# Making the ecological brick using powder residues of Ceramic Tiles

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## Abstract

*The residues generated by the ceramic factories, among the most varied types, represent a large part of the waste produced and the one that comes from the production of red ceramics such as tiles and bricks, reflects in great part of all the constituents of these residues. The use of tailings is becoming an increasingly common practice, often because it does not have a correct final destination and in some places, there is a shortage of natural materials. The present work aims to study the addition of residues of ceramic tiles dust in the characteristics and properties of ecological brick. A literature review on the topic was carried out, in addition to granulometric characterizations, absorption tests, thermal comfort and simple compression. After carrying out the tests, the possibility of using it as a component of the ecological brick and using it in the region of Teresina-PI was studied. The samples produced with tile powder residue showed excellent results, therefore, through this study it was possible to prove that the reuse of these residues is valid for use in civil construction.*

**Keywords:** Ceramics, ecological brick, tiles.

## 1. Introduction

The civil construction sector is structured around an open linear production chain, generating Civil Construction Waste (RCC) and Construction and Demolition Waste (RCD) as by-products. Such waste can be an alternative source of raw material to be reused by this sphere, changing the paradigm of industrial production to a closed model of production, where waste is recycled and incorporated into the production process[1]. The Civil Construction Industry is recognized as one of the most important activities for economic and social development, however, it still behaves as a major generator of environmental impacts[2]. The consumption of large quantities of natural resources and the consequent production of solid urban waste, generated by the accelerated development and the great population density, in most cities today are some of these factors. Among the solid urban waste, one of the ones that cause the greatest environmental impact is rubble or RCC- Civil Construction Waste[1].


Figure 1- Sources of losses at the construction site

Source: Adapted[3]

The residues from red ceramics such as tiles, generate the popularly known rubbish in large quantities, the use of these wastes has become an increasingly common practice, often because it does not have a correct final destination and also because there are some places where there is a shortage of waste natural materials. The RCD that will be used as fine aggregate in the manufacture of the ecological brick under study is classified as Class A, which according to resolution Nº 307, is reusable or recyclable waste as aggregates, such as: from construction and demolition, and may be ceramic components (bricks, blocks, tiles, cladding plates, etc.), mortar, concrete, soil from earthworks[4].

Currently, recycling of waste is a necessity for the preservation of nature, not only because of the risk of contamination of the soil and groundwater, but also because of the possibility of reducing the cost and energy consumption in the production of civil construction materials, in addition to minimize the extraction of natural resources[5].

Recycling is the process of reusing a waste, after being subjected to transformation and processing, it is the act of submitting a waste to operations and / or processes that aim to provide them with conditions that allow them to be used as raw material or product4. The recycling of the RCC reduces costs, with the extraction of raw material and thus these recycled residues can serve as input for the incorporation and development of new materials and artifacts used in the construction sector. As is the case with the incorporation of recycled class A aggregates in soil-cement bricks or ecological bricks, which are the object of study in this work[6].

Ecological materials have been widely discussed and their use encouraged, due to the catastrophic consequences to the environment caused by the lack of sustainability in civil construction, pointed out by the scientific community in recent years[7].

There is no construction that does not generate an impact, the search is for interventions that cause them on a smaller scale, that is, the fact that a material is considered sustainable does not assume that in its use there are no environmental impacts, but that, in comparison with others materials, cause such impacts in a reduced degree[8].

Ecological bricks are also pleasing from an ecological point of view, as they do not go through the burning process, in which large amounts of wood or fuel oil are consumed, as is the case with bricks produced in ceramics and pottery. The following materials are used in its production: soil, cement and water. The compressive strength of soil-cement bricks is similar to that of conventional brick, but the final quality is superior, as it presents regular dimensions and flat faces[9,10].

For the manufacture of bricks and blocks of soil-cement or ecological brick, a mixture consisting of soil, cement and water, duly pressed, is basically used. The pressing is carried out in molds and the varied form of these makes it possible to produce different types of elements. The manufactured elements are stored in an area for curing and kept moist, but they are saturated, for a period of no less than 7 days[11].

Facing the challenge of sustainable management of these residues and, taking into account the environmental issue, the objective of this work is to study the feasibility of using the powder from broken tiles improperly discarded in the city of Teresina-PI in the production of ecological brick with the aiming to search through dimensional tests, water absorption and simple compression results from the making of the specimens to obtain a block that meets all the minimum requirements of the standard and the market, thus contributing to reduce the impacts generated by the environment and thereby obtain a new form of source of economy and sustainability for the city of Teresina-PI.

## 2. Theoretical reference

The red ceramic industry is one of the generators of this waste, since Brazil annually produces 130 million tons of red ceramics, of which approximately 5% saw waste originating mainly from the failure in the production or storage process, in addition to waste from renovations, demolitions and new construction. In view of the growth of civil construction in recent years, which contributed to the growth of the ceramics sector, this segment started to contribute even more to the generation of solid waste, defined as being generated in the production processes and industrial installations[12,13].

ABRECON (Brazilian Association for the Recycling of Construction Waste and Demolition), the waste generated by construction is characterized as fragments or remnants of bricks, concrete, mortar, steel, wood and others from construction waste, the residues found in the rubble , which are renewable for reuse, belong to three groups: First group: Materials composed of cement, lime, sand and gravel: concrete, mortar, concrete blocks are materials that can be reused in ecological bricks and blocks and against flooring. Second group: soil, metal, wood, paper, plastic, organic matter, glass and Styrofoam can be used as fuel in ovens or in case of not having recyclable capacity they are discarded in landfills and discarded properly following the norms of the Brazilian Association of Technical Standards - NBR 15.113 / 04. Third group of ceramic materials: tiles, shackles, bricks, tiles can be reused as aggregate in the construction itself. Table 1 shows a destination for each type of waste based on its composition[14,15].

| MATERIAL | COMPOSITION | RECYCLING |
|---|---|---|
| Ceramics | White and ceramic brick, ceramic tile, ceramic plate, tile, ceramic floor and cladding, tubing and ceramic tableware, other derivatives. | Less resistant concrete: blocks, against floors, sidewalks, used with mortar or foundation paving and paving. |
| Concrete and Natural rock ral | Gravel, leftover natural rock, leftovers from: concrete, beam, concrete block and precast part. | Structural concrete, gravel granules for paving roads, substitute for gravel nº 1, 2, 3. |
| Mortar | Sand, cement and other aggregates | It can be used in the laying of bricks and cladding blocks, providing reducing the use of sand and lime. |

Table 1 - Destination of Construction Waste

The reuse of the rubble represents economic advantages for the municipal public administration, such as: reduction of costs with the removal of the material deposited illegally along public roads, vacant lots, water courses and slopes, increase in the useful life of landfills, reducing the need for areas for the implementation of new landfills, decreasing the costs of operating landfills, reducing debris, decreasing the costs of paving, urban infrastructure and construction of low-cost housing, generating employment and income and creating new opportunities for business[16].

The main advantages of recycling are, the high prices for depositing waste in landfills, make recycling more attractive from a financial point of view for waste generators, recycling reduces the volume of extraction of raw materials, minimizing the impacts generated by extraction, the production of recycled materials, reduction of pollution, the incorporation of waste allows the production of better quality materials, recycling promotes the reduction of landfills and, consequently, environmental contamination, public sanitation problems and social costs in the management of waste[17].

The reuse of RCD, decreases the consumption of clay, and the environmental impact due to the immense volume of RCD discarded inappropriately. When using waste as raw material to replace traditional materials, it is necessary that this input presents standards compatible with its use, in cases where recycled and natural material have the same cost, the differential will be the quality of the product, in order to ensure that the product is environmentally friendly[18,16].

The study on the reuse of waste from different means of production is one of the essential conditions for the development of nations. Bearing in mind that in Brazil around 50% of the waste generated has its origin in civil construction, the tendency to use these materials gains strength. Soil-cement bricks have the advantage of being able to incorporate other materials in their composition, such as recycled aggregates and industrial waste, in addition to representing significant energy savings, by eliminating the burning, and having their viability proven in several housing programs, for example collective effort system[19].

Soil-cement is an excellent source for the use of Construction and Demolition Waste (RCD), which allows the addition of up to 100% RCD in relation to the soil mass, without prejudice to the quality of the final product, in addition to whereas, the addition of RCD provided an evident reduction in material shrinkage.

Research using alternative construction materials and techniques, in the current context of using waste and preserving the environment, is assuming a prominent role in engineering, also because certain types of waste can be used with technical advantages and cost savings, as is the case with the addition of granular material, from construction waste, in soil-cement mixtures[20,21].

## 3. Materials and method

This research is interested in analyzing the characteristics of ecological brick with incorporation of ceramic tile residues, in different percentages, verifying the technical viability of this product. Figure 2 exemplifies the steps to be used in this work.

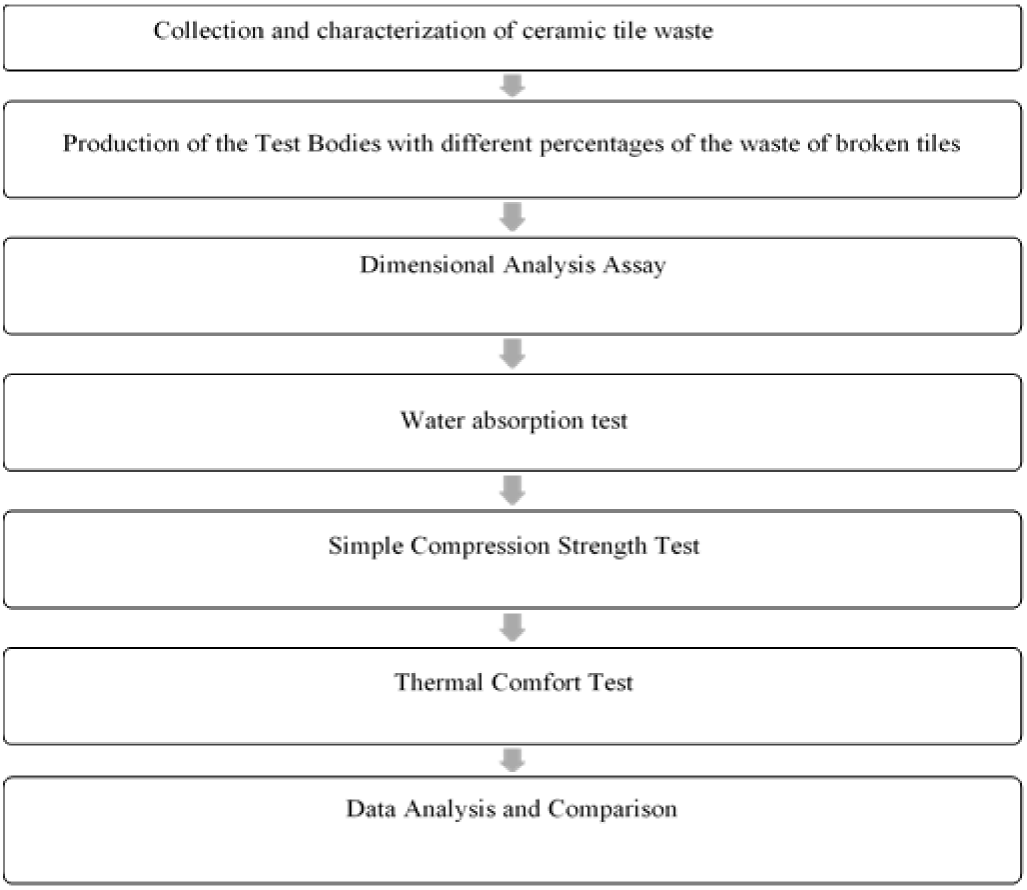



Figure 2- Flowchart with the steps performed in the study.

For the development of this work, waste was used of red ceramics generated during the production and transport of tiles from industries in the region of the city of Timon-MA. The shards of tiles were collected on the margins of the BR-316 between the cities of Teresina-PI and Timon-MA. After collecting the broken tiles (Figure 3), the material was subjected to the grinding process, through a fixed hammer mill equipped with a 4.5mm mesh opening filter at the bottom of the machine, poured into a feed box to be crushed.

Figure 3: Shards of tiles on the margins of BR-316

Then the material it passed through a classifier, right after it is passed through a 2mm mesh sieve, the grinding and sieving process was repeated three times in a row with the result shown in figure 4.

Figure 4- Shards of shredded and sieved tiles

## 4. RESULTS AND DISCUSSION

The residues generated in the tile manufacturing process are the entire tiles that do not have the characteristics required for commercialization after burning in the kilns and also pieces of tiles (shards) originated from the breaking of the tiles due to the movement to which they are subjected[21].
We started following the procedures presented in standard NBR-8491: 1984. The first step was a visit to the Teresinense Professional Association in Olaria, located in the São Joaquim S / N neighborhood in Teresina - PI.
For the granulometric analysis,100 g of the material was washed in 4.75 mm and 0.075 mm sieves on top of each other, the washing process was always repeated with the aid of a water jet, until the washing water was clean. The material retained in the sieves was transferred to an aluminum container and dried. The dry material passed through Nº 4, 10,16,30,40,50, 100 and 200 screens according to the NBR 5734/89 standard - ABNT - Test screens - Specification, in order to characterize them regarding the distribution and sizes of

solid particles (figure 5). The result obtained as a percentage of the dry sample retained in each sieve and arranged in the form of a graph.

Figure 5- set of sieves.

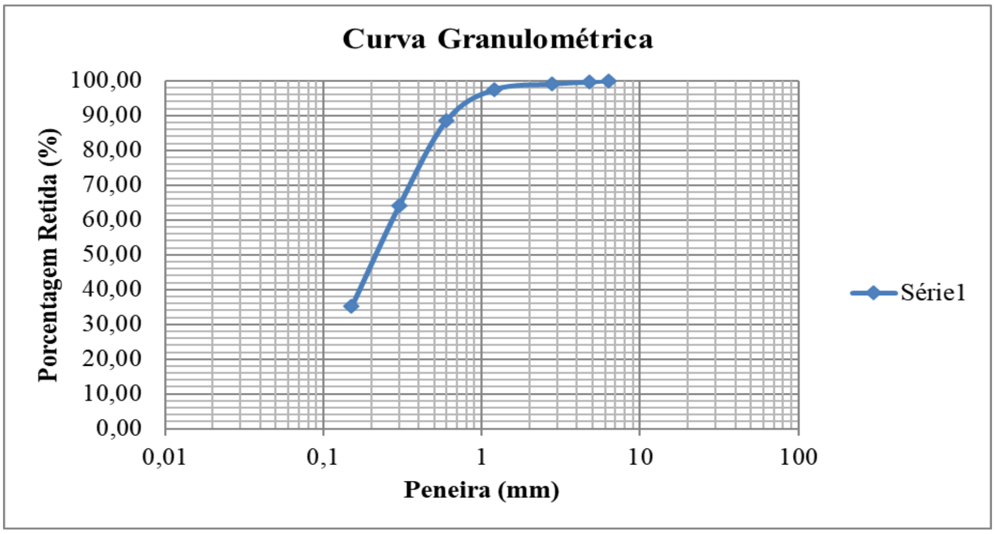
Table 1 presents the result of the granulometry test by sieving the samples of crushed tiles coconuts.

Table 2 - Grain size summary of crushed and sifted tiles.

| Sieves (in / mm) | (%) Retained |
|---|---|
| N ° 04 - (4.8mm) | 0.00 |
| N ° 10 - (2.0mm) | 0.00 |
| N ° 16 - (1.2mm) | 0.52 |
| N ° 30 - (0.60mm) | 0.63 |
| N ° 40 - (0.42mm) | 1.78 |
| N °50 - (0.30mm) | 9.96 |
| N °100 - (0.15mm) | 27.7 |
| N °200 - (0.075mm) | 32.8 |

The granulometry test showed that the material has a certain uniformity, since the retained part was concentrated in two final sieves, also expressing that it is a thin material, with greater retention in the 0.075mm sieve.

Graph 1- Granulometry of tile fragments after crushing and sieving




In the manufacture of ecological bricks (Figure 6), clay, drinking water, CP II F-32 cement were used, which meets the ABNT NBR 11578/91 standard and the tile waste from the crushing and screening process.

Figure 6- Press for the manufacture of ecological bricks.


For the manufacture of ecological bricks incorporated with powder from broken tiles, 36 bricks were molded using a manual press, according to ABNT NBR 10832 - Manufacture of solid soil-cement brick using a manual press. After molding, the bricks were submitted to the curing process until the control ages of 7, 14 and 28 days. Dimensional analysis, water absorption and resistance to simple compression tests were carried out in accordance with the NBR standard 8492/12.

The bricks were subjected to dimensional analysis, according to NBR 8492/12, with the aid of a pachymeter with a resolution of 0.5 mm and a length appropriate to the maximum dimension of the brick. Three dimensions were performed at different points on each face, one determination at each end and one in the middle of the specimen and the average values were recorded.

As can be seen in Table 2, none of the samples showed significant variations, greater than 1 mm, for the values of width (L), length (C) and space between holes (e). However, with the exception of ecological bricks without addition of residue and with an addition of 3%, there is a slight variation between the heights of the bricks, greater than 1 mm, which may be justified by the deficiency in the control of their compaction.

Table 3 - Average dimensions for the manufactured specimen.

| Sample | L | C | H | E |
|---|---|---|---|---|
| | (mm) | (mm) | (mm) | (mm) |
| 0% | 130.00 | 250.00 | 90.00 | 60.00 |
| 2% | 130.12 | 249.60 | 89.69 | 59.02 |
| 4% | 130.11 | 250.00 | 90.00 | 60.00 |
| 6% | 130.00 | 249.95 | 91.10 | 59.86 |
| **AVERAGE** | **130.05** | **249.88** | **90.19** | **59.72** |
| Note: L = width; C = length, H = height; e = Distance between holes | | | | |

The water absorption test was carried out in accordance with NBR 8492/92, the test was carried out in the Senai Ceramics laboratory, 12 specimens were separated for each percentage of tile powder addition. After the twenty-one day curing in a humid chamber, the samples were taken to dry in an oven (Figure 7) with a temperature between 105ºC and 110ºC for a period of twenty-four hours.

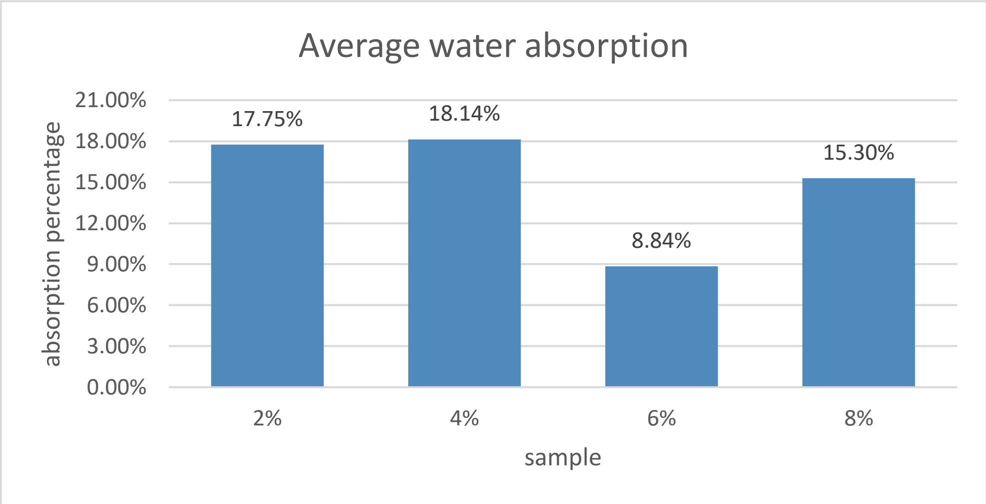
Figure 7- Greenhouse

For the results of water absorption tests 0% - 17.75% absorption (average); 2% - 18.14% absorption (average); 4% - 8.84% absorption (average); 6% - 15.30% absorption (average) the trend observed is the increase in water absorption compared to the reference sample. The results obtained are shown in Table 3 and shown in Graph 2.

Table 4 - Water absorption values for manufactured ecological bricks.

| Sample | Dry weight (g) | Wet Weight (g) | Average Absorption % |
|---|---|---|---|
| 0% | 3708.00 | 4366.00 | 17.75% |
| 2% | 3419.00 | 4039.00 | 18.14% |
| 4% | 3712.00 | 4040.00 | 8.84% |
| 6% | 3682.00 | 4245.00 | 15.30% |

Graph 2- Water absorption on average




For the resistance test according to ABNT NBR 10836/13 - Determination of resistance to simple compression. The test was carried out at the Senai ceramics laboratory from August to October 2019, and the results obtained with 7, 14 and 28 days of curing of ecological bricks were analyzed. Before the simple compression tests (figure 8), in order to reduce the variations of the tests, two rectangular metal plates with flat faces were placed to obtain parallelism and regularization of the work faces, and for regularization the fitting edges were removed from the specimens with the aid of a 12 inch saw. Initially, 21 specimens were broken with 0%, 2%, 4% and 6% with the addition of powder from broken tiles.

Figure 8- Compression test on ecological brick

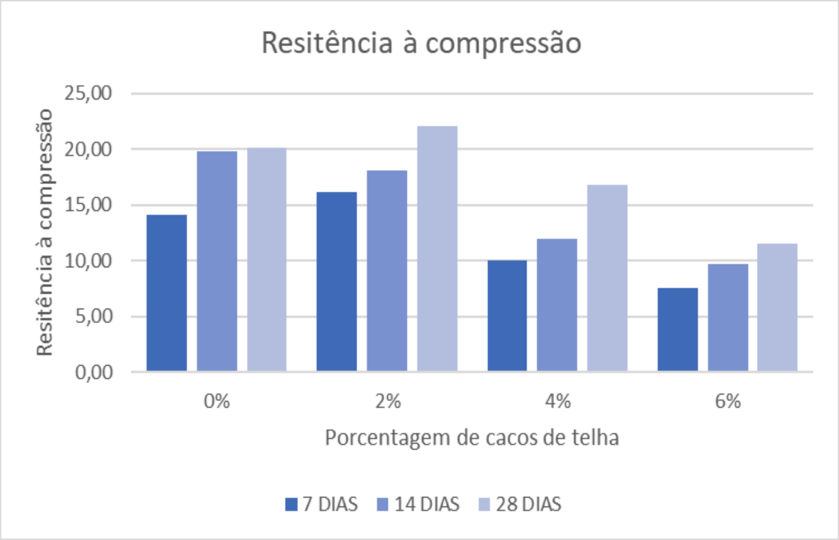
For the tests of resistance to simple compression according to the results it was elaborated in table 4 for each percentage of powder of broken tiles in average.

Table 4 - Average results of compressive strength tests

| Ecologic brick | 7 DAYS (Mpa) | 14 DAYS (Mpa) | 28 DAYS (Mpa) |
|---|---|---|---|
| 0% powder of broken tiles | 14.10 | 19.85 | 20.17 |
| 2% powder of broken tiles | 16.14 | 18.07 | 22.04 |
| 4% powder of broken tiles | 10.06 | 11.97 | 16.82 |
| 6% powder of broken tiles | 7.58 | 9.73 | 11.55 |

In the results presented in table 4 and illustrated in graph 3, it is possible to notice that for all percentages of addition of powder of broken tiles there is an increase in resistance compared to samples without addition and that only in the mixture with 2% was the percentage of addition that performed better.

Graph 3- Result of the compressive strength test




For the analysis of thermal comfort, the collection of temperature data was carried out at the pottery itself, as it has a model house (figure 9) with a length of 4m x 2.50m in height, green tiles of 2.40m x 0.50m and with the buildings in the natural color and the bricks with 0% mixture, since it is only desired to confirm the thermal comfort already mentioned in the literature. The test to measure the internal temperatures of the walls was carried out with the aid of a portable digital infrared laser thermometer scale -50 to 550ºC, with an accuracy of ± 1.5 ºC. Two temperature measurements were carried out daily between 12:00 and 18:00, for four consecutive days. These times were chosen to represent the afternoon and night shifts when the temperature in the region is higher.

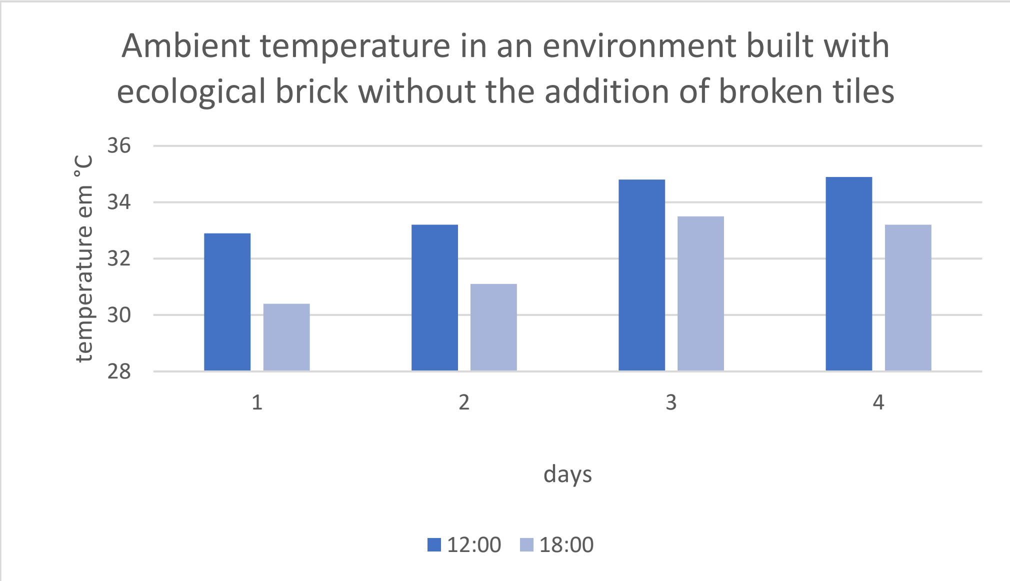
Figure 9 - house built with ecological brick

According to the results presented in table 5 and illustrated in graph 4, it is noted that during the afternoon and night shifts it is possible to obtain lower temperatures inside the house built with ecological bricks, the temperature in Teresina-PI reaches 40ºC in the period pm.

Table 5 - Temperatures in ºC for a masonry environment built with ecological brick without the addition of broken tiles

| **Soil-cement brick without the addition of tile dust** | | |
|---|---|---|
| **Morning** | **12:00 pm** | **6:00 pm** |
| 1 | 32.9 | 30.4 |
| 2 | 33.2 | 31.1 |
| 3 | 34.8 | 33.5 |
| 4 | 34.9 | 33.2 |

Graph 4- Result of the temperature measurement in the ecological brick model house




## 5. Conclusion

The results proved to be positive for the samples observed as to the increase in water absorption compared to the reference sample. For the percentage of 4% and 6% in relation to their resistance to bending, which were lower than the resistance of conventional bodies. However, only samples produced with 2% powder residue from tiles and bricks showed excellent results, based on the results presented, the use of broken tiles in the composition of ecological bricks meets the dimensional stability requirements described in NBR 8491/2012. In terms of dimensional tolerance, the values presented in the ecological bricks corresponded to the parameters established in this technical standard, therefore, it is possible to reuse these residues in the use of civil construction by directing a material previously discarded in the environment for the production of a sustainable brick with in order to reduce environmental impacts in the city of Teresina-PI.

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