

Effect of substitution of granulated slag by air-cooled slag on the properties of alkali activated slag

Hamdy El-Didamony^a, Ahmed A. Amer^{a,*}, Tarek M. El-Sokkary^b, Hamdy Abd-El-Aziz^b

^aFaculty of Science, Chemistry Department, Zagazig University, Zagazig, Egypt

^bNational Research Center for Building and Housing, Dokki, Giza, Egypt

Received 21 February 2012; received in revised form 5 June 2012; accepted 5 June 2012

Available online 15 June 2012

Abstract

This article assesses the mechanical and durability performance of replacement of GBFS by ACS activated by 3:3 NaOH:Na₂SiO₃ (3:3 SH:SSL) wt% (at optimum value 6 wt%) mixed with sea water (SW) and cured at 100% R.H. at room temperature. The kinetic behavior of activated GBFS-ACS mixes was measured by determination of setting time, combined water, bulk density and compressive strength up to 90 days. The rate of activation of the AAS has been studied from some selected samples by FT-IR, TGA, DTG analysis and SEM techniques. The compressive strength of dried activated GBFS-ACS pastes in comparison with saturated GBFS-ACS pastes up to 90 days was determined. The results revealed that the blended pastes of 80% GBFS+20% ACS gives the higher combined water, bulk density and compressive strength than those of 40/60 and 60/40% GBFS/ACS and lower than the 100% GBFS up to 90 days. Also, the compressive strength of dried samples at 105 °C for 24 h activated by (3:3 SH:SSL) mixed with SW and cured in 100% R.H. at room temperature up to 90 days is greater than saturated samples cured at the same conditions. On increasing the amount of ACS up to 40%, the setting time decreases then increases at 60% but still shorter than 100% GBFS. Finally, ACS can be used as partial substitution of GBFS in AAS.

© 2012 Elsevier Ltd and Techna Group S.r.l. All rights reserved.

Keywords: Alkali-activated slag; Air cooled slag (ACS); Granulated slag (GBFS); Sodium hydroxide

1. Introduction

Blast furnace slag (BFS) is a by-product generated during the manufacture of pig iron. The air cooled slag (ACS), is formed by allowing the molten slag to cool relatively slowly under ambient conditions. The cooled material is hard and dense, although it can have a vesicular texture with closed pores. The granulated blast furnace slag (GBFS) is formed by quenching molten slag with water. The very rapid cooling causes solidification of the slag as sand-sized particles of glass. The disordered structure of this glass gives the material moderate hydraulic cementitious properties when very fine ground and used as a replacement for Ordinary Portland cement (OPC) due to its latent hydraulic properties [1,2].

Cement containing water-cooled slag (WCS) has long been used in Egypt and in the world. However, there are

many other unexploited slag by-product such as ACS and steel-making slag. The feasibility of utilizing these types of slags with cement has been ignored due to the judgment that ACS is hydraulically unreactive. Consequently, little of these materials is used, or their use is limited to low-value applications. A comparative study of the hydraulic reactivity of ACS and WCS produced from the same blast furnace and the same raw materials has been conducted. Although the reactivity of ACS is lower than WCS, it can still be exploited as a hydraulic material [3].

GBFS has been also investigated as an alternative binder, when activated by alkali (NaOH, Na₂CO₃, KOH, etc.) solutions, slag dissolves forms C–S–H similar to that in OPC-based concretes [4].

The world-wide need to reduce the energy used and the greenhouse gases emitted during cement manufacture has led to the pursuit of more eco-efficient materials, such as alkali-activated slag cement (AASC). Alkali activated cements are a new generation of alternative building materials, whose the

*Corresponding author. Tel.: +20 1277766533.

E-mail address: drahmed.amer@yahoo.com (A.A. Amer).

main difference from traditional Portland cements is the use of a relatively alkali-rich, clinker-free binder matrix such as alkali-activated slag (AAS) or geopolymer [5]. AAS can have high strength development and using the adequate activators can lead to rapid setting, good durability and high resistance to chemical attack [6–11]. AAS cements are sometimes referred to as geopolymers, another alternative binder. However, due to the presence of calcium in slag, which prefers to form C–S–H as the primary strength bearing phase, this classification is not entirely accurate [12,13].

The main hydration products found in AAS are C–S–H with a low Ca/Si ratio related mainly to the composition of slag and the nature of activators used, hydrotalcite intimately intermixed with the C–S–H in the MgO containing slag [14–18]. The C–S–H produced by alkali activated systems may incorporate a higher content of Al₂O₃ based on the initial composition of the slag [19,20]. A better understanding of the effects of alkaline activators such as NaOH and hydrous sodium metasilicate (Na₂SiO₃ · 5H₂O) on the hydration mechanisms of alkali activated slag could indicate ways to optimize the use of alkaline activators [21].

In a previous study [22] it has been found that the increase of sodium hydroxide/sodium silicate liquid (SH/SSL) mixed activator for alkali activated slag content and mixed with sea water (SW) increase the combined water contents whereas, the bulk density and compressive strength increased with Na₂SiO₃ content up to 90 days.

The behavior and durability of AAS mortars and concretes have been extensively studied [23–27]. It has been shown that they can develop comparable, and greater, mechanical strength than OPC mortars [23,24]. These materials are also highly sulfate, sea water and acid resistant [25–27]. All these properties are essentially associated with the special nature of the main hydration product which is a less basic and more highly polymerized C–S–H gel than formed in OPC pastes with low porosity of the mortar and concrete [28–31].

The aim of the present investigation is to study the physico-mechanical properties of granulated slag replaced

with air-cooled slag activated by (3:3 SH:SSL) wt% mixed with sea water (SW) then cured at 100% R.H. The kinetic of activation can be studied by determining the setting times, combined water, bulk density and compressive strength up to 90 days. The rate of activation of the AAS can be also studied from some selected samples by using FT-IR, TGA, DTG and SEM techniques.

2. Experimental techniques

2.1. Materials

The materials used in this work are Granulated Blast Furnace Slag (GBFS) and Air Cooled Slag (ACS) which were provided by Iron and Steel Company, Helwan, Egypt. ACS is produced by slow cooling in air whereas, the GBFS was suddenly cooled by a jet of water to prevent crystallization. NaOH (SH) was produced by SHIDO Company with purity 99%, commercial sodium silicate liquid (SSL) consists of 32% SiO₂ and 17% Na₂O with silica modulus SiO₂/Na₂O equal 1.88 and density 1.46 g/cm³ was used [22].

The chemical composition of the starting materials was shown in Tables 1 and 2.

The X-ray diffraction (XRD) pattern of ACS is shown in Fig. 1. It indicates that the ACS is completely crystalline and consists of Wadalite, syn(W) (Ca₁₂Al_{10.6}Si_{3.4}O₃₂Cl_{5.4}), Mullite, syn(Ms) (Al_{4.64}Si_{1.36}O_{9.68}), Serbro-dolskite, syn(S) (Ca₂Fe₂O₅), Opal-A(O) (SiO₂ · xH₂O), Quartz (SiO₂) and Mullite (M) (3Al₂O₃ · 2SiO₂).

Fig. 2 illustrates the XRD of GBFS. It is clear that the GBFS is nearly completely vitreous with an amorphous structure.

GBFS and ACS were firstly crushed in a jaw crusher to pass through 2 mm diameter sieve, then passed through a magnet to remove any contamination of iron melt, then ground in steel ball mill to reach 4500 ± 50 cm²/g surface area. Different mixes were prepared from GBFS and ACS as shown in Table 3. In an earlier research [32] it was found

Table 1
Chemical composition of starting materials (wt%).

Oxide (%)	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	Na ₂ O	K ₂ O	L.O.I.
GBSF	37.81	13.14	0.23	38.70	7.11	1.19	1.03	0.19	–
ACS	35.60	12.43	4.95	38.35	6.09	1.32	1.21	0.11	–

Table 2
Chemical analysis seawater [22].

Test	pH	Cl ^{-a}	SO ₄ ^{2-a}	Ca ^{2+a}	Na ^{+a}	K ^{+a}	Mg ^{2+a}	TDS ^b
Sea water	8.13	22,300	1450	210	11,520	477	1341	43,300

^appm unit.

^bTotal dissolved solids.

Download English Version:

<https://daneshyari.com/en/article/1463447>

Download Persian Version:

<https://daneshyari.com/article/1463447>

[Daneshyari.com](https://daneshyari.com)