Application of Synthetic Aggregate from Bauxite Residue in Structural Elements

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Abstract

Synthetic aggregate has been used successfully in various fields of the construction industry. Because it is a manufactured product, its properties can be suitably modified depending on the intended applications. In this work, bauxite residue, clay, and silica were used to produce synthetic aggregate, whose specimens were made in different proportions of these raw materials and sintered at 1200 ºC. Leaching and chloride penetration tests were performed, to predict the behavior of the aggregates when submitted to natural conditions. The synthetic aggregates were applied in beams and slabs, where results indicated that the process performed and the products obtained are acceptable by the technical criteria for application in the construction industry, besides presenting a high capacity for the reuse of bauxite residue.

Keywords: Bauxite residue, Synthetic aggregate, Construction industry, Beam, Slab.

1. Introduction

The accelerated growth of the construction industry has resulted in a significant shortage of raw materials for the production of concrete, such as natural aggregates. The main sources of aggregates used come from rivers, seas, deserts, and industrialized sand. River sand or pebbles, for example, are used in construction but are becoming scarce worldwide due to depletion and environmental constraints [1].

The main component of concrete is inert aggregate, which is held together by cement. Aggregates can be composed of a wide variety of materials and are classified as coarse or fine [2]. The concrete mix is composed of 70 to 80 % volume of fine and coarse aggregates, which results in a constant decrease of natural sources due to the large amount used [3].

Synthetic aggregate is an alternative to natural aggregate, and the main type produced is lightweight expanded clay, which is mostly made up of silica (SO_2) in the morphological form of α-quartz; magnesium silicate ($Mg(SiO_4)$) and magnesium aluminum oxide ($MgAl_2O_4$) in spinel form [4]. In the production of the aggregate, different types of industrial and mineral waste can be used, such as gold mining tailings and limestone waste [5], bauxite waste and acid-leaching tailings [6], bauxite residue, fly ash and sodium silicate solution [1], among others.

This aggregate is among the materials commonly applied in engineering projects in countries such as Norway, Russia, Germany, Italy, Denmark, Switzerland, Finland, Portugal, United Kingdom, Iran, and India [7]. The production of this aggregate is done by heating clay in rotary kilns. During the production process, clay expansion results in grains with a heterogeneous structure composed of a rigid outer shell and a highly porous core, giving the material its characteristic lightness [8].

Due to the manufactured nature of the product, its characteristics, including grain weight density, diameter, and thickness, may vary depending on the desired specifications for the material's end use. In the construction industry, its main applications include its use as a lightweight filler in geotechnical works and in the production of lightweight concrete [8].

Synthetic aggregates are produced from clay or waste by-products, resulting in a product with a specific weight lower than that of crushed stone and with high water absorption. The sintering process is generally carried out between 1100 and 1350 ºC. The raw materials used are classified into three groups: natural, miscellaneous waste, or a combination of residues and natural raw materials with additives [9].

Synthetic aggregates have attracted considerable attention due to their diversity, which enables the beneficial use of these materials for various applications [3]. Synthetic aggregates uses can not only delay the extraction of natural aggregates but also minimize environmental pollution. Thus, the use of industrial solid waste in the production of these materials represents an effective strategy to reduce the consumption of non-renewable resources [10].

Bauxite residue (BR) is generated from the Bayer process (alumina production). This residue has a complex chemical and mineralogical composition, which depends on the origin of the bauxite ore and operating conditions during the Bayer process [11]. Due to the different oxides present in its composition [12,13], BR can be an important raw material for the production of synthetic aggregates [2]. In this context, the present work aims to carry out the production of synthetic aggregates with bauxite residue, clay, and silica for application in beams and slabs.

2. Materials and Methods

Bauxite residue, clay, and silica were dried in an oven at a temperature of 105 ºC for 24 h. Subsequently, the materials underwent comminution in a ball mill, as shown in Figure 1.

The drying and comminution processes aimed to adjust the humidity and granulometry of the raw materials, respectively. The clay in the production of synthetic aggregate aimed to greater plasticity to the mixture, keeping the material cohesive. While silica was used to promote better formation of mullite and the glassy phase, according to research published in the literature [14-16]. The production stage, as well as the use of raw materials, was based on a previous study in which the authors evaluated the chemical, mineralogical and mechanical characteristics of the synthetic aggregate using bauxite residue [17].

Figure 6. Puncture resistance test.

4. Conclusions

The results of the leaching tests indicated that the concentration of sodium in the leached extract of the synthetic aggregate is low, with values lower than those established by the standard. Furthermore, the results of chloride penetration tests in concrete produced with synthetic aggregate were similar to those obtained with conventional concrete.

Tests on beams with friezes at 30° and 45° showed that the synthetic aggregate performed better than conventional concrete in terms of strength and cracking, while on beams with crimps at 45°, conventional concrete was superior. The results of the structural tests on slabs were satisfactory and in compliance with the standards.

The application of synthetic aggregate from bauxite residue in structural elements has shown promising results, reinforcing the potential of this material as a reliable and efficient alternative for use in various concrete structures. This innovation enables the responsible use of industrial waste in civil construction, contributing to the preservation of the environment and the development of more efficient and durable materials.

5. References

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