Pilot Scale Zero Waste PB Smelting for Iron and SCM Production

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Abstract

A novel zero waste process has been demonstrated in an industrial pilot scale for Processed Bauxite (PB) (formerly referred as Bauxite Residue) utilization. Under the EC funded ReActiv project PB was carbothermicaly smelted in METLEN's 1 MVA Pilot Electric Arc Furnace to produce pig iron and a slag phase. The slag was granulated using a high-speed air jet to produce amorphous granules. These granules were tested at Holcim Innovation Centre as a new SCM material used successfully to replace part of the cement clinker used in cement formulations. Thus, the new process demonstrated has the potential to completely valorise Processed Bauxite producing two high added value products.

Keywords: Processed Bauxite, Bauxite Residue, SCM, Granulated Slag, Cement.

1. Introduction

The EC funded ReActiv collaborative project aims at producing Supplementary Cementitious Materials (SCMs) from Processed Bauxite (PB), the by-product of alumina production (formerly referred also as Bauxite Residue). SCMs are materials that exhibit pozzolanic and/or hydraulic properties and can therefore be used in cement composition as a partial substitute to Portland cement clinker and/or in concrete as an active addition [1]. They can be natural materials (limestone, pozzolans, etc.) or by-products from other industrial processes (blast-furnace slag, fly ash, silica fume, calcined clay etc.). As clinker production is a CO_2 intensive process (due to the calcination of limestone), partial substitution of clinker with SCMs has been known for decades as a way to abate the CO_2 emissions per tonne of cement [2] and is widely used. The decarbonization strategies of the cement industry published in 2024 emphasize the use of the SCM as the first lever available today to be used to tackle climate change with an average target of 65 % of substitution by 2050 [3] to reach a clinker binder factor of 0.52 [4]. However, all industries are pulled towards more sustainable processes and less side-products production, which made it evident that today's available SCM will become more and more scarcer, and/or less reactive [5]. Some investigations are consequently needed to identify the new sources of the next generation SCM, as well as their impact once included in the building materials.

In the current work, the first industrial pilot scale test of this technology is presented, along with pilot-scale evaluation of the produced SCM in concrete formulation. Smelting of more than 5 tonnes of PB took place in the alumina refinery of METLEN in Greece and following slag air granulation the produced SCM termed Smelted Bauxite (SB), was evaluated at the Holcim Innovation Centre in France.

2. PB Smelting Pilot Trials

2.1 Materials

The materials used in the smelting pilot trials were Processed Bauxite (filter pressed bauxite residue from METLEN's alumina refinery) along with lime, silica sand as slag fluxes and metallurgical coke as the reducing agent. The chemical composition of all materials is presented in Table 1 (XRF analysis).

Table 1. XRF analysis of Bauxite residue and kaolin samples.

Material %wt	Al_2O_3	Fe_2O_3	CaO	SiO_2	TiO_2	Na_2O	LOI	Fixed C
PB	20.27	40.71	9.17	8.29	5.00	4.00	9.29	
Lime			74.89				24.09	
Silica Sand				99.5				
Coke								97.20

2.2 Pilot Unit and Process

METLEN's pyrometallurgical pilot unit comprises of a 1 MVA AC electric arc furnace (AMRT-EAF) which can treat dusty material without agglomeration. The furnace processing capacity per heating batch is between 500 to 750 kg of material. The refractory lining of the EAF consists of alumina-silicon carbide brick (ALUCARBON H 8810 SiC) with an external refractory zone consisting of Refratherm 150 insulation bricks. Material is fed into the EAF through a chute while slag pouring and metal casting at the end of each trial is made by tilting the furnace to first pour slag into ladles and then pour pig iron into smaller 35 kg ingots.

In addition, the pilot also features an indirect fired rotary kiln (CEMTEC). The kiln tube is 6 m long, made of stainless steel and is heated by 5 natural gas burners, positioned on its exterior. Material is fed in the tube through a feeding screw, which in turn is fed from a double helix mixer. Material exiting the kiln, can be fed directly into the EAF through a closed steel conveyor belt.

All tests conducted started with weighing and mixing raw materials in a mixer for homogenous feed, followed by drying and calcination of the mix at 700 °C in the rotary kiln furnace, the output of which, was fed directly to the EAF for reductive smelting at 1600 °C to produce pig iron and a slag phase. The slag was subsequently poured into a transfer ladle and then pig iron casting took place. Metal and slag samples were taken during pouring for chemical analysis.

Dry slag granulation was achieved by pouring the hot slag into an air granulation pilot unit designed by HATCH. The unit consisted of an inclined trough at the lower end of which the slag was met with a high-speed air jet, generated from air blower fitted with an appropriate nozzle. The granulated slag particles were shot into a container, where they were eventually collected after cooling. Figure 1 shows the Slag pouring from the EAF and the subsequent slag air granulation process.

2.3 Results

In total 5 tonnes of PB were processed over a series of tests in order to optimize slag chemistry and air granulation unit operational conditions (air velocity, ratio of air flow to slag flow) to achieve good granulation results, meaning amorphous material with little to no slag fibre formation.

Georgiades and Prof. Rupert Myers from Imperial College of London in the LCA and Paraskevi Efstathiou and Anastasiou Kladis from ADMIRIS in the economic feasibility study.

6. References

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