Influence of the Amount of Dimension Stone Waste on Water Absorption of Soil-Cement Bricks

Influência da Quantidade de Resíduo de Rocha Ornamental na Absorção de Água de Tijolos Solo-Cimento.

Influencia de la Cantidad de Residuos de Piedra Dimensional em la Absorción de Agua de los Ladrillos de Suelo-Cemento

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Abstract
This paper shows the use of dimension stone waste in the manufacture of soil-cement bricks. Initially, a sample of the soil was analyzed for mineralogical composition, particle size distribution (classifying it in the proportion of silt, sand, and clay), and physical performance by plasticity (Atterberg limits specified by standard NBR 7180). A series of soil/waste/cement mixtures were prepared with contents up to 90% wt.% of dimension stone waste. The samples were characterized as mineralogical composition, microstructure, and water absorption after 7, 14, 21, 28, and 60 days. The composition with 20% wt.% of dimension stone waste presented individual and average values of water absorption according to the conditions established by standard NBR ABNT 10834 (≤22% and ≤20% respectively) and the other samples presented similar results, indicating that the dimension stone waste could be used for production of soil-cement bricks, helping to reduce the environmental impacts of the dimension stone industry.
Keywords: Soil-cement; Brick; Water absorption.

Resumo
Este trabalho apresenta a utilização de resíduos de rochas ornamentais na fabricação de tijolos de solo-cimento. Inicialmente, amostras de solo foram analisadas quanto à composição mineralógica, distribuição granulométrica (classificando-a na proporção de silte, areia e argila) e desempenho físico por plasticidade (limites de Atterberg especificados pela norma NBR 7180). Uma série de misturas de solo/resíduos/cimento foram preparadas com teores de até 90% em peso de resíduos de rochas ornamentais. As amostras foram caracterizadas quanto à composição mineralógica, microestrutura e absorção de água após 7, 14, 21, 28 e 60 dias. A composição com 20% em peso de resíduo de rocha ornamental apresentou valores individuais e médios de absorção de água de acordo com as condições estabelecidas pela norma NBR ABNT 10834 (≤22% e ≤20% respectivamente) e as demais amostras apresentaram resultados semelhantes, indicando que os resíduos de rochas ornamentais poderiam ser utilizados para a produção de tijolos de solo-cimento, contribuindo para a redução dos impactos ambientais da indústria de rochas ornamentais.
Palavras-chave: Solo-cimento; Tijolo; Absorção de água.

Resumen
Este trabajo muestra el uso de residuos de piedra de dimensión en la fabricación de ladrillos de suelo-cemento. Inicialmente, una muestra de suelo fue analizada para composición mineralógica, granulometría (clasificándola en la proporción de limo, arena y arcilla) y comportamiento físico por plasticidad (límites de Atterberg especificados por la norma NBR 7180). Se prepararon una serie de mezclas de tierra/residuos/cemento con contenidos de hasta 90% en peso

de desechos de piedra de dimensión. Las muestras se caracterizaron en cuanto a composición mineralógica, microestructura y absorción de agua a los 7, 14, 21, 28 y 60 días. La composición con 20% en peso de residuos de piedra de dimensión presentó valores individuales y medios de absorción de agua de acuerdo con las condiciones establecidas por la norma NBR ABNT 10834 (≤22% y ≤20% respectivamente) y las demás muestras presentaron resultados similares, indicando que los residuos de piedra de dimensión podrían utilizarse para la producción de ladrillos de suelo-cemento, lo que ayudaría a reducir los impactos ambientales de la industria de la piedra de dimensión.
Palabras clave: Suelo-cemento; Ladrillo; Absorción de agua.

1. Introduction

The search for sustainability has motivated a providential concern with environmental impacts, imposing effective actions toward a healthier environment (Siqueira et al., 2016). The construction and architecture sectors are the segments that consume the most non-renewable supplies daily and in large quantities, in addition to the massive production of industrial waste, therefore, this segment obliged itself to align with the environmental sustainability (Menezes et al., 2002).

Because of that**,** there is great interest in research into technologies that can replace traditional materials and techniques that are against the precepts and concepts of a sustainable environment. Among these technologies, stands out is the use of soil for the manufacturing of bricks, which promotes the development of new products with reductions in costs, water consumption, and energy (Grande, 2003; Oliveira; et al., 2021). This brick is formed by a mixture of soil, cement, sand, and water.

The soil-cement brick, also known as ecological brick, has technical and economic advantages when compared to the traditional brick**.** Thus, it is an alternative to serve the segment of the construction of residential properties, to reduce the housing shortage. Besides being a fitting product, there is no need for large sustaining pillars that indeed speed up the construction (Pires, 2004; Bodian et al., 2018, Martins et al, 2011).

The dimension stone industry is responsible for creating wealth and social development, despite the positive effects, it is an activity that generates huge amounts of solid waste (Taguchi et al., 2014). The intensive exploitation of dimension stone encourages the prospects of the use of dimension stone waste as raw materials to produce ceramics (Moreira; et al., 2005). The dimension stone waste presents similar physical and mineralogical characteristics to the raw materials used in conventional ceramics, and most of the products incorporated with these wastes present characteristics according to the conditions established by the Brazilian standardization (Moreira; et al., 2008).

Waste recovery is the most effective way to reduce environmental impacts, valuing and contributing to the search for sustainability (Rodrigues et al., 2012; Ribeiro, 2013). In addition, soil-cement brick incorporated with dimensional stone waste is a product of direct and indirect low costs, and the possibility of diverse shapes makes it quite versatile (Fay; et al., 2014).

In this study, the soil and the waste used were characterized, the soil-cement samples with different proportions of dimension stone waste were produced**,** and the influence of this waste on the water absorption was analyzed.

2. Methodology

The method used for this study is experimental. So, this involves laboratory experiments that helps this study development is defined in a quantitative approach. This methodology was based on the procedures used commercially for the brick production.

The materials used for this research were soil provided by Minerais Rio Doce Company, dimension stone waste provided by marble and granite stone factory (PEMAGRAN), and the cement CP-V commercialized by Votorantim.

The soil used was dried on a stove at 110ºC until a constant weight was obtained and comminuted in a hammer mill. The dry soil grading was done using 28 #, 270 #, and 325 # mesh sieves.

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The Atterberg Consistence for the soil (Liquid limit and plastic limit) was determined according to conditions established by standards ABNT NBR 6459 (Associação Brasileira de Normas Técnicas; 2016) and ABNT NBR 7180 (Associação Brasileira de Normas Técnicas; 2016) respectively.

The liquid limit (LL) was obtained using the Casagrande device, which consists of a shell that is struck against its base by the action of a crank. Previously, a soil sample was sieved into 28 # mesh and placed in a mortar. Water was added to achieve soil moisture homogeneity. The homogeneous paste was transferred to the Casagrande shell and with the aid of a spatula, the mass excess was removed so that 2/3 of the surface of the shell was filled, that the thickness in the center of the shell achieved 10 mm, and it was checked with the template. The chisel was used to cause a slot in the longitudinal direction of the device, in the way to separate the soil mass. Then the shell was blowing against the base of the device, rotating the crank at a rate of two turns per second, until the lower parts of the groundmass touched each other. Some mass soil present in the shell was transferred to stole where it was dried to a representative humidity for a given number of blows. These procedures must be performed at least 5 times, obtaining a curve, relating the number of blows to the humidity values. The Liquid Limit (LL) is the humidity value referring to the 25 blows.

The Plastic Limit (PL) test of the soil was performed using a ground glass plate. The soil sample was sieved in 28 # mesh and placed in a mortar, and water was added in small quantities (smaller amounts than those added in the liquid limit), to achieve homogeneity and plastic characteristics of moisture. Approximately 10g of the sample previously prepared was molded in the cylinder shape, and then placed on the surface of the glass and molded until 10 cm in length and 3 mm in diameter, all this process was handmade. Achieving the specific size requirements, parts of the cylinder were transferred to the stove until the mass obtained a humidity value. All the procedures described above must be repeated until 3 humidity values are obtained and cannot vary more than 2% from one value to the other. The result that expresses the value of the plastic limit (PL), is the average of the 3 values of humidity found for the cylinders.

Based on the LL and PL results the plasticity index (PI) was obtained by Equation A. The PI value shows how much, or the range that the soil can behave plastically.

$$IP = LL - LP \qquad \text{(A)}$$

The materials were characterized by X-Ray Diffraction - XRD, using Diffractometer Panalytical, Empyre, with copper tube, 2θ = 5-80º and 0.002 angular steps. The sample was previously crushed and sieved, leaving the fine powder form with particles <150 µm. The peaks were identified by comparison with the JCPDS datasheets, using the XPert High Score Plus program.

Preparation and characterization of the dimension stones waste

The dimension stone waste was dried in an oven at 110ºC, quartering, and sieved using a 400-mesh sieve. The dimension stone waste classification was performed using a Mastersizer 2000 sedigraph, a device with a red-light source (neon base - helium), wavelength defined of 632.38 nm, and the particle size range analyzed was 0.1 at 1000 µm and the analysis of the crystalline phases was performed by XRD at same condition mentioned above.

Preparation and characterization of the specimens

The compositions of the specimens are shown in Table 1. The powders were pre-mixed followed by adjusting the amount of water (around 20% to 35% wt.%) for the mixture to achieve plasticity.

Table 1. Soil-Cement-Waste composition.

Samples	Soil (wt. %)	Waste (wt. %)	Cement (wt. %)
A	0	90	10
B	20	70	10
C	45	40	15
D	45	45	10
E	45	50	5
F	70	20	10

Source: Authors.

The soil-cement-waste mix was compacted by hydraulic pressing of double action piston steel matrix, with a section of 120x30 mm^2, for 30 seconds, using 2 tons load. The pressed specimens were cured with water for 7 days and characterized by water absorption, apparent and real density, after 7, 14, 21, 28, and 60 days. The specimens were submitted to dimensional analysis, in duplicate according to ABNT NBR 8492 (Associação Brasileira de Normas Técnicas; 2012).

For the water absorption test, the specimens were dried on a stove at 110 ° C, at intervals of 6 hours to constant mass. These samples were weighed considering dry mass (m_0), and immersed in a container with water for 24 hours, followed by weighing, being considered a saturated mass (m). The water absorption values (Abs) were determined by Equation B.

$$Abs = \frac{(m - m_0)}{m_0} . 100 \qquad \text{(B)}$$

The specific mass of the specimens was determined by pycnometry. The pycnometer was filled with distilled water, the thermometer was placed, and then the ground glass cap. The excess water that flowed through the walls was dried with tissue paper, the temperature was recorded and the mass was measured.

A small part of the milled specimen was fractioned, weighed, and then carefully added to the pycnometer, in the way of not to lose any powder. After decanting, the thermometer and lid were introduced, the outside was dried and the mass was measured again (M_1).

This procedure was performed three times for each sample and the result is the average of the values obtained by Equation C.

$$\rho = \frac{m_s}{M - M_1} \times \rho_{water} \qquad \text{(C)}$$

Where m_s is the dry mass of the sample; M is the mass of the pycnometer with the water plus the mass of the sample; M_1 is the pycnometer mass with the water and the sample; and ρ_{water} is the density of water at the temperature recorded during the test.

The microstructure of the samples was analyzed by optical microscopy and the identification of the crystalline phases was performed by XRD.

Flexural strength measurement is a basic quality control procedure in most ceramic industries. The flexural strength was determined according to conditions established by standards ABNT NBR ISO 10545-4 (Associação Brasileira de Normas Técnicas; 2020). The modulus of rupture is a measure of the maximum load-carrying capacity and is defined as the stress at which the material breaks or ruptures. This measurement consists of the bending of a specimen with a rectangular cross-section, subjected to a concentrated load located at the central position of the specimen. The Flexural Strenght (F) values were obtained by Equation D:

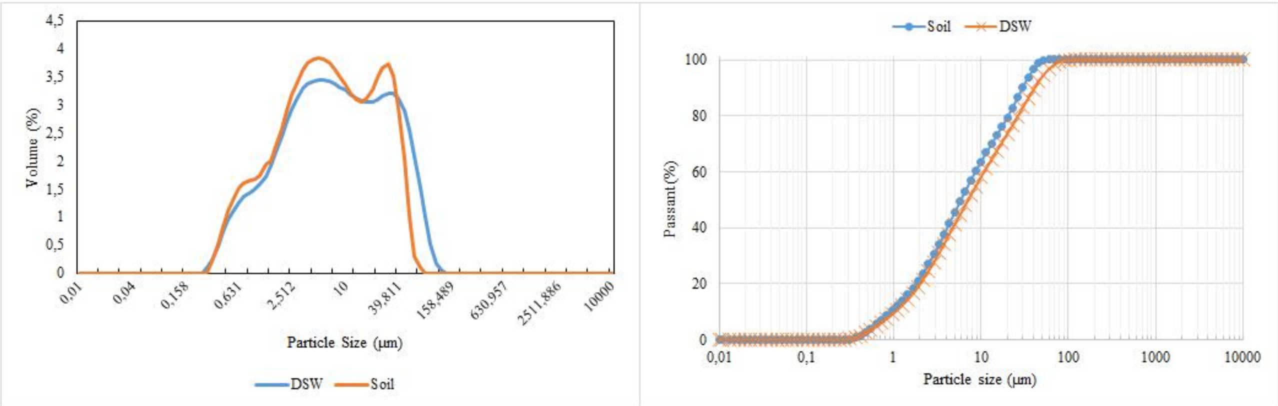
$$F = \frac{3F_a L}{2bh^2} \qquad \text{(D)}$$

Where F is the flexural strength; F_a is the maximum load applied; L is the span length; b is the specimen width and h is the specimen height.

3. Results and discussion

The soil and RRO particle size distribution are shown in Figure 1. The standard ABNT 6502/95 (Associação Brasileira de Normas Técnicas; 2012) has a classification based on the particle diameter, and according to the standard, the grains can be classified as coarse sand with grain diameter from 2.0 to 0.60mm; average sand of 0.60 to 0.20mm; and fine sand from 0.2 to 0.06mm. Grains of silt is in the range of 0.06 to 0.002mm and the clay grains are less than 0.002mm.

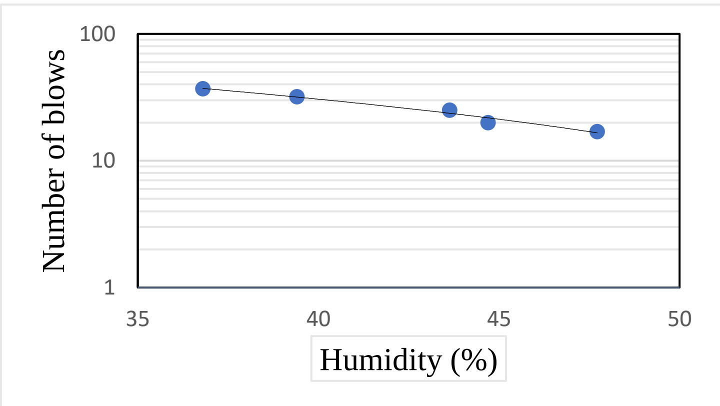
Figure 1. Soil particle size analysis.



Source: Authors.

The numbers of blows obtained in the liquid limit test were plotted as a function of the soil humidity, on a logarithmic scale, making a linear adjustment of the curve, to obtain the humidity content for 25 blows, as shown in Figure 2. The NBR 6459 (Associação Brasileira de Normas Técnicas; 2016) suggests a rounding of the nearest whole number, so the liquid limit of the studied soil is 44%. The plastic limit obtained was PL = 29.78 ± 1.33, and the plasticity index was PI = 14% (Ribeiro, 2021).

Figure 2. Liquid Limit of soil.

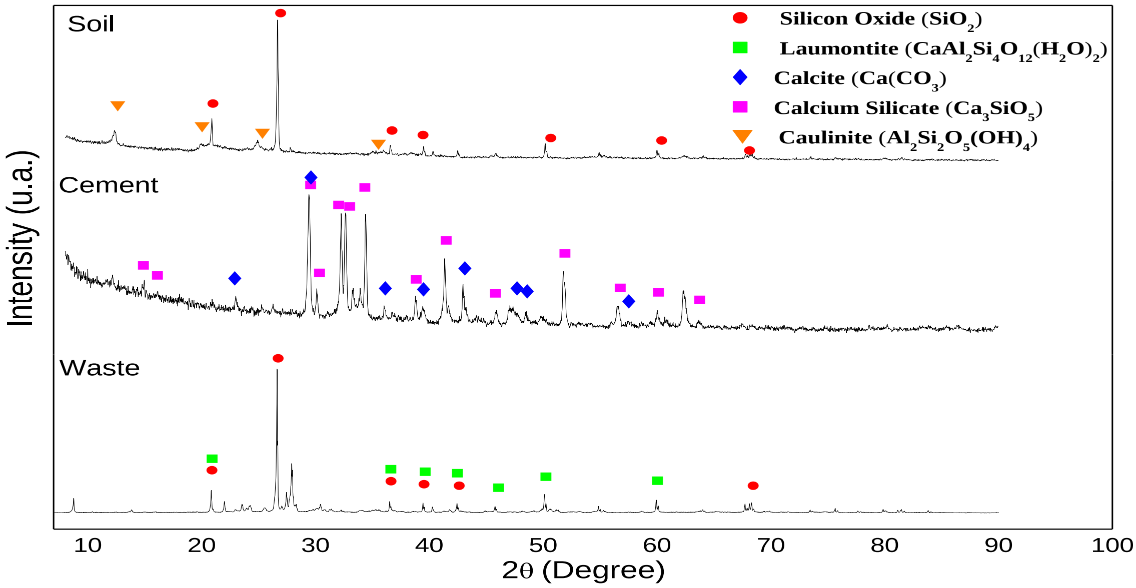


Source: Authors.

According to the American Association of State Highway and Transportation Officials (AASHTO) (American Association of State Highway and Transportation Officials; 2003) soils with IP≤10 are considered silt and when the soil has IP> 11 they are clayey soils. The clays are responsible for the plasticity of the soils because of the ability to absorb the water, which forms a film on the surface of its particles, transforming the behavior of the soil, from cohesive when dry to plastic when saturated (Skempton, 1953). As the soil used was milled and all of it passed through the 200μm sieve, as the result of IP =14 it can be classified as a silt-clay soil.

Figure 3 presents the results of mineralogical analysis of soil, cement, and dimension stone waste. In the soil, it is possible to observe the presence of Quartz (SiO_2) and Caulinite ($Al_2Si_2O_5(OH_4)$). In cement, there is Calcium Silicate (Ca_3SiO_5) and Calcite ($CaCO_3$), because the CPV cement has no addition of another compound. Also, the dimension stone waste presents Quartz (SiO_2) and Laumontite ($CaAl_2Si_4O_{12}(H_2O)_2$).

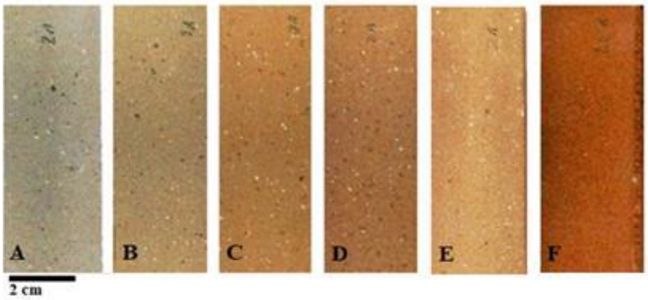
Figure 3. X-ray diffraction patterns of raw material.



Source: Authors.

Figure 4 presents the press specimens for each composition. It is possible to observe that samples B, C, D and F have clusters on the surface and the samples A and E were compared with the others, and the presence of agglomerates was lower.

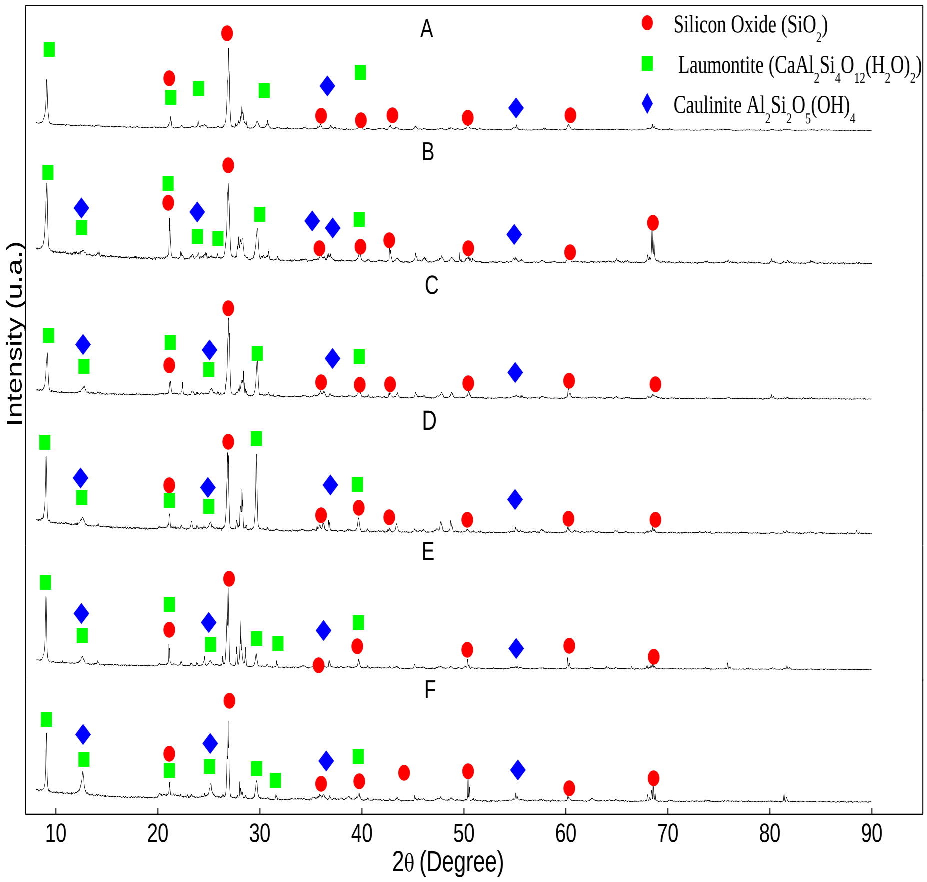
Figure 4. Soil-cement specimens.



Source: Authors.

Figure 5 shows the X-ray diffraction of the samples, where it is observed the crystalline phases of quartz (SiO_2), caulinite ($Al_2Si_2O_5(OH_4)$), and Laumontite ($CaAl_2Si_4O_{12}(H_2O)_2$).

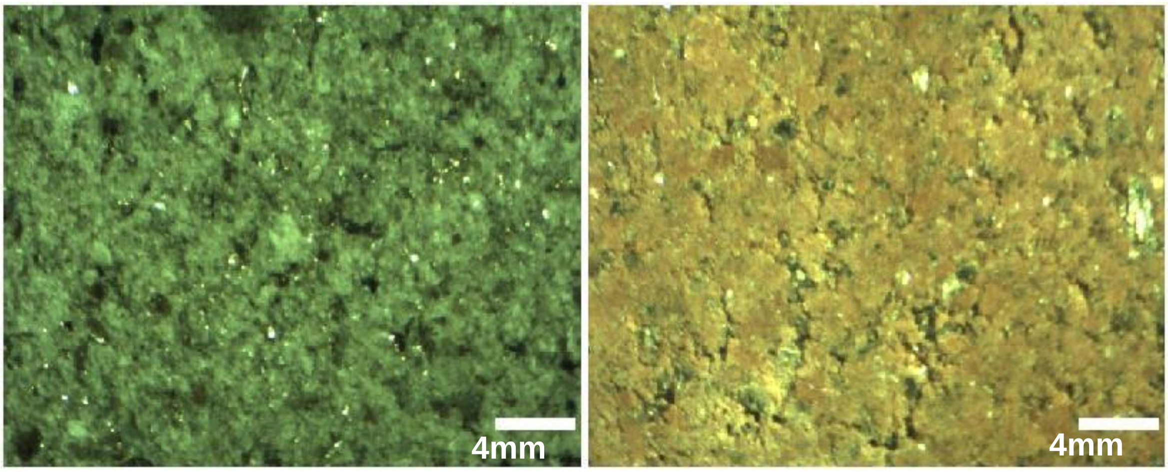
Figure 5. X-ray diffraction patterns of the cured specimens.



Source: Authors.

Figure 6 presents the image obtained by optical microscopy of the surface of the sample A and F, with 90% wt.% and 20 wt.% of dimension stone waste, respectively, within 60 days**.** The samples have a rough surface, with porosity distributed throughout the samples (dark regions), which apparently are not interconnected. In addition, it is possible to observe the presence of small agglomerates (the lighter color) possibly of waste**.** The A sample is more porous than the F, which may be related to the water absorption values found.

Figure 6. Optical micrograph of the surface of A and F specimens.



Source: Authors.

Table 2 presents the individual water absorption values, indicated in bold character, those that satisfy the parameters established by ABNT NBR 8491 (Associação Brasileira de Normas Técnicas; 2012), with $ABS_{individual} \leq 22\%$. It is found that samples F, D, and C presented all values according to the standard. These three compositions have smaller amounts of waste and higher amounts of soil, and therefore, they have a higher amount of water absorbed by the specimen during the cure, guaranteeing the closing of some pores due to the hydration reactions of the cement. This results in better water absorption results, as the specimen will possibly have lower porosity (Ribeiro, 2021).

Table 2. Water absorption of ceramic bodies.

Sample	Water absorption (%)				
	07 Days	14 Days	21 Days	28 Days	60 Days
A	23.34	22.25	22.23	23.31	21.70
	24.03	22.31	23.55	22.25	22.21
B	22.37	**21.61**	**21.23**	**21.14**	**21.53**
	21.54	**21.19**	**21.63**	**21.25**	**21.64**
C	**20.23**	**20.88**	**20.22**	**20.27**	**19.14**
	20.38	**20.45**	**19.07**	**20.31**	**19.28**
D	**19.66**	**21.17**	**20.36**	**18.72**	**19.83**
	19.57	**21.21**	**18.82**	**19.06**	**19.93**
E	-	22.94	**20.00**	22.18	**20.80**
	-	**21.05**	**20.20**	**21.11**	**20.60**
F	-	**17.29**	**17.35**	**18.44**	**18.47**
	-	**16.67**	**16.51**	**19.99**	**17.41**

Source: Authors.

Figure 7 presents the average water absorption values as a function of the age of the specimens and the limit established by ABNT NBR 8492 (Associação Brasileira de Normas Técnicas; 2012), which is $ABS_{average} \leq 20\%$. Only sample A did not fit the standard, and the other compositions that did not present acceptable individual values are very close to the requirements established. One way to circumvent this result is to change some processing parameters such as: improving the homogenization

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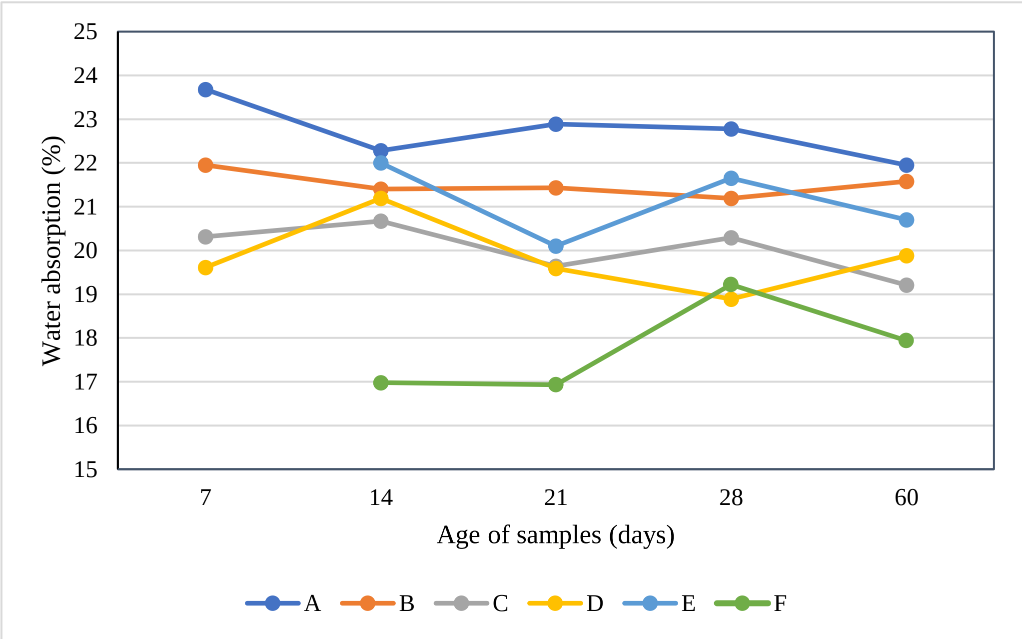
of the mixture, decreasing the amount of water for compaction, and adjusting the pressing load. An important observation is that according to the results, the time does not influence water absorption.

Figure 7. Average water absorption of soil-cement-waste specimens as a function of aging.



Source: Authors.

The Samples C, D, and E present individual and average values of water absorption that are very close to each other, this is due to the similar composition between them in terms of the amount of soil, indicating again that the amount of cement has lower influences in the composition of the brick than the amount of waste. Samples F and A show respectively the lowest and highest values of water absorption, precisely because the content of dimension stone waste is the main factor that affects the water absorption, being indicated by the proportion of up to 45% of the waste in the mixture to produce soil-cement-waste bricks (Oliveira; Meira; Chagas, 2021).

Table 3 presents the relative density values of each composition. According to the values obtained, it is expected that the compositions A and B have a higher water absorption value, considering that a lower relative density higher the number of pores in the specimen. The other compositions have lower water absorption values. The samples E and F have lower relative density values than C and D, this may be the result of the compaction load used, which resulted in a non-homogeneous specimen with a larger number of pores.

Table 3. Relative density of samples.

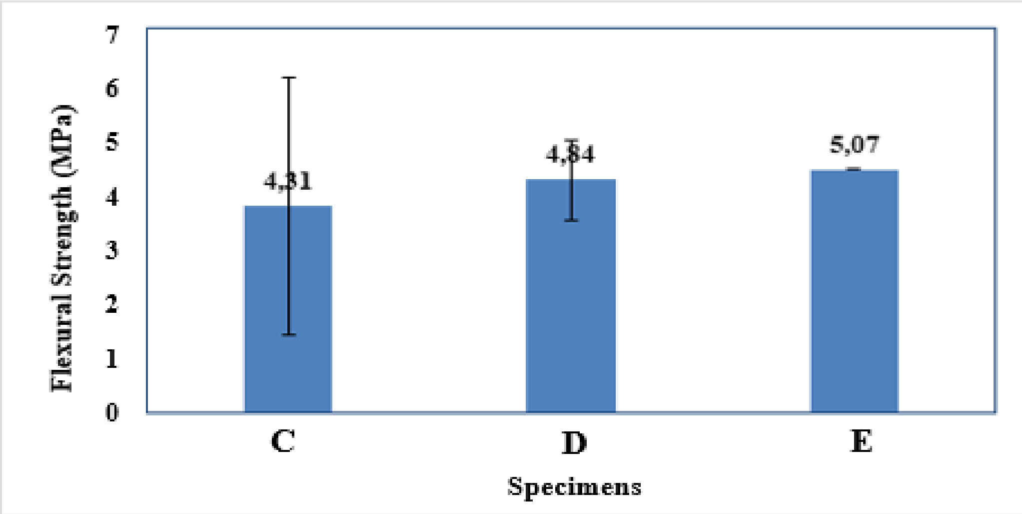
Relative Density (%)	**Sample**					
	A	**B**	**C**	**D**	**E**	**F**
	44.56	75.07	98.35	39.96	65.45	53.58

Source: Authors.

It is also noticed that increasing the amount of cement does not impact a better water absorption result. That is, the amount of 10% of cement is enough to determine a microstructure according to the value required by the standard.

Figure 8 presents the average flexural strength values of specimens C, D, and E. It is expected that compositions with lower water absorption values result in higher mechanical resistance values due to the higher density of the specimens. In this case, we note that all specimens have similar flexural strength, this can be justified by the similar compositions between the specimens. According to Venkatarama (2005), compositions with a cement percentage of around 10% yields results of flexural strength above those expected, which would be approximately 1,5 MPa (Venkatarama, 2005).

Figure 8. Flexural strength of the specimens.



Source: Authors.

4. Conclusions

The addition of dimension stone waste in the composition of soil-cement bricks is possible up to 45% to provide water absorption results according to the conditions established by NBR 8491. Using 5% above or below that 10% cement did not significantly change the results, being that the largest amount of samples that fit the water absorption value allowed by the standard was with 10% cement, which is the indicated amount for soil-cement-waste brick mixtures. Soil with a clay-silt characteristic, of caulinite origin, with particle size similar to the other constituents, seems promising for the production of soil-cement-waste brick.

The F sample (with 70% soil, 20%-dimension stone waste, and 10% cement) was the only one that presented all the individual and average values according to NBR ABNT 10834, but also, samples C and D presented values very close, indicating the possibility of adjustment in the process to fit them.

The insertion of approximately half of the brick composition made of dimension stone waste without changing the amount of cement in the process is encouraging for its use on an industrial scale. This favors the mitigation of the environmental impacts generated by the mining companies, contributing to the sustainability in both the mineral and the ceramic sectors.

It is suggested for future work to increase the percentage of waste used, since in the various studies found, the use of around 45% of waste (from different sources) yields the result commercially found. The main way to optimize this product is to replace the soil and/or cement with a higher percentage of waste.

References

American Association of State Highway and Transportation Officials AASHTO. (2003). AASHTO 411 M145-91, 2003. Standard Specifications for Classification of Soils and Soil-Aggregate 412 Mixtures for Highway Construction Purposes.

Associação Brasileira de Normas Técnicas: ABNT. (2016a). NBR 6459: Solo - Determinação do limite de liquidez: ABNT.

Associação Brasileira de Normas Técnicas: ABNT. (2016b). NBR 7180**:** Solo - Determinação do limite de plasticidade: ABNT.

Associação Brasileira de Normas Técnicas: ABNT. (2012a). NBR 8491: Solo-cimento – Requisitos: ABNT.

Associação Brasileira de Normas Técnicas: ABNT. (2012b). NBR 8492: Tijolo de solo-cimento — Análise dimensional, determinação da resistência à compressão e da absorção de água — Método de ensaio: ABNT.

Associação Brasileira de Normas Técnicas: ABNT. (2020). NBR ISO 10545-4: Placas Cerâmicas – Parte 4: Determinação da carga de ruptura e módulo de resistência à flexão.

Bodian, S., Faye, M., Sene, N.A., Sambou, V., Liman, O., & Thiam, A. (2018). Thermo-mechanical behavior of unfired brick and fired brick made from a mixture of clay soil and laterite. *Journal of Building Engineering*, 18, 172-179

Fay, L., Cooper, P., & Morais, H. F. (2014). Innovative interlocked soil-cement block for the construction of masonry to eliminate the settling mortar. *Construction and Building Materials*, 52, 391-395.

Grande, F. M. (2003). Fabricação de tijolos modulares de solo-cimento por prensagem manual com e sem adição de sílica ativa. Dissertação (Mestrado em Arquitetura, Urbanismo e Tecnologia) - Escola de Engenharia de São Carlos, Universidade de São Paulo, São Carlos.

Martins, M. N., Vieira C. M. F., & Holanda J. N. F. (2011) "Comportamento de massa cerâmica vermelha durante a compactação". In: CONGRESSO BRASILEIRO DE CERÂMICA, 45, 2011, Florianópolis – SC, Anais... Santa Catarina: 2011.

Menezes, R. R., Ferreira, H. S., Neves, G. de A., & Ferreira, H. C. (2002). Uso de rejeitos de granitos como matérias-primas cerâmicas**.** Cerâmica, volume 48, pág. 92-101.

Moreira, J. M. S., Manhães, J. P. V. T., & Holanda, J. N. F. (2005). Reaproveitamento de resíduo de rocha ornamental proveniente do Noroeste Fluminense em cerâmica vermelha. Cerâmica, 51, 180-186.

Moreira, J. M. S., Manhães, J. P. V. T., & Holanda, J. N. F. (2008). Processing of red ceramic using ornamental rock powder waste. *Journal of Materials Processing Technology*, 88, 88-93.

Pires, I. B. A. (2004). A utilização do tijolo ecológico como solução para construção de habitação populares. Monografia (Graduação em Engenharia Civil) – UNIFACS

Oliveira, J. V. C., Meira, F. F. D. de A., & Chagas, L. S. V. B. (2021). Soil-cement bricks with insertion of scheelite-tailings: Mechanical behavior and physico-chemical evaluation of kneading water. *Research, Society and Development*, 10(6), 1-13.

Ribeiro, S. V. (2013) "Reutilização de resíduo de rocha ornamental na produção de tijolo solocimento", Dissertação de Mestrado, UENF- Campos dos Goytacazes.

Ribeiro, V. A. S., Werdine, D., Barbosa, L. F., Pinheiro, M. V., Oliveira, A. F., Alves, A. L. Q., & Silva, L. R. R. (2021). Brick soil cement with addition of tire rubber waste. *Research, Society and Development*, 10(12), 1-13.

Rodrigues, D. V., Xavier, G. C., Saboya, F., Maia, P. C. A., & Alexandre, J. (2012). Durabilidade de peças cerâmicas vermelhas com adição de rejeito de rocha ornamental isenta de granalha. Cerâmica, 58, 286-293.

Siqueira, F. B., Amaral, M. C., Bou-Issa, R. A., & Holanda, J. N. F. (2016). Influência da adição de resíduo sólido industrial nas propriedades de tijolos solo-cimento. Cerâmica, 62, 237-241.

Skempton, A. W. (1953), The colloidal activity of clays. In: Proceedings of the third international conference on soil mechanics and foundation engineering. Zurich, Switzerland, ICOSOMEF, pp 57-61.

Taguchi, S. P., Santos, J. C., Gomes, T. M., & Cunha, N. A. (2014) Avaliação das propriedades tecnológicas de cerâmica vermelha incorporada com resíduo de rocha ornamental proveniente do tear de fio diamantado. Cerâmica, 60, 291-296.

Venkatarama Reddy, B. V., & Gupta, A. (2005). Characteristics of soil-cement blocks using highly sandy soils. *Materials and Structure*, 38:651-658.