MATERIALS ENGINEERING SEMINAR

"Implementation of Superabsorbent Polymers for Internally Cured Concrete"

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Purdue MSE Ph.D. Final Exam

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ABSTRACT

Hydrated portland cement provides the solid adhesive matrix necessary to bind aggregate (sand and gravel) into concrete. The hydration reaction requires water, however the products of the reaction limit further diffusion of water to unreacted cement. Superabsorbent polymer (SAP) hydrogel particles absorb mixing water, then subsequently desorb when the relative humidity drops, serving as internal water reservoirs within the cement matrix to shorten diffusion distances and promote the hydration reaction in a process called internal curing. Internally cured cementitious mixtures exhibit an increased degree of hydration and reduced shrinkage and cracking, which can increase concrete service life. Increased service life can, in turn, reduce overall demand for portland cement production, thereby lowering CO_2 emissions.

Practical implementation questions key to the translation of SAP hydrogel internal curing technology to from the benchtop to the field in transportation applications, including (1) What effects do mix design adjustments made to increase mixture flow when using SAP have on cementitious mixture properties? and (2) What effect does cement chemistry have on SAP performance?

The addition of SAP to a cementitious mixture changes the mixture's flow behavior. Flow behavior is an important aspect of concrete workability and sufficient flow is necessary to place well consolidated and molded samples. Often, additional water is added to mixtures using SAP to account for the absorbed water, however cementitious mixture workability is often tuned using high range water reducing admixtures (e.g., polycarboxylate ester-based dispersants). Fresh and hardened properties of mortars were characterized with respect to flow modification method (using the mortar flow table test; compressive strength at 3, 7, and 28 days; flexural strength at 7 and 28 days; and microstructural characterization of 28-day mortars). At typical doses, it was found that the addition of extra water lowers the resulting compressive and flexural strength, while high range water reducing admixtures administered at doses to achieve sufficient mortar flow did not compromise compressive or flexural strength.

The SAPs used in cement are generally poly(acrylamide-acrylic acid) hydrogels and are not chemically inert in high ionic-load environments, such as cement mixtures. The behavior of an industrial SAP formulation with characterized across five different cement binder compositions with respect the cement hydration reaction (using isothermal calorimetry, thermogravimetric analysis of hydration product fraction, and scanning electron microscopy (SEM)/energy dispersive x-ray spectroscopy (EDS) microstructural analysis), the absorption behavior of the SAP, and the fresh and hardened properties of SAP-cement composites (mortar flow and compressive and flexural strength). The change in properties induced by the addition of SAP was similar across ASTM Type I cements from three manufacturing sources, suggesting that SAP internal curing can be implemented predictably over time and geography. Excitingly, in analysis of cement systems meeting different ASTM standards (Type III and Type I with 30% replacement by mass with ground blast furnace slag), synergistic and mitigating reaction behaviors were observed, respectively, in Type III and slag cement, suggesting that further study of SAP with these cement systems could be of particular interest.

Date: Tuesday, April 11, 2023
Time: 2:30 P.M.
Place: ME 3006 or Zoom Meeting Link: https://purdue-edu.zoom.us/j/98876272332?pwd=WEVwMHhEcTA4UU1zRmZKZEd2OWl0UT09

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