Case Study for the Development of Heavy Traffic Pavement in Concrete with Bauxite Residue

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Abstract

Developing concretes with bauxite residue (BR) seems to be a good alternative for safe large-scale utilization of this waste. We proved in previous works that it is possible to produce products at a lab scale with a controlled performance in the fresh and hardened state, and some durability aspects similar to ordinary supplementary cementitious materials. However, scaling up from the lab to field is not trivial and sometimes many changes need to be implemented to adapt the process. This was the main purpose of this work. After the development of concretes on a lab scale for the production of paving blocks and monolithic components, a pilot area of approximately 250 m^2 was built using pavement for heavy traffic to monitor performance and durability over time. During the development at small scale, compositions were developed to achieve good flowability and pumpability, characteristic compressive strength higher than 50 MPa for the paving blocks, and flexure strength higher than 4.5 MPa for monolithic production. To scale up, concrete materials were produced at third party concrete plant site for the production of the paving blocks or monolithic material. The paving blocks were produced and kept in storage for a period of 28 days to allow curing of the concrete. A monolithic concrete area was also built on a compacted base and sub-base foundation including steel-bar reinforcement. Results showed that during the production in the field monitoring and adjustments were required during the mixing of concrete to maintain its workability. Careful control of the moisture of all raw materials and dose rate of each were the main challenges. With this control, the production went better than expected as the rheological properties of concretes helped the production of the concrete material. Some opportunities to improve further future production of concrete with BR were also identified.

Keywords: Bauxite residue, Portland cement, Large-scale application, Pavement, Case study.

1. Introduction

The search for applications to reuse bauxite residue is no longer a novelty and the efforts made by universities and industries have been significant. This search has increasingly narrowed the partnerships between Research Centers and Companies that generate the residue.

The main applications evaluated, presently, for BR include synthesis of zeolites, landfill capping, element recovery (like heavy metals, rare earth elements, and other minerals), soil amelioration, production of Portland cement clinker, manufacture of concretes and cementitious components, sub-base and sub-grade for road construction, geopolymers, water treatment, red ceramics, selective filters, and many others [1–14,17–21,24,28,29].

However, the high alkalinity and salinity, the presence of heavy metals, and the great variability of physicochemical and mineralogical properties from site to site are all challenges to the reuse of BR. This is the main reason why less than 4 Mt of the 140 Mt of BR produced annually is utilized [12].

Evans [12], discussing the history, challenges, and new developments in the management and use of bauxite residue concluded that the most successful large-scale uses include applications in cement production, and manufacturing of cement components, like concretes and mortars.

It was also proven in other works that BR has the potential to be used as a supplementary cementitious material (SCM) [15,16,20,22,23,25,27] as it can be a source of Ca, Al, and Si and has a good interaction with the binder. However, it is not yet commonly used in association with Portland cement because some aspects related to leaching and durability need to be better understood.

Another challenge is scaling up from laboratory development to practice in the field: many prototypes and processes developed on a small scale are not viable to be produced on large scale, due to their complexity, embedded costs, or even logistic issues.

In this present work, we carried out a case study to build a concrete (including BR) pavement for heavy vehicle traffic in a truck car park. Two construction techniques were chosen to show the flexibility to achieve the same goal with different concrete solutions: i. construction using paving blocks and, ii. using monolithic concrete. The project was implemented in sequence: the concrete compositions was developed at the lab scale, monitoring and control of the mixing properties was carried out at the concrete plant, production of paving blocks in the field and building the pavement. Finally, a post-installation monitoring of the degradation in use under natural exposure was done and it is planned to monitor the performance for another 2 years.

This strategy was chosen to show that it is possible to scale up the production of cementitious materials using a high amount of bauxite residue and to develop production techniques using existing plant and methods from the civil construction industry.

2. Case Study Area Preparation

The case study aimed to evaluate the use of BR in concrete using two different technologies: (1) jointed plain reinforced pavement, also called monolithic concrete; (2) interlocking concrete block pavement. A section of a parking lot for heavy-duty trucks was renovated, replacing the old floor with pavements using these two solutions.

The chosen area is located in the CBA truck parking lot (23°31'59.6"S 47°15'27.3"W), in the city of Alumínio, state of São Paulo/Brazil. Figure 1 shows how the area was divided between paving blocks (128.2 m²) and jointed plain reinforced pavement (123.6 m²). In this last application, five slabs (M1 to M5) of about 25 m² each, were built. The prepared area, with steel mesh reinforcement and joints with load transfer steel bars (dowels), is illustrated in Figure 2.

7. References

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