The Effects of Bauxite Residue on Mechanical and Architectural Properties of Portland Cement-Based Compositions

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Abstract

One of the most promising large-scale applications of bauxite residue of Bayer process (BR) is its direct addition in concrete composites. Over the past years, efforts have been made towards developing concrete mixtures proportions that fit the purpose to which they are intended for, including cladding, pavers, and monolithic concrete for light and heavy traffic. In addition to the feasibility of mixing and placing these concrete mixtures, i.e., understanding their rheology, it is of primary importance to evaluate their hardened characteristics as a function of BR content. This research comprises the evaluation of six mortar mixtures corresponding to the mortar fraction of the developed concrete mixtures, with partial replacement of sand by BR. The range of sand replacement by BR was based on the volume of cement and varied from 5 to 50 %, while keeping constant the cement content among the mixtures. The mechanical evaluation includes measurements of uniaxial compressive strength and elastic modulus, whereas color and efflorescence were evaluated for architectural purposes. In addition, the effect of BR replacement was evaluated in terms of water absorption by capillary porosity, a parameter that directly affects mass transport and durability of concrete components.

Keywords: Bauxite residue, Color, Mechanical properties, Capillarity and Efflorescence.

1. Introduction

The aluminum industry is actively engaged in exploring options to decrease both the volume of generated bauxite residue (BR) and the associated land area required for its storage. A crucial facilitator of this initiative involves the identification and development of opportunities for value adding uses of BR.

However, even with over 100 years of research, hundreds of publications and more than 3000 patents filed, the reuse of BR remains notably limited, reaching only around 4 % of the total generated volume. This constrained uptake can be attributed to several primary technical obstacles, including the elevated salinity, the occurrence of heavy and alkaline metals, and in certain instances, the presence of radioactive elements within the BR. Also, part of this barrier is the low costs of disposal, which typically ranges from $4 to $12 per ton of residue. However, the global demands of sustainability are increasing the speed for the search for applications that consume a large amount of the waste, aiming to considerably decrease, or even exhaust the entire world generation of BR.

The construction and infrastructure sector hold significant potential for addressing the issue of waste generated from various mining processes [1,2]. Given the increasing attention on sustainable methodologies and environmental awareness, the importance of waste handling and repurposing has grown significantly.

At present, the worldwide production of bauxite residue stands at approximately 160 million tons per year, which constitutes less than 4 % of the total global output of Portland cement, surpassing 4 billion tons annually. This notable contrast underscores the substantial potential for the current Portland cement production to absorb and utilize BR as a supplementary material.

The compatibility between BR and different types of Portland cement, as evidenced by recent literature, is a crucial aspect [2–7]. The high content of aluminum, silicon, and iron in BR makes it suitable for incorporation into cement compositions. These elements are essential constituents of cementitious materials, and their presence in BR suggests that it can serve as a potential raw material for cement production.

Our investigations, conducted over the last 15 years, have demonstrated the technical viability of employing bauxite residue sourced from various locations in Brazil [8–12]. The inclusion of bauxite residue in cement compositions holds the promise of delivering multiple benefits; however, it also holds the potential to compromise certain aspects concerning performance and durability.

Furthermore, according to the report of the Roadmap of International Aluminium Institute [13], the elevated alkali levels in supplementary cementitious materials (SCM) used alongside Portland cement must be carefully managed to prevent the potential for significant efflorescence. Although not intrinsically harmful, the aesthetic implications are deemed unacceptable. Therefore, the consequences of alkali contained in BR must be examined on a case-by-case basis. However, the evaluation of the aspects related to the architectural application of some compositions developed with BR is still poorly investigated [14,15].

So, the main purpose of this work was to evaluate the influence of incorporating varying amounts of bauxite residue (BR) on the mechanical properties as well as the visual architectural attributes of the produced cementitious compositions. Importantly, this evaluation was conducted while maintaining a constant cement consumption throughout the experiments.

2. Materials and Compositions

Bauxite residue (BR) from the Hydro alumina refinery located at Barcarena, state of Pará, Brazil, was used to produce the cementitious compositions. A high clinker content Brazilian Portland cement (CPV), which is equivalent to CEM I according to European standards or Type III in the US Standard, along with quartz sand, was selected for this purpose. This selection was made due to their widespread use in concrete plants situated near the location where the bauxite residue is generated, taking into account the logistical considerations pertinent to this study. As water reducer a midrange plasticizer (Mira Set 63 - GCP Chemicals) was incorporated. The primary physical characteristics of the raw materials are detailed in Table 1 while the chemical composition of both the cement and bauxite residue is provided in Table 2.

The particle size distribution of bauxite residue (BR) is notably broader in comparison to that of Portland cement, characterized by a d_{90} value of approximately 85 μm, while the binder's d_{90} value was around 45 μm. This disparity is attributed to the utilization of BR in its original form, without undergoing any form of treatment such as grinding or sieving, prior to its application. An additional noteworthy aspect pertains to the elevated volumetric surface area (product between specific surface area and specific gravity). The higher this value, the higher the water demand to

6. References

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