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Neutron Scattering Studies of Cement

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Despite more than a century of research, basic questions remain regarding both the internal structure and the role of water in Ordinary Portland cement (OPC) concrete, the world's most widely used manufactured material. Most such questions concern the primary hydration product and strength-building phase of OPC paste, the calcium silicate hydrate (C-S-H) gel. When cement and water are mixed, this phase precipitates as clusters of nanoscale (nearly amorphous) colloidal particles with an associated water-filled inter-particle pore system. Most attempts to characterize the C-S-H gel and the behavior of the associated water involve drying or other processes that, themselves, change the bound water content within and around the gel. Neutron scattering methods do not suffer from this disadvantage. Furthermore, the neutron isotope effect and the neutron's sensitivity to molecular motion have enabled considerable progress to be made in recent years by: (i) determining the C-S-H composition, density and gel structure in small-angle neutron scattering (SANS) H/D contrast variation studies; (ii) elucidating the changing state of water within cement as hydration progresses using quasielastic neutron scattering (QENS); and (iii) measuring the production and consumption of nanoscale calcium hydroxide (CH), a by-product of cement hydration that co-exists with the C-S-H gel, using inelastic neutron scattering (INS). These experiments have provided new insights into the physics and chemistry of cement hydration, and have implications for the design of new concretes with pozzolanic cement additions that are intended to address environmental concerns and sustainability issues.