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Sustainable Alternative: Economic Feasibility Analysis of Using Soil-Cement Brick in the Construction of Popular Housing

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***Abstract*—*The aim of this study is to present an analysis of the economic viability of using soil-cement bricks in the construction of popular housing. The study of this material is a way to promote an ecological, social and economic vision, fundamental for the civil construction. The present study presents a proposal for the use of soil-cement brick in the construction of a popular dwelling in accordance with the Manaus City Works Code. The items are made of Portland cement and ground sand, easy to assemble and at a much lower cost. It was concluded that the masonry of soil-cement modular bricks has a lower cost when compared to the masonry of structural ceramic blocks.*
Keywords*—Sustainability, Soil-Cement Brick, Economic Feasibility.

I. INTRODUCTION

Civil construction is one of the activities that most generates environmental impacts, using natural resources from the manufacturing process of materials to the execution of the work. The search for sustainable alternatives becomes necessary to mitigate the environmental impacts that may be allied to the cost reduction of a work.

Thus, ground-cement brick, known as a type of modular or ecological brick, emerges as an element that seeks to meet the demand for sustainable construction. This brick is produced from the pressing of soil, cement and water, standing out for presenting less aggression to the environment in its manufacture, when compared to the most used types of blocks - concrete blocks and ceramic blocks.

In addition to seeking to minimize environmental impacts, the use of soil-cement brick presupposes a reduction in construction costs due to the abundance of its raw material. Thus, this material can facilitate access to popular housing by low-income groups, showing itself as a way to find ways of promoting an ecological, social and economic vision, fundamental for sustainable development in the field of Civil Engineering.

II. THEORETICAL REFERENCE

2. 1 Sustainability in Civil Construction

Anthropogenic actions and activities related to economic and material development without causing harm to the environment are defined as sustainability[1].

Thus, a company must base its economic growth on strategies that allow the preservation of the environment. Solving environmental problems requires a new attitude from entrepreneurs and managers, who must consider the environment in their decisions and adopt administrative and technological conceptions that contribute to expand the carrying capacity of the planet [2].

Soil-cement brick emerges as a sustainable alternative, as its manufacturing process has a lower environmental impact and is economically viable due to the abundance of its raw material and other factors, such as reduction of material waste during its production and production. even execution of the work.

2.2 Soil-Cement Bricks

Soil-cement brick has been detached due to the abundance of its raw material and low cost, as well as its more economical manufacturing process, as it does not have to go through the burning process [3].

According to ABNT NBR 12023: 1992-Soil-Cement: compaction test, soil-cement is a hardened product formed from the cure of a compacted mixture of soil, cement and water [4].

2.2.1 Soil characterization for the manufacture of soil-cement brick

Soil particle size is a key feature to differentiate soil types, and specific determinations are employed for the various grain size ranges [5].The limits of these ranges are presented in Table 1 and vary according to the classification system adopted.

Table. 1: Soil particle size classification.

Soil Types	Size (mm)
Boulder	60 a 2
Sand	2 a 0,06
Silt	0,06 a 0,002
Clay	< 0,002

Source: [6]

Regarding the geotechnical profile of the soil, it is considered that the surface of the earth's crust has three distinct layers, called horizons (Figure1) [7].

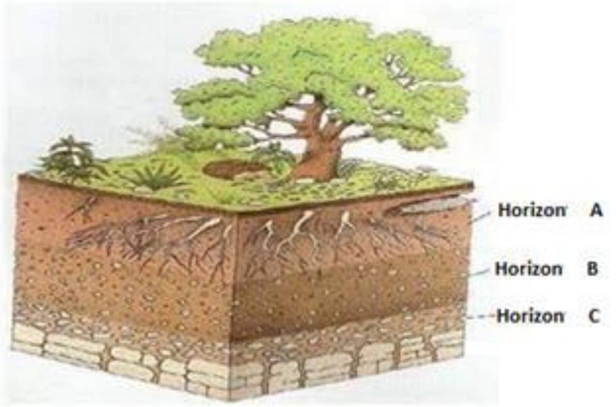

Fig. 1: Soil Formation Horizons, Source: [7].

Horizon A -It consists of products resulting from the decomposition of living things along with some mineral matter. In this layer some animals and plant roots can be found.

Horizon B –It is formed by mineral fragments and some materials from the decomposition of living beings.

Horizon C –It consists of mineral fragments, resulting from the breakdown of Mother Rock, a rock that gives rise to the soil.

Horizon C soils have sandy configuration, being preferable in the preparation of soil-cement. Sandy soils usually require smaller amounts of cement than clay and silt. However, the presence of clay in the soil composition is important to ensure cohesion to the soil and cement mixture when moistened and compacted, for demoulding and handling of the bricks after pressing. Soils containing organic matter should be avoided as this component influences cement hydration and soil stabilization [8].

2.2.2 Feasibility of using soil-cement brick

The determining factor for better soil-cement quality depends on the soil type, molding moisture, press type, soil / cement ratio, stabilizer type and the curing process. For higher compressive strength, absorption and durability of soil-cement, a higher percentage of cement should be used in the mix [9].

The manufacture of ecological brick helps in environmental preservation, due to the exclusion of the burning process and, consequently, the need not to promote the felling of trees for the production of firewood. Its technical viability occurs due to its great durability and reduced maintenance in buildings with its construction [10].

The benefits of using ecological brick are not only environmental, but also economical, as they provide material savings and do not require plaster to finish the walls, leaving them exposed.

III. APPLIED METHODOLOGY

O presente estudo apresenta uma proposta de utilização de tijolo de solo-cimento na construção de uma moradia popular em conformidade com o Código de Obras e Edificações do Município de Manaus, conforme medidas apresentadas no Art. 55 da lei complementar nº 003 do Plano Diretor (Tabela 2):

Table. 2: Measurements of a popular dwelling.

COMPARTIMENTO	*ÁREA MIN.*	*LARGURA MIN.*	*PÉ DIREITO MÍN.*
SALA	*8,00 m²*	*2,40 m*	*2,60 m*
QUARTOS	*8,00m²*	*2,40 m*	*2,60 m*
CÔMODO DIFERENCIADO	*7,00 m²*	*2,40 m*	*2,60 m*
COZINHA	*4,50 m²*	*1,60 m*	*2,20 m*
BANHEIRO	*2,00 m²*	*1,00 m*	*2,20 m*

Source: Lei complementar n° 003 (2014) adaptado.

The popular housing will have 46.80 m² of living space and will have 3D facade architectural plans, elevations, floor plan, roof plan, humanized plan and internal sections. To develop your architectural project, AutoCAD 2019.1 and SketchUp Pro 2018 software will be used.

The economic viability analysis of the work will be carried out by comparing with the apparent structural bricks (soil-cement brick) building system with the building system using ceramic sealing block through budget worksheets constructed from the Budget Price Composition Table - TCPO and SINAPI - National System of Costs Research and Indexes of Civil Construction.

IV. RESULTS ANALYSIS AND DISCUSSION

For the project of building a single-family house of 46.8 m2, according to the dimensions presented in Table 2,

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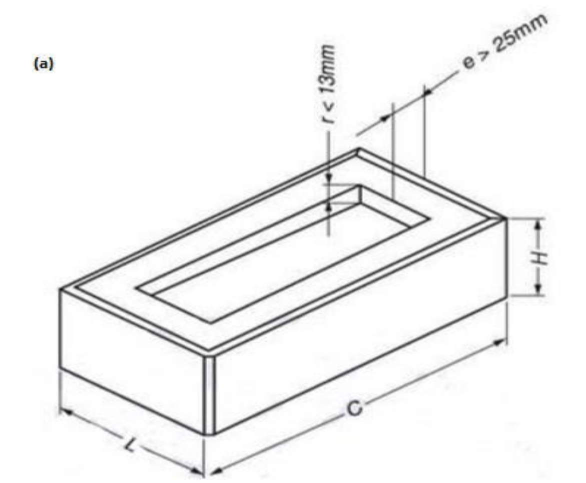
ABNT NBR 8491: 2012 determines that the soil-cement bricks should have a parallelepiped shape, in dimensions (in millimeters) shown in Figure3.



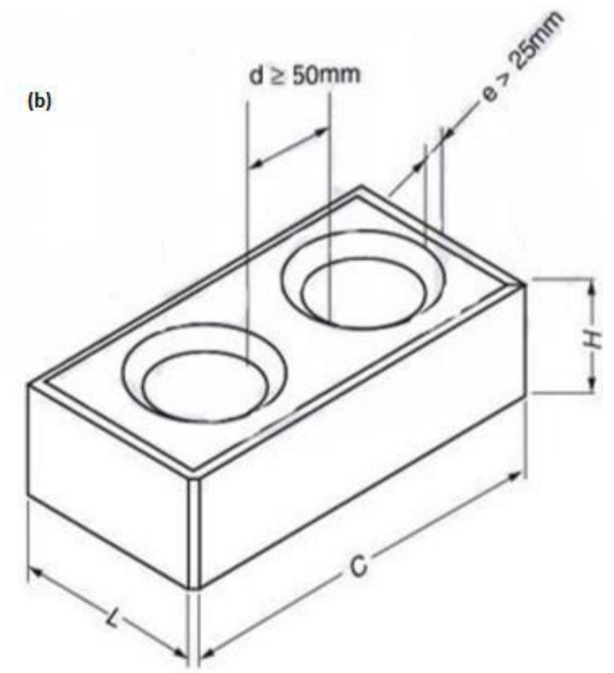


Fig. 3: (a) Solid cement-brick, (b) Hollow Cement Brick, Source:[11].

For budget composition, the following steps were considered:

For ground-cement brick masonry:

- Soil-cement brick with application of 45 un / m^2.
- Concrete columns of 0,066 m in diameter, with 1 steel bar of 8,00 mm for each 1,0 m of wall according to door and window openings, generating a concrete volume of 0,09 m^3 each m^2 of wall.
- Laying of bricks with cement and sand mortar in 1: 4.

The cost of one thousand pieces of soil-cement brick is around R $ 850.00 (RS 0.85 / piece), adding the amount charged for the execution of the installation work, the cost is estimated at R $ 38.25 / m2.

For structural ceramic block masonry:

- 14 x 19 x 29 structural ceramic block with application of 16 units / m^2 (Figure 4).

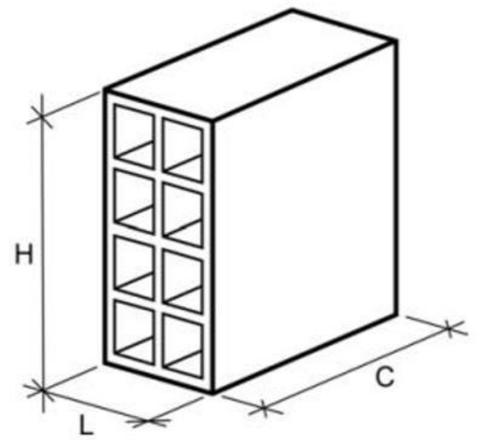


Fig. 4: Ceramic sealing block with horizontal holes, Source: [12].

The cost was around R $ 2,900.00 (R $ 2,90 / piece), adding the amount charged for the execution of the installation labor the cost is estimated at R $ 46,40 / m^2.

A cost survey was carried out for the construction of the popular housing, using soil-cement brick (Table 3) and using masonry with structural ceramic block (Table 4), following BDI according to TCU AGREEMENT, SINAPI 2018 COMPOSITION.

Table. 3: Budget for the construction of housing with brick soil-cimetno.

Budget 1			
Materials	Amount	Price Unitary	Total
Soil-cement modular bricks (m^2)	116,04	38,25	4438,53
Column Concrete (m^2)	0,573	416,84	238,94
Steel for bollards (8.0)	68,57	5,94	407,94
Mooring beams (steel 6.3)	12,86	5,99	77,03
Beams tie. (conc.) (m^3)	0,0036	416,84	1,50
Gutter beams windows and doors (steel 6.3) (kg)	5,76	5,94	34,21
Gutter beams windows and doors (concr.) (m^3)	0,0016	5,94	8,64
Lintel windows (steel) (kg)	3,67	5,94	21,80
Against lintel windows (concr.) (kg)	0,00092	416,84	0.38,34
Tile 20x20 (m^2)	28	31,80	890,4
External painting (m^2)	89,47	5,81	510,87
Total (R$)			6.621,94

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Table. 4: Budget for housing construction with structural ceramic block.

Budget 2			
Materials	Amount	Price Unitary	Total
Soil-cement modular bricks (m^2)	116,04	46,40	5384,25
Column Concrete (m^2)	0,573	5,94	238,94
Steel for bollards (8.0) (kg)	68,57	38,25	407,7
Mooring beams (steel) 6.3) (kg)	12,86	416,84	77,03
Mooring beams (concr.) (m^3)	0,0036	5,94	1,50
Gutter beams windows and doors (steel 6.3)	5,76	5,99	34,21
Gutter beams windows and doors (concr.) (m^3)	0,0016	416,84	8,64
Lintel windows (steel) (kg)	3,67	5,94	21,80
Against lintel windows (concr.) (kg)	0,00092	5,94	0.38,34
Tile 20x20 (m^2)	28	5,94	890,4
External painting (m^2)	89,47	5,81	510,87
Total (R$)			7.575,72

Tables 3 and 4 show that the popular housing project using soil-cement brick is less expensive. when compared to the cost of housing built using a structural ceramic block. The value reduction is approximately 15%. This reduction is justifiable since most of the popular housing is built by low-income families.

V. CONCLUSION

The cost of work with modular soil-cement bricks reduces by 15% the cost of work designed with structural ceramic block bricks. A significant reduction in the economic aspect of the project, since housing projects are executed by low-income families, who do not have surplus financial resources and seek savings in the realization of their projects. Therefore, it was concluded that its use in civil construction is feasible because there is a reduction in expenses with material, labor and construction time.

It presents itself as an environmentally positive alternative as it is manufactured using abundant raw material on the planet. Moreover, it is a simpler construction process than the others, which allows the construction of large-scale houses in social projects to favor low-income families.

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