Thermal Degradation and Microstructural Evolution of Crystalline Admixtures and Supplementary Cementitious Materials under Elevated Temperatures

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Abstract

The thermal stability of cementitious materials is fundamental to fire safety, post-fire structural integrity, and the long-term sustainability of the built environment. This study investigates the thermal stability and microstructural evolution of Ordinary Portland Cement (CEM II), Ground Granulated Blast Furnace Slag (GGBS), nano-silica and four crystalline admixtures used in Self-healing concrete production. Fourier Transform Infrared Spectroscopy (FTIR), Thermogravimetric Analysis (TGA), furnace exposure tests and Scanning Electron Microscopy (SEM) were conducted at temperatures ranging from 100°C and 1000°C at an interval of 100°C to assess mass loss, functional group evolution and residual microstructural integrity. Results show that cement, GGBS, and nano-silica exhibit minimal mass loss and maintain matrix integrity across the investigated temperatures, indicating high thermal stability. SEM observations confirm limited microstructural degradation and preservation of hydration products. In contrast, crystalline admixtures demonstrate formulation-dependent thermal behaviour. One formulation retained higher residual mass and showed delayed microstructural deterioration, while the remaining three displayed earlier decomposition and progressive structural damage with increasing temperature. Overall, the findings highlight significant differences in thermal resistance among SCMs, nanomaterials and crystalline admixtures. The incorporation of SCMs and nano-silica may improve high-temperature performance, while crystalline admixture performance is highly dependent on formulation. The study provides insights into material selection for thermally resilient and potentially self-healing cementitious systems and highlights the need for further investigation into long-term thermal stability mechanisms. This study provides material-level understanding critical for developing thermally resilient, self-healing cementitious systems, directly supporting the design of durable, fire-safe, and sustainable construction materials for resilient infrastructure.

Keywords: high-temperature exposure; crystalline admixture; supplementary cementitious materials (SCMS); thermal stability; Fire tests