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Special edition

Utilization of agate powder residue for manufacturing ecological bricks

Utilização de resíduo de pó de ágata para confecção de tijolos ecológicos

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ABSTRACT

In recent years, it has become increasingly important to search for alternatives for the development of new materials with sustainable characteristics. This is due to the fact that the environmental problems faced by the whole world have become increasingly worrying due to their serious short and long term impacts. In view of this, the use of materials from reuse and the disposal of polluting waste shows itself as an excellent alternative for the development of new products. Considering the mineral sector as a major generator of solid waste, this study proposed the reuse of agate powder, a residue from the extraction and processing process of agate stone, for the manufacture of ecological bricks. Mechanical compression tests were performed on bricks with 7, 14, 21 and 28 days, thus obtaining a mechanical strength profile. The results obtained were compared with those proposed by NBR 8491 (2012), which proved very promising, being above the values proposed by the standard in all cases.

Keywords: Ecological bricks; Sustainability; Agate; Waste

RESUMO

Nos últimos anos, mostra-se cada vez mais importante a busca de alternativas para o desenvolvimento de novos materiais com características sustentáveis. Isso se deve ao fato de que os problemas ambientais enfrentados por todo o mundo têm se tornado cada vez mais preocupantes devido aos seus graves impactos a curto e longo prazo. Tendo isso em vista, a utilização de materiais provenientes de reutilização e a destinação de resíduos poluentes se mostra como uma excelente alternativa para o desenvolvimento de novos produtos. Considerando o setor mineral como um grande gerador de resíduos sólidos, o presente estudo propôs a reutilização do pó de ágata, resíduo proveniente do processo de extração e beneficiamento da pedra ágata, para a confecção de tijolos ecológicos. Foram realizados testes de compressão mecânica em tijolos com 7, 14, 21 e 28 dias, obtendo assim um perfil de resistência mecânica. Os resultados obtidos foram comparados com os propostos pela NBR 8491 (2012), mostrando-se muito promissores, ficando em todos os casos acima dos valores propostos pela norma.

Palavras-chave: Tijolo ecológico; Sustentabilidade; Ágata; Resíduo

1 INTRODUCTION

The mining sector is responsible for the generation of large amounts of solid waste.

> The mining enterprises can be characterized by the simultaneous and/or sequential execution of potentially polluting activities, and the several operations performed in mining generate different types and volumes of waste, which must be adequately handled and properly destined. (Brasil, 2021)

Regarding waste generation, in Brazil there is the National Solid Waste Policy (Brasil, 2010), which brings a series of requirements that must be taken by generating companies involved in the entire waste generation cycle" (França Neta *et al*., 2021, p. 1136). Since the mining industry is a solid waste generating sector, there are still many advances to be made when it comes to the proper disposal of its surplus material.

Considering that mineral wastes are disposed of in many locations without any control, they become highly polluting by degrading water and soil, creating environmental problems.

"The state of Rio Grande do Sul is one of the most important in the country when it comes to stones, gems and jewelry" (Costa; Jornada, 2015, p. 4), having a very significant volume of waste generated by the processing of a specific stone, agate. "Agate is classified as a variety of microcrystalline silica, which occurs in cretaceous volcanic rocks" (Betat, 2006).

> The mining and gemological tradition of agate in Rio Grande do Sulcan be traced in two regions, the Mining District of Ametista do Sul (DMAS), located in the north-central region, and the Mining District of Salto do Jacuí (DMSJ), in the central region of the state. The southwestern border of Rio Grande do Sul has also been growing in agate production and commercialization. (Michelin *et al*., 2021, p. 356)

"In the processing of precious stones such as agate, in Rio Grande do Sul, the waste generated requires a direction for the accumulated waste from the process, which today is deposited in company yards." (Betat, 2006).

The waste generated in agate mining comes mainly from the processing of the stone, which is polished, cut and sanded. This processing generates a large accumulation of agate dust, in addition to the more robust waste from the extraction process itself.

"Agate powder is composed of approximately 98% finely comminuted with 95% below 74 µm" (Silva; Schneider, 2015, p. 13).

Considering the scenario of the agate extraction industry, the importance of disposing of this solid waste for useful purposes is evident. This will solve the problem of agate powder accumulation in the environment and will start the development of a new sustainable material from reuse.

In the environmental context in that we live, it becomes very important to develop alternatives in order to reuse waste and create materials that cause less impact on the environment when discarded. This is largely due to the various environmental problems that these accumulations can create.

> In 2019, atmospheric carbon dioxide () concentrations were higher than at any time in at least 2 million years, and methane ()) and nitrous oxide () concentrations were higher than at any time in at least 800,000 years. (IPCC, 2021, p. 68).

The point is that, different from what we often think, pollutants are not only generated by means of transportation or industries, but also by the waste discarded by different productive sectors.

When it comes to sustainable materials, the ecological brick is currently highlighted in the civil construction area. This brick is currently regulated by NBR 8491: Brick of soil-cement requirements (Associação brasileira de normas técnicas, 2012).

According to this norm, "the solid brick of cement soil is constituted by a homogeneous, compacted and hardened mixture of soil (which should not have harmful organic matter levels), Portland cement, water and, eventually, additives". (Ibidem, p. 1).

They can be classified as type I and II, with dimensions of (20 x 9.5 x 5) cm and (23 x 11 x 5) cm, respectively (length, width and height).

This class of bricks is considered ecological mainly because of the exemption of burning in the drying process, but the use of different types of soil also benefits its sustainable character.

The ecological brick presents itself as a great alternative for reusing the agate powder residue, mainly because of the high silica content that is presented in this material. This is because silica has proven to be an interesting material to be used with concrete.

> Silica-rich materials can be used as substitutes for traditional stabilizers such as cement and lime because of their high pozzolanic content. In general, pozzolanic reactions save energy and reduce pollution during the production of lime, cement and concrete, increasing the durability of these materials (Moayedi *et al*., 2019)

The pozzolan generally acts in concrete and mortar complementing the mixtures, "contributing to the increase in mechanical resistance by the physical filler effect (filling of empty spaces by the fine particles and consequent improvement in the density of the mixture), or even, by the presence of its active phases". (Baldin; Pereira Filho; Baldin, 2021). "The partial replacement of cement by a pozzolanic material makes the concrete less susceptible to cracking (related to shrinkage) and also ensures a more resistant and durable transition zone" (Mehtra; Folliard, 1992).

This pozzolanic effect refers basically to the material's ability to react with calcium hydroxide, a component generated by mixing cement and water in the mortar manufacturing process.

The effects caused by a pozzolanic material in concrete become interesting because the mechanical strength is the main characteristic to evaluate the practical application for bricks. Thus, according to NBR 8491 (Associação brasileira de normas técnicas, 2012) the sample of ecologic brick tested in compression test should present average values of compressive strength equal to or greater than 2 MPa and should not present individual value less than 1.7 MPa, with minimum age of 7 days.

Thus, it is noted the possibility of developing a new class of ecological bricks through the use of waste in its composition.

The insertion of agate powder in the mortar of the ecological brick not only benefits the improvement of mechanical characteristics of the brick, but also ensures the product a new sustainable characteristic, through the use of a reuse component in its manufacture.

Thus, seeking to dispose of the waste agate powder and develop a new sustainable material, this study will propose the possibility of producing an ecological brick based on waste.

With this, the main objective of the research will be to evaluate the feasibility of the proposed product through the evaluation of its mechanical strength characteristics.

2 METHODOLOGY

The first stage of the methodology was based on a bibliographic research of the theme, aiming at the possibilities of using the available residue and, later, of its possible practical application.

Through studies of agate powder and the emphasis on its pozzolanic characteristic, due to the high silica content, the viability of its use in the area of civil construction was highlighted, considering the important improvement of mechanical characteristics that materials rich in silica cause in cementitious materials.

With this, the interest in developing a material with a sustainable focus was also taken into account, since the beginning of the study was based on the reuse and adequate destination of a residue discarded in large quantities in the research region.

Considering the civil construction sector, the ecological brick has stood out within the context of reuse and sustainability, a product that already has environmentally friendly characteristics and allows the combination of agate powder with cement for its confection.

Figure 1 – Agate powder

Source: Authors (2023)

After defining the material to be developed using the agate powder residue, the method to be followed was then defined in order to enable the production of the new proposed material.

In Figure 1 it is possible to see the appearance of the residue used in the study.

Given the main interest of developing a material as sustainable as possible, it was defined that the composition of the ecological brick would have only 3 components, not using for its manufacture any aggregate other than the agate waste. Thus, the defined composition counted only with cement, agate powder and water.

In order to perform subsequent compression tests, the bricks were initially produced in the format of cylindrical samples to suit the test format standardized by NBR 5739 (Associação brasileira de normas técnicas, 2018), which defines the parameters for compression tests on ecological bricks.

According to NBR 5739 (Associação brasileira de normas técnicas, 2018), cylindrical samples for compression tests should have a diameter between 5 cm, 10 cm, 15 cm, 20 cm, 25 cm, 30 cm or 45 cm and the height of the specimens should have twice their diameter. In this study, the molds used were 5 cm in diameter and 10 cm in height, as shown in Figure 2.

Figure 2 – Cylindrical mold

Source: Authors (2023)

To define the proportions, considering an initial evaluation, it was decided to use a 1:1 mixture for the solid waste. Therefore, the final composition had the same amount of waste and cement. The cement used was CPII -F32, Votoran all works.

Considering the dimensions of the mold, 100 grams of cement and 100 grams of agate powder were used to make the samples. The water was added to the mixture little by little, in order to obtain a homogeneous mixture.

The mixing of the components was done manually and the drying, following the standard for ecological bricks, was done naturally, without the use of equipment.

Following the recommendations of NBR 5739 (Associação brasileira de normas técnicas, 2018), the molds and their bases were internally coated with a thin layer of

Singer® lubricating oil with ASTM D 287 density: from 0.850 to 0.860 g/cm³.

Aiming to analyze the mechanical capacity of the developed brick, compression tests were performed on the specimens produced in 4 different drying times in order to evaluate their mechanical strengths.

The drying times considered for the analysis were 7, 14, 21 and 28 days, and a total of 4 compression tests were performed, obtaining a resistance profile over time.

The compression tests were performed according to NBR 8492 (Associação brasileira de normas técnicas, 2012), which defines that the machine used must be equipped with two steel support plates that act on the upper face of the sample, in addition to ensuring uniform distribution of stresses to the sample and be able to transmit the load progressively and without shocks.

The sample to be tested should have flat faces so that there is perfect contact between the surfaces. The sample should be placed directly on the bottom plate of the testing machine and the load applied at a uniform rate of 500 N/s (500 kgf/s). After starting the test, the load should be gradually increased until the sample ruptures.

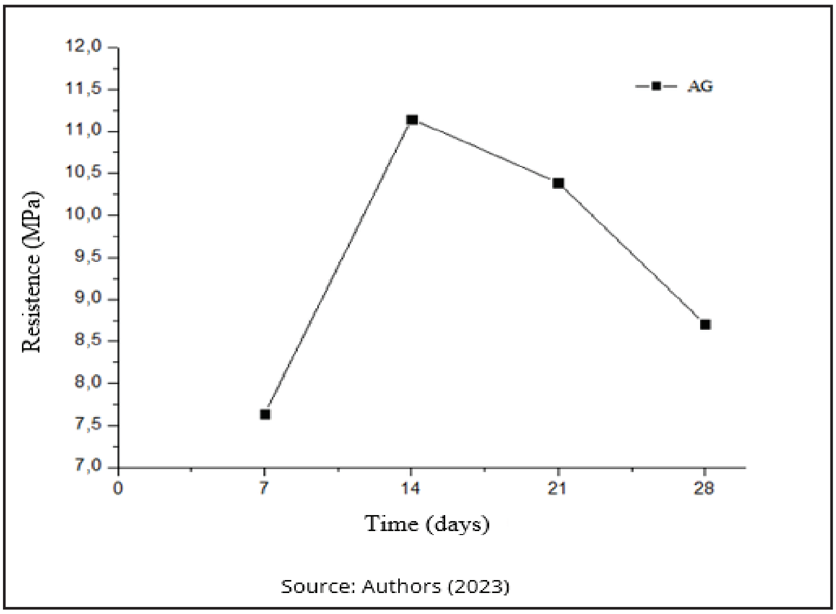
The individual compressive strength values obtained by means of the test, expressed in megapascals (MPa). The compression tests for this analysis were performed using the Alfred J. Amsler& Co. Figure 3 shows the physical aspect of the sample

Figure 3 – Cylindrical sample

Source: Authors (2023)

For the development of the study, 4 ecological agate powder bricks were made in the format of cylindrical samples. Each sample corresponded to a different curing time, and compression tests were performed on samples with curing times of 7, 14, 21 and 28 days.

Figure 4 – Resistence of agate powder brics



Source: Authors (2023)

After the compression tests, it was possible to obtain the strength profile of the brick over the maturation time, a behavior that can be seen in figure 4, where AG corresponds to agate.

In the image it is observed that the agate powder brick presented an increase in resistance in the period from 7 to 14 days of aging. However, after 21 days there was a decrease in resistance, a decrease that was also observed in the period between 21 and 28 days.

Below, in Table 1, are the strength values obtained for each aging time.

Table 1 – Mechanical resistances in MPa

7 days	**14 days**	**21 days**	**28 days**
7,64	11,15	10,39	8,71

Source: Authors (2023)

The NBR 8491 (Associação Brasileira de Normas Técnicas, 2012) defines that the individual values of compressive strength for ecological bricks should be equal to or greater than 1.7 MPa, with a minimum age of 7 days. Analyzing the individual results of compressive strength obtained in the tests, we see that all samples presented values well above the values defined by the standard. The highest resistance value occurred in the 14 day aging period.

3 FINAL CONSIDERANTIONS

The development of ecological brick composed of concrete and agate powder proved to be feasible both considering its physical characteristics such as appearance and homogeneity, and with respect to its mechanical characteristics.

The physical aspect of all samples was very satisfactory, showing structural consistency and usability of the developed product.

When dealing with the mechanical characteristics, the main point to be analyzed, it can be observed that all strength values obtained were well above those proposed by NBR 8491 (Associação brasileira de normas técnicas, 2012) for ecological bricks, proving the great potential of this composition for practical applications.

Considering the obtained results, it is possible to see the feasibility of the agatepowder ecological brick, showing that the reuse of this waste enables not only the development of a new class of ecological bricks, but also an extremely useful destination for a waste until then without proper purpose.

The production of ecological bricks composed of elements from reuse also ensures the product a more sustainable character, due to its composition and its subsequent disposal, which will causeless damage to the environment.

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