INVESTIGATION OF LIGHTWEIGHT GEOPOLYMER MORTARS AS FIREPROOFING COATINGS

Lorenza Carabba, Department of Civil, Chemical, Environmental, and Materials Engineering (DICAM), University of Bologna, Bologna (Italy)
lorenza.carabba3@unibo.it
Raffaela Moricone, DICAM, University of Bologna, Bologna (Italy)
Giordano Emrys Scarponi, DICAM, University of Bologna, Bologna (Italy)
Alessandro Tugnoli, DICAM, University of Bologna, Bologna (Italy)
Maria Chiara Bignozzi, DICAM, University of Bologna, Bologna (Italy)

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Fireproofing coatings are passive fire protection (PFP) systems adopted to increase the fire safety of structural components in several civil and industrial applications. They are generally spray-applied systems that behave like thermal barrier for heat transfer to the substrate. Their use is aimed at slowing down the temperature rise of the substrate and maintaining the temperature of the component below its critical temperature (e.g. steel loses about one-half of the strength at 500 °C), thus providing time to control or extinguish the fire. When good resistance to high temperature is required, geopolymers are considered highly competitive materials thanks to the intrinsic thermal resistance of their structure. For this reason, this study investigates the possibility of using fly ash-based geopolymers, activated at room temperature, as fireproofing coatings for steel components.

Lightweight geopolymer mortars (LWGs) were synthesized at room temperature using low-calcium coal fly ash as precursor and 8 M NaOH and sodium silicate solutions as activators. The weight ratio between the sum of the alkaline solutions and the fly ash was maintained constant, whereas the amounts of 8M NaOH and sodium silicate solutions in the mix were varied, thus obtaining two different geopolymer matrices with different compositional SiO_2/Al_2O_3 and Na_2O/SiO_2 ratios. The mix design was completed using expanded perlite (EP) as aggregate and hydrogen peroxide solution as foaming agent to increase thermal insulation properties and to decrease products density, both essential features for fireproofing coatings.

Physical, mechanical and thermal properties of the lightweight geopolymers were investigated as a function of the compositional parameters and of the amount of lightweight aggregate and foaming agent. Furthermore, considering that the performances of a fireproofing coating are temperature dependent, the variation of thermal conductivity and specific heat as a function of temperature were studied to provide data on the heat transfer to the substrate during heating.

Thermogravimetric analysis confirmed the remarkable weight stability at high temperature of all the investigated geopolymers, which showed a total mass loss always lower than 8% at 900°C. Results showed that the use of expanded perlite as lightweight aggregate, combined with the foaming agent, allowed obtaining lightweight geopolymer mortars characterized by bulk density of 0.77 g/cm^3 and thermal conductivity of 0.23 W/mK at T = 20°C. These features are comparable to the ones of commercially available cementitious-based fireproofing coatings.

Results obtained from the experimental characterization were used to simulate the performance of the most promising LWG as fireproofing coating during a fire accident. A finite volume software set-up was used to simulate the temperature rise of steel components covered by different thickness (15, 20, and 25 mm) of the selected LWG, under cellulosic and hydrocarbon fire curve conditions. The performance of a commercial Portland cement-based fireproofing mortar (LWC) was also simulated for comparison.
The simulations confirmed that the selected lightweight geopolymer mortar was effective in delaying the increase of the steel temperature, providing a protection for the steel substrate for at least 30 minutes in the case of cellulosic fire conditions. In addition, the thinnest layer (15 mm) of LWG coating considered in this study exhibited the same behavior of a 20 mm layer of cementitious-based product.