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Cementitious and pozzolanic behavior of electric arc furnace steel slags

Luckman Muhmood [a], Satish Vitta [a,*], D. Venkateswaran [b]

[a] Department of Metallurgical Engineering and Materials Science, Indian Institute of Technology Bombay, Mumbai 400076, India
[b] Indorama Cement Ltd., Navi Mumbai 400705, India

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ABSTRACT

The cementitious and pozzolanic behavior of electric arc furnace steel slag, both as received and treated has been studied in detail. The as received slag was completely crystalline and multi-phasic with Fe-substituted monticellite as the predominant phase. Treatment of this slag, remelting and water quenching, results in reduction of Fe-oxide content coupled with an increase in basicity index which makes it more hydraulic compared to the as received slag. The remelted slag has several phases with merwinite as the dominant phase. Thermal analysis of the hydrated slag shows that treating the as received slag increases the water absorption capacity, a property essential for cementitious behavior. Compression strength of the slag blended cements was studied and it was found that substitution of 20% ground granulated blast furnace slag with electric arc furnace steel slag does not decrease the strength beyond 28 days. The control cement has a strength of 58.6 MPa compared to 58 MPa for the cement comprising of 20% untreated slag. The substitution of this untreated slag with treated slag exhibits the highest strength, 61 MPa and a potential for further strength increase after 28 days. In the case of cement mix with no blast furnace slag, substitution of 15% clinker with steel slag does not decrease the strength significantly, 64.4 MPa compared to 66.5 MPa for the control cement. Substituting 30% clinker in the cement mix with electric arc furnace slag however results in significant decrease in strength, 53.4 MPa. The pozzolanic strength of the slag was found to increase significantly due to remelting from 2.0 MPa for the as received slag to 8.0 MPa for the treated slag.

1. Introduction

Slag in general is a byproduct of various metals extraction and refining processes. In the specific case of making steels, the slag is generated at 3 different stages of processing and accordingly classified as: blast furnace slag, electric arc furnace slag and ladle slag. Among these the blast furnace slag constitutes the maximum tonnage with electric arc furnace slag coming close to the blast furnace slag. The blast furnace slag liquid when poured into water granulates and also becomes highly amorphous due to the high rate of cooling. Grinding the amorphous granules into a fine powder renders them highly active during the process of hydration in the presence of cement clinker and hence makes them suitable for the manufacture of blended cements [1]. The chemical composition of the granulated blast furnace slag is quite different compared to that of the cement clinker as seen from Table 1. It is however still used in the manufacture of blended cements because of its latent hydraulic activity and also the blended cements have been found to provide comparable compressive strengths [2–4].

The electric arc furnace slag (EAFS) on the other hand has a chemical composition more close to that of the cement clinker compared to the blast furnace slag as seen from Table 1. Hence recently it was shown to have potential application as partial substitute for raw materials in clinker production. Addition of up to ~20% EAFS in the kiln feed was found to improve burnability index of the raw material mix [5]. It is however not used in the manufacture of blended cements because of its lack of hydraulic or pozzolanic activity [6–8]. The high Fe-oxide content coupled with the highly crystalline nature of the slag are proposed to be the reasons for its chemical inactivity during the process of hydration in the presence of clinker or lime. Hence the EAFS is used mainly as aggregates for landfills and roads [9–11]. The electric arc furnace technology facilitates recycling of steel scrap but also leads to production of EAFS. Due to increasing contribution of electric arc furnace made steel to the total quantum of steel produced, the EAFS quantity is increasing annually. This is far in excess of the requirement for landfills and aggregates and is leading to unused EAFS production. Hence the objective of our work has been to find alternate uses for EAFS and in this context the cementitious and pozzolanic properties of both as received and treated slag have been investigated. The as received slag is made by cooling the electric arc furnace steel liquid slag in air at the industrial production site. This as received slag was subjected to a remelting treatment followed by quenching into a pool of water. This was done in order to increase the amorphous content which will have a hydraulic behavior, as found in the case of blast furnace slag. The chemical composition, microstructure and phase analysis of the slag both before and after treatment was studied by X-ray fluorescence, scanning electron microscopy and X-ray diffraction. The various tests to characterize

* Corresponding author.
E-mail address: satish.vitta@iitb.ac.in (S. Vitta).

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