CHAPTER 96

Mechanical properties of ecological bricks formulated with civil construction waste

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ABSTRACT
The soil-cement bricks, better known as ecological bricks represent an alternative fully in line with the guidelines of sustainable development because they require low power con-sumption in the extraction of raw materials, exempt the firing process and reduce the need for transport once the bricks are produced with the floor of the work site itself. The aim was to evaluate the use of construction waste in the production of ecological bricks. The bricks were manufactured basically by a mixture that consisted of soil, cement, and different per-centages of construction waste. The results were compared with current standards. Although the dosages of the bricks produced do not achieve the compression strength values required by NBR 10834 (1994), the addition of construction waste significantly improved characte-ristics of the same, both the water absorption, since only the witness received no the rate expected by NBR 10834 (1994), and the mass loss, all met the standard that is below 5%.

Keywords: Soil cement. Environmental sustainability. Resistance to compression

1 INTRODUCTION

That civil construction is the branch that provides the most employability, this is undeniable, but what the majority of the population does not know is that in construction, the amount of waste left is about five times greater than the amount of products, making with this branch becoming the center of discussions. For companies that bet on a more sustainable construction, research shows that the immediate cost is 5% higher than the normal cost, but the savings generated in the long term can reach up to 30%, in addition to helping nature (NETO, 2014).).

Soil has been the most used material in civil construction since the earliest times, as it has good thermal and acoustic insulation, is low cost and is very abundant. Studies indicate that the first record of stabilized earth, earth mixed with ash and molded into adobe are from 4,500 BC and were found in the region of Tépé Gawa (PEREIRA et al., 2010).

This context makes new materials, or even high performance materials, and more efficient construction systems the main objectives in the attempt to establish a healthy relationship between low cost and quality of our works without neglecting the culture, the reality of consumption and the limits of manpower.

Soil-cement bricks, currently better known as ecological bricks, according to Grande (2003) represent an alternative in full harmony with the guidelines of sustainable development, as they require low energy consumption in the extraction of raw material, do not require the burning process , thus reducing the emission of carbon dioxide to the environment, in addition to reducing the need for transport, since the bricks can be produced with the soil at the construction site itself.

The soil-cement brick according to NBR 8491/1994 is one that has 85% of its volume consisting of a homogeneous mixture of soil, Portland cement, lime, water and any additive in proportions that meet it. According to the Brazilian Association of Portland Cement, soil-cement was initially used for paving roads (PEREIRA et. al., 2010 apud ABPC, 1986).

To manufacture "normal" bricks, that is, ceramic blocks that use firing for curing, a large part of "fat" clay is used in the manufacture with a small part of "lean" clay to homogenize the mass. The "fat" clay has a high plasticity index, on the other hand, the lean clay has a low plasticity index due to the large amount of quartz, in addition to a greater granulometry than that of the fat clay (MOTTA et al., 2001). In some shipments, when the lean clay does not meet expectations to homogenize the mass, it is necessary to use a kind of additive to make the correction in the mass. This additive is called chamotte , which is nothing more than the ceramic residue burned and rejected from the process; for this case, a range of 5 to 10% is used (Manfredini & Schianchi , 2009).

For the soil-cement brick to be characterized as a quality product, it must meet the requirements of NBR 8491/1984 with regard to dimensions and respective tolerances, compressive strength and water absorption, so it can be made available to the consumer market.

One of the most important characteristics that ecological bricks have to demonstrate is their compressive strength. According to (SOUZA, et. al., 2011 apud FUNTAC, 1999) the greater the increase in the Portland cement content in the soil-cement brick paste, the greater its resistance, being possible to obtain a resistance of up to 2.8 MPa, by adding 10% of it.

Research and development projects dedicated to the manufacture and study of these bricks have gained space and their diffusion in the civil construction market is starting to grow. Ecological bricks are currently sold at prices quite similar to burnt clay bricks, in addition to having the environmental preservation factor associated with their purchase.

According to (OLIVEIRA et al., 2014 apud TAVEIRA, 1987), in addition to the many advantages , ecological bricks benefit from: i) they do not provide conditions for proliferation and housing for insects harmful to health, due to their smooth finish ii) they provide a construction clean, where waste can become future ecological bricks. iii) increases structural strength, and functions as a thermal and acoustic system. iv) if the bricks are manufactured with holes, they do not need conduits for electrical and hydraulic installations. v) reduction of up to 80% in the use of cement, among others.

The objective of this article is to show that with the exorbitant amount of waste from civil construction, something useful can be done with such waste, in addition to providing cleaner buildings, which are buildings with a seal of sustainability, in addition to evaluating the use of these waste from the civil construction in the production of ecological bricks. Contributing an alternative for recycling these wastes and reducing the environmental impact of buildings promoting sustainable development.

2 MATERIALS AND METHODS

In order for the mechanical properties to be fully evaluated, we selected a company from the central region of the state of Goiás, where it collects stationary buckets with construction waste and transports it to its patio, in the Agroindustrial zone of Aparecida de Goiânia - GO. .

As soon as the raw waste arrives in the yard, it undergoes a “gross separation”; which is nothing more than the removal of the Class B, C and D material and after that it is placed in the crusher, as shown in Figure 01. The materials resulting from this process are classified as: i) crushed stone 02; ii) crushed stone 01; iii) crushed stone 0; iv) coarse sand; and v) medium sand.

As it is soil-cement bricks, type v residue was used, which is the classification for medium sand; so all construction waste was provided free of charge by the company RENOVE.

For the manufacture, the company TIJOLEKO, based in Anápolis-GO, provided its space, press and some instruments necessary for making them.

Figure 01 - Material removed in loco

Source - Authors' collection

According to NBR 10832 - Solid soil-cement brick, it was used in the manufacture of the same, basically a mixture consisting of soil removed from the vicinity of the industry in Anápolis-GO, Portland Cement type CP V - ARI, and as an additive , different percentages of construction waste (0%, 10%, 20%, 30%, 40%, 50%), duly calculated. The amount of portland cement was set at 10% for each of the types set.

As described above, the tests strictly followed the current technical standards, and the samples with the following nomenclatures were used:

A - Soil + 50% waste + 10% Portland Cement;

B - Soil + 40% waste + 10% Portland Cement;

C - Soil + 30% waste + 10% Portland Cement;

D - Soil + 20% waste + 10% Portland Cement;

E - Soil + 10% waste + 10% Portland Cement;

X - Soil + 00% waste + 10% Portland Cement.

Before mixing, the components were passed through a 200 mm sieve, in order to break up small clods present in some materials; after this process, the cement, soil, civil construction residues are gradually added, and a rigorous manual homogenization is carried out until acquiring a uniform color ; at the end of the homogenization stage of the dry materials, the drinking water was gradually introduced and a new homogenization was carried out, until the mixture acquired a crumbly appearance.

The mixture needs to have the appearance of farofa, since for the manual press it is not possible to press the dry material, nor too wet. In the first case, the ceramic block would not be pressed and would fall apart as soon as the form was removed; and in the other case, it would turn to clay and not be pressed.

The mixture, as described above, is contained in NBR 10833 (2012) and was taken to the manual press where the pressing was done in molds. All manufactured elements, as shown in Figure 02, were stored in an area for curing and kept moist for 07 days, so that there was no dehydration.

Figure 02 - Molded and pressed bricks

Source - Authors' collection

After curing, the molded bricks were transported to the soil laboratory at Universidade Paulista – UNIP. The duly cured specimens were submitted to the Compression Resistance test, following the standard of NBR 8492 (2012), which prescribes the methods that must be used in the tests for solid bricks; The tests were carried out after 40 and 80 days of curing in the hydraulic press of the Soil Laboratory of Universidade Paulista.

NBR 8492 (2012) describes the methods to be performed for the tests to be validated:

4.3. Simple compression test
4.3.1. From each sample, seven specimens must be prepared as follows:
a) cut the brick in half, perpendicular to its greatest dimension;
b) superimpose the two halves obtained and the cut surfaces inverted on their larger faces, bonding them with a thin layer of pre -shrinked Portland cement paste (rest for approximately 30 min), 2 mm to 3 mm thick and wait for the paste to harden. The strength of the cement paste cannot be less than that of the brick under test;
...
4.3.3. After hardening of the material used, the specimens must be identified and immersed in water for at least 6 hours.
4.3.4. The specimens must be removed from the water immediately before the test and superficially dried with a slightly damp cloth. This operation must be carried out in a maximum of 3 min.
...
4.3.6. The specimen must be placed directly on the lower plate of the compression testing machine, so that it is centered in relation to it.
4.3.7. Load application must be uniform and at a rate of 500 N/s.
4.3.8. The load must be gradually increased until the rupture of the specimen occurs. ABNT NBR 8492 (2012, p. 6-7).

Therefore, following the NBR above, all the specimens that should be tested by the compression method were cut, and after that, Portland cement paste was inserted between the two halves of the blocks, as shown in Figure 03 .

After curing the Portland cement paste , the glued bricks were immersed in water for 24 hours as can be seen in Figure 04.

Figure 03 - Bricks resurfaced with portland cement paste

Source - Authors' collection

Figure 04 - specimens immersed in water for 24 hours

Source - Authors' collection

Continuing the compressive strength test, the specimens were removed from the water (Figure 05), dried and taken to the hydraulic press until they were broken, as shown in Figure 06.

Figure 05 - specimens removed from the water to go to the hydraulic press

Source - Authors' collection

Figure 06 - Broken specimen in the hydraulic press

Source - Authors' collection

The water absorption test was also carried out in accordance with NBR-8492 (2012), where the bricks were dried in an oven at a temperature of 110 °C for 24 hours as shown in Figure 07 and weighed after the temperature of the specimen was identical. at room temperature, thus acquiring the mass value M1 .

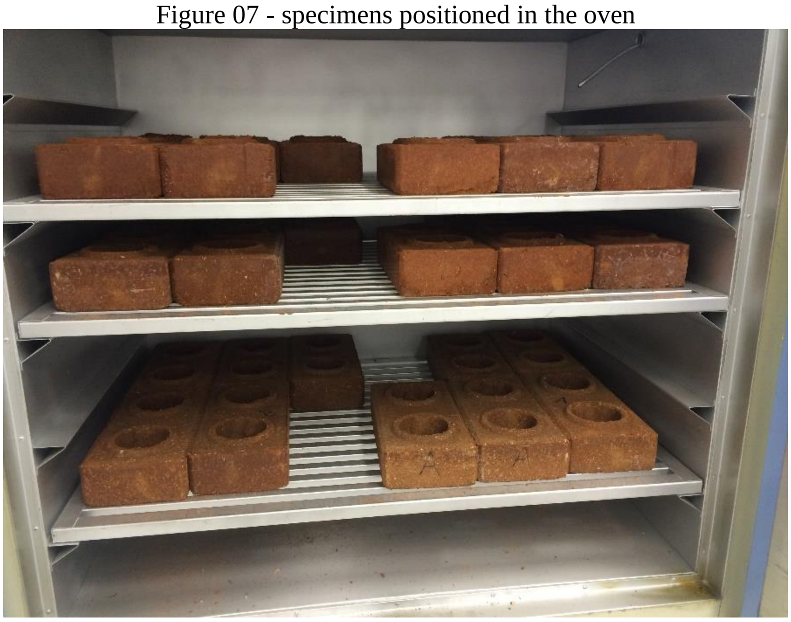
After the bricks were at room temperature, they were immersed for 24 hours in water as shown in Figure 08, from where they were removed for further weighing after being superficially dried, thus acquiring the value of mass M2.

To calculate the respective absorption values, we have the following equation:

$$A = \frac{M2 - M1}{M1} \times 100$$

Being:
M1= mass of kiln-dried brick;
M2= mass of saturated brick;
A= water absorption, in percentage.

Figure 07 - specimens positioned in the oven



Source - Authors' collection

Figure 08 - submerged specimens after being removed from the oven

Source - Authors' collection

NBR 8692 (2012) requires only these two tests, but one more test was performed concerning the loss of mass by immersion. This trial was performed in accordance with the guidelines of ME 26 – IPT/BNH.

The specimens used for the aforementioned test were the same used for the absorption test, evidently taking due care, such as: the specimens are placed in the oven (Figure 07), after the specimens are removed from the study , were immersed in still water without any part coming into contact with the surfaces of the container, (except the lower part where the block is supported) care was taken so that the water was at least 10 cm above the specimen .

In the same way as in the previous test, the bricks remained submerged for 24 hours, after which the percentage of the brick was collected through a 0.075 mm sieve, where the loosened and weighed mass was added to the equation:

$$Pi = \frac{Md \times 100}{M0} \times 100$$

Being:
Md = mass released from the specimen;
Mo = mass of the specimen after oven;
Pi= mass loss by immersion, in percentage

3 RESULTS AND DISCUSSIONS

The results obtained for each of the tests performed are individually presented below, namely: compression analysis; mass loss analysis; and analysis of water absorption.

To make the comparison, values taken from ABNT NBR 8491:2012 Soil-cement bricks - Requirements are used as a reference, which are given as:

> 5.2. compressive strength
> The sample tested in accordance with ABNT NBR 8492 cannot have the average compressive strength values lower than 2.0 MPa (20 Kgf/cm²) nor an individual value lower than 1.70 MPa (170 Kgf/cm²), with a minimum age of seven days.
> 5.3. water absorption
> The sample tested in accordance with ABNT NBR 8492 cannot have the average water absorption values greater than 20% or individual values greater than 22%, with a minimum age of seven days. ABNT NBR 8491 (2012, p. 8).

Therefore, after compiling the data obtained in the tests, it will be possible to verify, in accordance with NBR's 8491 and 8492, if the soil cement bricks with additive of the Civil construction waste type meet these norms, being able to be commercialized and used in more clean and environmentally friendly.

Compression Analysis

Table 01 shows the average strengths referring to the age of the specimens - 40 and 80 days.

Table 01 - Data obtained in the compressive strength test

Dosage	**Average Resistance (MPa)**	
	40 days	**80 days**
Soil + 00% residue + 10% cement	0.54	0.67
Soil + 10% residue + 10% cement	0.65	0.67
Soil + 20% residue + 10% cement	0.65	0.66
Soil + 30% residue + 10% cement	0.79	0.82
Soil + 40% residue + 10% cement	1.07	1.01
Soil + 50% residue + 10% cement	1.08	1.20

Source – The authors.

Analyzing Table 01, an increase in resistance is observed when incorporating construction waste into the soil. This increase was higher mainly in soil bricks with 40 and 50% residue, the strength coincidentally doubled.

However, according to NBR 8491 (2012), the sample tested must present at least seven days of age, an average of compressive strength values equal to or greater than 2.0 MPa, and individual values equal to or greater than 1.7MPa. Through the data described in that table, it is possible to observe that none of the dosages studied reached the values established by the standard.

It is noticed that the dosages had their resistances increased at 80 days in relation to 40 days. This behavior indicates that the chemical reactions that occur in cement improve the mechanical properties over time.

Mass Loss Analysis

Table 02 shows the mass losses of bricks with different amounts of additives and different age of the specimens - 40 and 80 days. For checking the loss of mass by the same.

Table 02 - Data obtained in the mass loss test

Dosage	Weight loss (%)	
	40 days	80 days
Soil + 00% residue + 10% cement	0.09	0.10
Soil + 10% residue + 10% cement	0.20	0.20
Soil + 20% residue + 10% cement	0.20	0.20
Soil + 30% residue + 10% cement	0.20	0.20
Soil + 40% residue + 10% cement	0.20	0.20
Soil + 50% residue + 10% cement	0.22	0.21

Source – The authors.

The tested bricks showed mass loss within the specified standards since they did not lose even 1% of the mass at any of the tested ages.

Analysis of Water Absorption

Table 03 presents the values of water absorption in the bricks of different amounts of additives and different age of the specimens - 40 and 80 days. To check the percentage it absorbs.

Table 03 - Data obtained in the water absorption test

Dosage	Water absorption (%)	
	40 days	80 days
Soil + 00% residue + 10% cement	21.32	23.58
Soil + 10% residue + 10% cement	21.93	21.57
Soil + 20% residue + 10% cement	19.15	19.67
Soil + 30% residue + 10% cement	18.55	20.19
Soil + 40% residue + 10% cement	15.30	15.55
Soil + 50% residue + 10% cement	16.95	18.60

Source – The authors.

NBR 8491 (2012) prescribes that the average of water absorption values must be less than or equal to 20%, and the individual values equal to or less than 22%, at 28 days.

Through Table 03, it can be seen that only the type of block that does not have any percentage of residue (type x), is not in accordance with the Standard, showing that the inclusion of the residue can be beneficial, reducing the porosity of the block and automatically absorb water by the bricks.

4 FINAL CONSIDERATIONS

Soil-cement bricks are an alternative for a cleaner construction, since most of them do not need cuts, as they have internal holes that allow the passage of conduits and conduits , or even water pipes, sanitary sewage and even even rainwater.

In addition, we still have the issue of carbon dioxide emission to the environment, which in the case of soil-cement bricks is zero, since the block is not directed to burning.

Regarding the civil construction waste, it was observed that the amounts of this additive incorporated into the soil were not sufficient to achieve the technical feasibility of soil-cement bricks.

As no Standard regulates the amount of additive that can be placed in the mixture, a maximum of 50% was chosen, which is half of the total mass; comparing with the compression results, it is observed that, increasing the residual additive even more, there is the possibility of increasing the strength, as well as increasing the percentage of portland cement ; however, one must not forget that it is a soil-cement brick, and the presence of soil in it is extremely important.

Although none of the dosages of the produced bricks reached the compressive strength values prescribed by NBR 6491 (2012), the addition of civil construction waste significantly improved their characteristics, both in terms of water absorption, since only the witness did not obtain the expected index, as in mass loss, where all obtained the index well below the limit, which is below 5%.

In addition to significantly improving, this type of brick is a means of keeping the construction clean, reducing costs in purchases of inputs, waste in construction, in addition to helping the environment, as it is an ecological brick.

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