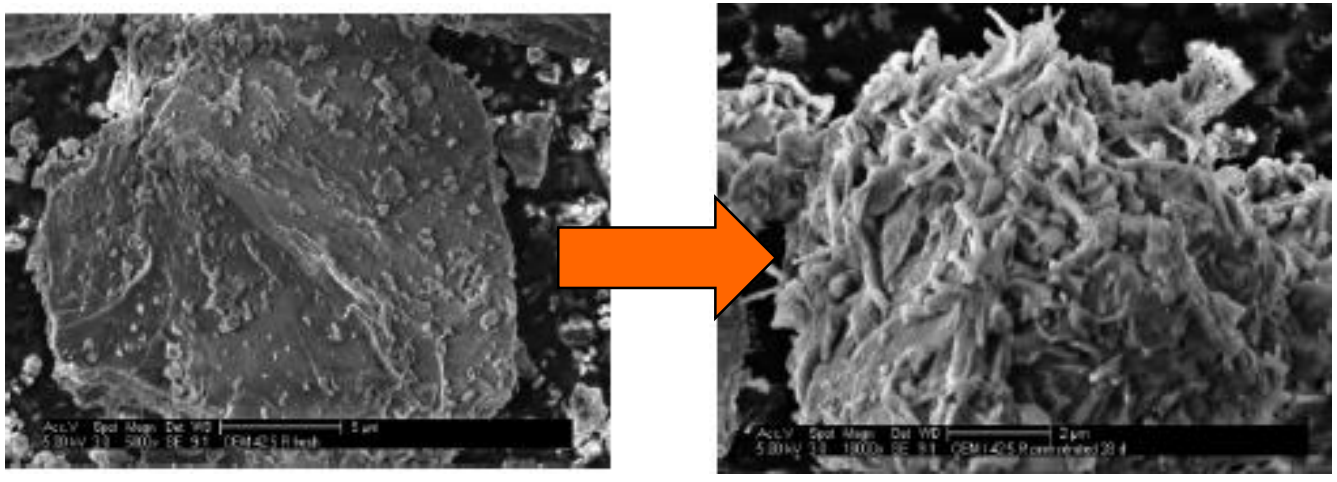

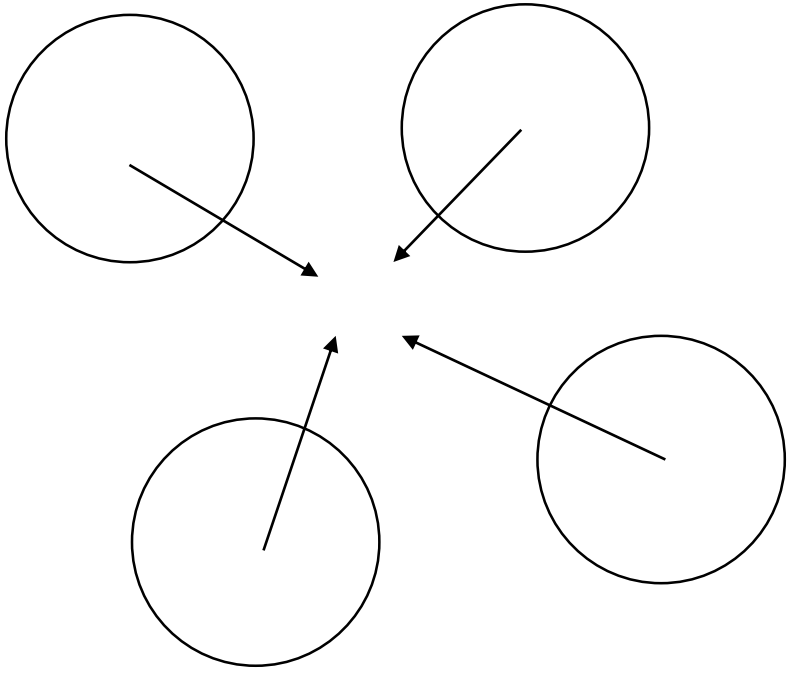

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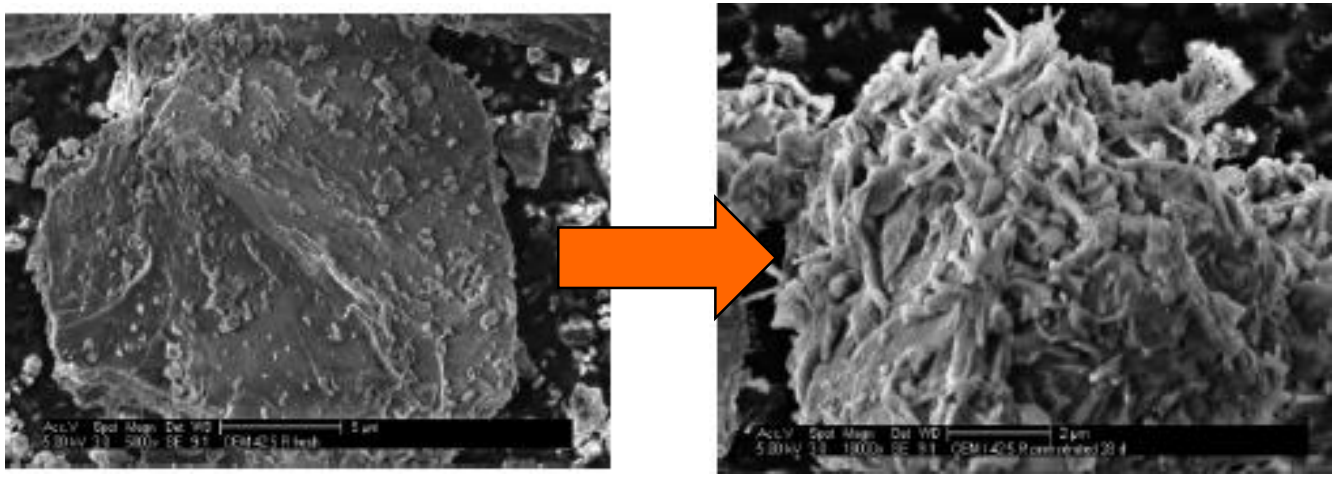

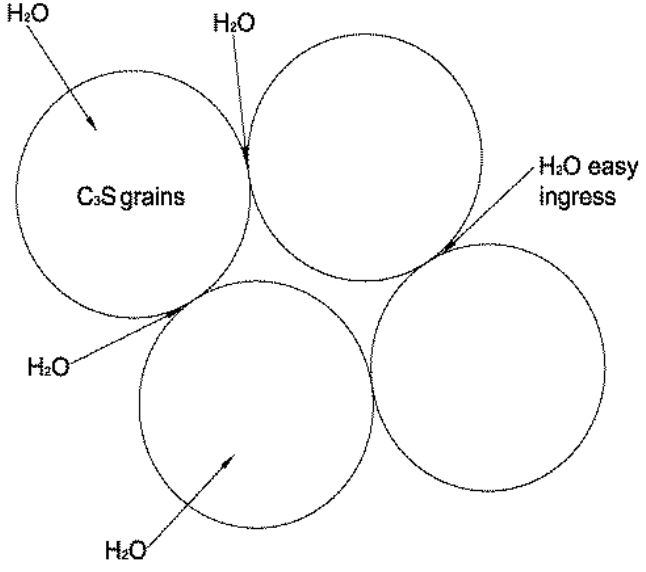


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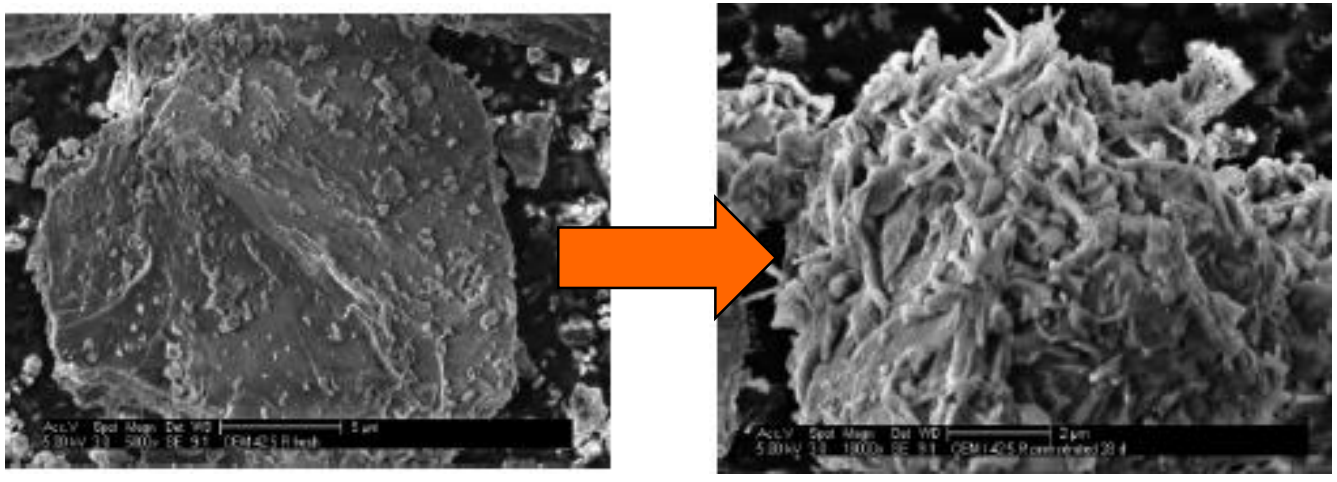

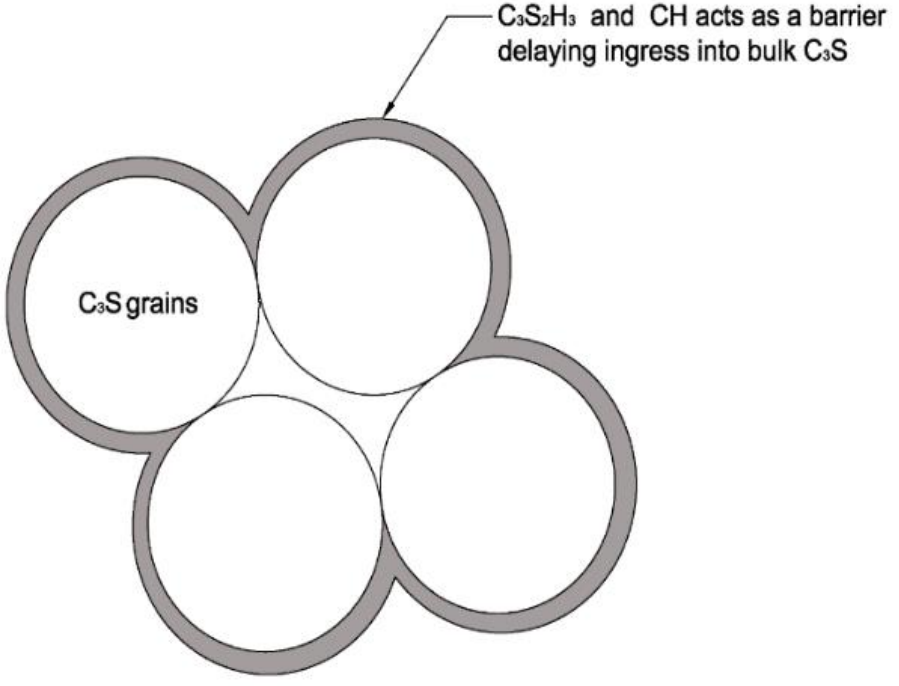


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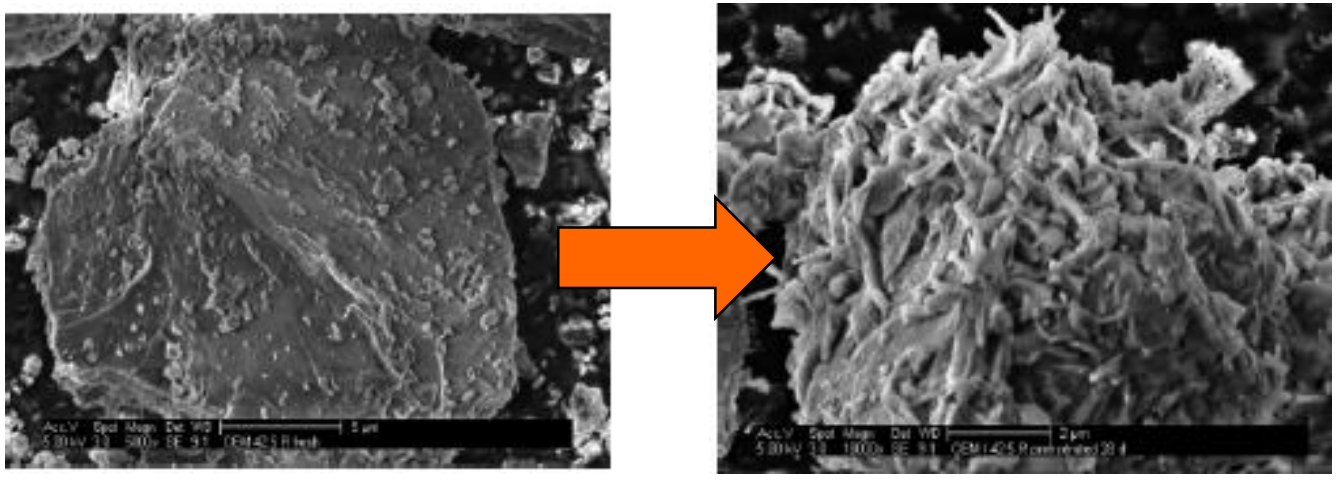

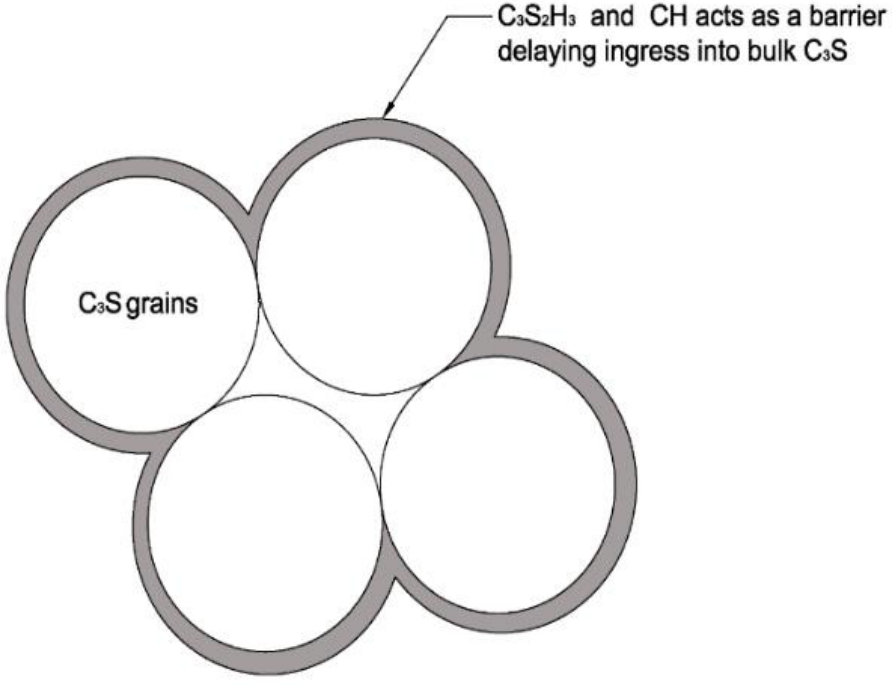


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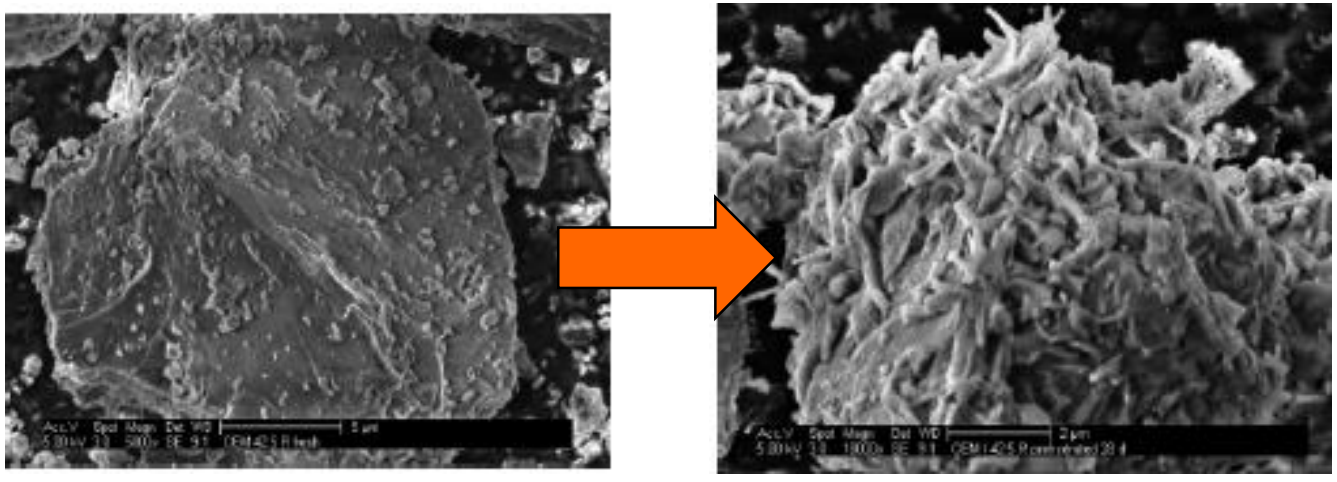

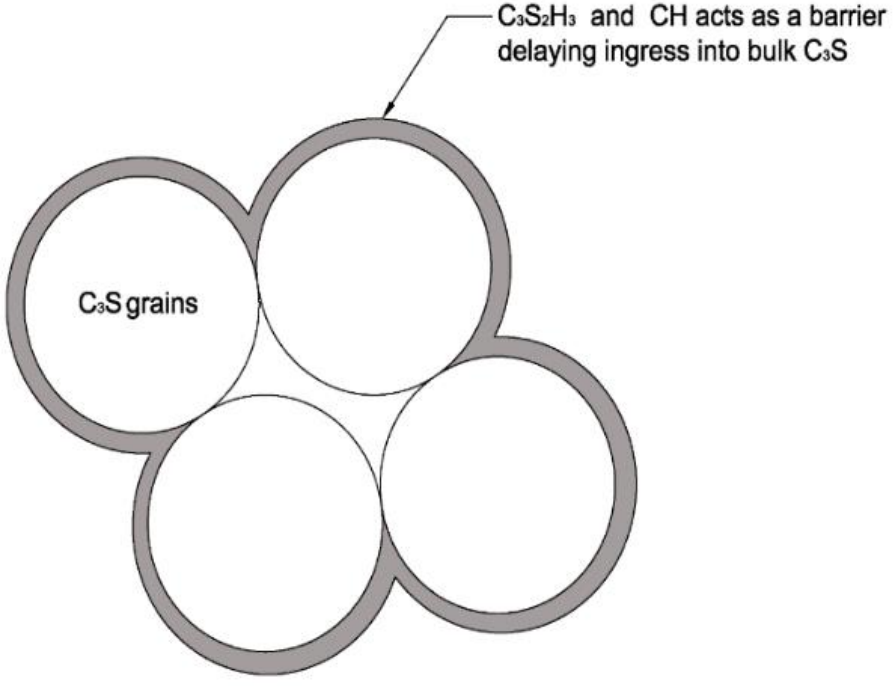


So What?

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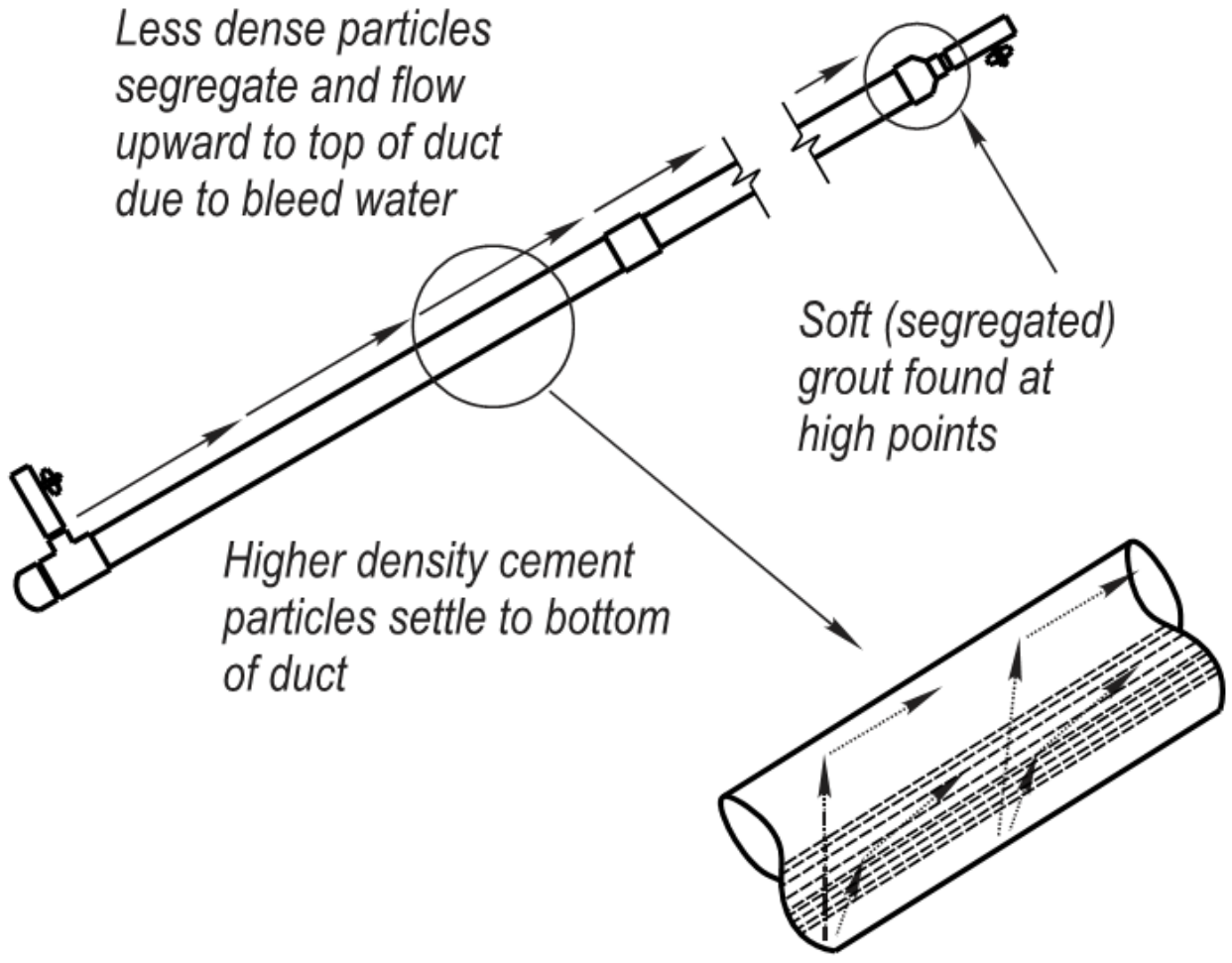
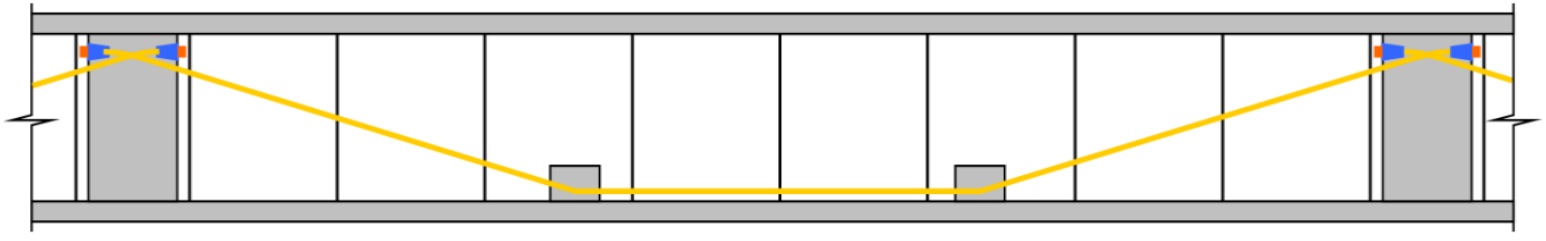
# Grout Rheology

- Grout is a suspension: fluid and particles
- Particle size, surface characteristics, and interaction affect the rheology
- Crystalline growth during early hydration "builds structure" in the suspension, **which stops movement of particles**
- Why is this important?



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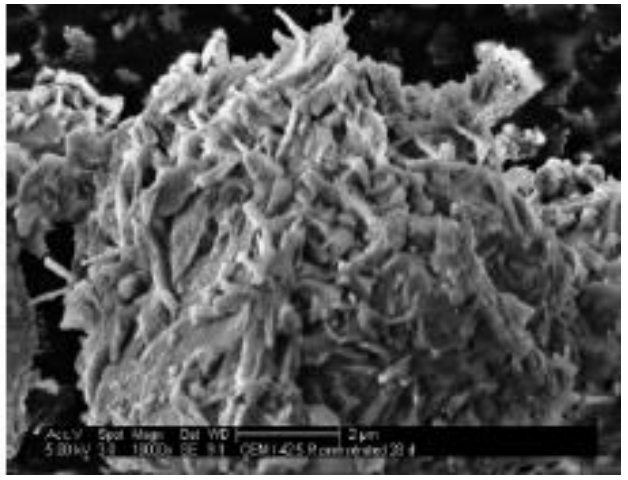
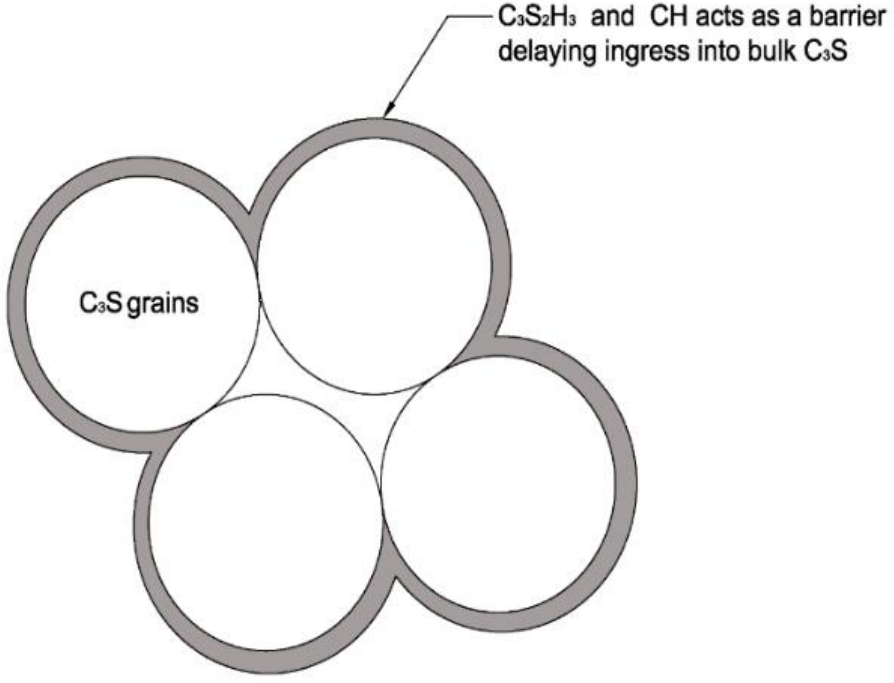
# *What clues might we turn to?*

- Change in mass
- Change in particle characteristics



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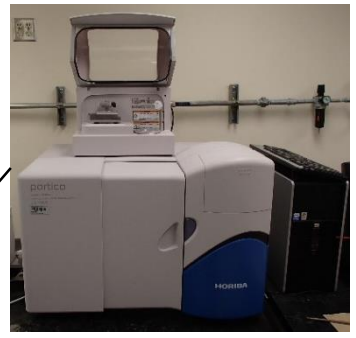
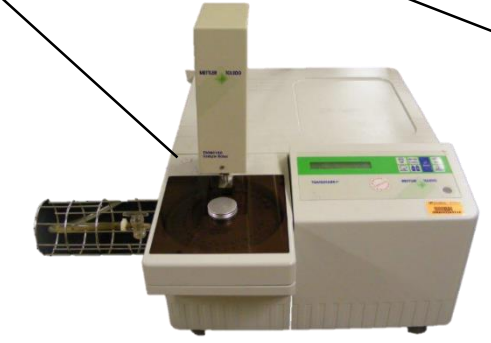
# *Sensitivity*

- Particle characteristics
  - ✓ Particle Size Analyzer (PSA)
  - ✓ Blaine Fineness (BF)
- Mass
  - ✓ Small Scale Mass Gain (SSMG)
  - ✓ Loss on Ignition (LOI)
  - ✓ Microwave Moisture Content (MMC)
  - ✓ Thermogravimetric analysis (TGA)

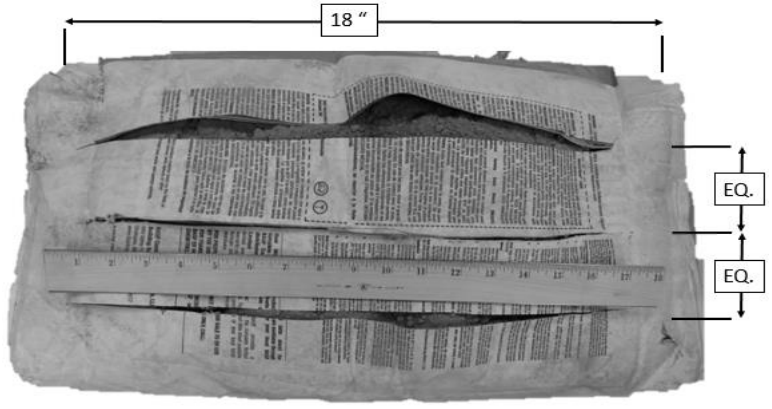






# Exposure

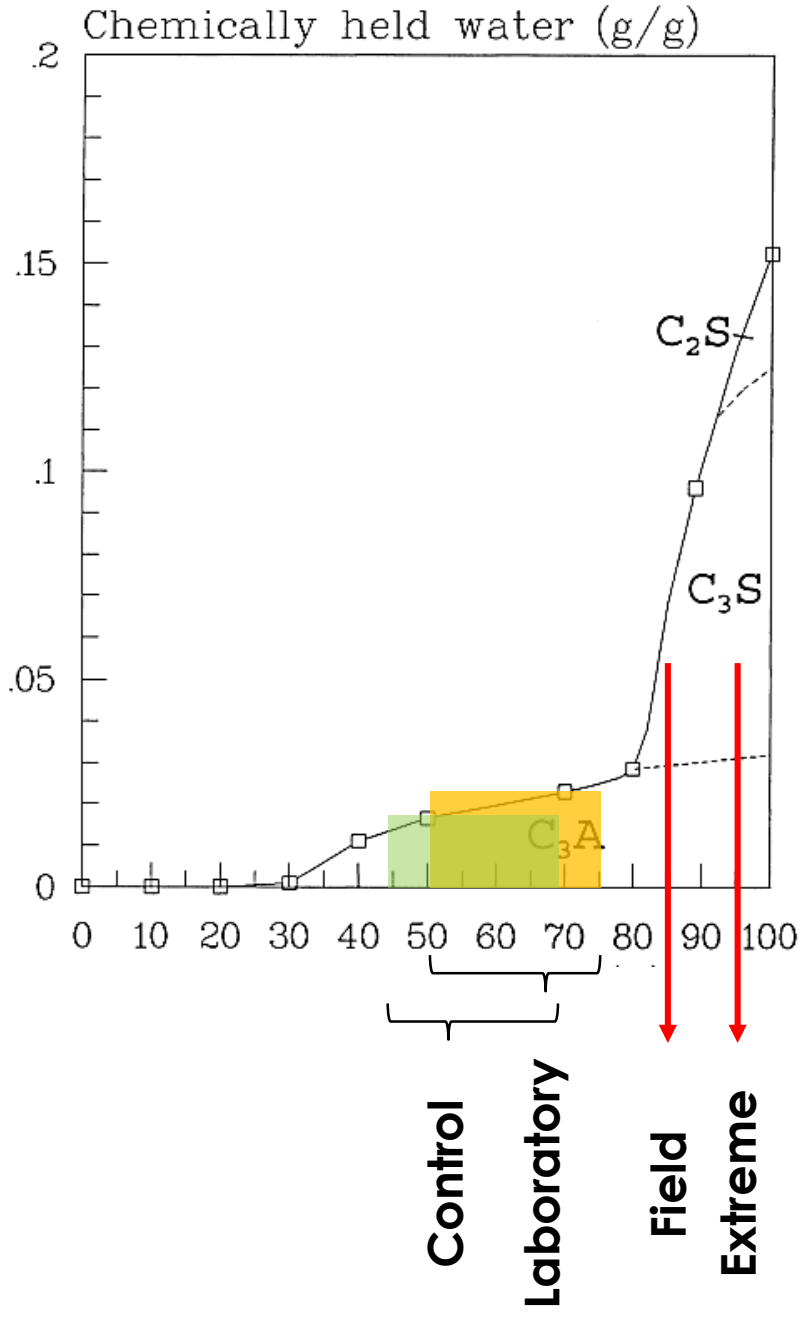
**Control:**
65˚F, 45-60% RH




**Laboratory:**
65˚F, 50-75% RH

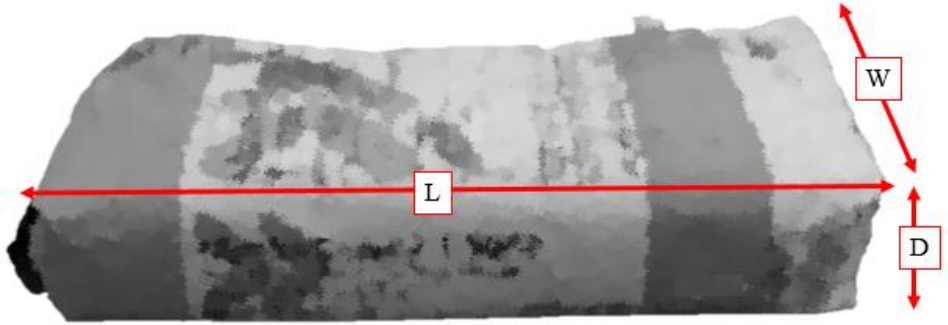
**Field:**
85˚F, ~85 % RH

**Extreme:**
95˚F, ~ 95% RH



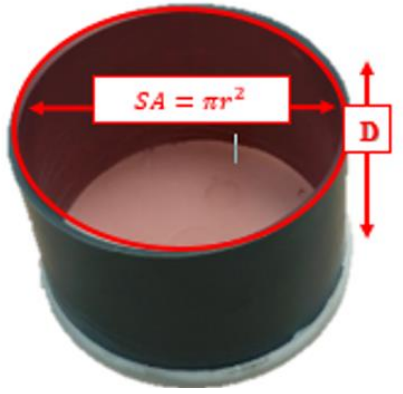
# Exposure Bag vs. Small Scale

## Bagged material




Dimensions:
L: 23.5 in W: 15.75 in D:4in
S/V ratio:0.66 (1/in)

## Small Scale Sample




Dimensions:
D:1.5 in r:1.5 in
S/V ratio:0.66 (1/in)

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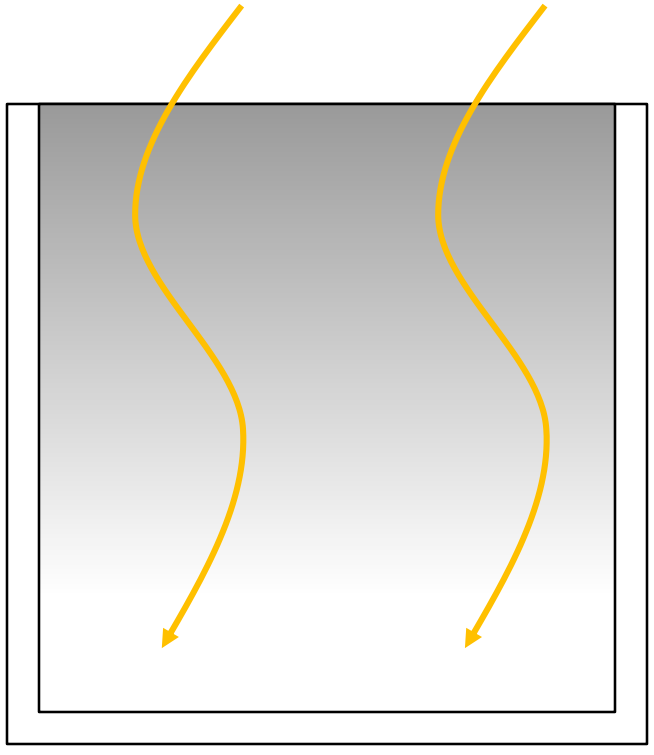
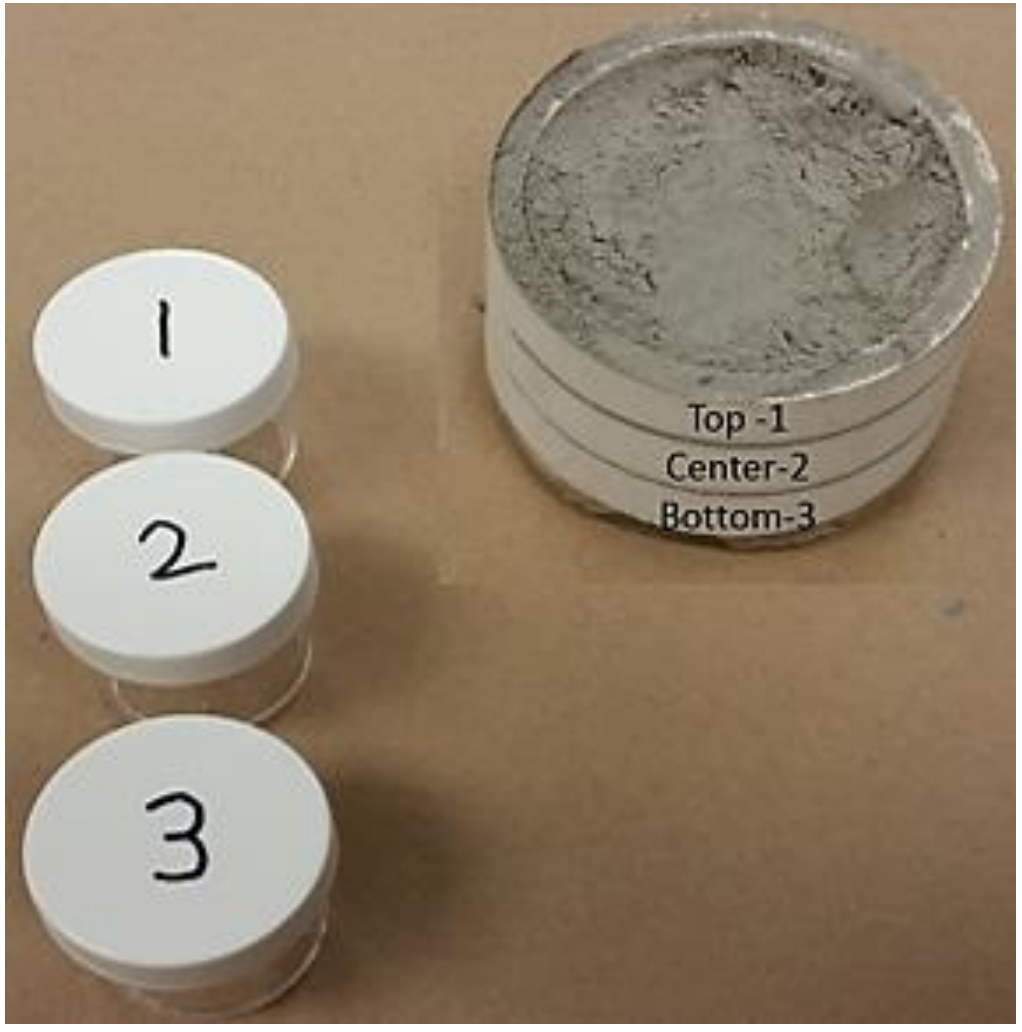
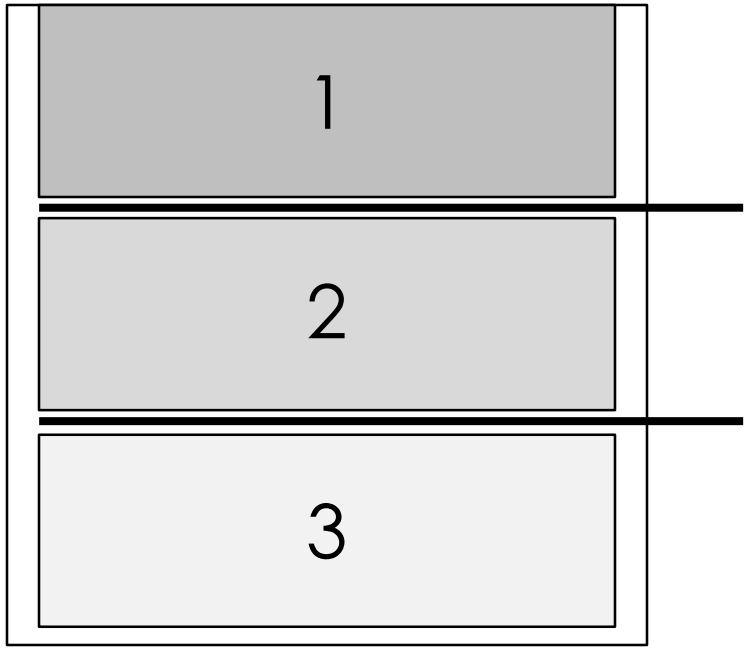
# Moisture penetration

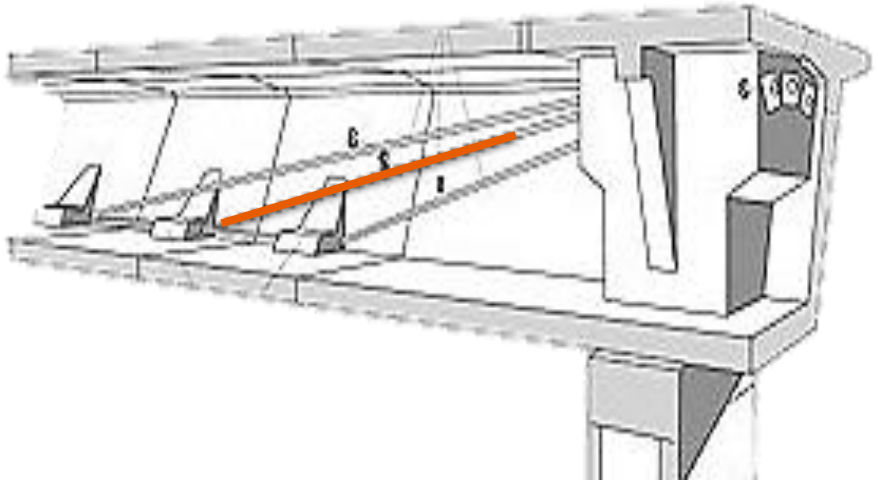


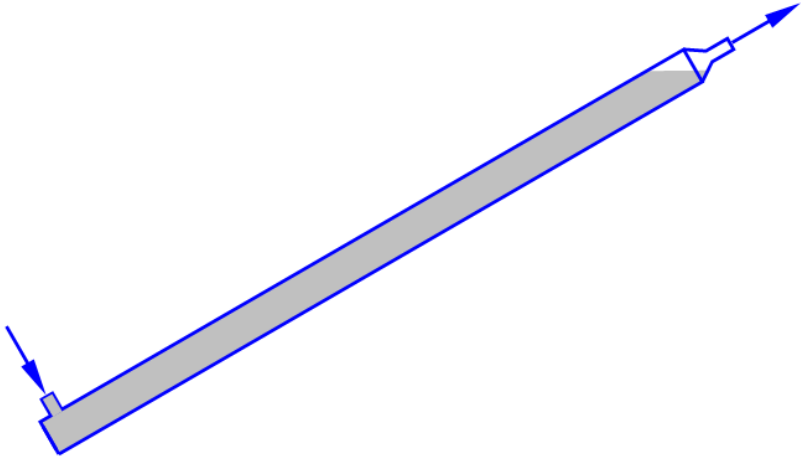


# *Moisture penetration*



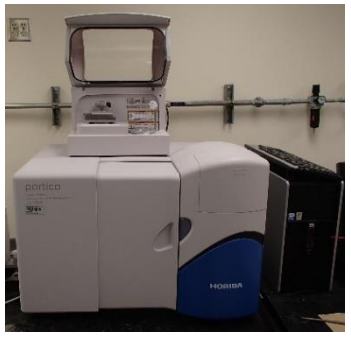

# Testing





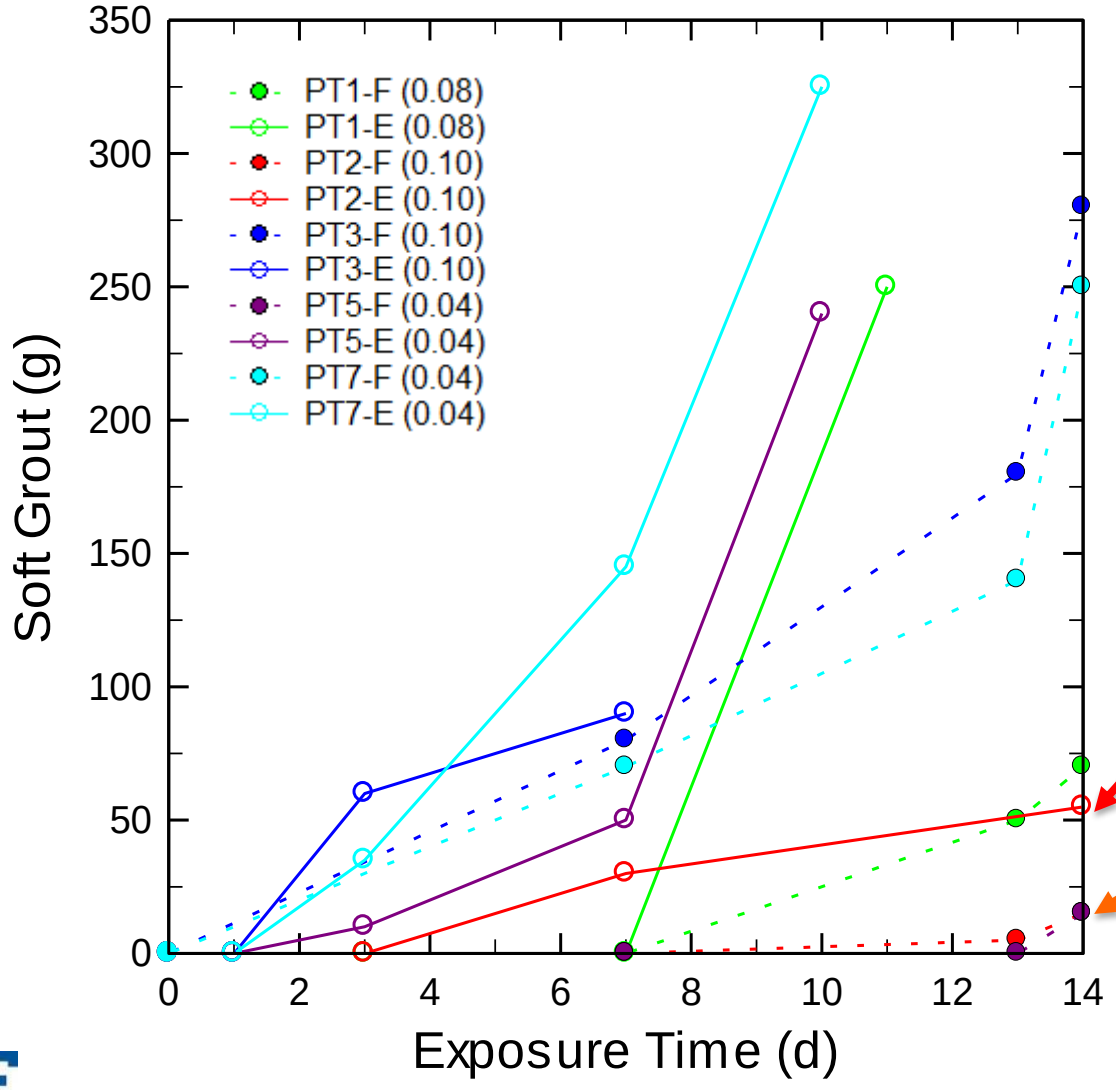
Modified Inclined Tube Test
(soft grout)

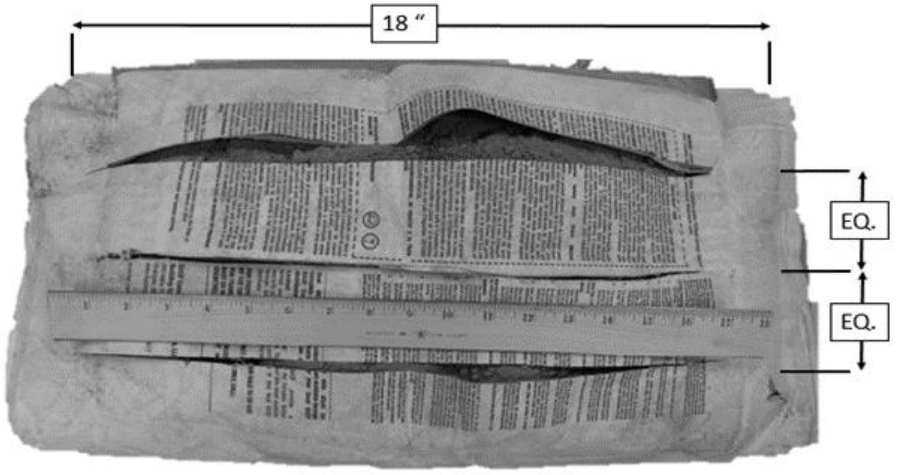
Compare




Moisture
Sensitivity

# Results-soft grout

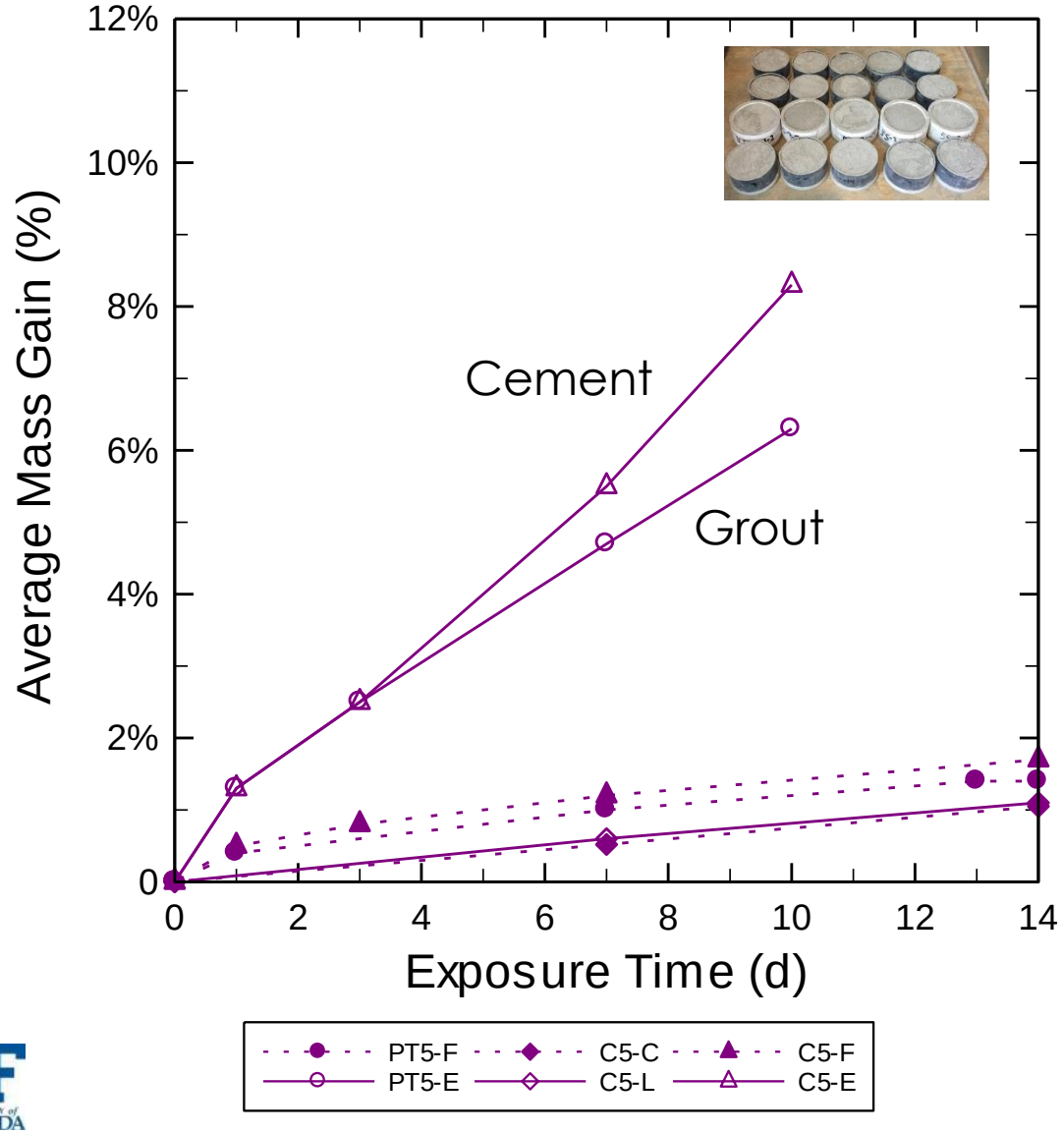


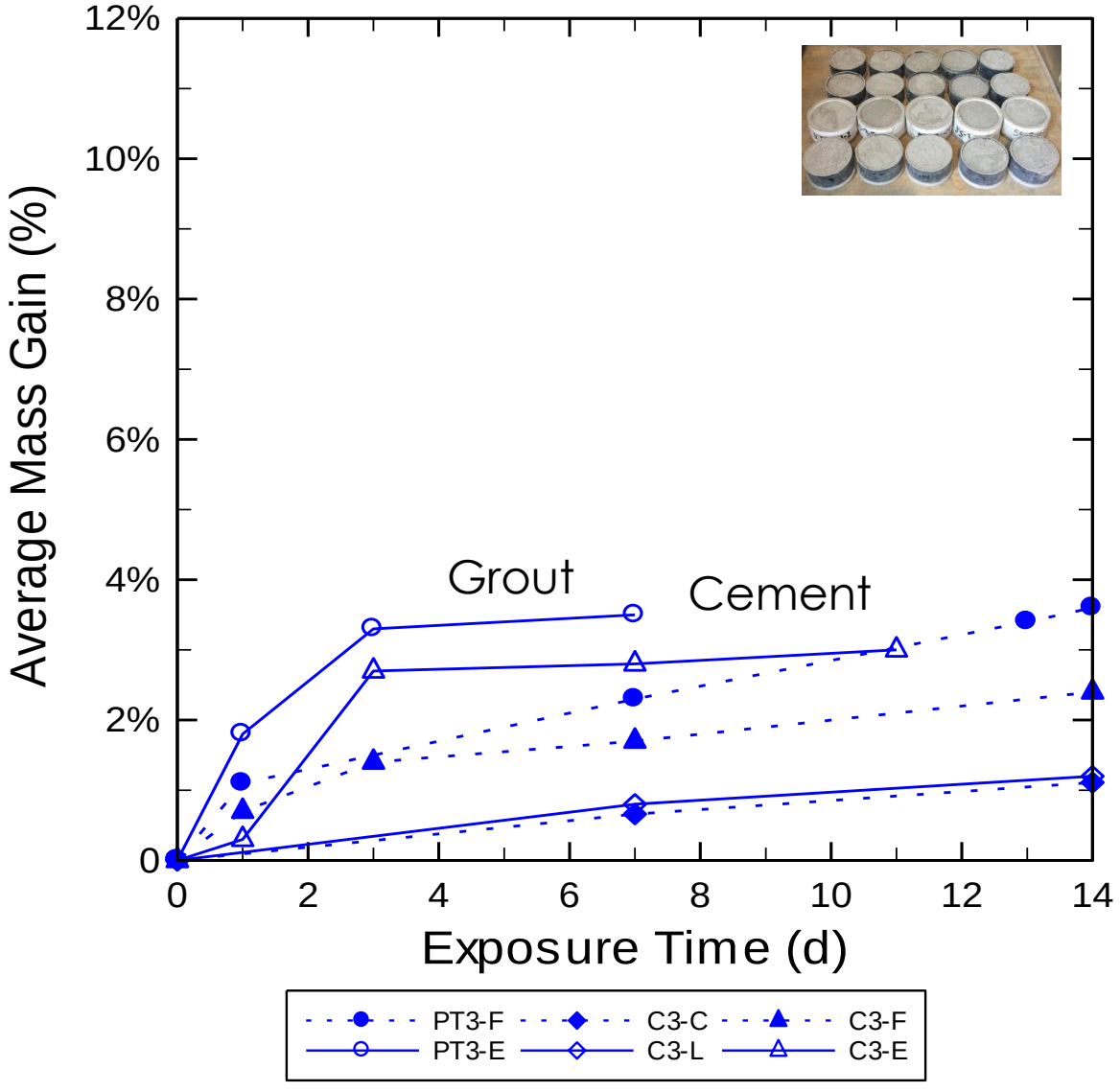




95°F -95 %RH (Extreme)

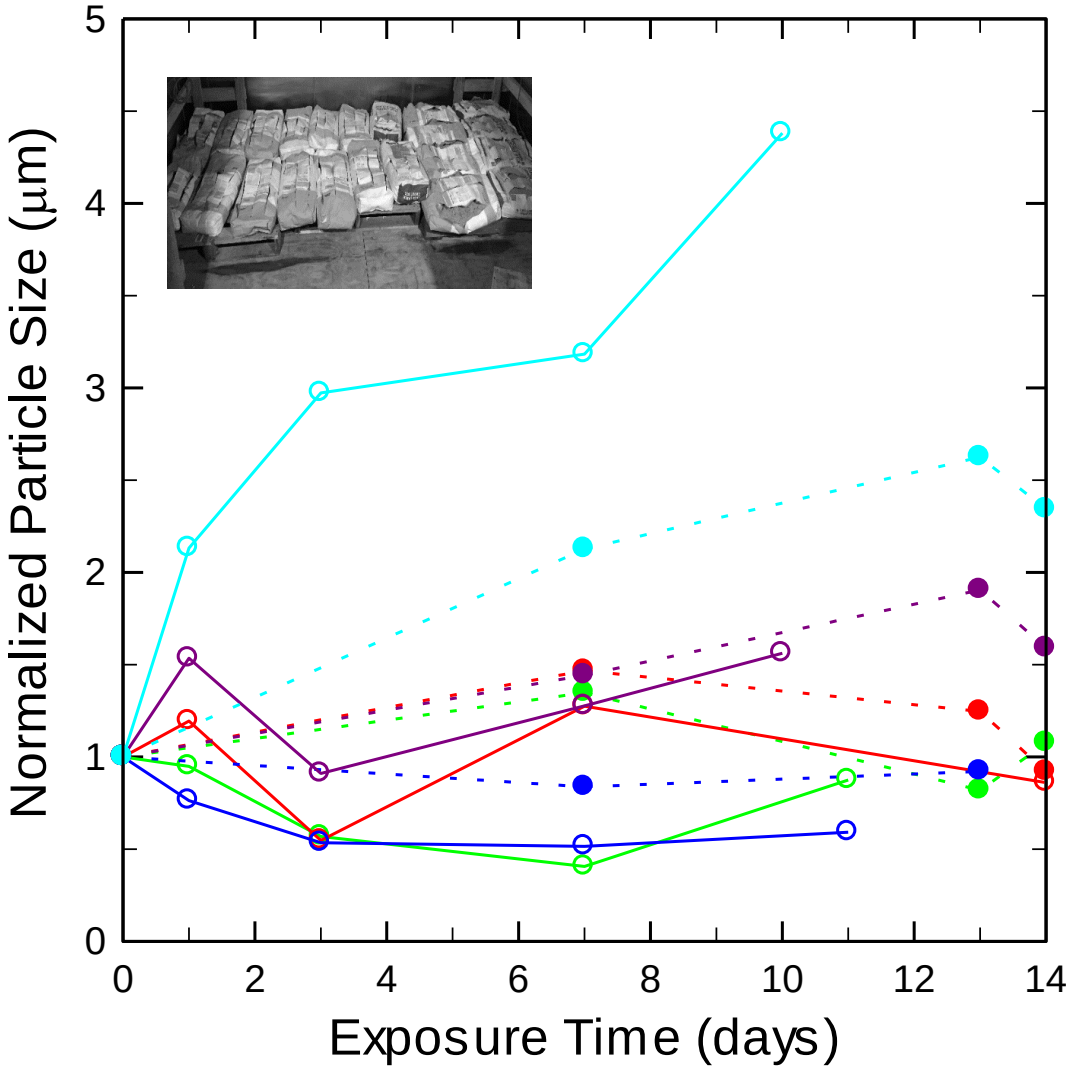
85°F -85 %RH (Field)

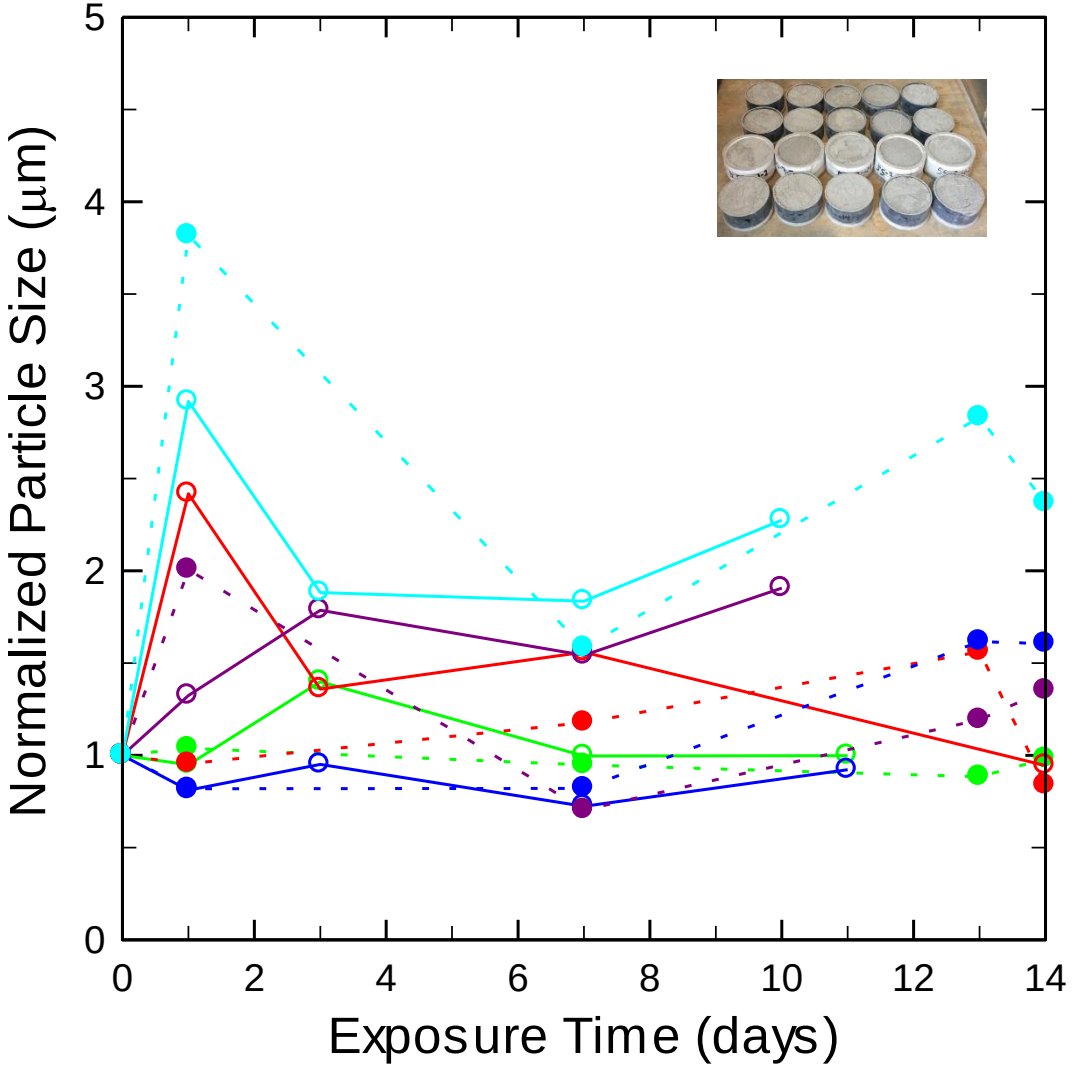
# *Results-is it the portland cement?*



# Particle Size Analyzer (PSA)




PT1-F PT2-F PT3-F PT5-F PT7-F
PT1-E PT2-E PT3-E PT5-E PT7-E

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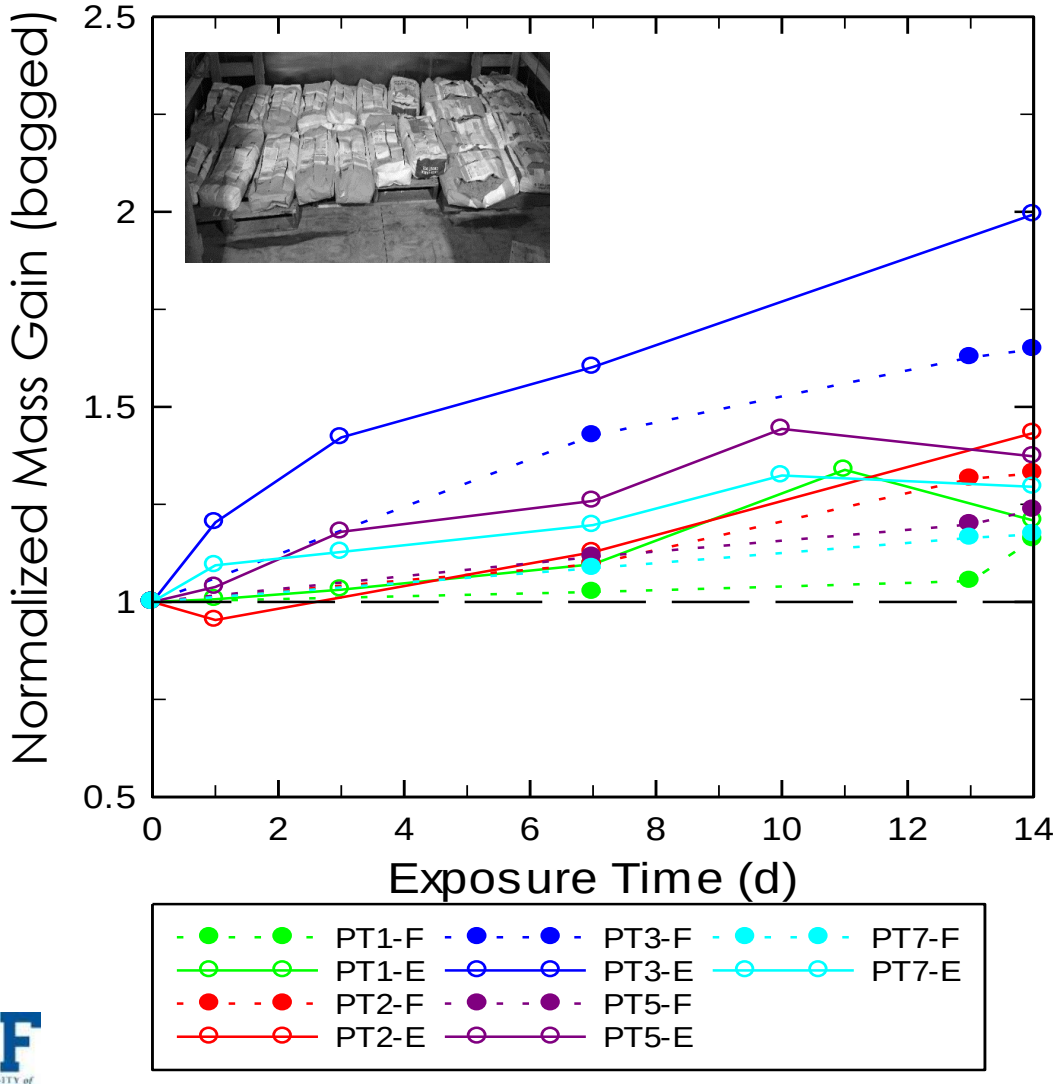
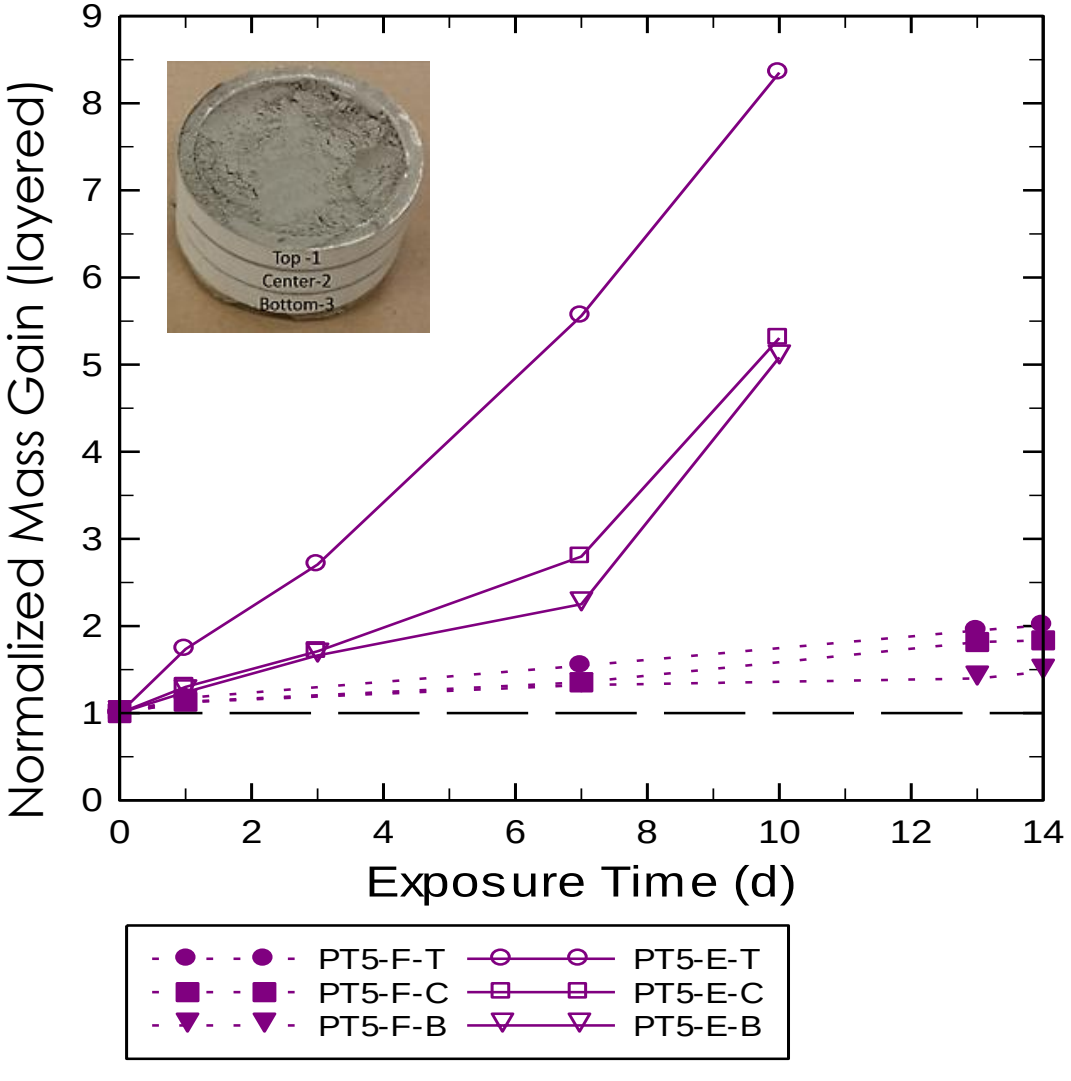
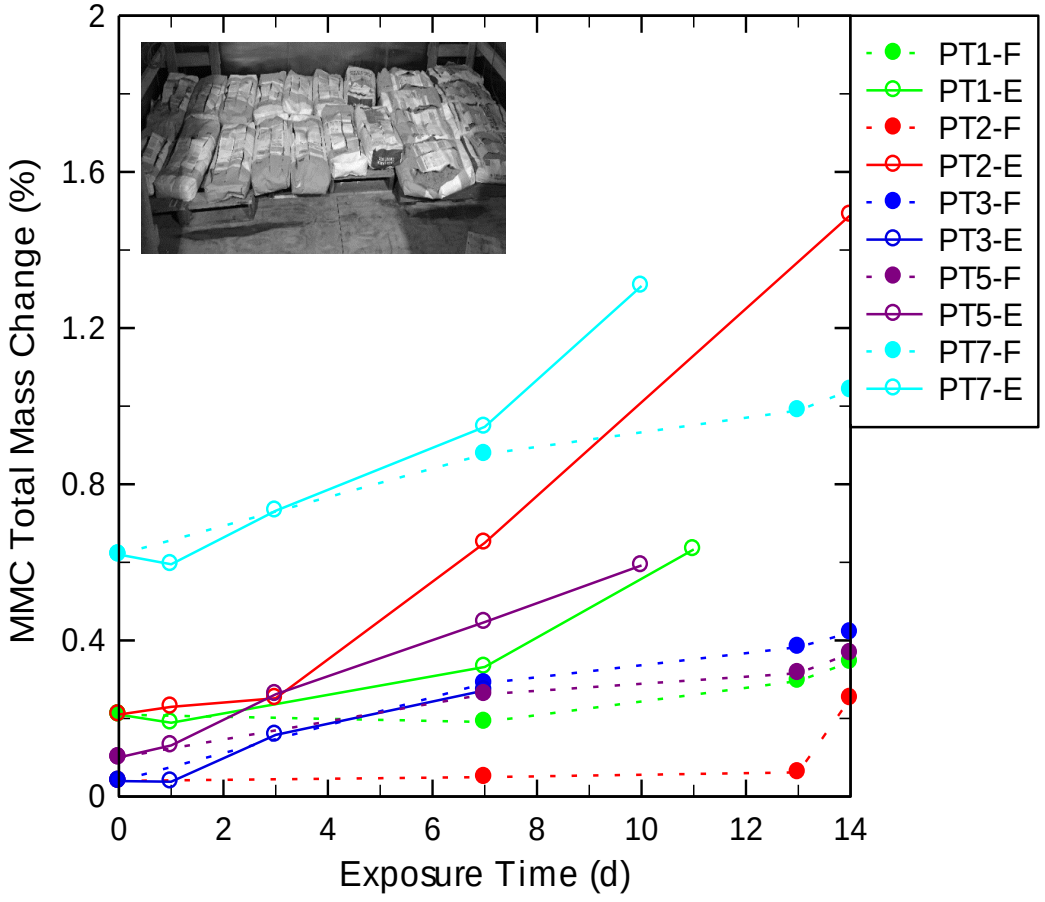
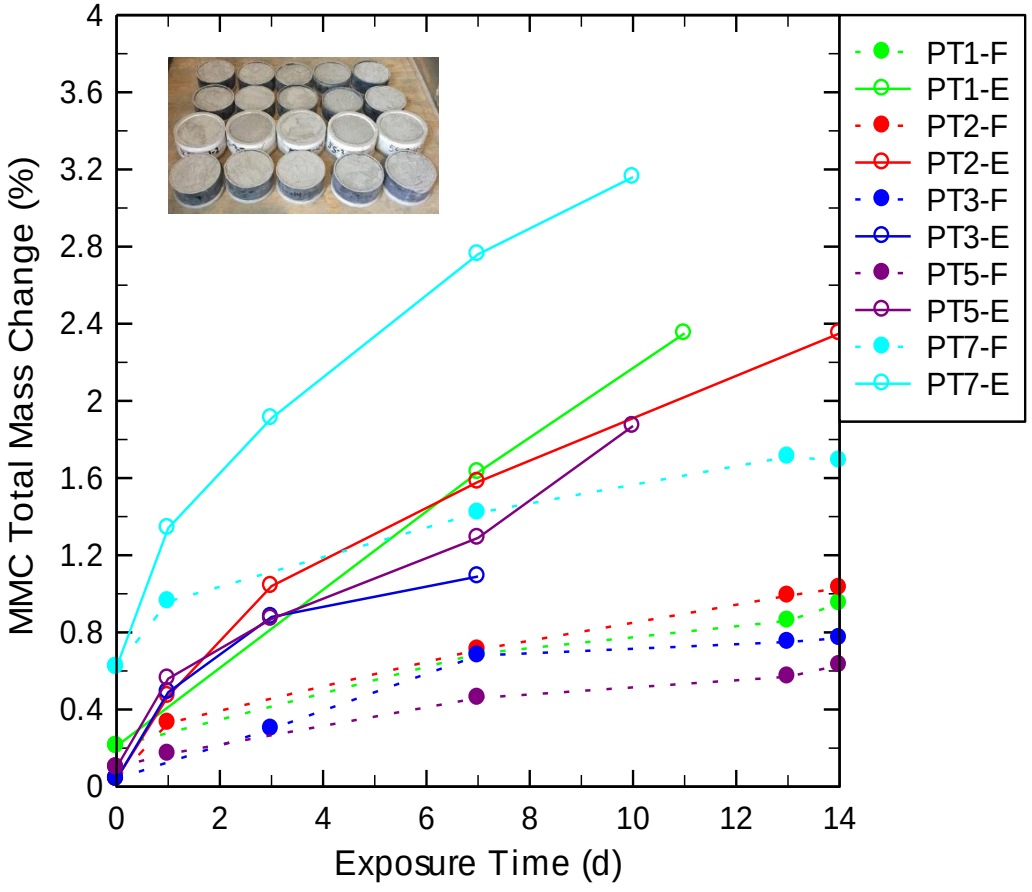
# Loss on Ignition (LOI)



# Microwave Moisture Content (MMC)

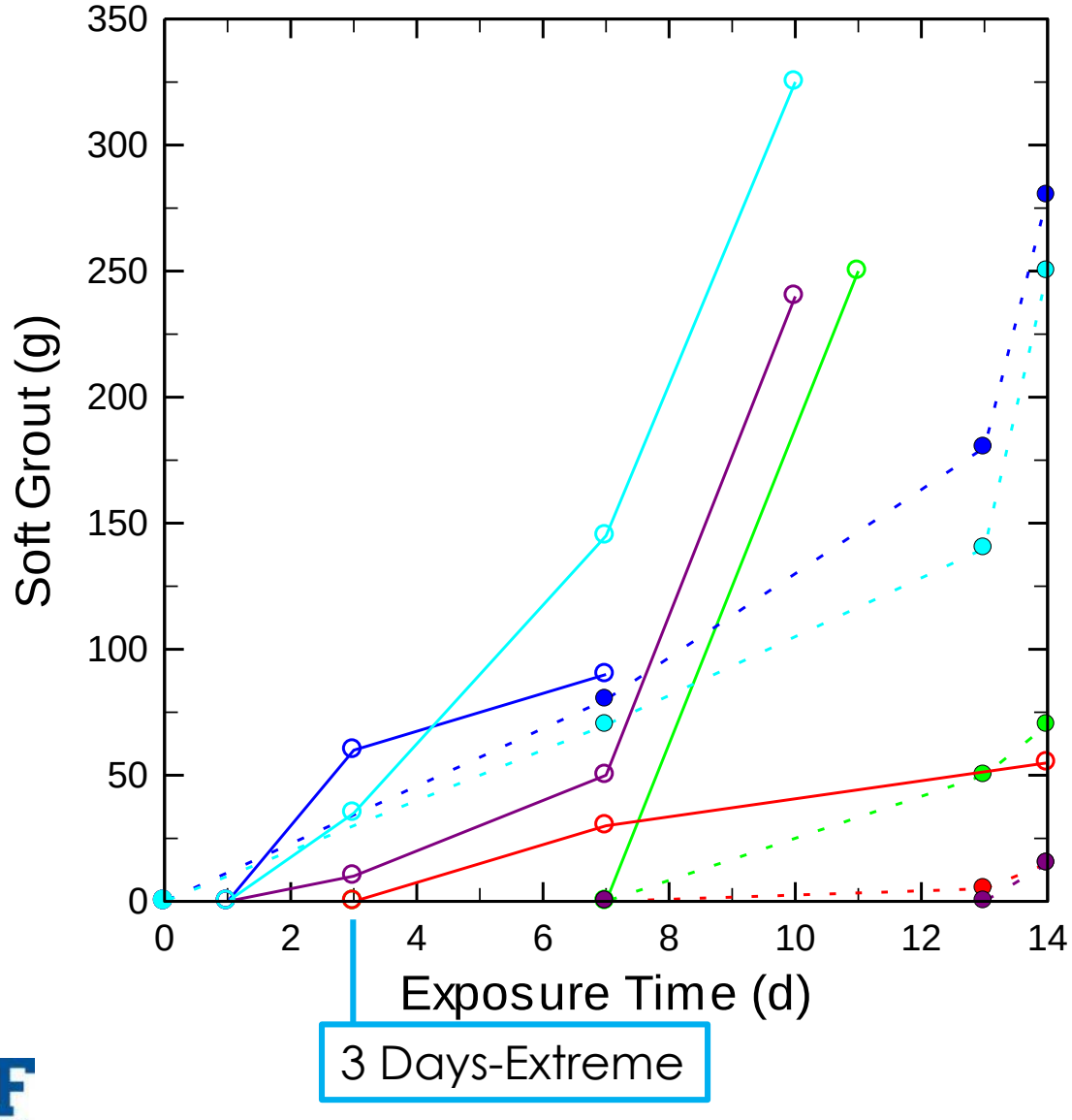


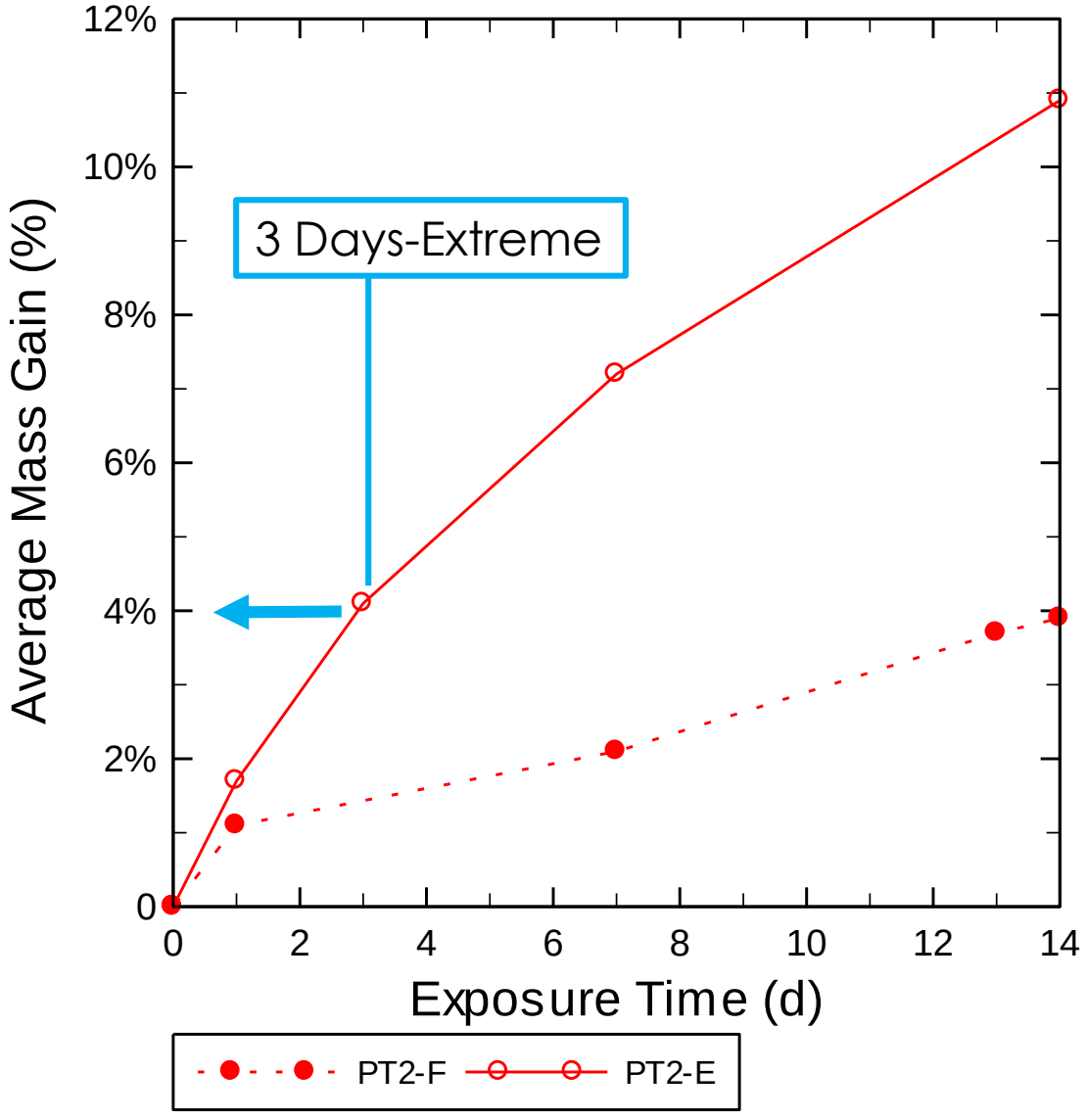



# *Findings*

- High temperature and relative humidity increased the susceptibility of soft grout formation
- Prolonged storage increased soft grout at all storage conditions
- Increase in mass and change in cement particle characteristics agrees well with increases in soft grout

# Looking ahead: Shelf life?



# *Acknowledgements*


**FDOT-SMO**
Mike Bergin
Patrick Carlton
Mark Conley
Dale DeFord
Richard DeLorenzo
Thomas Frank
Shelby Brothers
Charles Ishee
Kingsley Lau
Jordan Nelson
Teresa Risher
Duane Robertson

**UF Students**
Marlo Chumioque
Devon Minich
Kapill Salokhe
Dong Wang
Pablo Soto Lopez
William Broxton
Eugene Peter Cho
Kaimian Yang

**Materials**
Norm Nowosinski, Five Star Products
Fred Goodwin, BASF Construction Chemicals
Jack Torok, Target Products
Bill McCord, Euclid Chemical

**Testing**
Noel Schull, PSI

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