



Preparation and characterization of one-part non-Portland cement

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Abstract

This work aims at enhancing the mass production and commercial viability of non-Portland cement (NPC) by preparing one-part-NPC (just add water). NPC is an eco-efficient material compared to Portland cement (PC). It was prepared by mixing of blast-furnace slag (BFS) with 2, 4, 6, 8 and 10% sodium hydroxide (SH) by total weight of BFS, and then mixing it with water. The homogeneous slurry is immediately dried in an oven at 80 °C for 24 h, followed by pulverization to a fixed particle size. Two main compositional factors were examined: first is the increase of SH wt%, while the amount of water to slag (W/BFS) ratio is kept maintaining constant, and the second includes increasing of W/BFS ratio at constant SH dosage. One-part NPC was mixed with water at W/NPC ratio of 0.25, and then cured. A conventional two-part NPC, containing SH solution (liquid part) and BFS (solid part), was prepared for comparison. The results showed that, the amount of NPC hydration products increase with SH wt% and W/BFS ratio. The compressive strength values of hardened cements proved that, the activation of slag continues after the addition of water to NPC. After 90 days of curing, the compressive strength of one-part NPC mixture decreased by 10% compared to that of the two-part-NPC containing the same activator content. Some selected hardened pastes were analyzed using FTIR, TGA/DTG and SEM techniques. The results of the different analyses are in a good harmony with those of mechanical properties and prove that; one-part NPC can be beneficially used as an alternative to PC.

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1. Introduction

Nowadays, the sustainability of the construction sector must be a priority for the civil engineering scientific and technological community. The development of innovative materials and methods aiming at extending the life-time of both existing and new structures is mandatory. Manufacturing of Portland cement (PC) is one the most contributing industries in the environmental pollution due to CO₂, dust, oxinitrides (NO_x) and oxisulfides (SO_x) emissions [1,2]. Alkali activated aluminosilicate cements are considered more environmental friendly because of their low CO₂ emission and energy requirements compared to PC [3]. One of the most common alkali activated aluminosilicate cements containing high calcium ions, is alkali activated slag cement or non-Portland cement (NPC) [4–6]. Conventional NPC is prepared from two

components: the alkaline solution and an aluminosilicate powder, fly ash, blast-furnace slag (BFS), metakaolin and so on [4,6–10]. The alkali activation of slag mainly produces calcium silicate hydrate (CSH) gel with low calcium to silica (Ca/Si) ratio [11,12] in which silicon is present in one-dimensional chains with some substitution of Al and Mg for Si and Ca [13]. The alkali activation of BFS is occurred in three stages; the first is the dissolution process in which the alkali activator cleavages the Al–O–Al and Si–O–Si series in BFS network. The second step includes the condensation of broken activated species to form oligomers. The final step is the polycondensation of oligomers into polymeric structure [14]. However, the dissolution and polycondensation probably occur simultaneously when the solid aluminosilicate material mixed with liquid activator [15].

The alkaline solutions (NaOH, KOH and Na₂SiO₃ with SiO₂/Na₂O=1) are categorized as corrosive products, which must be handled with gloves, masks and glasses. They are not user friendly and would be difficult to use for bulk production

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without appropriate safety procedures. There is a great need to produce one-part-NPC, like PC, which reacts with the addition of a small amount of water. The dry mixes based on dry NaOH/KOH with aluminosilicate or calcium aluminosilicate materials are corrosive in nature and may not be used [16].

As a matter of fact, very few studies have been conducted regarding preparation and properties of one-part aluminosilicate mixture to enhance the mass production and commercial viability of NPC. Koloušek et al. [17] prepared one-part geopolymer, with low strength (1 MPa after 7 days), by calcination of kaolinite or halloysite together with dry sodium hydroxide. Peng et al. [18] also prepared one-part geopolymer by calcination of low quality kaolin at different temperatures in the presence of sodium hydroxide (SH) or sodium carbonate (SC). Hajimohammadi et al. [19] developed one-part geopolymer by mixing geothermal silica and solid sodium aluminate (SA). Feng et al. [20] prepared one-part geopolymer from thermal activation of albite. Nematollahi et al. [21] developed one-part geopolymer mixtures by mixing fly ash (FA) with sodium silicate. In similar trend, Yang and Song [22] synthesized one-part geopolymer by mixing sodium silicate with BFS or FA or combination of them. Abdollahnejad et al. [23] studied the durability performance of one-part geopolymers concerning water absorption, penetration of chloride, carbonation resistance and resistance to acid attack.

In this work an innovative experimental method was used to produce one-part NPC by controlling the BFS dissolution/condensation processes. The BFS was dry-mixed with SH, and then the amount of water lower than that required for the workable activated BFS paste formation was added, where, water plays an important role in the dissolution/polycondensation process. The higher the liquid to solid ratio, the faster the dissolution and polycondensation rates occur until the optimum ratio is reached, after which the addition of water could accelerate the dissolution

rate, while that of polycondensation is hindered [24]. The addition of too much water hinders the condensation rate whereas too low amount of water also leads to the same result. Water supports the required medium for the aluminosilicates dissolution, forming Al^{3+} and Si^{4+} , which condense to form aluminosilicate geopolymer. As the amount of mixing water decreases, the dissolution rate also decreases also. Thereby, there is no sufficient amount of activated species to be condensed.

Hence, BFS was mixed with SH solution at W/BFS ratio, which makes activated BFS paste in a non-workable form. The BFS dissolution starts after mixing with alkaline solution. The removal of water was performed by drying BFS paste in an oven drier at 80 °C for 24 h, yielding solid material, which is crushed to produce powder with a fixed particle size. The individual effects of SH content and W/BFS ratio on the strength properties of hardened NPC-pastes were studied.

2. Materials and methods

2.1. Materials

The materials used in this work are granulated blast-furnace slag (GBFS) and sodium hydroxide (SH). BFS was provided by Iron and Steel Company, Helwan, Giza Governorate. SH with 99.99 percent purity was obtained from SHIDO Company, UK. The glassy amorphous structure of BFS was confirmed by XRD as shown in Fig. 1. The chemical oxide analysis of BFS as determined by XRF is listed in Table 1. Its particle size distribution indicates that, it has a major particle size of < 90 μm (Fig. 2).

2.2. Preparation of one-part non-Portland cement (NPC)

The details of mix proportions are given in Table 2. The NPC-1, NPC-2, NPC-3, NPC-4 and NPC-5 mixes were designed by varying SH content such as 2, 4, 6, 8 and 10 wt% of total weight of BFS at constant W/BFS ratio of 0.10. In order to evaluate the effect of water content on the performance of NPC, NPC-6 and NPC-7, the mixes were designed by varying W/BFS ratio (0.15 and 0.20, respectively), while SH content was kept constant at 6 wt%. BFS was ground and dry-mixed with SH; after that the water was added and mixed for 5 min, using mechanical mixer. The homogenous slurry was then poured in stainless steel container and sealed with aluminum sheets to avoid moisture loss. All specimens were dried at 80 °C for 24 h. The hardened samples were pulverized and sieved through 90 μm sieve to obtain cement powder at a fixed particle size.

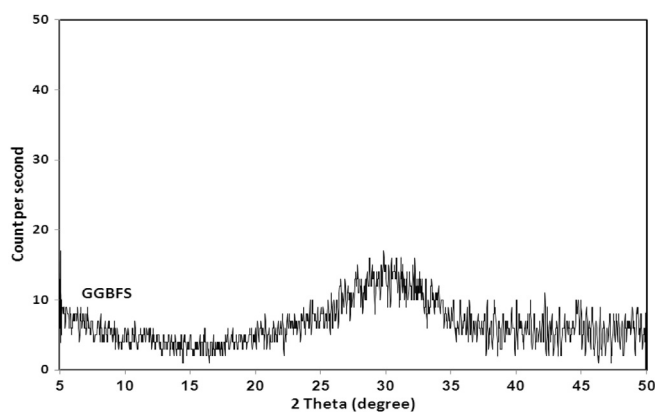


Fig. 1. XRD pattern of BFS.

Table 1
Chemical composition of BFS, wt%.

Oxide, %	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Na ₂ O	K ₂ O	SO ₃	TiO ₂	P ₂ O ₅	L.O.I	Total
GGBFS	37.81	13.14	0.23	38.70	7.11	1.03	0.19	1.19	0.40	0.17	–	99.97

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