RECYCLING OF ELECTRIC ARC FURNACE SLAG FROM HYDROGEN-BASED IRON PRODUCTION IN CEMENTITIOUS BINDERS

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A significant contribution to the greenhouse effect has been linked to CO_2 emissions from industrial activities such as cement and steel manufacturing. Thus, the cement and concrete industry is looking for alternative materials to replace cement, one of which is blast furnace slag (BFS), a residue from the iron and steel industry. However, the steel industry is also taking steps to transition to a low CO_2 steelmaking process by decarbonizing the process. For example, in Finland and Sweden, SSAB is taking a leading role in the decarbonizing of the steel industry and has initiated the world's first pilot project to develop hydrogen-based iron production with direct reduction, in which hydrogen will be used to reduce iron oxides to metallic iron without the use of metallurgical coke. In the next step, the direct reduced iron (DRI) is refined into steel using an electric arc furnace (EAF). This transformation of the steelmaking process will cause a shortage of BFS in the coming years, as the transition affects the composition and quantity of side streams. Therefore, the EAF slag from the hydrogen-based iron production is a new raw material for use in cementitious materials[1,2].

In this work, we studied the chemical and mineral composition of 4 EAF slag samples from hydrogen-based iron production with different chemical composition as well as their cementitious properties when mixing with alkaline silicate and hydroxide solutions. Fresh (i.e., flowability and setting time) and hardened properties (i.e., compressive strength, microstructure, microchemistry) have been evaluated.

Compared to EAF slag from other production sites, the current slag exhibited a distinct and variable chemical and mineral composition. The studied samples are high in Fe and Ca, while Si was the second, third or fourth component in the original samples. Generally, the slag has a low amorphous content (represented by calcium silicates) with numerous crystalline phases, including wüstite-periclase ($Fe^{2+}O$ to MgO), åkermanite-gehlenite ($Ca_2Mg[Si_2O_7]$ to $Ca_2Al[AlSiO_7]$), and magnetite-magnesioferrite solid solution ($MgFe_2^{3+}O_4$ to $Fe^{2+}Fe_2^{3+}O_4$), as well as other crystalline silicates.

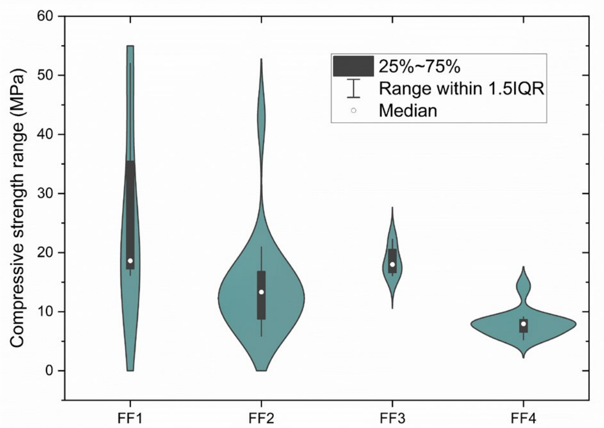

Figure 1 – Compressive strength range for alkali-activated EAF slags

When mixed with alkaline solutions, fresh pastes showed a very short setting time, but a decrease in the modulus of waterglass and an increase in the ratio of solution to slag can be used to delay the setting time. The alkali-activated pastes and mortars showed different values of compressive strength (10-50 MPa) for different samples and mix designs with a median value of about 20 MPa for lower basicity slags and about 10 MPa for slags with higher basicity (Figure 1). The improvement of the mechanical characteristics of some mix designs can be explained by 1) an increase in the curing time; 2) increased alkali content in the activating solution; and 3) higher relative humidity of curing. On the contrary, the change of curing temperature, modulus of waterglass and fineness of particles had little effect on the mechanical characteristics of the produced materials.

In summary, alkali activation of EAF slag under optimal conditions can produce a strong material with mechanical properties comparable to OPC-based concrete, but further investigation of their long-term durability is required.

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