Co-Calcination of BR with Kaolin for Economic Production of SCM. Industrial Pilot Results

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Abstract

Adequate supplementary cementitious materials (SCMs) with an interesting influence on the strength of cement mortars can be obtained by co-calcining bauxite residue (BR) with kaolin clay. The process has proven its technical feasibility in lab scale for a variety of BRs and different grades of kaolin clays, under the EC funded ReActiv project and has been presented in ICSOBA 2022. In the present paper the co-calcination of BR with kaolin clay in an industrial pilot plant is reported. Using a 6 m long indirect heated rotary kiln located at METLEN, several tons of BR have been mixed with clay in a 70 %–30 % weight mix range and calcined at temperatures between 700–800 °C, in the length of the kiln. Heat of hydration obtained by R3 test using calorimetry at VITO confirms the activity of the calcined material, while further laboratory testing at Holcim validates its potential as a new SCM material that can replace part of the clinker used in cement formulations.

Keywords: Bauxite Residue, Supplementary cementitious materials, SCM, Calcined Clay, Cement.

1. Introduction

The EC funded ReActiv collaborative project aims at producing Supplementary Cementitious Materials (SCMs) from 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 is one of the main decarbonization strategies of the cement industry [2,3].

Calcination has been shown to be especially useful for boosting the reactivity of clays, leading to the potential for high clinker replacement levels such as in the case of limestone calcined clay (LC3) cements [4], where kaolin minerals are transformed into reactive metakaolin. Similarly, but not as extensive as for clay, the reactivity of BR can be improved using a calcination process.

As shown in previous publications [5, 6, 7] calcined BR exhibits low pozzolanic activity (~100 J/g after 7 days acc. R^3 heat release test) and might result in severe setting acceleration, but when mixed with kaolin and calcined to temperatures 650–800 °C, it can produce a reactive material without detrimental effects on the workability, potentially suitable for substitution of Portland cement clinker as supplementary cementitious material. Laboratory scale investigations performed at VITO on this technology on a variety of BRs has shown that, following the calcination step, the reactivity of the mixed material can be attributed to both the newly formed metakaolin phase from the kaolinite and to the calcined desilication products (DSPs) from the BR. Due to the high reactivity of the DSP phases, the kaolin clay used for co-calcination does not have to be high purity. Furthermore, the reaction of the DSP phases occurs very fast, providing already a positive effect on the early strength (2–7 days), which is rather unique for SCMs. On the other hand, the metakaolin phase captures the free sodium contained in the BR, eliminating the issues with severe setting acceleration.

In the current work, the first industrial pilot scale test of this technology is presented, along with lab-scale evaluation of the produced SCM in concrete formulation. Co-calcination of 5 tonnes of BR with kaolinite took place in the alumina refinery of METLEN in Greece and the produced SCM was evaluated at the Holcim Innovation center in France.

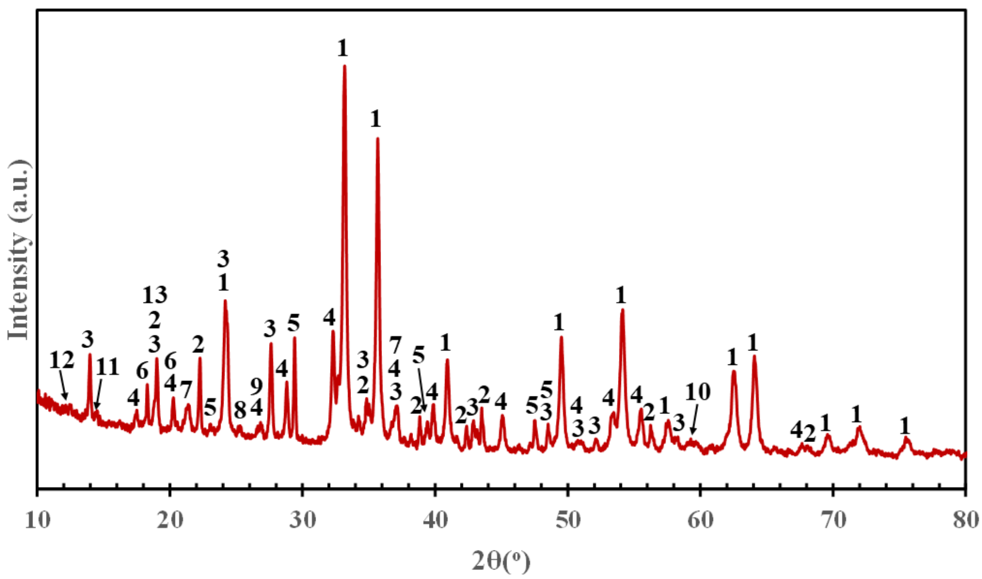
2. Co-Calcination Pilot Trials

2.1 Materials

The materials used in the pilot trials where filterpressed bauxite residue from METLEN's alumina refinery and kaolin clay with ~80 % kaolinite provided by HOLCIM. The chemical composition of both materials is presented in Table 1 (XRF analysis). The XRD patterns of the bauxite residue and kaolin samples are shown in Figures 1 and 2, and their mineralogical compositions are given in Tables 2 and 3 respectively.

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

Material	Al_2O_3 %	Fe_2O_3 %	CaO %	SiO_2 %	TiO_2 %	Na_2O %	LOI %
Bauxite Residue	20.27	40.71	9.17	8.29	5.00	4.00	9.29
Kaolin	36.35	1.07	0.07	47.72	0.45	ND	12.48



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