Concrete Sustainability Hub@MIT Research Profile Letter – February 2013

Nucleation Seeding of Alkali Activated Paste

Problem

Understanding the mechanisms that control the rate of cement hydration and development of the nanoscale structure play an important role in improving the long term properties of concrete and reducing its environmental impacts. One approach is to discover the importance of nucleation seeding on the hydration process, which can be extended to supplementary cementitious materials. The rate of hydration reaction is a function of dissolution, diffusion, nucleation and growth. The mechanisms that control the hydration kinetics of alkali activated pastes and accelerate this process are the subject of this investigation.

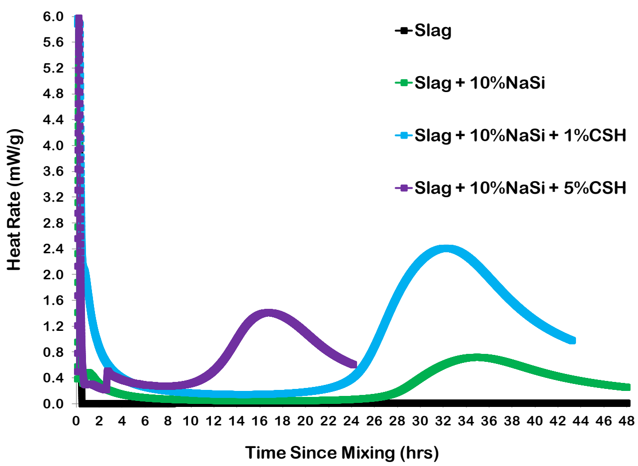

Figure: Rate of heat evolution at 20˚C of slag pastes activated with 10% sodium metasilicate, and 1% and 5% by mass C-S-H seed. All pastes are made with w/s = 0.40.

Approach

The addition of calcium silicate hydrate (C–S–H) to alkali activated slag (AAS) pastes increases the hydration rate peak, shortens the long dormant period prior to the main hydration peak, and results in higher compressive strengths. The C–S–H seed, prepared in the lab by combining separate solutions of sodium metasilicate ($Na_2SiO_3 \cdot 5H_2O$) and calcium nitrate ($Ca(NO_3) \cdot 4H_2O$), is added to slag mixes. The alkali activator used is solid sodium metasilicate ($Na_2SiO_3 \cdot 5H_2O$), added in amounts ranging between 0-10% of the dry mix. Isothermal calorimetry is used to study the early hydration kinetics of slag pastes. Compressive strength tests are performed on compression cylinders, subjected to different curing conditions.

Findings

The paste without seed or activator (i.e. only slag and water) results in a very low heat output. Addition of 10% sodium metasilicate activator in the absence of seed produces a well-defined hydration peak after a lengthy induction period of around 25 hours. Since the addition of seed in the absence of activator has little effect, studies focus on the use of seed with 10% activator. Seeding provides nucleation sites for the growth of the hydration product, leading to a significant reduction in the induction period and an increase in the height of the hydration peak. Increasing the amount of C-S-H seed from 1% to 5% at a fixed activator concentration of 10% produces a hydration rate peak at a much earlier stage. In addition to AAS, current work also focuses on the activation of fly ash, where the small calcium content required for alkali activation is compensated by the addition of Portland cement or $Ca(OH)_2$. A very high heat output is produced by fly ash mixes in the presence of activator if sufficient calcium ions are provided to react with silica for the further formation of C-S-H, which then seeds the hydration process.

More

Research presented by Dr Cise Unluer, postdoc in the CSHub, in collaboration with Prof. H. Jennings.

Impact

This study examines the rate controlling step that leads to a better understanding of how to use supplementary cementitious materials such as slag and fly ash to produce more sustainable mixes.

CSH concrete sustainability hub

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