Advanced characterization of cement-based materials

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Workshop

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Summary: Most concretes today are engineered by using supplementary cementitious materials for controlling the strength and overall durability of concretes. The inclusion of micro/nano additives leads to a complex microstructure during the early stage of cement hydration which require careful monitoring to understand the role of these additives during the hydration process. The multifarious and disordered nature of cement paste spans orders of magnitude from nanometers to millimeters. Advanced micro/nano characterization is required to decipher the microstructural evolution of cement paste which ranges from angstrom to micron level length scales.

Advanced instrumental methods using synchrotron and neutron-based experimental techniques are useful to characterize cement-based materials with nano and micro additives. These beamline techniques are more popular and widely used by the biological and materials community, whereas, only limited exposure to these methods is occurring among the cement and concrete research community. Spallation sources and high-flux isotope reactors are used to produce a high-intensity neutron beam that can decipher multi-scale morphology when the cement paste hydrates. State of the art neutron and x-ray facilities are able to provide more intense and brighter sources of neutrons and x-rays that allow measurements of greater sensitivity, higher speed, and better resolution. Use of these techniques enables examination of the hydration dynamics and kinetics at various time-scales, simultaneously revealing the resulting microstructure of soft and hard matter.
This workshop covers the applications of neutron and x-ray based techniques to decipher the multi-scale morphology of cement paste with natural and synthetic additives. Advanced techniques such as small angle x-ray/neutron scattering, wide angle x-ray scattering (WAXS), quasielastic neutron scattering (QENS), inelastic neutron scattering (INS), and x-ray/neutron pair distribution function (PDF), and x-ray micro tomography are used for monitoring structural evolution, water dynamics and internal pore structure of cement-based materials. QENS and INS help in detecting the binding capacity of water and the diffusion coefficients which are detected at faster timescales compared to proton nuclear magnetic resonance (NMR) analysis. The small angle x-ray and neutron scattering technique examines the structural evolution via detecting the fractal morphology and specific surface area of the hydrating cement paste. Whereas WAXS detects the origin of nano-level phases due to pozzolanic reaction during the course of hydration. At an angstrom level, atom-atom correlations of disordered amorphous calcium silicate hydrate products were detected via PDF analysis.

These techniques provide necessary multi-scale insight and support the development of realistic computational models involving crystalline and amorphous hydration products. They also provide necessary critical insights into hydration dynamics along with morphological information as a basis for engineering natural supplementary cementitious materials for use in Portland-cement-based systems.