Analysis of the optimization of the construction process of ecological brick compared to ceramic brick: A literature review

Abstract

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Abstract

The brick is composed of water, soil and cement, having an easy manufacturing process, with short construction and low cost is not subjected to burning is manufactured by a very different process from *ceramic blocks, the same goes through a hydraulic press. This type of brick has characteristics that provide quality, sustainability, beauty, and above all savings in the total cost of the work. When used in construction are eliminated some steps and the execution time in the work. A block wall or ceramic brick will need roughcast, sketch, plaster, seamer and painting, besides considering the cost of these materials can not forget the labor that corresponds to an average 50% of the value of the work. But the great advantage over the other bricks is its construction system, once raised the wall this is ready, does not need finishing, and the pillar structure and beams are ready with it. Electrical and Hydraulic Installations are easily installed without the need for breakage and waste. These bricks do not require the use of mortars for laying, coatings such as plastering for regularization and finishing of walls, in addition to accelerating the work with their fittings that facilitate the alignment and plumb of the walls. The objective of this work is present through a literature review of optimization processes that involve the ecological brick. in addition to accelerating the work with their fittings that facilitate the alignment and plumb of the walls. The objective of this work is present through a literature re-view of optimization processes that involve the ecological brick. in addition to accelerating the work with their fittings that facilitate the alignment and plumb of the walls. The objective of this work is present through a literature review of optimization processes that involve the ecological brick.*

Keywords: Ecological Brick, Materials, Optimization.

1. Introduction

Construction is certainly the largest consumer of natural resources in any economy, it is an activity that involves a large number of variables, being developed in a particularly dynamic and changing environment [1]. In an attempt to contribute to the well-being of the environment, Civil Engineering has been increasingly concerned with using alternative construction materials. In search of alternatives capable of satisfying a sustainable system, in the manufacture of modular bricks of soil-cement or ecological brick, there is the alternative of reducing the environmental impacts caused due to its abundant raw material, the soil [2] The brick ecological has essential characteristics to follow the sustainable development model. The ecological brick or soil-cement is also pleasing from an ecological point of view, as it does not go through the burning process, in which large amounts of wood or fuel oil are consumed, as is the case of bricks produced in ceramics and potteries [4] . According to the literature [5], "there is no construction that does not gene-rate impact, the search is for interventions that cause them on a smaller scale", that is, the fact that a mate-rial is considered sustainable does not assume that in its use there is no environmental impacts, but rather that, compared to other materials, they cause such impacts to a reduced degree. Civil construction is concerned with sustainable development, due to many raw materials that are used, which are scarce and generate pollution during the processing or extraction process. There is a search for lower costs and mainly in an attempt to minimize the emission of pollutants [6]. In its production the following materials are used: soil, cement and water. The compressive strength of soil-cement bricks is similar to that of conventional bricks, but the final quality is superior, as it has regular dimensions, flat faces, allow fitting between pieces, which can be done with little or no mortar [7]. According to [8], it can be added that the soil cement brick has abundant raw material all over the planet because it is raw earth. The author also emphasizes that the product does not need to be burned, which pro-vides energy savings, in addition to providing comfortable environments with little energy expenditure, al-lowing thermal and acoustic comfort, as it has insulating characteristics. The Brazilian market has several models of soil-cement bricks, as shown in Table 1, and they can be specified according to the application. These are chosen according to the project, labor, materials, local equipment, in addition to other specific conditions [8].

Table 1. The types of ecological bricks that are produced and marketed.

Type	dimensions	Characteristics
common massif	5×10×20 cm. 5×10×21 cm.	Laying with mortar consumption similar to bricks massifs.
Solid brick with inserts	5×10×21 cm. 5×11×23 cm.	Laying with recesses with low mortar consumption.
½ brick with inserts	5×10×10.5 cm. 5×11×11.5 cm.	Element produced so that there are no breaks in the formation of appliances with mismatched joints.
Bricks with two holes and fittings	5×10×20 cm. 6.25×12, 5×25 cm. 7.5×15×15 cm.	Dry laying, with white glue or very plastic mortar. Pipes pass through the vertical holes.
½ brick with hole and socket	5×10×10 cm. 6.25×12.5×12.5 cm. 7.5×15×15 cm.	Element produced to set the devices, without the need for breakage.
Pens - see Figure 1	5×10×20 cm. 6.25×12, 5×25 cm. 7.5×15×30 cm.	Element used for the execution of lintels, structural reinforcements, mooring straps and piping passages horizontal.

Source: Extracted from PISANI, 2005

[9] report that the use of modular soil-cement brick provides a quick and practical settlement, avoiding material waste, in addition to providing an execution with a non-specialized workforce, generating a final economy of the work. The use of soil-cement brick has several advantages, among the main ones, the saving of up to 50% of the final cost of the work compared to conventional ceramic blocks, the reduction of up to 30% of the final construction time and the saving of up to 100% of the use of laying mortar and also eliminates the use of 100% wood for making columns, in addition to the easy finishing, durability and cleanliness of the work due to the absence of debris [10]. This article seeks, through a systematic literature review, to understand the optimization techniques used in the production and construction process applied to the ecological brick and at the same time compare them to ceramic bricks in relation to the time spent

on labor between the masonry to promote the intelligent use of production and more reliability.

2. Theoretical reference

In civil construction, the waste of materials is common, due to lack of monitoring and planning of services, and in this way, the final cost of the work exceeds estimates. It is very important to be able to combine practicality with economy when building, which is why several construction methods and materials are chosen. This work presents a literature review on: Optimization in the production and construction process of ecological bricks and the comparison with ceramic bricks in relation to the time spent on labor in order to avoid waste, adding economic, ecological and logistical value.

2.1. Optimization

Process optimization requires the simultaneous development and use of a set of activities that basically involve: mathematical modeling, construction of objective functions and their constraints and the choice and adequacy of algorithm and numerical treatment to be used, depending on the purposes of the optimization [11]. There is currently a great incentive for process simulation and optimization. This is due, in part, to the constant need to obtain more competitive processes. Among the possibilities to achieve these goals are the applications of simulation and optimization, as a way to promote evaluations of an economic nature and process operability, aiming at productivity. Due to the minimization of losses and the maintenance of globalization policies. According to [12], the globalization process causes companies to be impacted by fierce market competition. In the struggle to stand out in a competitive market, industries are looking for a way to develop competitive advantages. The implementation of continuous improvement techniques enables major changes with little investment, which reduces waste in the production system, reduces unnecessary costs and provides greater customer satisfaction.

According to [13], within the scope of operations management, the costs normally attributed are composed of expenses with material, personnel, expenses with third-party contracts, expenses with consumables, expenses with application materials and the investments necessary for technological updating.

2.2. Ecological Brick

With population growth, and the great growth of cities, use of materials with reduced useful life; lack of quality materials and workmanship; Disorganized urbanization that leads to the generation of failures due to increases in adaptations and reforms facilitates the development of civil construction, it was necessary to develop sustainable constructions that solve environmental problems and everything involved in a construction, such as debris, water, garbage, effect gases greenhouse, among others. It was necessary to think of a medium that used the environment, but at the same time preserving it, reusing it and bringing harmony to the work. Ecological materials have been widely discussed and their use encouraged in civil construction in re-cent years [14,15,16].

The ecological brick is presented as an alternative in the search for more and more sustainable buildings, as it adds lower cost, reuse of materials and eliminates the burning process. Another positive aspect is the rationalization of the construction technique due to the use of modular blocks that provide a reduction in material waste, in addition to ensuring greater speed in the construction process, thus resulting in savings in labor [17].

According to [18] its regular shapes and precise measurements of the soil cement brick provides savings with the use of laying mortar, as it is only applied in 30% of its liquid area, its ducts facilitate the laying and alignment of the bricks and they also work with thermal and acoustic insulation. According to [19], these are bricks that have a structural function and not only seal as the common brick made from burning clay, they have their own characteristics that make them different from common bricks. According to its smooth face and its double fitting (figure 1), it facilitates a perfect leveling and finishing, reduces the time to complete the work and its structure does not require the use of nails, wires, wooden forms, in addition to avoiding cuts on the wall. ready to embed the hydraulic, electrical network.

Figure 1 - Examples of soil-cement joint masonry bricks

Source: Let's Build (2011).

Constructions made of soil-cement bricks can be 30% to 40% cheaper than conventional constructions, mainly due to the reduction of material waste and transportation costs, as the bricks can be made at the construction site. There are experimental projects that reach 50% savings. The gain also comes from saving mortar, reducing finishing material and breaking walls to install windows and doors. The mortar, in addition to having reduced use, is composed of earth, cement and white glue, which also makes its production cheaper. The masonry of bricks with blocks of soil-cement has some advantages because they are also manufactured in half brick, eliminating the breakage of bricks on the job, generating savings. The production of soil-cement bricks varies according to the objectives of their use coatings.

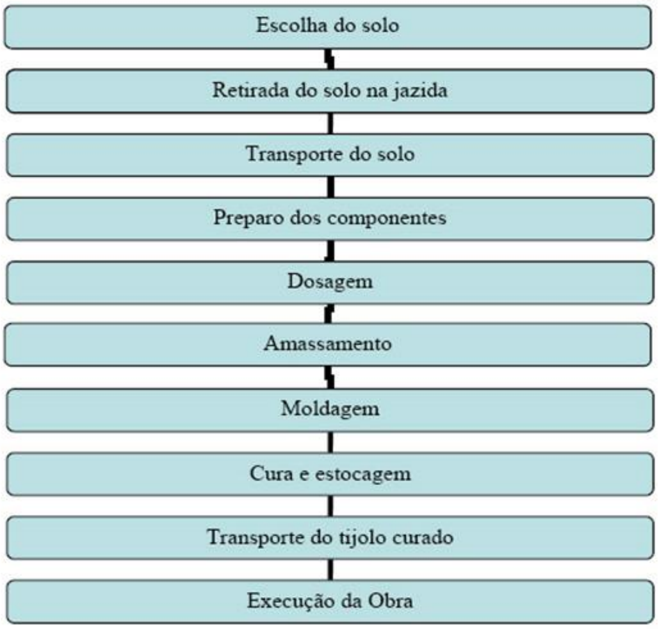
The ecological brick, in addition to contributing to the environment by avoiding the emission of greenhouse gases, will massively contribute to the country's economy, in view of the reuse of disposable materials, as it is a product that is durable and resistant, in addition to being low cost and high applicability potential in civil construction with regard to the construction of affordable housing [23].

2.3 Ecological Brick Production Process

The manufacture of ecological bricks is an intelligent solution for civil construction, which increasingly seeks constructive solutions, the use of new tools, waste recycling, sustainable development, meeting the housing deficit and reducing waste at the construction site with rationalization of materials and labor. In this context, soil is an appropriate material for several applications in the sector due to its abundance, easy reach, handling and low cost, enabling its use in various solutions [24].

The steps of the ecological brick manufacturing process start with the choice of soil, soil preparation, soil mixing, molding the bricks and finally the curing and storage process. Taking these aspects into account, the following manufacturing steps can be listed, as illustrated in Figure 2.

Figure 2 – Flowchart of the steps in the manufacture and use of soil-cement bricks.



Source: PISANI, 2004.

According to [25], the preparation of the soil begins with its removal and sieving. Afterwards, cement is added to the soil and the mixing and homogenization of dry products is promoted. Finally, water is added to the mixture until it reaches the same moisture throughout the mass, thus ending the process of preparing the mixture. After the entire process of obtaining and separating the ideal material, the homogenized mixture of soil-cement is transferred to the press, which has a mold of variable dimensions, where for each type of pressing, solid bricks or with two holes, known by modular brick [26].

[25] states that, in the production of soil cement bricks, the equipment used to mold the brick is essential, as it is in the pressing process that the soil grains are packed, resulting in a product with low porosity and high density. The molding can be done in hydraulic, manual or mechanical presses. The process of choosing the soil is important because it is added in greater quantity, NBR 108322/13, defines the necessary soil parameters for the production of solid soil-cement bricks or ecological bricks summarized in Table 1.

Table 1 – Soil characteristics for the manufacture of ecological bricks.

Characteristics	Requirement (%)
% of soil passing through the ABNT 4.8 mm sieve (No. 4)	100
% of soil passing through the ABNT sieve 0.074 mm (No. 200)	10 - 50
Liquidity limit (LL)	≤ 45
Plasticity Limit (LP)	≤ 18
% of sand	50 - 70
% Silt	10 - 20
% clay	10 - 20

Source: NBR 10832/2013.

To finish, going to the curing of the ecological brick, it is necessary that they be intensively wetted in the first 6 hours after its making and periodically for seven days. The bricks must generally be covered with plastic tarpaulin, to keep the moisture present and to avoid the rapid exit of water through evaporation, thus ensuring the homogeneous curing of the bricks [27]. The curing process must be rigorously monitored until the product is finished, finally obtaining a material that is mechanically resistant and of good appearance [28], the confection of the cement soil brick is a revolutionary technique for being an intelligent, fast, ecological way of building, being absolutely resistant to all the standards required by the Technical Norms. In addition, this type of brick has characteristics that provide quality, solidity, beauty, and economy in the total cost of the work.

3. Materials and method

For the development of this work, completed works were analyzed through bibliographical research. The data survey was carried out on academic google and CAPES journal portal, admitting publications from 2000 to 2018. The bibliographic survey was carried out seeking published studies on ecological brick and optimization. As selection criteria, studies on the chosen topic were used, selecting publications in annals (national and international congresses), articles (national and international journals) and theses. The inclusion criteria were the following logical operators and key expressions: (a) Ecological Brick; (b) Optimization methods. The expressions used were chosen in order to cover as many studies related to the ecological brick (a), as with a focus on optimization methods, being chosen based on keywords of articles on the topic. After the initial search, the repeated articles within the same search were removed. After that, a reading of the abstracts was started to verify if the work consulted is of interest to the work to be developed, followed by a detailed reading to select the studies that are directly related to the research object.

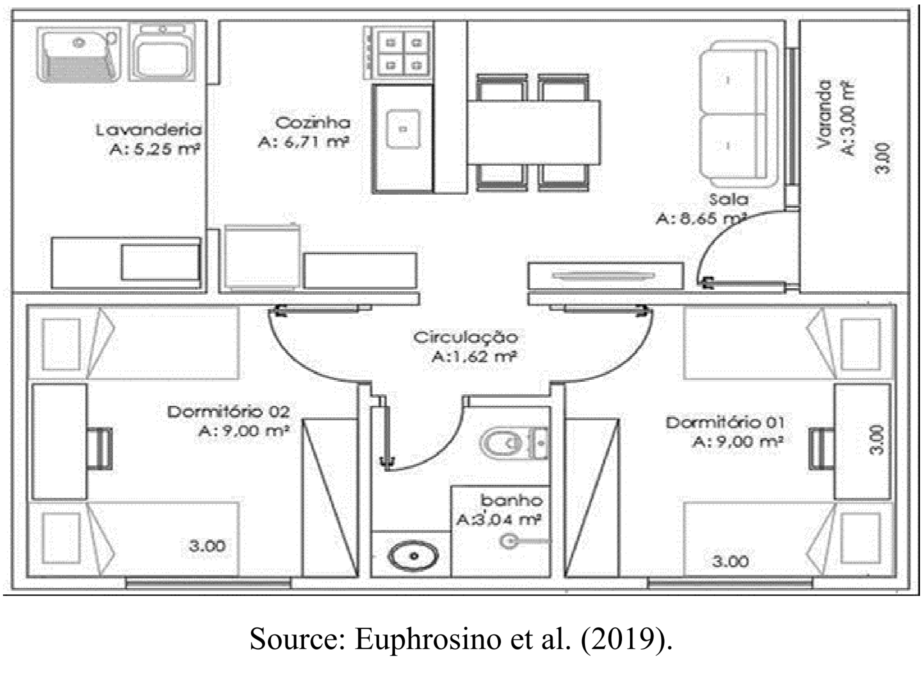
4. Analysis of optimization methods

In this topic, the methodology will be presented through a bibliographic survey on the concepts and technical aspects of optimization in the productive and constructive process applied to ecological brick and also to ecological brick with addition of demolition waste (RCD) comparing the time spent on labor between masonry that uses ceramic bricks used in the works chosen for analysis. In general, it will be shown how the authors presented optimization concepts in the development of their work.

4.1 Analysis 01

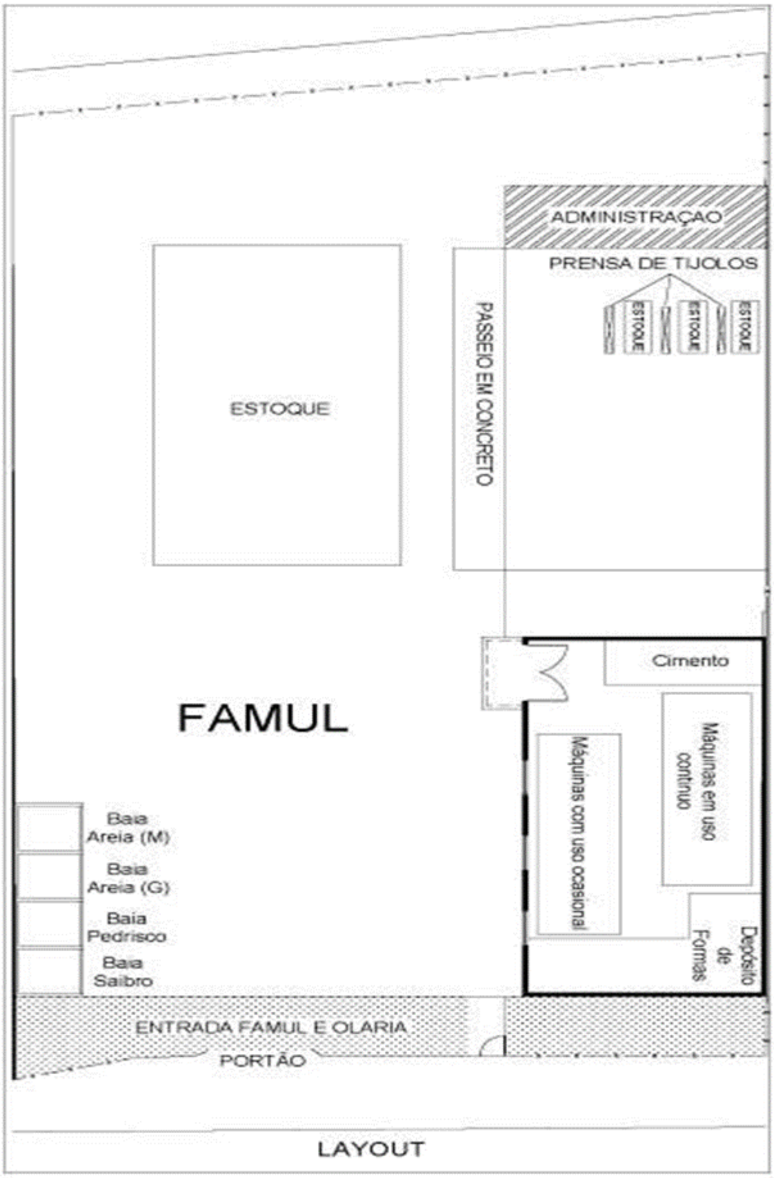
The work performed by [29], aimed to make a case study of the production and construction process with soil cement brick, better known as ecological brick, of a HIS (Housing of Social Interest) in the city of Limeira-SP. The brick production process was mapped, which are produced by the borrower in the city hall's pottery, and the construction of the masonry in the works was mapped. Lean concepts were addressed, such as: Lean Construction and Value Stream Mapping (MFV). For the MFV in the production of bricks in the pottery and in the receipt of these and construction of masonry on site, the floor plan of the work to be carried out and the FAMUL layout were reproduced, which are presented in figures 3 and 4 below. The floor plan project for a two-bedroom house was chosen as it was the most requested by SEHAB's clients. In this work, a current map was organized and pointed out waste such as rework and queues of accumulated processes which impacted the total Lead Time of the project execution, thus delaying the execution of the work. In these surveys, it can be seen that in every area where there is the development of a product, waste of time, cost, and problems with information flow are frequent. With the Lean MFV tool it is possible to identify this waste and propose changes, generating benefits. and problems with information flow are frequent. With the Lean MFV tool it is possible to identify this waste and propose changes, generating benefits and problems with information flow are frequent. With the Lean MFV tool it is possible to identify these wastes and propose changes, generating benefits.

Figure 3: Two-bedroom residential floor plan.



Source: Euphrosino et al. (2019).

Figure 4: FAMUL Layout



Source: Euphrosino et al. (2019).

[29] showed the weekly distribution of families (Table 2) in the use of ecological pottery. Only 4 families participate simultaneously in the program in the ecological pottery until the end of the production necessary for the construction of the residence. In addition, the FAMUL space for the production of bricks can only be used from Monday to Thursday, from 8:00 am to 12:00 pm and from 2:00 pm to 6:00 pm. After Friday, the space is used for other productions of urban furniture in the city.

Table 2**:** Weekly distribution of families to use the pottery

Time/Day	**Second**	**Third**	**Fourth**	**Fifth**
08:00 to 12:00 h	Family 1	Family 3	Family 1	Family 3
2:00 pm to 6:00 pm	Family 2	Family 4	Family 2	Family 4

Source: Euphrosino et al. (2019).

Each family has 8 hours of work per week, and only one person in the family usually participates in the production. The project chosen for the mapping of the work, needs approximately 8000 bricks, being 10% channel blocks, 10% half blocks and 80% whole blocks [29].

Thus, according to the observations made by [29], the total production time of the bricks for a work is 44.5 weeks + 1 week (Cure Time), that is, 45.5 weeks. With these data, the production schedule (Table 2) was constructed for families that opt for the two-bedroom residence project.

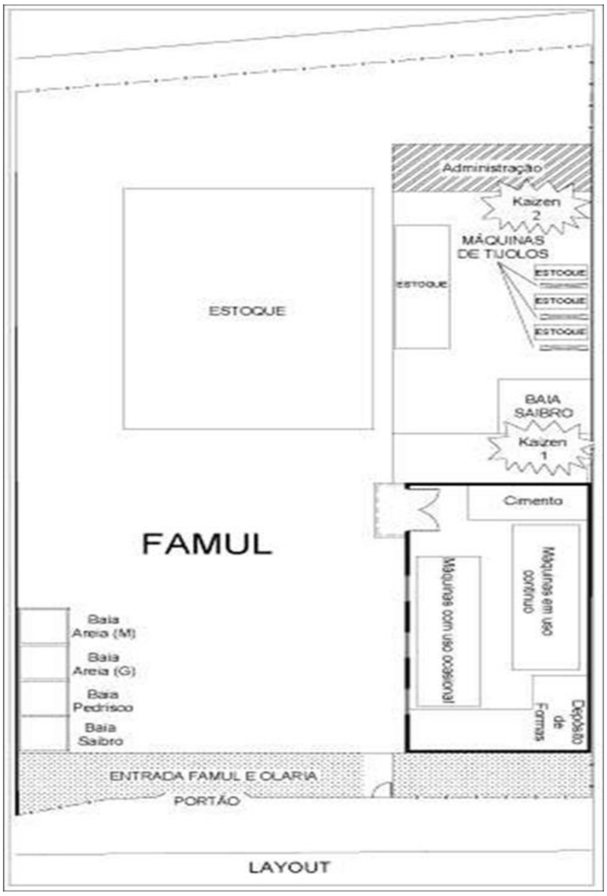
Table 2**:** Current production schedule.

weeks	1 to 32	33 to 39	40 to 45
whole blocks			
half blocks			
Channel blocks			

Source: Euphrosino et al. (2019).

During the development of the research [29], new tools and techniques were incorporated into the system in order to optimize production time and increase the quality of the brick, first a change in the FAMUL Layout (Figure 5), new tools were introduced in production as the electric sieve and the concrete mixer. In order to increase the quality of the product, the bricks are no longer stored directly on the ground. During the curing period, the bricks are covered with a plastic sheet, preventing the loss of water to the environment [29].

Figure 5: Proposed layout of the ecological FAMUL.



Another suggestion presented by [29] that can be taken to optimize production and that has not yet been incorporated into the process is the adoption of simultaneous work by two families. The factory has three manual machines for pressing bricks (1 full brick, 1 channel block and another half block). Thus, a new weekly distribution of the use of pottery by families was proposed, as shown in Table 3, where F=family.

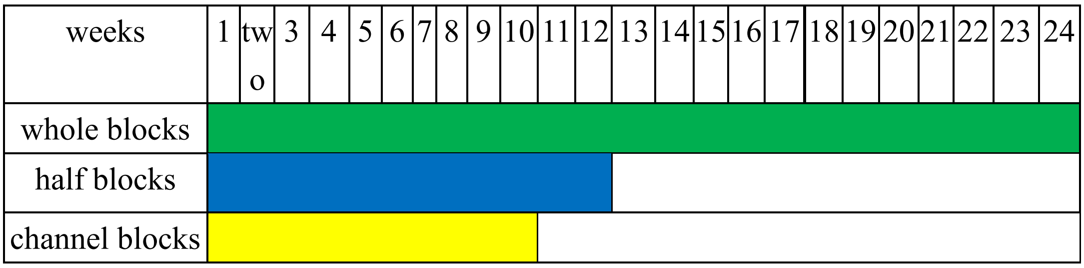
Table 3: Proposed weekly distribution of families in the use of ecological pottery

Time/Day	Monday	Tuesday	Wednesday	Thursday
8:00 AM TO 12:00 AM	F1 - Entire block	F3 – Entire block	F1 - Entire block	F3 – Entire block
	F3 - Channel block	F1 - Channel block	F3 - Half block	F1 - Half block
2:00 pm TO 4:00 pm	F2 - Entire block	F4 - Entire block	F2 - Entire block	F4 - Entire block
	F4 - Channel block	F2 - Channel block	F4 - Half block	F2 - Half block

Source: Euphrosino et al. (2019).

In this way, each family would have 8h/week to produce whole blocks, 4h/week for half blocks and 4h/week for channel blocks. Thus, starting the manufacture of half blocks and channel blocks simultaneously with the entire blocks, the total production time will drop to 24 weeks, as shown in the production schedule (Table 3).

Table 3: Proposed production schedule.



Source: Euphrosino et al. (2019).

With the changes proposed by [29], the brick production time for a two-bedroom residence dropped from 44.5 weeks to 24 weeks (Figure 6), which represents a 46% decrease from the initial time. It is also noteworthy that the changes in the storage of materials improve the quality of the bricks.

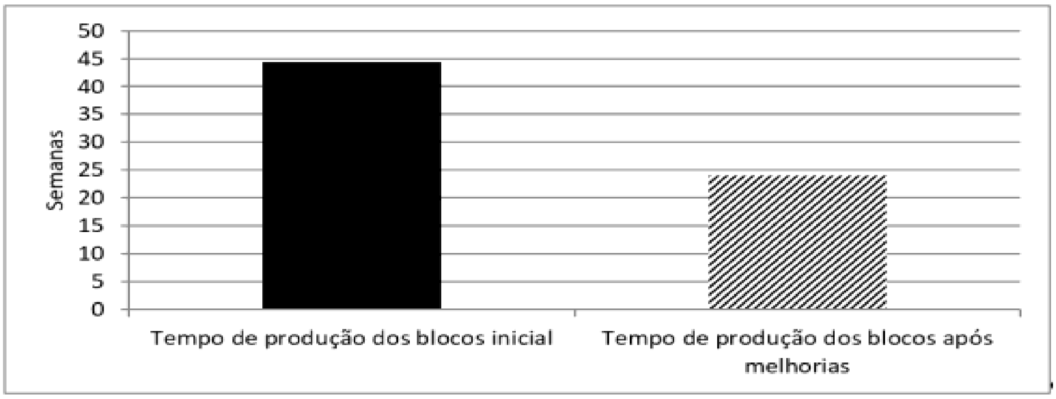


Figure 6: Production time of bricks in cement soil before and after improvements.
Source: Euphrosino et al. (2019).

[29] concluded that the total construction time of one meter of masonry work fell to 32 h. Therefore, productivity increased from 0.28 m2/H/h to 0.32 m2/H/h, and the total construction time of the masonry decreased to 96 h, which in a workday of 8h/day is 11 days . Therefore, it is possible to complete the construction of the masonry in two days less.

4.2 Analysis 02

In the work developed by [30] presents a study on ecological brick with addition of demolition waste (RCD) comparing the time spent on labor between masonry using ceramic bricks, the results obtained by the two types will be presented in the course of the work. of masonry. Subsequently, the results obtained by the two types of masonry will be presented. And with that, to present which method becomes more viable for the elaboration of a one story residential building.

According to [30], for the purpose of comparative calculation of men hours worked, three single storey residential building were used: 1st Residential building located in Varginha MG used soil cement bricks with addition of RCD built by the owner with an area of 252.45 m² . It will be studied regarding the term in the executive conditions. 2nd residential building located in São Bernardo do Campo SP, built by the Alroma construction company with an area of 56 m², using soil cement bricks with the addition of RCD. 3rd Residential building with a fictitious floor elaborated from the project carried out in Varginha – MG with an area of 252.45 m² for comparative calculation purposes, with ceramic brick masonry. Following the process of optimizing the construction process developed by [30], Table 4 shows the consumption of soil cement bricks with the addition of CDW to be used for the construction of a one storey residential building located in Varginha, MG. With 275m² of built wall.

Table 4: Quantity of soil-cement bricks with the addition of RCD, spent on the first building.

Quantitative of soil cement bricks with addition of RCD			
X walls	bricks by walls	Y walls	bricks by walls
Wall x1	1380	wall y1	1225
Wall x2	336	wall y2	358
Wall x3	745	wall y3	422

Wall x4	336	Wall y4	1829.6
Wall x5	567	Wall y5	1450
Wall x6	458	wall y6	1380
Wall x7	698.8	wall y7	1320
x8 wall	168	wall y8	1450
Wall x9	936	wall y9	1450
Wall x10	795	wall y10	1280
Wall x11	448		
Wall x12	784		
Wall x13	672		
Wall x14	356		
Wall x15	593.6		
Wall x16	562		
Number of bricks	9835.4		12164.6
Total bricks: 22000			

Source: Szurkalo (2016).

Table 5 shows the consumption of soil cement bricks with the addition of CDW to be used for the construction of a one-storey residential building located in São Bernardo do Campo SP. With 135m² of built wall [30].

Table 5: Quantity of soil-cement bricks with the addition of RCD, spent on the second building.

Quantitative of soil cement bricks with addition of RCD			
walls	bricks by walls		bricks by walls
Wall x1	925.3	wall y1	1424.7
Wall x2	342	wall y2	935
Wall x3	428	wall y3	885
Wall x4	745	Wall y4	560
Wall x5	792	Wall y5	856
Wall x6	795	wall y6	432
Wall x7	1248	wall y7	432
Number of bricks	5275.3		5524.7
Total bricks: 10800			

Source: Szurkalo (2016).

Table 6 shows the consumption of ceramic bricks to be used to carry out the study of man hour worked, based on the project implemented in Varginha – MG [30].

Table 6: Quantity of ceramic bricks, spent on the third building.

Quantity of ceramic bricks.			
X walls	bricks by walls	Y walls	bricks by walls
Wall x1	235	wall y1	450
Wall x2	156	wall y2	358
Wall x3	186	wall y3	285
Wall x4	98	Wall y4	285
Wall x5	155	Wall y5	178
Wall x6	158	wall y6	175
Wall x7	245	wall y7	250
x8 wall	480	wall y8	235
Wall x9	320	wall y9	146
Wall x10	250	wall y10	146
Wall x11	440		
Wall x12	350		
Wall x13	420		
Wall x14	356		
Wall x15	198		
Wall x16	320		
Number of bricks	4247		2628
Total bricks: 6875			

Source: Szurkalo (2016).

[30] presented the quantity of bricks collected from the three works analyzing the consumption of the material, the first work carried out in Varginha - MG the consumption presents about 11200 soil cement bricks with addition of RCD more than the second work carried out in São Bernardo do field – SP. For the work under study carried out in Varginha - MG, which used cement soil bricks in its masonry with the addition of RCD with a dimension of 5 x 12.5 x 25 compared to the third work prepared for comparative calculation purposes using 9 x 19 ceramic bricks x 19 had in consumption 15215 ceramic bricks less than the first work. With the established indexes and the value of bricks spent on each work, it is possible to carry out the study of man-hour worked.

Table 4 shows the time to carry out the masonry with soil-cement bricks with the addition of RCD, adopting a journey of 8 hours a day.

Table 4: Time spent per man hour worked in the Varginha project – (MG).

Productivity of brick masonry systems with the addition of RCD					
Components	Unit	Resource	Index	The amount	Total (h)
Masonry in soil cement bricks with addition of RCD	H	Official	0.66	275	181.5
	H	servant	0.50	275	137.5
	Duration required: 21 days				

Source: Szurkalo (2016).

Also according to [30], the amount of duration needed is directly related to the amount of materials, with the index of each resource together with a workday of 8 hours/day. Using only 1 officer and 1 helper for each activity, the required duration from the previous table (table 4), is as follows equation 1:

$$\text{Duration required} = \frac{\text{Quantity of material x index}}{\text{Journey 8h x Resource amount}} = \frac{275 \times 0.66}{8 \times 1} = 21 \quad (1)$$

Table 5 shows the time to carry out the masonry with soil-cement bricks with the addition of one-floor RCD, in the construction site in São Bernardo do Campo – SP, adopting a journey of 8 hours a day.

Table 5: Time spent per man hour worked on the construction site in São Bernardo do Campo (SP).

Productivity of brick masonry systems with the addition of RCD					
Components	Unit	Resource	Index	The amount	Total (h)
Masonry in soil cement bricks with addition of RCD	H	Official	0.64	135	86.4
	H	servant	0.67	135	90.45
	Duration required: 11 days				

Source: Szurkalo (2016).

[30] calculated the amount of duration needed is directly related to the amount of materials, with the index of each resource together with an 8-hour workday. Using only 1 officer and 1 helper for each activity, the required duration from the previous table (table 6), equation 2 is as follows:

$$\text{Duration required} = \frac{\text{Quantity of material x index}}{\text{Journey 8h x Resource amount}} = \frac{135 \times 0.64}{8 \times 1} = 11 \quad (2)$$

Table 6: Man-hour time spent working in the fictitious project elaborated from the project carried out in Varginha – (MG), for the purpose of comparative calculation

Productivity of ceramic brick masonry systems					
Components	Unit	Resource	Index	The amount	Total (h)
Masonry in soil cement bricks with addition of RCD	H	Official	0.54	275	148.5
	H	servant	0.75	275	206.3
	Duration required: 19 days				

Source: Szurkalo (2016).

[30] calculated the amount of duration needed is directly related to the amount of materials, with the index of each resource together with an 8-hour workday. Using only 1 officer and 1 helper for each activity, the required duration from the previous table (table 6), is as follows equation 3:

$$\text{Duration required} = \frac{\text{Quantity of material x index}}{\text{Journey 8h x Quantity resource}} = \frac{275 \text{ x } 0.54}{8 \text{ x } 1} = 19 \quad (3)$$

[30] concluded in his research that the use of soil cement bricks with the addition of RCD is ecologically correct, the form of application of soil cement bricks with the addition of RCD increases productivity in the general context of the work, as they are produced with pipelines that serve as fitting, reducing labor time and facilitating leveling and alignment, in addition, the use of these bricks ensures a cleaner work with little debris. For [30], in relation to the execution step of the masonry with soil cement bricks with the addition of RCD, it resulted in a longer time than the conventional one, because in its construction process the layout of the places where the conduits and pipes will pass must be provided. hydraulics. Subsequently, the time spent to carry out the electrical and hydraulic installation activity will be optimized.

5. Conclusion

According to the results and conclusions found in analysis 01 and analysis 02 throughout this study, benefits are presented for the production and application of ecological brick, as its advantages in construction go beyond promoting sustainability, they provide beautification, improvement and economy to the construction process and are easy to manufacture. Furthermore, knowledge about the optimization process can encourage professionals in the ceramic industry and stakeholders to achieve excellent results, reducing waste and the time needed to carry out activities. These results can support new proposals to encourage these actions.

6. References

[1] MATTOS, A. D. (2010). Planejamento e controle de obras (1. ed.). São Paulo: PINI.

[2] PEREIRA, J. O.; DANTAS, V. B.; SILVA, S. L.; BATISTA, R. O.; PORDEUS, R. V.; DINIZ, M. J.;

OLI-VEIRA, F.A.; LINHARES, P. (2019). Soil Structural Behavior as a Function of the Amount of Coverage of Maize and Oat Straw on Oxisol on Subtropical Region. Journal of Agricultural Science, v. 11, p. 246.
[3] GONÇALVES, C. P.; CARDOSO, A. F. A utilização da cerâmica nas técnicas construtivas em busca da inovação e sustentabilidade. In: 201 Congresso Brasileiro de Cerâmica, 60. 2016. Águas de Lindóia, São Paulo, 2016. p. 577 - 587.
[4] SOUSA, A. A. P; OLIVEIRA, D. F; FARIAS, G. G; SOUSA, M. F. N E JORDÃO, M. T. (2007). Sinal Verde – Gestão Ambiental: a experiência do CEGAMI, EDUEP. Campina Grande/PB.
[5] PISANI, M. A. J. Um material de construção de baixo impacto ambiental: o tijolo de solo-cimento. AE ensaios, 2010.
[6] PENTEADO, P.T.; MARINHO, R.C. (2011). Análise comparativa de custo e produtividade dos sistemas construtivos: alvenaria de solo-cimento, alvenaria com blocos cerâmicos e alvenaria estrutural com blocos de concreto na construção de uma residência popular, p.9.
[7] FERRAZ, A.L.N. (2004). Análise da Adição de Resíduos de Argamassa de Cimento em Tijolos Prensados de Solo-Cimento. Dissertação (Mestrado) – UNESP. Ilha Solteira-SP, 2004, 92p.
[8] PISANI, M. A. J. (2005). Um material de construção de baixo impacto ambiental: o tijolo de solo-cimento. In: SINERGIA. v.6. n.1. São Paulo
[9] FRAGA, Y. S. B. et al. (2016). Tecnologia dos materiais: a utilização do tijolo de solo-cimento na construção civil. Caderno de Graduação-Ciências Exatas e Tecnológicas-UNIT, v. 3, n. 3, p. 11.
[10] SAMPAIO, G. S.; NUNES, I. E. S. (2017). Estudo interdisciplinar da viabilidade de aplicação do tijolo de solo-cimento na construção civil: economia aliada à sustentabilidade. Faculdade Integradas Teresa D' Ávila – FATEA.
[12] TONDOLO, R. da R. P. et al. (2016). Gestão dos custos operacionais na empresa de pequeno-porte: um estudo de caso no sul do Brasil. Revista Espacios, v. 34.
[13] SUZUKI, T. (1994). TPM in Process industries. Portland, USA: Produtivity Press.
[14] ARAUJO, M.A. A Moderna construção sustentável. Disponível em:< http//s3.amazonas.com/academia.edu.documentos/305088580/moderna.pf?AWSAAcessoKeyld=AKIAIWOWYYGZ2Y53UL3A&Expires=152934877&Signature=dyF9MVkDjYuV9Sg5xMtKMDp%2F%3D&response-content-disposition=inline%3B%20filename%3DA_moderna_construção_sustentável.pdf> Acesso em 18/01/2021.
[15] SOUZA, U. E. L. et al. (2004). Diagnóstico e combate à geração de resíduos na produção de obras de construção de edifícios: uma abordagem progressiva. Ambiente construído, Porto Alegre, v. 4, n. 4.
[16] CORRÊA, L. R. (2009). Sustentabilidade na Construção Civil. Dissertação (Monografia). Escola de Engenharia UFMG - Curso de Especialização em Construção Civil.
[17] NASCIMENTO, A. M.; FEITOSA, A. DE O.; ALMEIDA, T. DA S. (2018). Tijolo modular de solo-cimento como material na construção civil. Interscientia, v. 6, n. 1.
[18] WENDLER (2014). A Construção fácil. Revista Téchne. São Paulo, n. 205. Não paginado. Disponível em: < http://techne.pini.com.br/engenharia-civil/205/artigo 310706-1.aspx. Acesso em: 15 maio. 2021.
[19] PINATTI, A. (2015). Engenheira de Materiais, especialista em cerâmicas, e consultora em planejamento ambiental, eficiência energética, gestão da qualidade. Comentário sobre aspectos do tijolo solo cimento

Revista Negócios da Comunicação. São Paulo n.86 p. 26.

[20] REVISTA ONLINE SUTENTABILIDADE (2019). Construções com Solo-Cimento. Disponível em: <http://www.revistasustentabilidade.com.br>.

[21] COMISSÃO EXECUTIVA DE PLANEJAMENTO DA LAVOURA CACAUEIRA –CEPLAC. Construção com solo-cimento. Cruzeiro: CEPLAC, 2011. Disponível em:<http://www.ceplac.gov.br/radar/semfaz/solocimento.htm> Acesso em: 18 de dezembro 2020.

[22] PISANI, M.A.J. (2004) Execução do tijolo de solo-cimento. Relatório de Pesquisa: Promoção do Desenvolvimento Sustentável do semiárido da Bahia. Universidade Presbiteriana Mackenzie, São Paulo.

[23] NEVES, C. M. M. (2004). Resgate e atualização do construir com terra: o projeto pro- terra. In: Conferência latino-americana de construção sustentável, 1, 2004, encontro nacional de tecnologia do ambiente construído, 10., 2004, São Paulo. Anais... São Paulo: [S.n.], 2004.

[24] GRANDE, F. M. Fabricação de tijolos modulares de solo-cimento por prensagem manual com adição de sílica ativa. São Carlos: EESC-USP. Dissertação Mestrado, 2003. 165p

[25] SILVA, M. V. Desenvolvimento de tijolos com incorporação de cinzas de carvão e lodo provenientes de estação de tratamento de água. Dissertação (Mestrado em Ciências na área de Tecnologia Nuclear), Universidade de São Paulo, USP, São Paulo, 2011.

[26] COPARI, V. P.; OLIVEIRA, M. B. Confecção de tijolos ecológicos como alternativa para reutilização dos resíduos gerados por centrais dosadoras de concreto.” REINPEC-Revista Interdisciplinar Pensamento Científico 2.1 (2016).

[27] VALADÃO, I. C. R. P.; Vilela, F. O; Faria J. Produção de tijolos ecológicos no UGB. V.8, N.1, p.43, 2015. Disponível em: http://www.ugb.edu.br/revista- episteme-transversalis/edicao8/ARTIGO4.pdf Acesso em: 09 agosto 2017.

[28] SANTOS, A. F. R.; BAUMGART, L. N.; WOICIOKOSKI M.; TABARELLI J. O.; JATZAK S.; Nicoletti V. Utilização de resíduos da construção civil em tijolos ecológicos. Trabalho Interdisciplinar, Administração da Produção II. Associação do Vale do Itajaí Mirim, 2009.

[29] EUPHROSINO, C. A.; Pimentel, L. L.; Camarini, G.; Ortigara, Y. V. B.; Ruiz, P. V.; Fontanini, P. S. P. Mapeamento do processo produtivo e construtivo de alvenaria de tijolo de solo-cimento para habitação de interesse social. Revista Matéria, vol. 24, n.04, 2019.

[30] SZURKALO, V. R. R. Estudo de viabilidade do uso de tijolos solo cimento com adição de resíduo de obra para redução do prazo de construção de edificação residencial de um pavimento. UNIS/MG. Varginha-MG, 56p, 2016.