Case Study of a Potential Large-Scale Application for Bauxite Residue in the Composition of Paver Blocks: Evaluations of Producing, Building and Monitoring Performance and Durability

Roberto Cesar de Oliveira Romano[1], Markus Samuel Rebmann[1], Caio Cesar Amorim de Melo[2], Marcelo Montini[3], Raphael Vieira da Costa[4] and Rafael Giuliano Pileggi[5]
1. Researcher
5. Professor
Polytechnic School of the University of São Paulo, São Paulo, Brazil
2. Specialist R&D
3. Senior Chemical Consultant
4. Head of Technology B&A
Norsk Hydro Brazil, Barcarena, Pará, Brazil
Corresponding author: rcorjau@gmail.com

Abstract

The roadmap of the International Aluminium Institute pointed out that one of the most impactful applications for bauxite residue (BR) is in association with Portland cement, during the production of clinker or as a supplementary cementitious material in mortars or concretes. In our previous research, we showed, on a laboratory scale, that it is possible to produce different kinds of cement products and components with BR, like rendering mortar, urban furniture, hydraulic tiles, or concrete for general application. The pursued strategy was to apply BR while reducing the environmental impact (reducing Portland cement content, using a safe but high percentage of BR, producing components with low environmental risks etc.), and cost (no intermediary process or treatment of residues were necessary, like calcination or other thermal treatments). However, scaling-up production may introduce new difficulties, representing a significant challenge. This work was performed with the main purpose of building an area for light traffic with concrete paver blocks produced with Portland cement and bauxite residue. So far, the research has gone through the stages of the concrete composition development (two compositions with BR and one reference concrete), component production in the field in the order of several thousand pieces, preparation of area and installation of the paver blocks, and monitoring of performance of the applied products. Mechanical properties, abrasion resistance and water absorption were some of the properties evaluated over the first year after production. Results allow us to understand the challenges to produce concretes using a waste with many restrictions, the impact on the global CO_2 released, the classification of compositions according to environmental standards, and others. The performance and durability evaluation for one year of the developed components indicate a safe potential large-scale application for BR, but the monitoring continues to be performed for longer periods.

Keywords: Bauxite residue, Portland cement, paver blocks, field application, performance, resistance to abrasion.

1. Introduction

As the world population continues to grow, there is a need to increase and improve the urban infrastructure and the number of houses[1]. Thus, the use of cementitious materials such as concrete and mortar tends to increase worldwide [1,2]. By keeping the current composition dosage strategies and construction practices, an increase in environmental impact is expected. High

[1] www.unhabitat.org

amounts of Portland Cements are currently produced worldwide to feed this production chain, releasing a considerable volume of CO_2 into the atmosphere [2–5].

Therefore, the need to reduce cement consumption has grown, mainly in scientific research. As a replacement, supplementary cementitious materials, reactive or not, has been increasingly sought and studied, but some of them have limited reserves, requiring a continued search for other options [3,4,6–10].

In parallel, the search for large-scale applications for bauxite residue (BR) has been intensified in recent years and the association with Portland cement in such compositions has been shown to be one of the most promising options [11–21].

The presence of aluminium, silicon and iron in high amounts can help in the chemical interaction between BR and cement during the formation of hydrated compounds [12,17,22–24]. However, an observed problem is that BR shows considerable chemical, mineralogical and physical variations between production sites, and a suitable solution for a collected sample may not be adequate for another one [25,26]. A monitoring study carried out by Garcia [27] indicated that the iron content can range from 20 to 60%, aluminium from 10 to 58%, silica from 3 to 65%, and sodium from 0.4 to 15%, reflecting considerable chemical and mineralogical variability.

Furthermore, the cement-BR interaction depends on the type of Portland cement used and its properties. It is not possible to simply develop a mixture without specific technical criteria and evaluations consistent with the type of components and their production process [22]. So, this is a complicating factor for the implementation of this application [13].

In some research, both in literature and websites, extremely high BR levels can be used in cementitious compositions, sometimes exceeding 20% of the concrete volume [11,15–18,20, 24,25,28–30], replacing cement or sand. However, although components were produced with good appearance and some properties suitable for application in different sectors, it was not possible to guarantee that the environmental aspects were safe, mainly due to the lack of control of the chemical fixation of soluble alkalis or due to durability issues, i.e., leaching, efflorescence, alkali-silica reaction, steel bar corrosion and others.

Thus, despite the search for large-scale applications for BR and the reduction in cement consumption being global needs, the interaction between them must be done in a safe and responsible way.

In addition, the proposed solutions must also consider logistical issues, seeking to be adapted to the local market, reducing the need to transport raw materials over long distances, production in regions close to the BR generating plants and consumer markets.

An application with the potential for large-scale use of BR is the production of urban infrastructure components, such as paving blocks. The production of compositions can be made in concrete batching plants and sent to be molded in loco; or a production plant can be built inside or close to the BR generating plant, greatly reducing the need for transportation.

In this sense, this work was carried out with the objective of producing paving blocks and building a test area for light vehicle traffic within Alunorte's plant facilities, to monitor the degradation of the product and the environmental aspects related to leaching of soluble ions into the environment over several years.

During and after the exposure time, some performance parameters were monitored on the exposed concrete blocks and compared to similar unexposed blocks. Both concretes with bauxite residue performed similar to the reference concrete without BR.

Regarding environmental aspects, the binder intensity, CO_2-emission index and water content of the concrete where bauxite residue partially replaced the sand performed similar to the reference composition. However, some improvements were obtained when part of the Portland cement was replaced by bauxite residue allowing ecoefficiency gains.

Monitoring is ongoing and will be conducted for a longer time (several years are planned), also considering aspects related to durability of product and chemical stability. So far, it can be said that the solution adopted in this case study provides a sound option for large-scale application for the bauxite residue with good technical performance and with environmental gains from different points of view.

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6. References

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