Evaluating the Curing Efficiency of High Early Strength Concrete by Neutron Radiography

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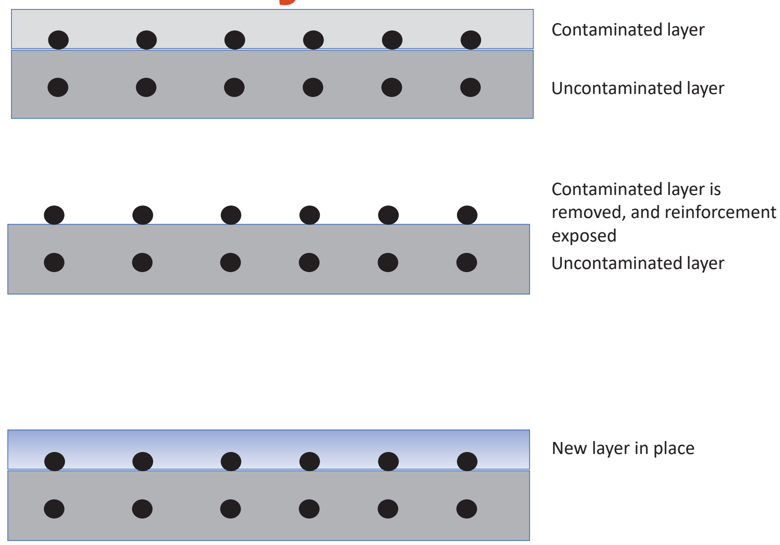
Research Motivation

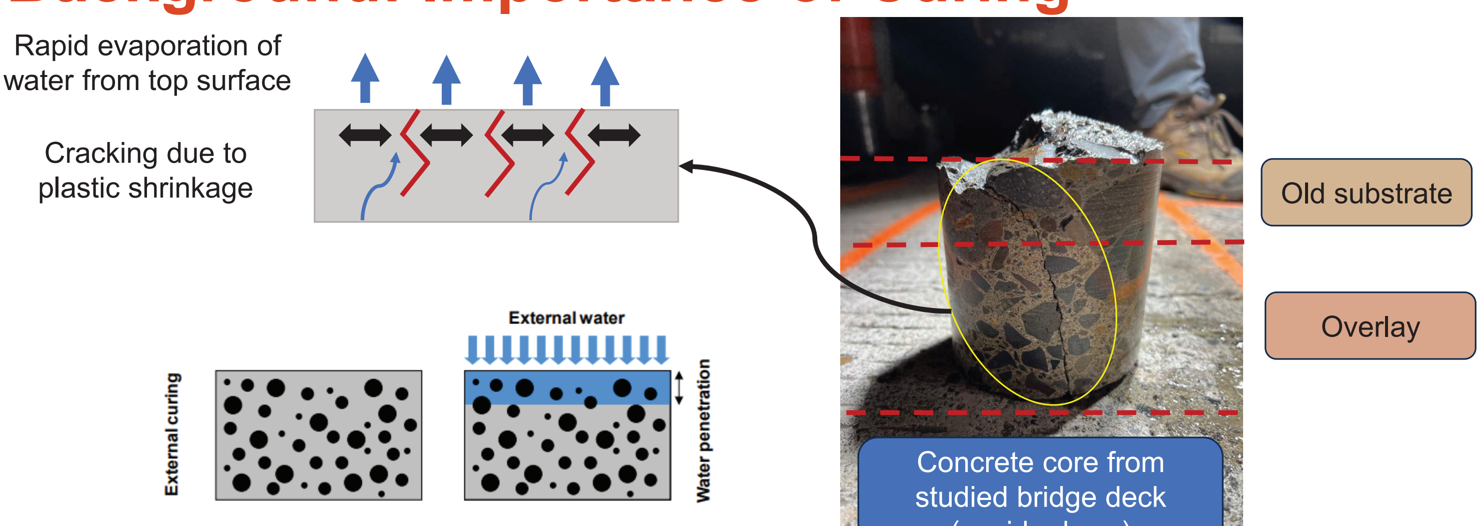
- Interest in using HESC (High Early Strength Concrete) for overnight structural bridge deck overlays
  - minimize the opening time to traffic within 3~6 hours.
- Calcium sulfoaluminate (CSA) based HESC can gain ~20 MPa (3000 psi) in 3 hours.
- Conventional curing practices are based on the performance of Portland cement concrete

Background: Structural Overlay

- Remove 100-150mm of concrete
  - Depth can depend on how far chlorides have penetrated
- Encompassing the reinforcement
- Replace with new material

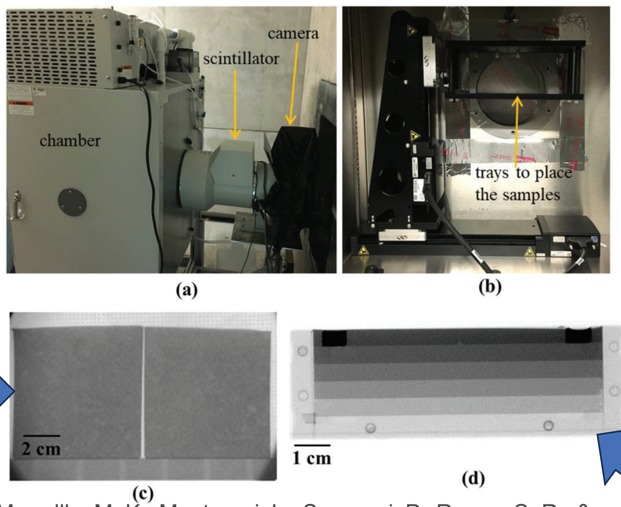


Background: Importance of Curing

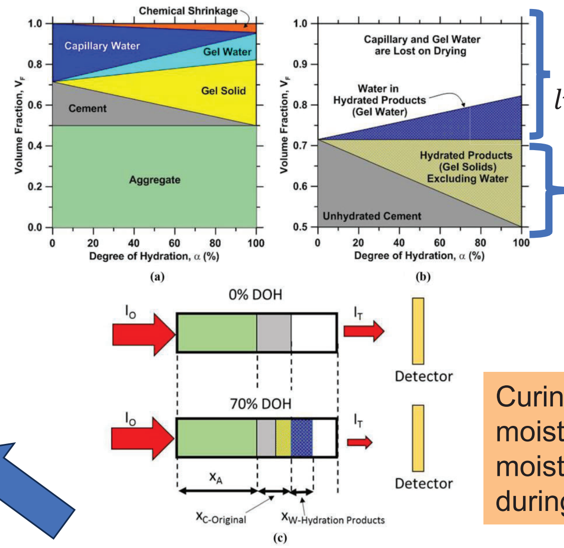


Dale P Bentz & Weiss, 2011

Background: Neutron Radiography



Moradllo, M. K., Montanari, L., Suraneni, P., Reese, S. R., & Weiss, J. (2018).



$$\ln\left(\frac{I_T}{I_O}\right) = -\mu_S x_S$$

Curing efficiency, moisture adsorption, moisture transport during drying process

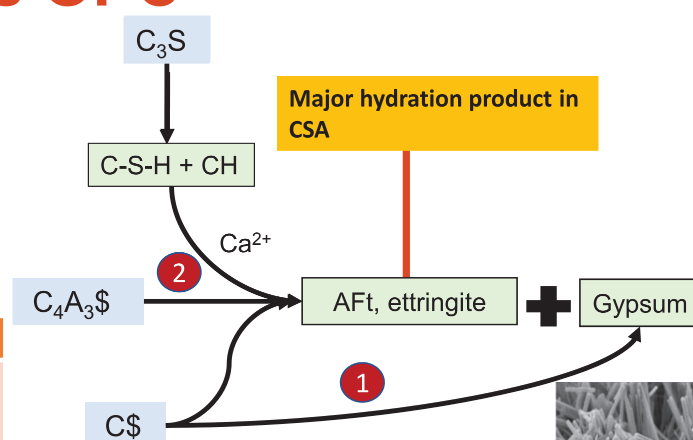
Hydration: CSA versus OPC

C_3S+ water → C-S-H+ CH + heat

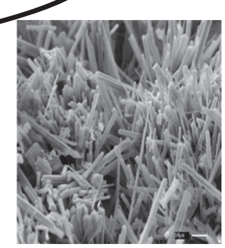
50-60%, 3000 Psi or 20MPa compressive strength can be achieved in between 7~28 days

OPC	CSA
• Maximum 14 calendar days of moist curing (ODOT) • Minimum 7 days (ACI 318)	?

Kim et al. (2012)



~20MPa or 3000 psi in 3~24 hours.



Noor et al. (2023)

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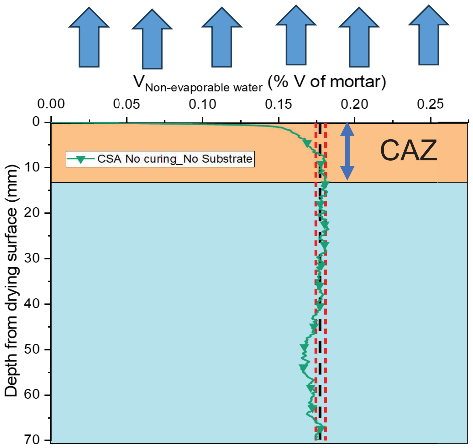
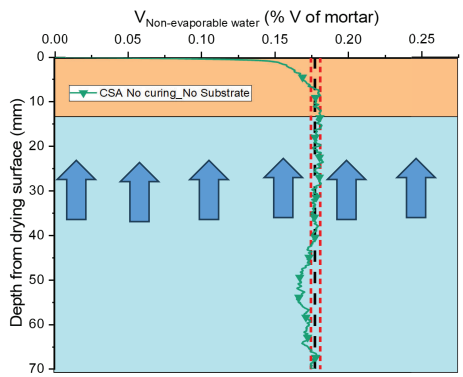
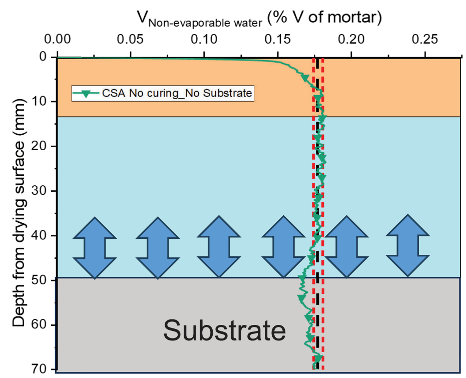
Research Objective



Effect of external curing practices on CAZ (Curing Affected Zone) of HESC



Effect of external curing practices on volume of non-evaporable water



Effect of substrate moisture condition on the volume of non-evaporable water

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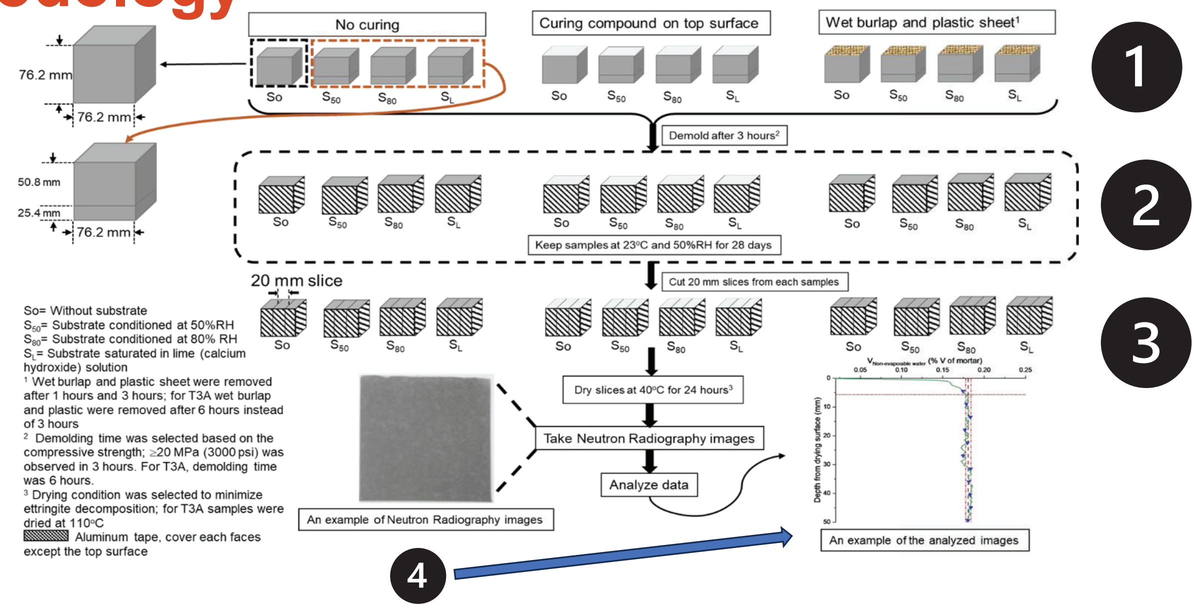
Methodology: Materials

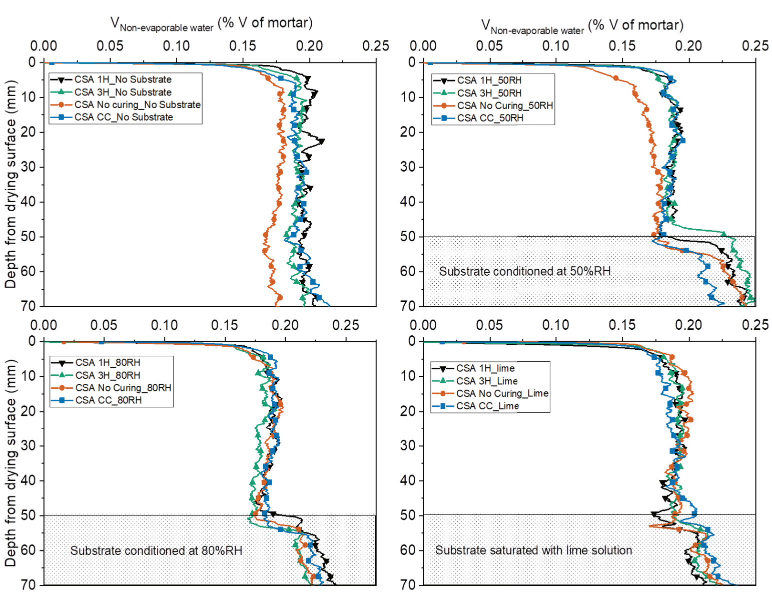
Mixture	w/c	Cement, kg/m³ (v*)	Sand, kg/m³ (v)	Water, kg/m³ (v)	Admixtures[b]		
					Retarder (%)	Superplasticizer (%)	Set accelerating admixture and gypsum
CSA	**0.38**	**664 (0.22)**	**1305 (0.53)**	**252 (0.25)**	**0.20**	**0.40**	**NA**
PrCSA1[a]	0.38	664 (0.22)	1305 (0.53)	252 (0.25)	NA	NA	NA
PrCSA2[a]	0.38	664 (0.22)	1305 (0.53)	252 (0.25)	NA	NA	NA
CSA/PC(80/20)	0.37	664 (0.22)	1326 (0.53)	246 (0.25)	0.20	0.40	NA
T3A	0.35	710 (0.22)	1305 (0.53)	249 (0.25)	NA	0.50	4.00 and 1.00

[a] PrCSA= Commercial proprietary CSA based Cement with polymer modifiers
[b] Based on cement weight; Citric acid was used as a retarder and a high range water reducing admixture was used as superplasticizer
*Volume proportion
NA= Not Applicable

Methodology



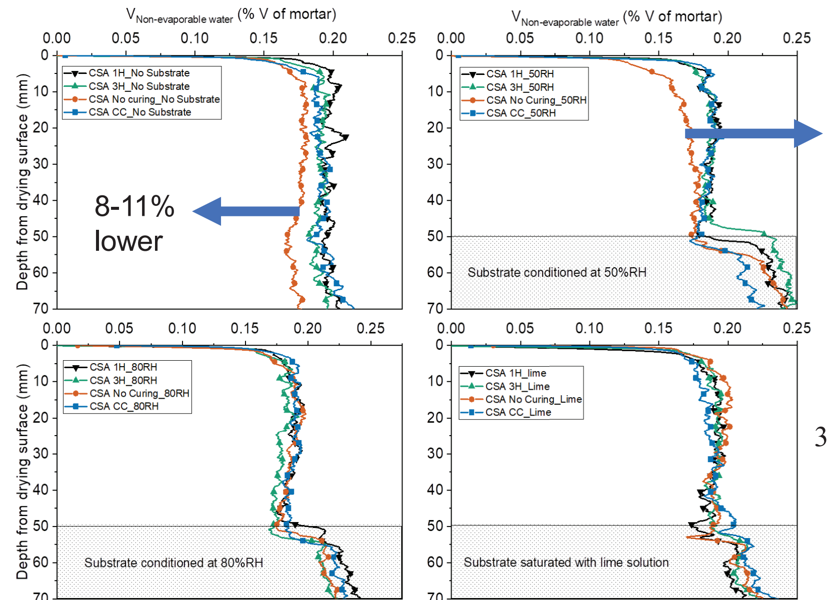
Determination of non-evaporable water



- $$V_{non-evaporable\ water} = -\left[\frac{1}{\mu_w}\right]\left[\frac{\ln\frac{I_o}{I_T}}{\chi_s} - \mu_a V_a - \mu_c V_c\right]$$
- Here, $V_{non-evaporable\ water}$ is the volume of non-evaporable water at different depth of the specimen.
- μ_w = attenuation co-efficient of water.
- Io= intensity of the original beam
- μa = attenuation coefficient of the fine aggregate
- Va= volume fraction of fine aggregate,
- μc = attenuation coefficient of the cement.
- Vc= volume of the unhydrated cement

Determination of non-evaporable water

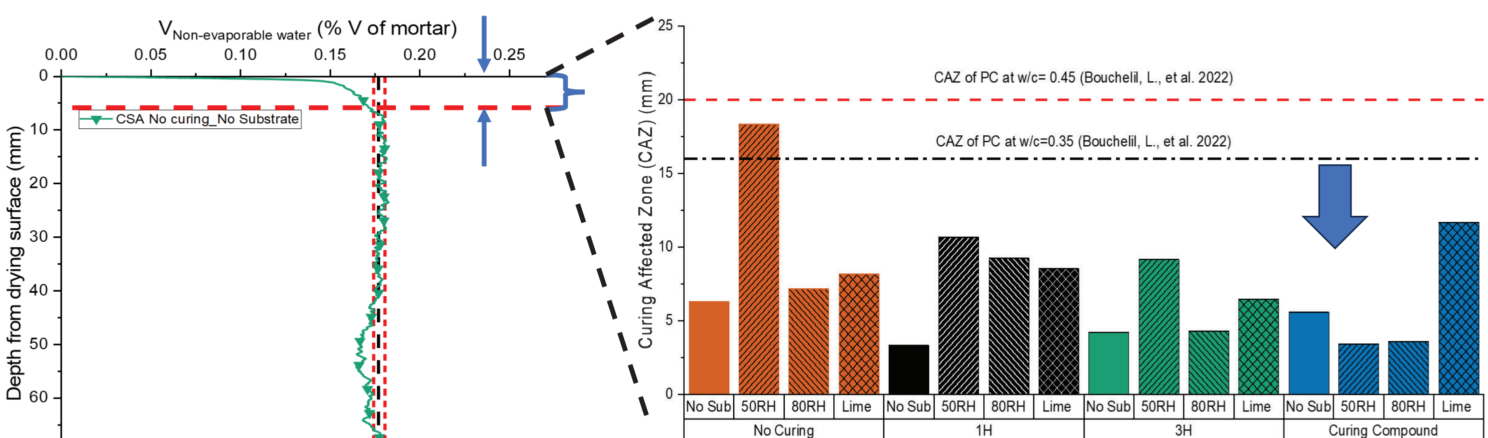
No significant deviation



12% lower

3-6% higher

Determination of CAZ (Curing Affected Zone)



Results: Summary

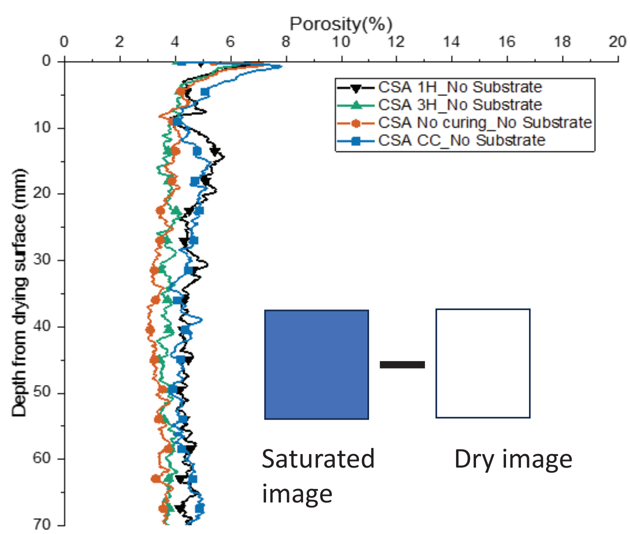
- CSA showed lower CAZ compared to OPC for the investigated external curing practices
- Effect of external curing practices and substarte on the non-evaporable water
  - No substrate- 1 hour curing with wet burlap and plastic sheet
  - 50%RH- 1 hour curing with wet burlap and plastic sheet
  - 80%RH- No curing, 1 hour curing with wet burlap and plastic sheet, or curing compound
  - Lime- Curing compound> 1hour or 3 hour curing with wet burlap and plastic sheet

Ongoing Research

- Effect of external curing practices on porosity of HESC

$$Porosity\ (\%) = \frac{\left[\frac{\ln \frac{I_{OD}}{I_{Sat}}}{\mu_w}\right]}{t} \times 100$$

Porosity is (low/very low) compared to OPC systems hydrated at sealed condition for 28 days with 0.37 w/cm (Rößler, 1985)



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Thank You!

Stay connected

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