Large-scale Valorization of Bauxite Residue for Inorganic Polymers

Tobias Hertel¹, Remus Ion Iacobescu², Bart Blanpain³ and Yiannis Pontikes³

1. Research Associate,
2. Senior Researcher,
3. Professor

KU Leuven, Department of Materials Engineering, Leuven, Belgium
Corresponding author: Tobias.Hertel@kuleuven.be

Abstract

A process is suggested in this paper to valorize bauxite residue (BR) on a large-scale. The resulting material is a binder that can be used, depending on its properties, in the production of bricks and tiles, or as an aggregate which can be safely stored in landfills or used in concrete or asphalt. The strategy is to develop a precursor that upon mixing with alkalis will lead to an inorganic polymer. To achieve the above, thermodynamic calculations were carried out. It was found that reducing conditions and additional silica promote the formation of an Fe²⁺-rich liquid phase during heating, which is expected to result in an amorphous phase upon solidification. In practice, this implies minor additions of silica and carbon to the bauxite residue, and firing at temperatures of about 1200 °C to produce a semi-glassy precursor. Experimental work verified the above hypothesis and indeed a highly reactive alkali activated binder was formed. Mixing this binder with “fresh” filter-pressed BR at a ratio 3:7 led to a hard, water-insoluble, reddish composite that can find different applications. An industrial implementation seems to be straightforward since existing installations can be adapted and only minor additions have to be carried out.

Keywords: Bauxite Residue; valorization; inorganic polymer; aggregate; firing.

1. Introduction

Bauxite residue (BR), also referred to as ‘red mud’, is generated during the digestion of bauxite in the Bayer process, exceeding a yearly production of 150 Mt [1]. The global inventory of BR is estimated to be above 2.7 Gt in 2007 [2]. BR is still considered as a problematic waste stream of alumina production, and as a result, one of the potential uses of it entails incorporating it in existing industrial processes. The main driving forces for the valorization of BR are the lack of storage volume in the disposal areas, as well as the long-term liability such storing incurs. The composition of BR with substantial amounts of Fe₂O₃, Al₂O₃, TiO₂ and critical minor elements makes it attractive as a raw material for the recovery of valuable major metals or rare earth elements (like scandium) [3,4] but also in ceramics [5] or in building materials [6].

In addition to the use of BR as source for Al and Fe in ordinary Portland cements (OPC) or in low-energy binders, such as calcium sulfoaluminate (CSA) cements, attempts have been made to valorize BR in inorganic polymers (IP). The strength development of these alternative cementitious binders is based on polymerization reactions in alkaline media [7]. BR has been used in IP binder systems in combination with reactive materials such as metakaolin [8] or ground granulated blast furnace slag (GGBFS) [9]. Generally, an addition of BR to these reactive precursor materials leads to decreasing properties of the binder, with the result that the BR fraction in these binders is kept low to reach satisfying mechanical properties. Chemical and also partially thermal modifications of BR have been carried out by Hairi et al. who transformed it into a reactive material by using raw or tempered (500 °C) BR and mixing it with different additions like amorphous silica fume (6-26 wt%) and alumina (0-20 wt%) [10].