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Structural characteristics and hydration kinetics of modified steel slag

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ABSTRACT

This study investigates the structural characteristics and hydration kinetics of modified basic oxygen furnace steel slag. The basic oxygen furnace steel slag (BOFS) was mixed with electric arc furnace steel slag (EAFS) in appropriate ratios and heated again at high temperature in the laboratory. The mineralogical and structural characteristics of both BOFS and modified steel slag (MSS) were characterized by X-ray diffraction, optical microscopy, scanning electron microscopy, Raman and Fourier transform infrared spectroscopies. The results show that modification increases alite content in MSS and decreases alite crystal size with the formation of C_6AF_2. One more obvious heat evolution peak appears in MSS's heat-flow rate curves in comparison to BOFS, becoming similar to that of typical Portland cement paste. As a result, its cementitious activity is much improved.

1. Introduction

Steel slag is a by-product from either the conversion process of iron to steel in a basic oxygen furnace (BOF), or the melting of scrap to make steel in an electric arc furnace (EAF) [1]. The global amount of steel slag has increased continuously. In 2002, about 50 million tons of steel slag was produced worldwide [2], but today nearly 80 million tons of steel slag is discharged every year in China alone. The chemical compositions of steel slags vary greatly with the raw materials and process used, but generally fall within the range CaO 45–60%, SiO_2 10–15%, Al_2O_3 1–5%, Fe_2O_3 3–9%, FeO 7–20%, and MgO 3–13% by mass [3]. The presence of C_3S, C_2S, C_4AF and C_2F in steel slag makes it potentially usable as a cementitious material, but due to its low C_3S content it gives lower strengths than typical Portland cement clinkers [4]. Cement blended with steel slag usually has a longer setting time and lower early strength, and sometimes shows a larger volume expansion due to a high content of dead-burned free-CaO [5,6]. Therefore, steel slag has not yet found a wide application as a cementitious material in concrete. Steel slag is well characterized as there is a long-term experience with its use as aggregate for road construction in Europe. Owing to the intensive research work during the last 30 years about 65% of available steel slag is now used in qualified applications [7]. However, in China, only 10% of steel slag is currently reused [8], while the large volumes that go unused are stored externally leading to emission of various poisonous elements that can contaminate groundwater, water and also soil (due to the dust). Many activation approaches, such as mechanical [9], thermal [10,11] or chemical methods [12], have been used for improving the cementitious performance of steel slag. These techniques are referred to as "back-end modification techniques", in which additional energy and chemical activators are usually needed, and the modification effect varies with the chemical and mineral compositions of steel slag.

Molten basic oxygen furnace slag contains much heat and has good fluidity. By adding some mineral admixtures to the molten slag during the discharging process, it is possible to increase the content of cementitious minerals in the product, resulting in improved hydraulic activity. Fig. 1 is the schematic diagram of the modification process in steelworks. In this study, this process was simulated in laboratory, and the structural characteristics and hydration kinetics of the modified steel slag were investigated.

2. Experimental

2.1. Materials

The basic oxygen furnace steel slag (BOFS) used in the experiment was from the Shaoguan Iron and Steel Company of China. The electric arc furnace steel slag (EAFS) used as composition adjusting material was from the same company. BOFS and EAFS were dried, crushed and ground to Blaine specific surface areas of 415 and 420 m^2/kg [13], respectively. The cement used was an ordinary Portland cement (OPC) with a Blaine specific surface area of 346 m^2/kg. The chemical compositions of the raw materials are shown in Table 1, from which it can be seen that BOFS contains more iron oxide and less CaO than OPC, while EAFS has more CaO and SiO_2 but less iron oxide than BOFS.

Fig. 2 shows that BOFS is mainly composed of alite, belite, calcium ferrite, calcium oxide and RO phase, the latter being a solid solution between MgO (periclase) and FeO (wustite). The phases observed

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