The use of sugarcane bagasse ashes (sba) in the confection of concrete’s traces and precast, replacing and adding to cement

O uso de cinzas do bagaço da cana-de-açúcar (CBC) na confecção de traços e pré-moldados de concreto, em substituição e adição ao cimento

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RESUMO

O concreto é um dos materiais da construção mais utilizados no mundo, tendo o cimento um dos seus principais ingredientes. A incorporação da Cinza do Bagaço da Cana-de-açúcar (CBC) na produção do concreto pode apresentar soluções para o aproveitamento do subproduto agroindustrial e minimizar impactos ambientais advindos da retirada de calcário na produção do cimento, além de contribuir para redução da emissão de gás carbônico e preservar jazidas naturais produção do cimento. Este estudo teve como objetivo utilizar a CBC na adição e substituição parcial do cimento na produção de concreto. Os corpos de prova (TBs) foram fabricados seguindo as NBRs 7223 e 5738, em que se adotou uma relação: (1:1,98:3,23:0,61) como proposta primária (T1) e foram realizadas a substituição (T2) e adição (T3) em massa de 5% do cimento Portland. Os rompimentos dos corpos de prova foram efetuados pelo ensaio de resistência à compressão de corpos de prova cilíndricos de concreto aos 7, 14, 21 e 28 dias de idade, após a retificação. Os resultados obtidos demonstram ser viável o uso de CBC, desde que a relação água/cimento e a quantidade em massa a ser substituída ou adicionadas sejam adequadas, pois tanto na adição, quanto na substituição de 5% de cimento por CBA, obteve-se um ganho de resistência do concreto.

Palavras-chave: Cinza; bagaço de cana-de-açúcar; construção civil; Concreto; Resistência à compressão;
ABSTRACT

Concrete is one of the most used construction materials in the world, with cement being one of its main ingredients. The incorporation of Sugarcane Bagasse Ash (SBC) in the production of concrete can present solutions for the use of this agro-industrial by-product and minimize environmental impacts arising from the removal of limestone in the production of cement, in addition to contributing to the reduction of emission of carbon dioxide and preserve natural deposits for cement production. This study aimed to use sugarcane bagasse ash in the addition and partial replacement of cement in the production of concrete. The specimens (TBs) were manufactured following the NBRs 7223 and 5738, in which a ratio was adopted: (1:1.98:3.23:0.61) as primary proposal (T1), and the replacement (T2) and addition (T3) of 5% of Portland cement by mass was performed. The ruptures of the specimens were performed by the compressive strength test of concrete cylindrical specimens at 7, 14, 21 and 28 days of age, after rectification. The results obtained show that it is feasible to use SBA, since the water/cement ratio and the percentage of mass to be replaced or added are appropriate, because both in the addition and the replacement of 5% cement by SBA obtained a gain in strength of concrete.

Keywords: Ash; Sugarcane bagasse; Construction; Concrete; Compressive strength.
INTRODUCTION

The inputs used in the construction industry are classified as raw materials with high amounts of incorporated carbon, which means that they release large volumes of greenhouse gases into the atmosphere in the production process (Tran et al., 2018). Linked to this, there are advances in technology, growth and development of the world population, which contributes to the increased demand for construction processes, the scarcity of natural resources and the need for large amounts of energy for the extraction and processing of raw materials (Moura et al., 2021). Such factors generate environmental and economic concerns, as they influence climate change and increase the cost of construction materials, requiring the search for alternative materials and sustainable construction techniques for this industry (Danso et al., 2015).

Cement-based composites are the most used materials in civil engineering structures (Amiri et al., 2021; Ibrahim, 2021). This is due to several factors such as ease of acquisition, water resistance, thermal resistance and adaptability to different sizes and shapes (Khan et al., 2022; Manjunatha et al., 2021). However, the manufacture of cement contributes significantly to the emission of greenhouse gases (Bayasi and Zhou, 1993), with estimated values around 1,350 million tons per year, mainly carbon dioxide (CO2) (Ahmad et al., 2021).

One way to reduce the environmental impacts arising from the use of cement is to partially replace it with alternative cementitious materials, such as the ash produced by the sugar and alcohol industry, which can produce approximately 25 kg of residue for each ton of bagasse burned (Paul et al., 2019). This material, not only has sustainable characteristics, but also is rich in silica (SO2), with mass values above 60% and, depending on its pozzolanic activity, can improve the strength and durability of concrete (Sampaio et al., 2014).

The amorphous silica and alumina content present in the ash residue makes it an excellent substitute for cement in concrete (Inbasekar et al., 2016). Thus, when burning conditions are controlled at a temperature between 600ºC and 800ºC, it is possible to obtain SO2 in its amorphous state, an essential characteristic for its use as a pozzolanic material (Kantiranis, 2004). The amount of SO2 in ash changes depending on a variety of factors, including burning method and temperature, the type of soil used to grow the sugarcane, and the properties of the raw material (Kumari and Kumar, 2015).
Due to the need for correct disposal of this residue and to minimize the environmental impacts arising from the incorrect disposal of SBA and cement production, this study aimed to analyze the effects of adding and replacing sugarcane bagasse ash on the resistance to concrete compression.

MATERIALS AND METHODS

Preparation of test specimens

This study is characterized as experimental research, due to the fact that some variables related to the object of study were manipulated in order to find the best result for the strength of concrete (Fonseca, 2002; Silveira; Córdova, 2009). Thus, a literature review was carried out to define the dosage of concrete mixtures, since, according to Silva et al. (2021), this definition constitutes a necessary procedure to obtain the best mix between the materials that are part of the concrete.

The ideal proportion of materials that make up the concrete traces was in the following order: (cement/sand/gravel/water). Through studies for the manufacture of conventional mass concrete, with resistance of 20 MPa (Kgf/cm²) after 28 days of curing, the ratio: (1:1.98:3.23:0.61) was adopted as primary proposal, whose basic composition was multiplied to meet the quantity demanded in all conditions, with expected break-up ages of 7, 14, 21 and 28 days.

This experimental planning took place in the subdivision of three distinct traces, namely, (T1) was used as a reference and in T2 and T3 the replacement and addition, respectively, of cement by SBA in 5% mass percentage. The specimens (TBs) were manufactured following NBR 7223, using fine and coarse aggregates, Portland cement (TBIII) and sugar cane bagasse ash (SBA). The SBA came from the burning of sugarcane bagasse to generate electricity in the production of ethanol at the Serra dos Aimorés Alcohol Distillery (DASA), located on BR-418, nº 333 between the municipalities of Nanuque and Serra dos Aimorés - MG, the cement used was from the altos-fornos Cauê TB III 40 RS brand, and the other items were donated by the MIX Mattar concrete factory.

In addition, the constituents were weighed on a digital scale and the mixture was made with the aid of a concrete mixer. Then, the concrete was inserted into metallic cylindrical molds with dimensions of 10 cm in diameter and 20 mm in height, being arranged in two layers with manual recessing of 12 strokes in each one of them using a compaction rod, which had the objective of reducing to the maximum its porosity and
taking care that it does not suffer segregation, according to the recommendations of NBR 5738, NBR 10342 and NBR 7223.

The grinding of the specimen was performed in accordance with NBR 5738, with a Stuhlert grinding machine, removing 0.1 mm of the outer layer of the material. Thus, the removal occurred in 0.05 mm at each end (top and base), enabling geometric control and providing the specimen a smooth surface to obtain greater precision in the results.

After that, the resistance to simple compression was determined by the recommendations of NBR 5739, where the TBs were broken, using a digital electric press, Solocap brand, with a maximum load of 1000KN. Then, the strength of each TB was calculated at 7, 14, 21 and 28 days of cure, according to equation 1.

\[
\frac{f_{ck} \, (K\text{N})}{Acp} = \frac{f_{ck} \, (M\text{p}a)}{9.81} \times 100 \quad Eq. \, 1
\]

Where:
fck: Characteristic strength of concrete
ACP: Specimen area.

In the static analysis of the results, the Software Graph Pad Prism was used, and the normality of the data was verified by the Shapiro Wilk test. In addition, the ANOVA test and Tukey's multiple comparison were applied to verify the statistical correlation between the strength of concrete mixes (T1, T2, T3) and Student's t test in the static study of the SLUMP Test

RESULTS AND DISCUSSION

To verify the possibility of using SBA in substitution or addition to Portland cement, the compressive strength test and SLUMP test of the concrete specimens was carried out, containing 5% SBA replacement for the T2 trace and addition of 5% SBA for T3, as shown in Table 1

<table>
<thead>
<tr>
<th>Trait</th>
<th>% ashes</th>
<th>Average resistance of specimens (MPa)</th>
<th>Slump Test(cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>7 days</td>
<td>14 days</td>
</tr>
<tr>
<td>T1</td>
<td>0</td>
<td>14.78±0.65</td>
<td>16.02±0.14</td>
</tr>
<tr>
<td>T2</td>
<td>5</td>
<td>14.59±0.19</td>
<td>16.05±0.06</td>
</tr>
<tr>
<td>T3</td>
<td>5</td>
<td>15.54±0.43</td>
<td>17.02±0.23</td>
</tr>
</tbody>
</table>

Source: Authors (2023)
The workability of the concrete was analyzed using the Slump Test, which together with the resistance results show good quality, with no static difference being verified when compared with T1, both in the replacement and in the addition of SBA. The maximum strength of concrete is related to an adequate degree of workability due to the self-compacting capacity. Thus, the higher the measured slump height, the better the workability, indicating that the concrete flows easily but at the same time is free from segregation (Srinivasan and Sathiya, 2010).

Analysis of variance (ANOVA) applied to the compressive strength data showed, at a 5% probability level by Tukey’s multiple comparison test, that there was no significant difference between the strength of the 3 traits for failure in 7 and 21 days, and on the 14th day there was also no difference in T1 vs. T2. However, it was verified that at 14 days (T1 vs. T3; T2 vs. T3) and at 28 days, the compressive strength of the specimens had a statistical difference, indicating an increase in strength. Figure 1 shows graphs referring to the average compressive strength of concrete.

**Figure 1** – Average strength of concrete to axial compression at 7, 14, 21 and 28 days

Source: Authors (2023)
In Figure 02, the coherence of the evolution curves of the compressive strength of the specimens of the different composites studied can be observed, making it possible to verify the increase in resistance at different ages of failure for all the traces studied.

**Figure 1** – Representation of the curves of evolution of the compressive strength of the specimens

Source: Authors (2023)

Statistical analysis showed a better performance for the traces with addition and replacement of cement by ash, this is due to the physical and chemical effects in the preparation of the concrete. As stated by Cordeiro et al. (2008) in their study, the physical effects are related to the packaging characteristics of the mixture, which depend on the size, shape and texture of the SBA particles used in the composition of the mixes. The chemical effects are linked to the presence of siliceous/aluminous compounds that chemically react with calcium hydroxide in the presence of water.

Regarding the compressive strength values for the trace that was replaced and the trace that was made with the addition of ashes, it was verified through the statistical analysis that there was an increase when compared with the T1 pattern. These values may indicate high levels of silica (SiO$_2$) present in the ash composition, which contributes to a better pozzolanic activity of the material (Paula et al., 2009). Amorphous silica reacts with calcium hydroxide present in hydrated cement and forms hydrated calcium silicate, which is responsible for the strength of concrete (QI et al., 2009).

The replacement of cement by ash provides an increase in the compressive strength values of conventional concrete, especially at more advanced ages, a fact that
suggests pozzolanic reactions of the material used, as described in the study by Cordeiro et al., (2021).

The Trace T3, in which only SBA was added, obtained better compressive strength when compared to the standard and T2. In this way, Castro and Martins (2016) states that the addition of SBA to concrete has as some of its physical effects the microfiler effect: refinement of the pore structure and refinement of the hydration products of the cement; alteration of the microstructure, which results in a better performance of the concrete in terms of mechanical resistance and durability

CONCLUSION

The use of sugarcane bagasse ash as an aggregate in the production of concrete has shown to be a promising way of using this type of residue, as it allows it to be disposed of correctly and, at the same time, reduces the environmental impacts of the production of cement. For this study, it was possible to note that both in the addition and in the replacement of 5% of cement by SBA, a gain in resistance was obtained in the concrete, which can be considered positive, due to the fact that the addition/replacement of the residue did not negatively affect the trace, indicating a pozzolanic activity in the ash used. One of the limitations of this study was the lack of chemical characterization of the SBA and the need for more tests for concrete analysis. Thus, it is suggested that in future works, the analysis of the characterization of the residue and the analysis of the final concrete need to be done, and new percentages need to be tested.
REFERÊNCIAS


