Effects of Sulfate Attack on Local Atomic Structure of Alkali-Activated Slag Cement

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Concrete accounts for up to 8% of worldwide CO_2 emissions. Alkali-activated cement (AAC) is an environmentally sustainable alternative to ordinary Portland cement (OPC) and can reduce OPC CO_2 emissions by up to 97%. Concrete structures are exposed to sulfate attacks in seawater, soil, and sewage. Sodium hydroxide (NaOH) is commonly used to make AAC. This study examines the effects of sodium sulfate (Na_2SO_4) and magnesium sulfate ($MgSO_4$) on the atomic structure of NaOH-activated slag cement. This is the first study to investigate the changes to cement caused by sulfate attack on the nanoscale and the first study to use varying sulfate concentrations. AAC samples were divided into three groups and eight subgroups: control (dry, wet), Na_2SO_4 immersion (1%, 5%, 10% wt concentrations) and $MgSO_4$ immersion (1%, 5%, 10% wt concentrations). Samples were tested in a beamline at the Advanced Photon Source particle accelerator at Argonne National Laboratory. Each subgroup had 6,000 data points for a total of 48,000 observations. X-Ray pair distribution functions (PDF), involving a Fourier transform of the scattering data, enable nanoscale analysis of disordered materials such as cement. An original software application was created to perform the PDF analysis. Na_2SO_4 had an insignificant effect on the atomic structure of AAC. 1% $MgSO_4$ had a small effect, while both 5% and 10% had moderate but similar effects. Increasing concentrations of $MgSO_4$ resulted in increasing degree of polymerization. NaOH-activated slag cement would be suitable for use in environments containing Na_2SO_4. AAC is more resistant to Na_2SO_4 attack than OPC.