The use of Dealkalised Bauxite Residue in Cement Applications

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Abstract

The cement industry today is considering the use of alternative supplementary cementitious materials (SCM) in cement formulations to mitigate the environmental burden of cement clinker production. Special focus for development of new SCMs, apart from natural pozzolans and clays, is given to industrial by-products. Bauxite residue (BR) is the main by-product of the alumina industry, for which the use in a cementitious environment is still limited to less than 2% addition in the clinker raw meal. Extensive use of BR in cement either in clinker raw meal or as a SCM is currently impeded due to its high alkaline nature. Thus, dealkalisation of BR increases the potential for valorisation. In the present work, BR dealkalisation is achieved by a hydrothermal process, with calcium hydroxide, in which the insoluble alkalis are converted into soluble ones and removed by water washing. By conducting statistical analysis, the effect of processing time and liquid over solid ratio to sodium removal is underpinned. The dealkalised BR (DBR) produced, free of alkalis, is calcined with pure kaolin at 750 °C to be transformed into a SCM. Acceptable reactivity could be obtained from co-calcined DBR and kaolinite blends when mixed with water, but desirable strength development could not be obtained due to a false flash set that was observed microstructurally, as a result of the formation of some local high strength agglomerates. Along with these local points there were also other zones which were depleted in the necessary elements for producing the cement hydration products, required for defining the strength. Apart from the use of DBR as SCM, based on DBR's chemical and mineralogical characterisation its suitability for direct use in cement clinker production is demonstrated, which is currently limited by the alkali presence.

Keywords: Bauxite residue, Dealkalisation, Supplementary cementitious material, Blended cements, Calcination, Kaolin.

1. Introduction

Bauxite residue (BR) is the alkaline residue resulting from the production of aluminium hydroxide in the Bayer process [1], [2]. The cement industry has the potential to reuse the large amounts of BR that are available. Thus, researchers have explored several valorisation paths, including BR use as a supplementary cementitious material (SCM) [3] . However, the industrial implementation is inhibited mainly due to the high sodium (Na) content and the low reactivity of BR in cementitious environments [4]. A dealkalisation process has been proposed so that BR is transformed into a Na-free solid, the dealkalised BR (DBR), while recovering caustic soda, which could be reintroduced in the Bayer process. BR dealkalisation with lime addition was initially implemented on a laboratory scale back in the 1980s [5] and when it is compared to other methods as sintering [6], pyrolysis [7], calcification-carbonation [8], acid leaching [9], this method has considerable potential to be incorporated on an industrial scale as part of the desilication step in the Bayer process.

The effect of the slurry density, lime addition and processing time is examined on the Na removal. A leaching test on the heavy metals that could be released from the DBR is also performed in order to investigate the potential of DBR incorporation as raw material in clinker production without adverse impact.

However, even if the absence of Na from the DBR inhibits the undesired alkali-silica reaction when it is part of cementitious systems, the reactivity of the DBR still needs to be increased. Further beneficiation techniques to enhance the reactivity of BR have been proposed by researchers that entail the realisation of either pyrometallurgical or hydrometallurgical processes. To the best of our knowledge, DBR has not been processed further to be transformed into a potential reactive precursor for use in blended cements.

Co-calcination of DBR with pure kaolin is performed herein, which is based on the concept described in a study by Peys et al.[10] and can transform DBR into a reactive SCM that increases cement hydration. This paper presents the factors affecting the dealkalisation process, the optimal conditions for the maximum Na removal and the transformation of DBR with kaolin into a potential promising SCM.

2. Materials and Methods

BR samples were obtained from MYTILINEOS S.A., Greece. The chemical composition of the BR was determined with a SPECTRO XEPOS ED-XRF Analyzer, and the major oxides are presented in Table 1. Phase identification of BR was performed with Bruker™ DIFFRAC.EVA software and use of ICDD™ Diffraction databases PDF-4+ και PDF-4 Minerals. Quantitative analysis of the identified phases was performed with the Bruker™ DIFFRAC.TOPAS software and is presented in Table 2.

Table 1. Chemical composition of MYTILINEOS BR, as measured by XRF.

Element (as oxide)	wt%
Fe_2O_3	39.1
Al_2O_3	23.8
SiO_2	7.7
Na_2O	3.4
CaO	8.1
TiO_2	5.0
L.O.I.	10.4

Table 2. Mineralogical composition of the MYTILINEOS BR, as defined by Quantitative XRD.

Mineral phase	wt%
Diaspore	11.6
Anatase	0.3
Quartz	0.9
Gibbsite	7.5
Chamosite	3.2
Calcite	4.4
Perovskite	0.3
Hematite	30.6
Boehmite	2.5

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6. References

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