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Abstract

Evaluation of the Potential of Metakaolin, Electric Arc Furnace Slag, and Biomass Fly Ash for Geopolymer Cement Compositions †

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The application of a circular economy paradigm, in which, e.g., virgin raw materials are replaced by by-products or waste streams from the same or other industries, is a key factor in the industry's path towards sustainability, enabling a critical reduction in extracted materials, generated waste, and greenhouse gas emissions. In this context, geopolymerization technology has shown the potential to incorporate a significant proportion of inorganic by-products or waste streams into the formulation of new and added-value materials, such as geopolymer cement (GPC). Despite the potential of GPC as an eco-friendly binder, the understanding of its synthesis process and technology is far from being complete, hindering its widespread use as an alternative to more conventional binders associated with a larger environmental footprint. In this respect, knowledge of the rate and extension of dissolution of aluminate and silicate species from the raw materials used is paramount since the elemental composition alone will not enable a suitable characterization and control of the geopolymerization process.

In the current work, the alkaline dissolution process of metakaolin, electric arc furnace slag, and different types of biomass fly ashes was studied and correlated with the raw materials' composition and with the mechanical strength achieved by geopolymer cement specimens prepared from these materials. A 10 M sodium hydroxide solution was used as the alkaline medium at a liquid/solid ratio of 200, and a 30 min contact period with controlled agitation was applied. The extent of dissolution of aluminate and silicate species from the solid raw materials into the alkaline solution was then determined by simple spectrophotometric methods—the Eriochrome Cyanine R method [1] and the silicomolybdic acid method [2], respectively. The elemental composition of raw materials was obtained by X-ray fluorescence (XRF), and the compressive strength at 7 days of one-component geopolymer cement prepared from each of the raw materials of interest was determined.

It was shown that metakaolin and electric arc furnace slag were the most reactive materials in the alkaline dissolution test, i.e., those with a higher extent of dissolution of silicate and aluminate species. Additionally, the extent of dissolution of silicon and aluminum was less than 10% of the total amount present in the raw materials (as determined by XRF), the fraction of dissolved aluminum being higher than that of silicon, in general.

Finally, the relative reactivity of materials, even if assessed only by a simple 30 min contact test, was shown to be related, in general, to the 7-day compressive strength of the geopolymer cement specimens—the higher the amount of silicon and aluminum dissolved, the higher the compressive strength achieved. These results support the usefulness of a simple method for the screening and evaluation of the relative potential of aluminosilicate-containing materials in the geopolymerization process.

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