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Analysis of the benefits of the addition of granite residues in the production of ecological brick

Francisca Oliveira, Rebeka Sousa, Paulysendra Silva, Phillype Lopes, Gilvan Moreira, Rodolpho Leite, Roberto Arruda

Instituto Federal do Piauí- IFPI- PPGEM, CEP: 64000-040, N°94, Teresina-PI- Brasil.

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***Keywords*— Ecological Brick; Granite; Waste.**

Abstract*— *The activities of the ornamental rock sector generate huge amounts of solid waste, which can cause negative consequences to the environment. Given the need for environmental preservation and a greater concern with the concepts of sustainability, we have been seeking to use natural resources intelligently, thus aiming at a better future of the planet, the ecological brick presents itself as a possible alternative to reuse these granite residues presenting an alternative destination for ornamental rock tailings. This work seeks through a brief bibliographic survey to evaluate the potential of the insertion of waste from granite in the production of ecological bricks.

I. INTRODUCTION

According to [1, 2] it is estimated that the construction sector consumes around 9.4 ton./hab. year of building materials. The discussion around the challenges found to reinsert these materials used in civil construction back into the production chain, the way these resources will be generated in the reuse processes and how this alternative contributes to sustainability [3].

[4] emphasize that, for Civil Engineering, the concept of sustainable development involves the use and production of high-performance materials at reasonable costs, with the least possible environmental impact. The principle of sustainable development is a better distribution of humanity's economic resources, with a concern for the preservation of nature. Production processes must save energy and not generate dangerous by-products, which endanger nature and human beings [5].

The civil construction market presents itself as one of the most effective alternatives to consume recycled materials, since the construction activity is carried out in any region, with the ever increasing expansion of the built environment, which will reduce transport costs. In addition, most of the components necessary for the production of buildings can be produced without great technical sophistication [6].

The processing activities of ornamental rocks generate a significant amount of residues, part of these residues have forms of rock flakes such as casqueiros, broken plates and other residues as a form of residual powder (mud), usually composed of water, rock powder and some type of abrasive [7]. Taking into account the large amount of waste generated and trying to contribute to sustainable development, the use of granite cut waste in civil construction, some researchers have been studying the production of mortar [8], ceramic bricks [9] and ceramic pieces [10].

Over the years, laws to encourage sustainable development have become stricter, causing the productive sectors that generate pollutants and waste to minimize their impacts. In Brazil, in 2010, the National Solid Waste Policy (PNRS) was sanctioned, with the purpose of not generating waste or reducing its potential risk to the environment and human health through the perspective of recycling, reuse and environmentally appropriate disposal. of tailings [11].

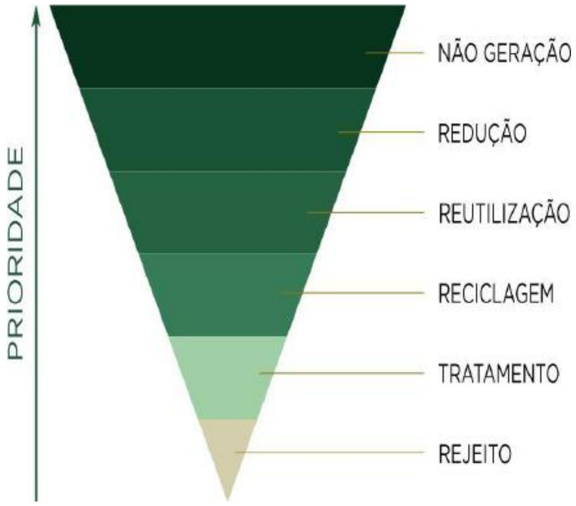


Fig.1: Priority of waste generation

Fonte: PNUMA (2015).

The inverted pyramid model, shown in Figure 1, is applied to PNRS from the perspective of two perspectives that bring production closer to sustainable consumption: shared responsibility and reverse logistics [11].

One of the materials already disseminated that concerns the concern with environmental issues and sustainable development is the soil-cement brick. With soil-cement bricks, production is clean and with less waste and debris, since the perfect fit structure facilitates calculations, reduces the amount of cuts, eliminates the need for nails, wires and holes in the finished wall [12; 13]. Ecological bricks are so named due to their manufacturing process, which does not make it necessary to go through the firing process as in the conventional, avoiding a reduction in the cutting of trees as well as reducing the gases released into the atmosphere [14].

This article is a bibliographic review on the application of granite dust residues in the production of ecological bricks. This review was carried out from the history of publications until the year 2020 and aims to raise the main information on the quality of the products produced in order to show the effectiveness of adding granite powder to ecological brick through mechanical characterization. according to the rules in order to encourage new research.

II. THEORETICAL REFERENCE

2.1 Ecologic Brick

Ecological brick is a brick model (table 1) that promotes positive environmental impact, reducing the consumption of different materials in the construction area and applying concepts of sustainability in its manufacture and during the execution of the work, produced from waste generated by construction , allowing the reuse of most of these materials being manufactured with manual or hydraulic presses, resulting from the homogeneous, compacted and cured mixture of soil, cement and water in appropriate proportions resulting in a material with good mechanical resistance, water absorption index, small retraction volumetric and satisfactory durability compatible with the recommendations of technical standards [15].

Table 1: Dimensions of bricks sold in Brazil.

	Dimensions	**Characteristics**
Common massif	5 x 10 x 20 cm 5 x 10 x 21 cm	Settlement with consumption mortar similar to that of ordinary solid bricks
Solid with fittings	5 x 10 x 21 cm 5 x 12,5 x 25 cm 5 x 11 x 23 cm	Fitting with low mortar consumption
½ plug-in brick	5 x 10 x 10 cm 5 x 10 x 11,5 cm	Element produced so that there are no breaks in the formation of devices with mismatched joints
Bricks with two holes and fitting	5 x 12,5 x 25 cm 5 x 12,5 x 12,5 cm 7,5 x 15 x 30 cm	Dry laying with white glue or very plastic mortar. Pipes pass through vertical holes
½ bricks with holes and fitting	5 x 10 x 10 cm 5 x 12,5 x 12,5 cm 7,5 x 15 x 15cm	Element produced to seat the devices, without the need for breakage.

Fonte: (Instituto de tecnologia e pesquisa de São Paulo 18/06/2012).

According to [16], several physico-chemical factors such as solids, water and air that make up the soil can influence the characteristics of the final product of the soil-cement, among them the cement dosage, nature of the soil, moisture content and compaction or pressing [17]. The cohesion of the cement soil is determined by the constitution of the cement, its fineness, amount of water and the ambient temperature.

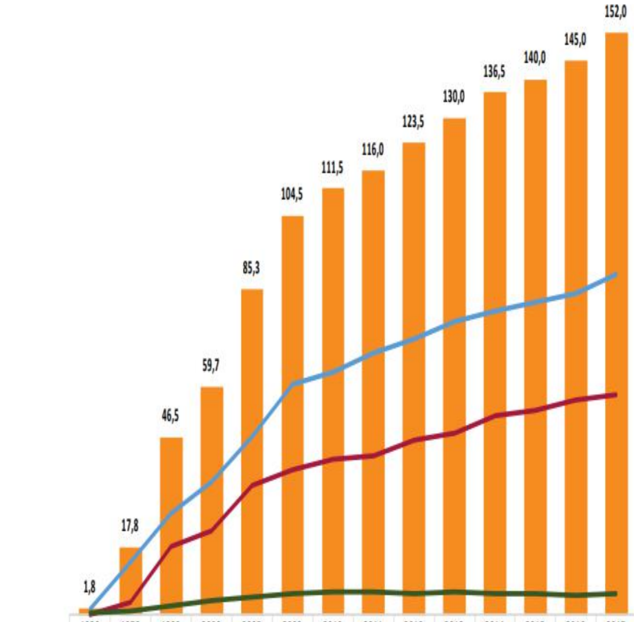
As for the constructive aspect, the two holes in the ecological brick provide thermal, acoustic insulation and protection against humidity, as they form air chambers [18]. Ecological bricks, when overlapped in the settlement, form ducts through which the wires and pipes are passed, avoiding tears in the walls and ensuring greater savings in materials and labor. Its installation is carried out through successive male and female fittings with simple leveling and alignment, being recommended for the union of the construction elements, mortar for laying floors and PVA glue, in the respective proportion of 20/1 and can be used as apparent masonry, receiving only a waterproofing paint, or to be coated with plaster and textures [19].

2.2 Ornamental Stone Waste

The world production of ornamental stones is approximately 68 million tons / year, of which 59.2% are related to carbonate rocks (marble), 35.8% to silicate rocks (granite) and 5% to slate. other rocks. In the ornamental stone beneficiation industry, the various stages of production generate large losses, with a very significant waste volume, it is estimated that the amount of waste generated is 40% of the volume of the processed block. This figure can reach 41%, so it is estimated that 3.26 million tons of processing waste were generated in Brazil in 2018, with 2.12mt of fine waste (rock dust) and 1 , 14m tonnes of coarse waste (shells and shavings) [20]. Since the 1990s, the ornamental stone sector has grown at a rate of approximately 4.5% a.a., and in the last 5 years, between 2013 and 2017, 4% a.a. [21].

Brazil is one of the countries that stands out most in the world in the production and commercialization of ornamental stones. According to data from the Brazilian Association of the Ornamental Stones Industry [22], the country is the seventh largest world exporter of rocks in physical volume, behind only China, India, Turkey, Italy, Iran and Spain. The Brazilian extraction of rocks totals 5.2 million tons / year, with the states of Espirito Santo, Minas Gerais and Bahia responsible for 80% of this production. Among these states, Espírito Santo stands out as the main producer, with 47% of the Brazilian total [22].

The high national production generates a strong industrial activity of extraction and processing of ornamental rocks, such as granite, marble, gneiss, slate, among others. This activity has made a great contribution to the national economy, generating wealth and social development. It is noteworthy that Brazil is the center of production of ornamental rocks richest in granites [23].



	1926	1976	1990	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total	1,8	17,8	46,5	59,7	85,3	104,5	111,5	116,0	123,5	130,0	136,5	140,0	145,0	152,0
Mármores	1,2	13,6	26,5	34,5	46,8	60,4	63,2	68,5	72,3	76,8	79,2	81,5	83,8	89,0
Granitos	0,2	3,4	17,6	21,7	34,0	38,0	40,5	41,7	45,8	47,5	51,9	53,2	56,0	57,5
Outros*	0,4	0,8	2,4	3,5	4,5	5,7	5,8	5,8	5,5	5,8	5,4	5,3	5,3	5,5

Fig.2: Evolution of world ornamental stone production (millions of tons / year)

Fonte: Bezerra (2018).

According to [24], granite is a type of ornamental rock with great applicability in the area of civil construction, it is an igneous rock (plutonic magmatic), the result of the solidification of magma at great depths.

As explained by [25], among the phases of the rock production process there are extraction, unfolding, polishing and finishing. During the extraction, the mining residue is generated, consisting of pieces of unused rock and cracked rocks. At sawmills, blocks are transformed into slabs. When sawing blocks, cutting is carried out with looms because it combines factors such as: greater flexibility, high productivity, relatively low costs, in addition to a good cost / benefit ratio for the initial investment. In this process, a slurry in the form of an abrasive pulp is generated, basically consisting of water, shot (used as an abrasive that facilitates sawing), lime (used to lubricate and cool the sawdust blades, in addition to cleaning the channels between the sheets) and ground rock. The last phase is the cutting and polishing process that transforms the granite sheet into mosaics. In this step, the surface is smoothed, polished, polished, cut and finished in order to comply with the specifications that the final product requires. It is at this stage that a small amount of waste is generated, the so-called shavings. After finishing, the rock is ready for commercialization. Figure 3 shows the phases of the granite beneficiation process and the residues obtained in each step.

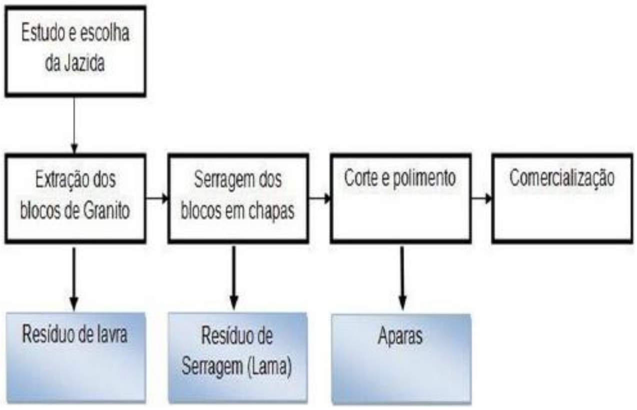


Fig.3 :Flowchart of the granite beneficiation steps.

Fonte: Lima (2010).

According to [26], in the granite beneficiation process, about 30% of the material turns into waste, which is usually disposed of directly from the soil and without any cover. Despite the fact that granite mud is considered inert and non-toxic, its indiscriminate generation and inadequate disposal generate discomfort and expense for companies, in addition to numerous impacts on the environment, such as: alteration of soil drainage conditions, air pollution, visual pollution, modification and destruction of the natural landscape and damage to human health, where when it dries, the mud forms a powder that can cause silicosis, if inhaled.

2.3 Granite residues added to ecological brick: Main benefits

According to [27], the use of granite residues in the manufacture of soil-cement bricks can be configured in an ecologically correct practice as it contributes towards reducing the volume of material discarded in nature and the exploitation of natural resources, preserving the environment. In addition, its specific characteristics show potentialities for its use as an additive material for the manufacture of ceramics, such as the modular brick of cement soil.

Studies show that granite sawdust residues (RSG) and marble and granite sawdust residues (RSMG) have great potential for use as cladding mortars, compacted landfills and precast floor tiles [28].

According to [29], the use of marble and granite powder in bricks reduces the cost, since its use reduces the consumption of cement or sand, in addition to minimizing the environmental impacts due to these materials being extracted from nature, contributing to sustainable development, reducing the emission and transmission of pollutants, reducing costs and the use of non-renewable raw materials, in addition to improving living conditions and nature.

III. METHOD

The methodology adopted is a bibliographic survey carried out on the academic google and CAPES journals portal, admitting publications until 2019, on the application of granite powder in the manufacture of ecological bricks, aiming to show its sustainable, economical points and its main characteristics. According to the theme of the work and the doubts on this topic, we sought to analyze the reading of the titles and abstracts in order to verify the choice of the article.

IV. RESULTS AND DISCUSSIONS

As raised in the literature researched for this work, several authors carried out works with the incorporation of residues from different sources and compositions to obtain a mixture that contributes to the improvement of the ceramic mass for the production of bricks, among them the rubber of tires [30], demolition residues [31], banana peel residues [32], rice husk ash [33], marble and granite sludge [34], sludge from the treatment plant [35] and ornamental rocks from the diamond wire loom, among other researches [36; 37].

[32], used granite powder residues as part of the raw material for the manufacture of soil-cement bricks in order to reuse part of this residue from the unfolding of ornamental rocks for the manufacture of ecological bricks in proportions that the quality and the good performance of the material are not damaged. The ecological brick is composed of portland cement, soil, waste and water; the residue in this research work will replace part of the sand used in the production of the soil-cement brick. The research had as tests the substitution procedure of the aggregates for the mud coming from the cutting and polishing of the granite, the manufacture of specimens with the traces 1/7 (cement and soil) was made, incorporating residues percentages of 60% , 45% and 30% in soil replacement. For each composition obtained in Factorial Planning, there was a variation in the water / cement ratio of 3, 2 and 2.5 and the percentage of residue. Seven types were obtained and a total of 28 specimens were made. The compaction test was conducted according to the NBR ABNT 12023/90 standard.

[32], evaluated the tests of resistance to simple compression, through the rupture of the specimens in a specific press for this test. The results of determining the

simple compressive strength of specimens manufactured with different combinations of granite powder as a percentage of this residue, at 28 days, are shown in Table 1. For each type, four values were obtained, which were discarded the value that least came close to the other points of the test, being, therefore, represented by three values. These data underwent statistical treatment, in which it obtained significant results.

Table 1: Data from the studied specimens

Tipo	% Resíduo	Fator água/ cimento	Tem-po (dia)	Códi-go	Valor obtido no ensaio	Resistên-cia (Mpa)
A	60	3	28	A1	110	1,476
				A2	110	1,476
				A3	102	1,275
B	30	3	28	B1	105	1,409
				B2	103	1,383
				B3	117	1,570
C	60	2	28	C1	147	1,973
				C2	179	2,403
				C3	180	2,416
D	30	2	28	D1	178	2,389
				D2	189	2,537
				D3	189	2,537
E	45	2,5	28	E1	155	2,080
				E2	156	2,094
				E3	165	2,215
F	45	2,5	28	F1	155	2,080
				F2	155	2,080
				F3	150	2,013
G	45	2,5	28	G1	165	2,215
				G2	177	2,376
				G3	180	2,148

Fonte: Silva et al. (2016).

Following the studies by [32], table 2 presents a descriptive summary for the values of resistance to simple compression of the mortar of the soil-cement bricks. There is an average resistance of 1.97 MPa and a coefficient of variation of 21.83%, which shows an average dispersion of the data.

Table 2: Descriptive Values of Simple Compression Strength

Valores Descritivos da Resistência a Compressão Simples				
Média (MPa)	Desvio Padrão (MPa)	Coeficiente de Variação (%)	Máximo (MPa)	Mínimo (MPa)
1,97	0,43	21,83	2,53	1,39

Fonte: Silva et al. (2016).

After performing the simple compression resistance tests [32], he observed that the independent variable water-cement factor is the most influential factor in the process, because with the increase in this factor, a reduction in resistance is observed (Figure 1). The pareto graph (figure 4) for resistance and compression allowed an easy visualization and identification of the most important causes or problems, allowing the concentration of efforts on them. In addition, the Pareto diagram for the two response variables (Resistance to Simple Compression and Water Absorption) allows to determine which coefficients of the models really have statistical influence at the 5% significance level.

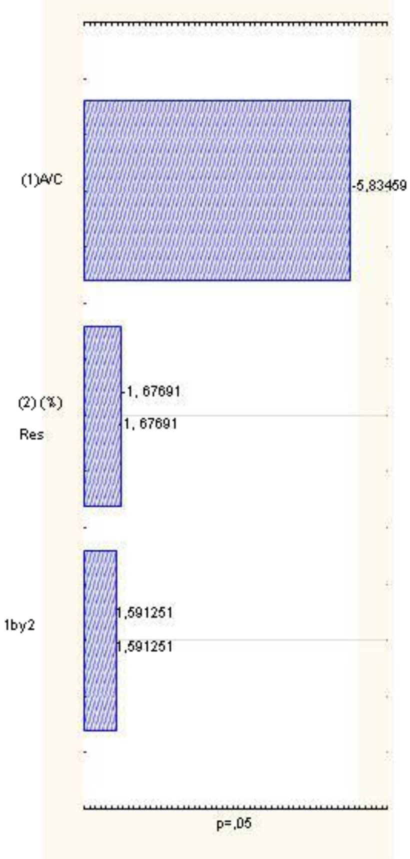


Fig.4: Pareto chart for compressive strength

Fonte: Silva et al. (2016).

The response surface has a higher resistance to a water-cement factor and a percentage of residue around 2 and 30%, respectively. Figure 5 shows the response surface of Factorial Planning.

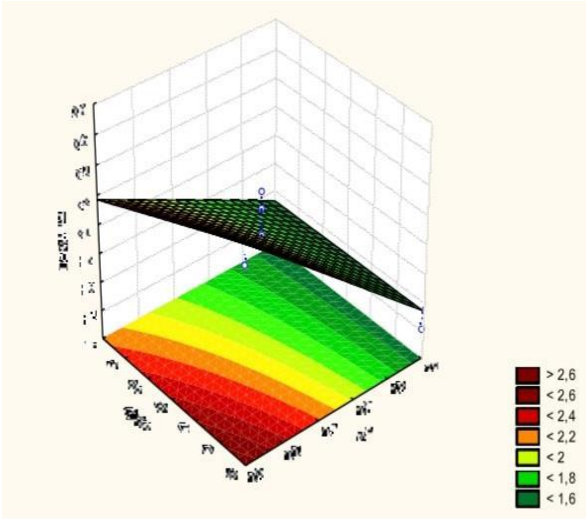


Fig.5: Response surface of Factorial Planning

Fonte:Silva et al. (2016).

The work carried out by [38], aimed to develop in the teaching of chemistry the recycling of granite waste, in the manufacture of ecological bricks of soil-cement, working in the classroom the relationship of chemical knowledge in teaching with this technology aiming mainly the reduction of the environmental impact. This work aims to develop Environmental Issues in the teaching of Chemistry, using as its theme the recycling of abrasive sludge for the manufacture of ecological soil-cement bricks, thus preserving an age-old culture aimed at combating the housing deficit. The type of soil used was the scaffolding, which meets the standards ABNT NBR 10832 and NBR 10833, the cement CPII-F-32 was used, which has compatible characteristics for the elaboration of modular soil-cement bricks. Abrasive sludge consists of water, lime, shot and granite powder, the abrasive sludge comes from the sawdust of the rock blocks, where it is usually thrown to the decantation tanks in the companies' yard. The abrasive sludge was processed through ABNT No. 80 dry sieves.

In the manufacture of ecological bricks, 4 features were adopted: 1: 7: 2; 1: 6: 3; 1: 5: 4 and 1: 4,5: 4,5 (Cement, soil and granitic residue respectively). The soil-cement bricks under study have dimensions of 25 cm in length, 6.5 in height and 12.5 in width. The variation in the water / cement ratio adopted was based on data from Oliveira (2004), where the relationships adopted are within these ranges. For each line, the study was carried out with three water / cement factors 1; 0.86 and 0.72. The tests of the water absorption content are directly linked to the degree of porosity of the material. The determination of water absorption was made according to NBR 10836/94, the samples were placed for 24 hours in an oven at 110ºC and weighed, then they were immersed for 24 hours in water and weighed again. Resistance to simple compression is one of the most important parameters of soil-cement. Current regulations state that the average resistance of cement-bricks should be equal to or greater than 2.0 Mpa after 7 days of curing [38].

According to studies by [38], in addition to the seven days, tests were also performed at 28 and 60 days with the respective factors a / c 1, 0.86 and 0.72 - T1, T2 and T3 respectively, thus verifying their resistance of the test groups for the ages such molding ages, for the wet curing process. It can be seen, according to Figure 3, that the greatest resistance to simple compression occurred with the water / cement ratio 0.86 (T2); The tests show that the ecological brick has an increase in its resistance with time, mainly with 40% of addition of residue (trace 1: 5: 4) of ornamental rock, where the value was 7.6 Mpa for a 60-day cure . It is also seen that practically all the strokes presented results that met the requirements of NBR 10836 of minimum resistance of 2Mpa at 28 days. The greatest resistance to simple compression, happened for the trace 1: 5: 4 because, the individual values are in accordance with the NBR 10836, where it is observed (figure 6) that this trace has a larger amount of residue than the 1: 7: 2 trace; the values of resistance to simple compression, increase with the decrease of the amount of soil and the increase of the granite residue content, both for the 7 days of curing, as well as for the 28 days of curing and 6th days of curing; Therefore, it is observed in the 1: 5: 4 line that it obtained less absorption, so this also explains the good resistance that this line was for the manufacture of soil-cement bricks.

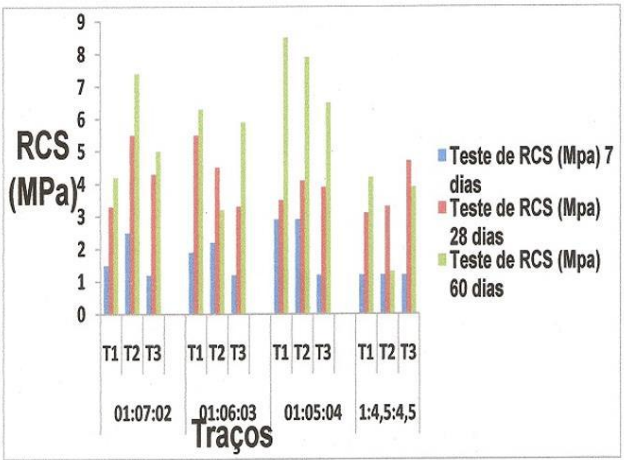


Fig.6: Traces used in the manufacture of soil-cement bricks and the results of simple compressive strength tests

Fonte: Silva et al. (2016).

Another example of studies on the application of residues generated in the processing of ornamental rocks applied to soil-cement bricks is mentioned by [27], as his research attempted to find the ideal water / cement factor for the manufacture of ecological soil bricks- cement incorporated with granite residue from the unfolding of ornamental stone blocks for the construction of popular housing, preserving the environment contributing to sustainable development and trying to economically mitigate the costs of popular buildings through ecologically correct solutions. This research aimed to evaluate the water / cement factor of bricks manufactured with solid waste generated in the processing of ornamental rocks. For the determination of the ideal water / cement ratio of each composition (with respective contents of residues), tests were carried out by varying the a / c ratio (three for each line) where, according to the tests, the greatest resistance to simple compression occurred with the water / cement ratio 0.86.

In determining the ideal water / cement ratio of each composition (with respective levels of granite residue), tests were carried out by varying the a / c ratio. This ratio is given by dividing the amount of water (g) by the amount of cement (g), this value being dimensionless. For each a / c ratio, 3 (three) bricks were molded, and their respective masses and resistance to simple compression (RCS). The hand test criterion was also observed - which consists of forming a “cake” with the hands that would keep its shape unchanged when opening the hand (Figures 7, 8 and 9) and the presence of water veins in the bricks right away. after molding [27].

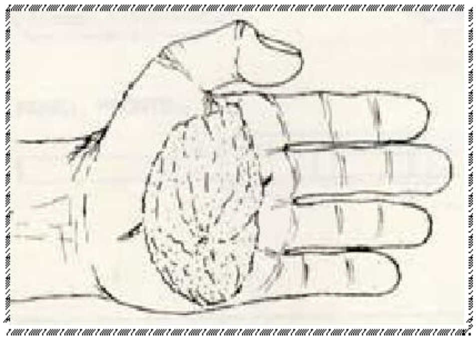


Fig.7: Hand with the mixture

Fonte: Cartilha 1999. Santiago et al.(2012).

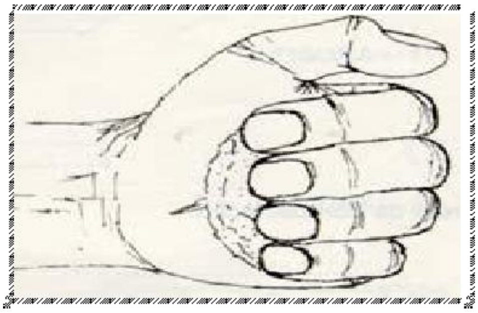


Fig.8: Hand with cake

Fonte: Cartilha 1999. Santiago et al.(2012).

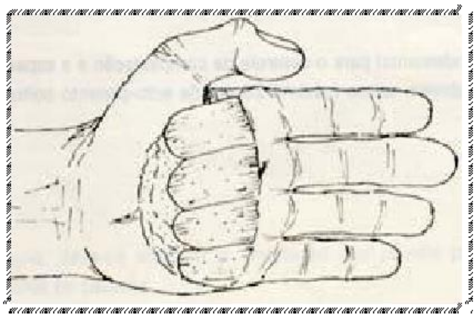


Fig.9: Open hand with cake

Fonte: Cartilha 1999. Santiago et al.(2012).

The variation of the water / cement ratio initially adopted was based on data from the literature, mainly in studies by [39], where the adopted relationships are within these ranges of variation, for the same traits studied. For each line, the study was carried out with three water / cement factors. Four traits were adopted: 1: 7: 2, 1: 6: 3, 1: 5: 4 and 1: 4,5: 4,5 (Cement, soil and granitic residue respectively). For each composition, 18 bricks were made, which served as the basis for technological tests in accordance with all technical standards.

According to [27], the resistance to simple compression was determined according to the standard ABNT NBR 10836/94 - "Hollow block of soil-cement without structural function - Determination of Resistance to Compression and Water Absorption". The current standard determines that the average resistance of the cement soil bricks must be equal to or greater than 2.0 MPa at seven days of age, with individual values greater than 1.7MPa. To analyze the RCS, the ABNT NBR 10836 standard was followed. / 94. Where it managed to obtain better water / cement factors in relation to strength as shown in Table 3.

Table 3 - RCS test and water / cement factor ratio.

		Período de Cura (dias)		
Traço	(a/c)	7	28	60
	1,00	1,5	3,3	4,2
1:7:2	0,86	2,5	5,5	7,4
	0,72	1,2	4,3	5,0
	1,00	1,9	5,5	6,3
1:6:3	0,86	2,2	4,5	3,2
	0,72	1,2	3,3	5,9
	1,00	2,9	3,5	8,5
1:5:4	0,86	2,9	4,1	7,9
	0,72	1,2	3,9	6,5
	1,00	1,2	3,1	4,2
1:4,5:4,5	0,86	1,2	3,3	1,3
	0,72	1,2	4,7	3,9

Fonte: Santiago et al.(2012).

After the results [27], they observed according to Table 3 that the tests used to obtain a better water / cement factor in relation to the resistance were performed with the following values 1.00, 0.86 and 0.72 where According to the tests, the greatest resistance to simple compression occurred with the water / cement ratio 0.86. The tests show that the ecological brick has an increase in its resistance with time, mainly with 40% of addition of residue (trace 1: 5: 4) of ornamental rock, where the value was 7.9 MPa for a curing of 60 days. It is also seen that practically all the lines presented results that met the requirements of NBR 10836 for minimum resistance of 2 MPa at 28 days.

V. CONCLUSION

It can be seen from this literature that there are several studies aimed at the use of waste for materials in the civil construction chain. Based on the results obtained in the research, it is concluded that: For the sectors of ornamental stones and civil construction to act in a sustainable partnership, the addition of granite residues for the manufacture of ecological bricks is, therefore, a excellent alternative for the use of these residues, being a new proposal to combat the housing deficit, configuring an ecologically correct practice, since it can contribute to reduce the volume of material discarded in nature, reduce the exploitation of natural resources, and thus contributing to preserving the environment. As a suggestion for future work may be the reduction of cement consumption in soil-cement mixtures, as well as the feasibility of economic and environmental analysis between ceramic bricks and soil-cement bricks.

REFERENCES

[1] Oliveira, A. M. C. P. Andrade, R. V. (2017). ‘‘O uso de resíduos de pedras ornamentais na composição de tijolos cerâmicos’’.Journal *of open research – JOR*. Disponível em: https://stellata.com.br/journals/jor. Acesso em nov.2020.

[2] Conto, V., Oliveira, M. L. D. E, Ruppenthal, J. E. (2017). Certificações Ambientais: Contribuição à Sustentabilidade na Construção Civil no Brasil. Gepros: Gestão da Produção, Operações e Sistemas, 12(4), 100–127. Disponível em: https://revista.feb.unesp.br/index.php/gepros/article/view/174. Acesso em: 07 jun. 2020.

[3] Luchezzi, C.; Terence, M. C.(2012). Logística Reversa Aplicada na Construção Civil. Revista Luz, A. B. D; Almeida, S. L. M. D. Manual de Agregados para Construção Civil. Rio de Janeiro.. Disponível em: http://mineralis.cetem.gov.br/handle/cetem/2043. Acesso em: 16 jun. 2020.

[4] Bilodeau, A., Malhotra, V.M. (2000). "High-volume fly ash system: Concrete solution for sustainable development." *Materials Journal*, *97* (1), 41-48.

[5] Pentalla, V.(1997). ‘‘Concrete and Sustainable Development’’. *In: ACI Materials Journal*. V.94. Nº 5, Set/Out, USA, p. 409–416.

[6] John, V. M. (1996). Pesquisa e desenvolvimento de mercado para resíduos. In: Workshop sobre Reciclagem e Reutilização de Resíduos como Materiais de construção, São Paulo: PCC-USP, Departamento de Engenharia Civil, p. 21 –30.

[7] Silva, S. C.(1998). Caracterização do resíduo de serragem de blocos de granito: Estudo do potencial de aplicação na fabricação de argamassas de assentamento e de tijolos de solo-cimento. Tese (Mestrado): Universidade Federal do Espírito Santo.

[8] Calmon, J.L., Tristão, F. A., Lordêllo, F.S.S., Silva, S.A. (1997). ‘‘Aproveitamento do resíduo de corte de granito para a produção de argamassas de assentamento’’. *In: II Simpósio Brasileiro de Tecnologia das argamassas, Anais*. Salvador, BA: ANTAC, p. 64-75.

[9] Neves, G., Patricio, S. M. R., Ferreira H. C., Silva, M. C.(1999). ‘‘Utilizaçãode resíduos da serragem de granitos para a confecção de tijolos cerâmicos’’. *In: 43º Congresso Brasileiro de Cerâmica. Anais*. Florianópolis/SC.Jun.

[10] Lima F., V. X., Bezerra, A. C., Santos, F. C., Nogueira, R. E. F. Q., Fernandes, A. H. M.(2000). ‘‘Estudo da viabilidade técnica da substituição dos pós cerâmicos convencionais por pó de granito na injeção de peças cerâmicas à baixa pressão’’. *In: Congresso Nacional de Engenharia Mecânica. Anais*. Nov/2000, Natal/RN.

[11] PNUMA.(2015). GUIA PCS - Tendências e oportunidades para o setor de negócios. São Paulo. Disponívelem:<https://nacoesunidas.org/wpcontent/uploads/2015/06/PNUMA_Guia-de-Produ%C3%A7%C3%A3o-e-Consumo-Sustent%C3%A1veis.pdf. > Acesso em: 16 nov. 2020.

[12] Lopes, W. G. R.(2002).Solo-cimento reforçado com bambu: características físico-mecânicas. Tese (Doutorado em Engenharia Agrícola) – Universidade Estadual de Campinas. Campinas, SP, 2002, 158 p.

[13] Iteva.(2013). Construção Sustentável: Construindo com tecnologia. Disponível em: Acesso em: 24 set. 2020.

[14] Fiais, B. B. & Souza, D. S.(2017). Construção sustentável com tijolo ecológico. Revista Engenharia em Ação UniToledo, v. 2, n. 1.

[15] Karolina, S. J. M. (2010). Estudo da incorporação de cascalho proveniente da perfuração de poços de petróleo em formulações para tijolos de solo-cimento. - Dissertação (Mestrado). Natal - RN.

[16] Bauer, L. A. F. (1994). Materiais de construção. 5.ed. Rio de Janeiro: Livros Técnicos e Científicos. 2v. (Vol. 2).

[17] Bilodeau, A., Malhotra, V. A. (2000). High-Volume Fly Ash System: Concrete Solution for Sustaintable Development. In: *ACI Materials Journal*. V.97. Nº 1, Jan/Feb, USA, p. 41–48.

[18] Ferraz, A. L. N.(2004). Análise da adição de resíduos de argamassa de cimento em tijolos prensados de solo-cimento. - São Paulo: UNESP, 92 p.

[19] ALROMA. Máquinas para tijolos ecológicos. Disponível em: < http://www.alroma.com.br/tijolo-vantagens > Acesso em 22 dez. 2020.

[20] Chiodi, F. C.(2019). Balanço das exportações, importações e consumo interno brasileiro de rochas ornamentais em 2018. Brasília: ABIROCHAS, 2019. (Informe n. 01/2019).

[21] Bezerra,F.D.RochasOrnamentais.Fortaleza.(2018).Disponívelem:<https://www.bnb.gov.br/documents/80223/2809571/21_rochas_12-2017%28V4%29.pdf/c67-7c88-d155-0b446052618f1301>. Acesso em 18 dez.2020.

[22] ABIROCHAS - Associação Brasileira da Indústria de Rochas Ornamentais (2009). O setor de rochas ornamentais e de revestimento**.** Informe 005. São Paulo.

[23] Chiodi, F. C. (2005). ‘‘Situação do setor de rochas ornamentais e de revestimento no Brasil’’ – mercados interno e externo. IN: Simpósio de rochas ornamentais do Nordeste, 5. Anais... Recife: Deminas, DAU, PPGEMinas, SBG, SINDIPEDRAS, 28p.

[24] Pacheco, C. P., Gonçalves, L. P. N., Lorenzoni, R., GÓIS, T. S., Siqueira, W. L.(2009). Mármore e Granito. Trabalho Interdisciplinar, Materiais de Construção aplicada à Engenharia Civil. Universidade Federal do Espírito Santo, Vitória.

[25] Lima, R. C. O. (2010). Estudo da durabilidade de paredes monolíticas e tijolos de solo-cimento incorporados com resíduo de granito. Dissertação (Mestrado). Universidade Federal de Campina Grande. Campina Grande, 2010. 107p.

[26] Mota, J. D., Oliveira, D., Sousa, A., Laranjeira, E., Monteiro M. (2003). ‘‘Utilização do resíduo proveniente do desdobramento de rochas ornamentais na confecção de tijolos ecológicos de solo-cimento’’. *2º Seminário da Região Nordeste sobre Resíduos Sólidos. Anais.*

[27] Santiago, O. N., Oliveira, F. D., Souza, A. A., Muniz C. S., Silva L. M. M., Sousa M. D. (2012). Estudo do fator

água/cimento para a confecção de Tijolos Ecológicos de Solo-cimento incorporados com resíduos gerados no beneficiamento de rochas ornamentais. Paraíba: *Encontro nacional de educação, ciência e tecnologia*/UEPB.

[28] Gonçalves, J. P. & Moura, W.A. (2002). Reciclagem do resíduo do beneficiamento de rochas ornamentais na construção civil. In: *Anais do III Simpósio de Rochas Ornamentais do Nordeste*, 26 a 29 de novembro de 2002, Recife. Rio de Janeiro: CETEM/MCT, 2002. p.179- 189.

[29] Cardoso, R., Pereira, S., Canciglieri, O. (2011). ''Uma Visão Tecnológica sobre o Desenvolvimento de Produtos e a Sustentabilidade''. Cogresso Brasileiro de Gestão de Desenvolvimento de Produto. Porto Alegre.

[30] Bandeira, F. O. (2016). Estudo da resistência ao cisalhamento de misturas de solo argiloso com resíduo de borracha de pneus. Universidade Federal da Fronteira do Sul. Chapecó.

[31] Reis, L. R. M. (2017). Utilização de resíduos da construção e demolição na fabricação de tiolos de solo-cimento. Dissertação. Programa de Pós-Graduação-Mestrado em Ciência dos Materiais da Universidade Federal do Piauí (UFPI). Teresina.

[32] Silva, A. O., Oliveira, D. F., Paiva, W., Severo, M. C., Lopes, T. S. A., Miranda, C. B. (2016). "Resíduos sólidos industriais: uma fonte alternativa para o desenvolvimento de tijolos ecológicos de solo cimento". *XIV Fórum latino americano de engenharia e sustentabilidade* – ENEEAMB. Brasília.

[33] Vessozi, C. S. (2016). Estudo da viabilidade de fabricação de tijolos de solo-cimento com a adição de cinza de casca de arroz. 60p. 2016. Trabalho de Conclusão de Curso (Graduação em Engenharia Civil) – Universidade Federal do Pampa, Campus Alegrete, Alegrete.

[34] Ribeiro, S. V. (2013). Reutilização de resíduo de rocha ornamental na produção de tijolo solo-cimento. Dissertação (Mestrado em Engenharia e Ciência dos Materiais) -- Universidade Estadual do Norte Fluminense Darcy Ribeiro. Centro de Ciência e Tecnologia. Laboratório de Materiais Avançados. Campos dos Goytacazes.

[35] Akamatsu, C. & Ross, N. C. M. (2017). Estudo da aplicação para lodo de estação de tratamento de água na produção de tijolos ecológicos. 52 f. Trabalho de Conclusão de Curso (Engenharia Química) - Universidade Tecnológica Federal do Paraná, Ponta Grossa, 2017.

[36] Marques, C. R., Albertin, R. M., Taboni, L. R., Viotto, H. G. F., Silva, F. F., Angeoletto, F. (2020). ''Avaliação da gestão de resíduos gerados em marmoraria : estudo de caso aplicado em Maringá''. *Revista Técnico-Científica Do CREA-PR*, *24*(Agosto), 1–19.

[37] Nascimento, L.P.C., Silva, S.K.B.M., Lima, E.S., Magalhães, H.L.F., Lima, W.M.P.B., Gomez, R.S., Lima, A.G.B. (2020.). "Secagem de tijolos cerâmicos argilosos industriais: uma investigação teórica usando modelos concentrados''. *Research, Society and Development*, vol.11, e (44291110064). https://doi.org/10.33448/rsd-v9i11.10064.

[38] Mota, J.D. Trajano, M.F., Oliveira, D.F., Carneiro, K.A.A., Mello, V.S. (2011)."Reciclando resíduo de granito na confecção de tijolos ecológicos''. *9° Simpósio Brasileiro de Educação Química*. Natal - RN.

[39] Oliveira, D. F.(2004). Contribuição ao Estudo da Durabilidade de Blocos de Concreto Produzidos com a Utilização de Entulho da Construção Civil. Universidade Federal de Campina Grande. Tese de Doutorado.