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FULL LENGTH ARTICLE

Geopolymer synthesis by the alkali-activation of blastfurnace steel slag and its fire-resistance

Nour T. Abdel-Ghani [a], Hamdy A. Elsayed [b], Sara AbdelMoied [b,*]

[a] *Faculty of Science,Cairo University, Egypt*
[b] *Housing and Building National Research Center, Cairo, Egypt*

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KEYWORDS

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Abstract Geopolymer has been synthesized by the activation of blastfurnace steel slag (GGBFS) using 6% (NaOH) or 3% NaOH + 3% Na_2SiO_3. The geopolymer obtained in both cases exhibits an amorphous homogeneous and tightly-packed structure as well as a high compressive strength exceeding, that obtained by conventional mortar. In testing the response toward elevated temperatures it has been found that the geopolymer formed using 3% NH + % NS as activator reveals high stability and fire resistance where it retains high strength values even upon exposure to temperatures up to 500 °C. The results clarify, also, that the geopolymer possesses stability and fire resistance higher than those exerted by normal concrete. The current study indicated the feasibility of the alkali – activated BFS geopolymer as a fire resistant coat substituting the reinforced concrete coat to lightweight polystyrene panels used for walls, roofs and partitions in construction work. Such introduced coat offers the following merits relative to the reinforced concrete coat: lower density, higher strength, higher fire-resistance, free of steel mesh reinforcement and reduced cost. The results of the present investigation clarify that geopolymerization could be considered as a viable technology for the conversion of industrial by-products having an aluminosilicate composition into attractive construction materials.

Introduction

Intensive research work has been carried out in developing alkali – activated binders (geopolymers) indicating that this new binder could have an enormous potential to become an alternative to Portland cement binders. Geopolymers are a class of inorganic polymeric materials formed by the reaction between an alkaline solution and an aluminosilicate source at relatively low temperature (below 100 °C) yielding an amorphous to semi-crystalline three dimensional polymeric structure consisting of Si–O–Al bonds [1,2].

* Corresponding author.
E-mail address: chemist-sara@hotmail.com (S. AbdelMoied).
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Theoretically, any material composed of silica and alumina could be alkali-activated. The investigations performed worldwide have used the following materials as sources for the needed silica and alumina, for example:

- Kaolinitic clays [3,4].
- Metakaolin [5,6].
- Fly ashes [7].
- Blastfurnace slag [8–11].
- Mixtures of fly ashes and slag [12].
- Mixtures of fly ashes and metakaolin [13],and
- Mixtures of slag and metakaolin [14–16].

Accordingly, alkali-activation (geopolymerization) could be considered as an economically viable technology for the transformation of industrial wastes and/or products of aluminosilicate composition into attractive beneficial construction materials. Several studies have been devoted to investigate the durability of geopolymers and their response toward various affecting environments [e.g. [17,18]]. The target of this work was to investigate the formation of geopolymer by the alkali-activation of BFS and the feasibility of the product as a fire – resistant coating to some construction units.

Experimental

Material

The industrial waste utilized as an aluminosilicate source is BFS obtained during the manufacture of pig iron (Helwan iron and steel company, Cairo, Egypt). The activators used are as follows:

- Sodium hydroxide, NaOH.
- Sodium silicate, $Na_2SiO_3{\cdot}9H_2O$.
- Mixes of both alkalies.

Table 1 presents the chemical composition of BFS (WCS).

Mixes preparation and curing

The slag used as silica and alumina source was prepared passing 90 μm sieve. The activator was added to the mixing water; then, the solution was added to the fine slag in a rotary mixer with 0.25 w/s, mixed for 3 min. The paste mixture was cast into $25 \times 25 \times 25$ mm cubic-shaped molds, vibrated for compaction and sealed with a lid to minimize any loss of evaporable water. All mixes were left to cure undisturbed under ambient temperature (23 °C) for 24 h, demolded and left in a fog room at 38 °C and >90% humidity. The specimens were taken from the fog room for further investigation.

Techniques and apparatus

The chemical analysis of the starting material was carried out by the X-ray fluorescence technique (XRF) using Philips Spectrometer PW 1400 with Rubidium Rb-Kα radiation at 50 kV and 50 mA. The crystalline phases were identified using XRD diffraction technique.

The analysis was recorded on a Philips PW 1050/70 diffractometer using a Cu-Kα source. The compressive strength

Table 1 Chemical composition of the BFS, wt%.

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	TiO_2	MnO_2	P_2O_5	Cl^-	BaO	Total
35.95	10.01	1.48	33.07	6.43	3.52	0.74	1.39	0.52	3.44	0.10	0.05	3.0	99.69

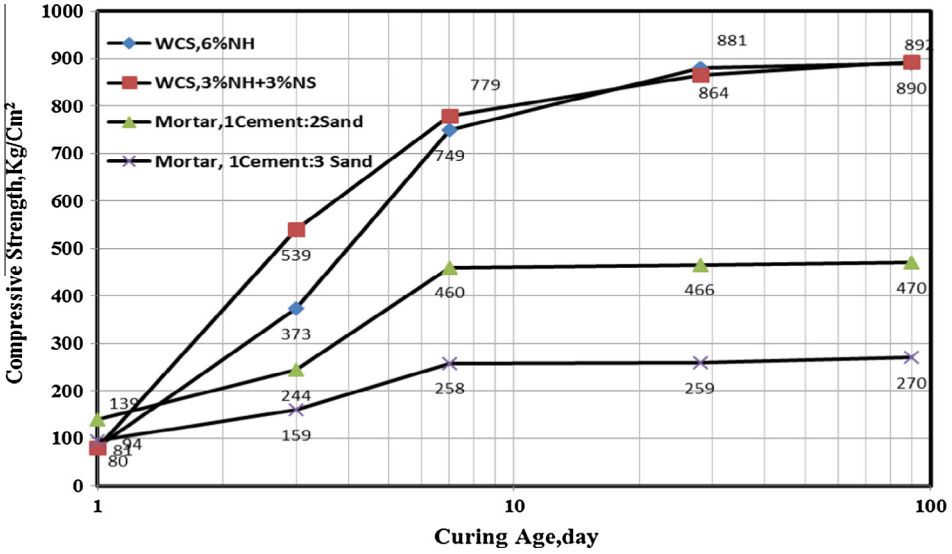

Fig. 1 Variation of compressive strength with the progress of the curing time for (WCS) using 6% NH and 3% NH + 3%NS as activator compared to the mortar at the ratios 1:2 and 1:3 cement:sand.