Impact of Using Bauxite Residue in Association with Portland Cement during the Early Age of Suspensions

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Abstract

As reported in the roadmap of the International Aluminium Institute the association of bauxite residue (BR) with Portland cement, during the production of clinker or as supplementary cementitious material in compositions of mortar or concrete can be the most impactful applications for this waste. However, while considering the first application it is possible to apply up to 3% of BR replacing the clay in the composition of clinker (without any reduction on the CO2 released during the clinkerization), the use in compositions of mortars or concretes could allow replacing at least 10% of binder. Nevertheless, these values can change a lot in function of the main physical, chemical, and mineralogical properties of BR, and of the level of substitution. In our strategy for the search of a safe large-scale application to BR, we started the research evaluating the impact caused in the hydration reaction of Portland cement, because this is the main indicator of the chemical interaction between them. However, the impact on the workability and hardening of compositions is another aspect to be considered: the increase in the mixing water demand impacts directly on the performance and durability of materials in use. So, the main purpose of this work was to evaluate the impact of using different proportions of BR (from 5 to 40%) during the hardening of the cement compositions, from a combined evaluation of isothermal conduction calorimetry, rotational and oscillatory rheometry. Results indicated that the impact of using the residue collected in Aluminio (state of São Paulo - Brazil), had negligible impact on the chemical reaction, during the flow or even during the hardening of compositions. This information is one of the most important steps to define the BR content that can be applied in compositions with lower impact on the hardened state properties.

Keywords: Bauxite residue, Portland cement, chemical reaction, rheology.

1. Introduction

Bauxite residue (BR), or as commonly also known, red mud, is an insoluble residue from the Bayer process whose was not yet developed any large-scale application. So, it is disposed into the lakes of mud specially built for this purpose [1,2].
As the production of aluminium and alumina are increasing worldwide, its generation is following the same tendency: it is estimated that for each ton of Al is discarded from 1 to 2 tons of BR depended on the chemical characteristics of ore, process of digestion, and the process of disposal (slurry or made by filter press) [1,3].
It is reported by some different researchers [1,2,4–8], that one of the most impactful potential for a large-scale application for this residue is the association with Portland cement in compositions of cementitious components [1,9,10] or even during the production of clinker Portland [10,11].

Cement sector was responsible for the production of more than 3.6 billion tons of the binder in 2012 [12], representing the industrial material most used worldwide. However, during its production can be released up to 1 ton of CO_2 per each 1 ton of cement produced [13]. In this context, BR generated represents around 3-4 % of Portland cement production.

At the same time, cement industry is constantly looking for alternatives to reduce the impact of CO_2 release to the atmosphere, and some strategies reported are: improvements on the kiln efficiency, use of better fuels, application of the concepts of carbon capture and storage, and use of supplementary cementitious materials (SCM) [14]. The RoadMap [15] did by the cement association pointed out a challenge to reduce around 33% of CO_2 up to 2050, indicating that the most significant strategy is the use of SCMs.

By definition, supplementary cementitious materials comprise those that, in the presence of water, because they have calcium in their composition, or react with the calcium released in Portland cement hydration, set and hardens forming hydraulic products, that is, resistant to the action of water [16,17]. This name was extended to all material that, in some way, interferes with the hydration of cement, as is the case of the limestone filler that interacts with C_3A [13,18–21] or another kind of material that could promote the nucleation effect for the grow of hydrated compounds.

Although there are many types of SCMs (slag, silica fume, metakaolin, fly ash etc.), they are scarce resources to attend the demand of the Portland cement production, due to logistic aspects or availability of each material [22].

Additionally, the replacement of Portland cement by different kinds of SCM is not trivial, because they have different physicochemical and mineralogical characteristics, and its association promotes different microstructural development during the hardening, and performance in use [2,13,23]. Figure 1. , adapted from the work of Lothenbach *et al* [13], illustrates a ternary diagram of calcium oxide, silica, and alumina content for the SCM commonly used in the present days. The ratio between these chemical species in the composition of bauxite residue evaluated worldwide was also illustrated, to indicate that if BR will be used as a SCM, can be a product characteristics different from the others [3,24].

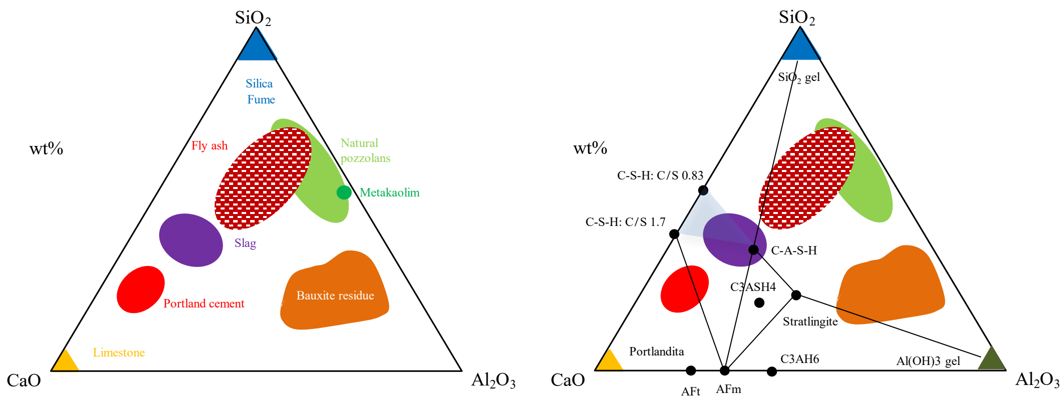

Figure 1. A) CaO–Al2O3–SiO2 ternary diagram of cementitious materials, B) hydrate phases in the CaO–Al2O3–SiO2 system. Adapted of Lothenbach et al [13], using bauxite residue.

Association of any mineral addiction with Portland cement is important have a three characteristics chemical: Calcium, aluminates, and silicates; that in association with Portland cement improve the hydrates formation of thugs. In this case, bauxite residue is rich in aluminates,

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6. References

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