High-temperature resistance of $CaO-FeO_x-Al_2O_3-SiO_2$ alkali-activated materials

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Abstract

Alkali-activated materials (AAMs) are emerging in the construction sector by providing an opportunity to up-cycle several wastes in the production of highly performant and added-value materials for technical applications. One of the most attractive properties of AAMs is their performance under considerable thermal loads. Being generally praised for their refractory and high-temperature resistant features, the thermal behavior of AAMs is dictated by their chemical composition, phase assemblage, and crystallized phases upon exposure to high temperatures. Hence, the thermal performance of AAMs produced from $CaO-FeO_x-Al_2O_3-SiO_2$-rich residues may significantly differ from the most commonly described $(Na_2O/K_2O)-Al_2O_3-SiO_2$ ternary systems. Therefore, the purpose of this research was to ascertain the resistance to high temperatures of CaO-FeOx-$Al_2O_3-SiO_2$ alkali-activated materials. Mortars specimens were exposed to different temperatures (up to 1100 °C) and heating rates (1 and 10 °C/min), and the properties of the resulting materials were evaluated in terms of visual appearance, weight loss, apparent density, and compressive strength. These analyses were further complemented by evaluating the morphological and mineralogical modifications that occurred during thermal exposure using scattering electron microscopy (SEM) and X-ray diffraction (XRD) techniques. The findings of this work demonstrated the significant effect of temperature and heating rate on the properties of the fired AAMs.

At low heating rates, there were no visible macroscopic effects on the samples apart from volumetric reduction and a gradual lightening of their color as the temperature raised. The mechanical strength of AAMs underwent an abrupt decline at 750 °C widely recovered at higher temperatures, reaching the maximum value of 184 MPa at 1100 °C that corresponds to a 115% increase compared to the parent AAM. With the increase of heating rate to 10 °C/min, a strength loss at 750 °C persisted, but the maximum compressive strength was halved (97MPa) and reached at 900 °C. At 1100 °C a significant reduction of compressive strength was observed (17 MPa), but all the samples were able to maintain their structural integrity. Except for samples exposed to 1100 °C with a heating rate of 10 °C/min, all AAMs presented residual compressive strength values higher than 40 MPa. These results have shown that $CaO-FeO_x-Al_2O_3-SiO_2$ AAMs present interesting refractory and high-temperature resistant features and can be potentially used as high-temperature resistant mortars and concrete or as a thermal coating to protect pre-existing cement-based concrete elements.

Keywords: Alkali activated materials, High-temperature resistance

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