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STUDY OF THE INFLUENCE OF THE LOAD GENERATED BY THE SEALING MASONRY ON THE DIMENSIONS OF THE STRUCTURAL ELEMENTS

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INTRODUCTION

Given the current economic situation in Brazil, the construction industry has been affected by the high cost of materials such as steel, ready-mix concrete, and wood, which in some cases makes projects unfeasible due to the large investments required.

In order to save on the overall construction budget, a comparative analysis of the dimensions of a structure using sealing elements should be carried out, analyzing which one requires the least load on a given structure, thereby reducing its final cost, expenses, and material consumption. Such sealing masonry elements are: ceramic blocks and autoclaved cellular concrete blocks.

To determine the masonry, an analysis can be made based on the most well-known sealing materials on the Brazilian market. These materials require laying with mortar, in which the execution process is basically the same for different types of sealing, thus providing consistency for the comparative dimensioning between materials. The traditional ceramic block is known to most of the Brazilian population, while autoclaved aerated concrete blocks (AAC), although not a new material, are unknown to many in Brazil and are not widely used in the market.

As SCCB is little known to Brazilian builders due to cultural factors, where builders always use the same materials, SCCB manufacturers seek to develop catalogs and manuals for its use, since it is a lightweight material, with larger dimensions than the others, and its application is through mortar.

Another major problem encountered in relation to it is its commercialization in the country. While it is used on a large scale in Europe and the United States, in Brazil it is not yet available in all building material stores, being a product generally found in large building material chains or in large shopping centers in the country, where stores already have the material in stock. The name by which BCCA is known in the city of Alfenas, Minas Gerais, and the surrounding region is Bloco Sical, and it can only be found in large building material chains in the city by special order.

If there are already several types of masonry blocks on the national market, why use a material that is not so widely available, when the other types can be easily found in any city and building supply store? Because its specific weight is relatively lower than that of a ceramic block, concrete block, or solid brick.

The importance of conducting a comparative study of load distribution in masonry is to determine the cost of the masonry wall and how much it will reduce the use of wood, concrete, and hardware in the calculations for slabs, beams, pillars, and foundations, resulting in a lower investment for the owner or company executing a given project.

The research aimed to conduct a comparative study on the financial viability of using cellular concrete blocks and ceramic blocks in order to determine which construction system generates greater material expenditure in its support structure.

THEORETICAL REFERENCE

INFLUENCE OF THE WEIGHT OF THE MASONRY ON THE STRUCTURE

The structural design must take into account the purpose of the building, as the loads to be considered in the dimensioning will be in accordance with its occupation. According to Alva (2007), the elements must be dimensioned in such a way as to withstand all possible stresses, ensuring safety for users, maximum economy, and greater durability, without neglecting the aesthetics of the building (PINHEIRO, 2007). Such as:

1. Permanent load: This type of load consists of the weight of the structure itself and the weight of all fixed construction elements and permanent installations, which may vary in values close to their average (SUDBRACK, 2016);
2. Variable load: This is any action that acts on the structure, related to furniture, people, vehicles, etc. Its load values generally vary in values greater than the average expected loads (PINHEIRO, 2007);
3. Exceptional loads: These are actions that have a low probability of occurring in buildings, but in certain cases, it is essential to consider them in structural calculations, such as vehicle collisions, fire, explosions, earthquakes, etc. (ARANGUIZ, 2006).

NBR 6120/14 defines the characteristic values of materials to be considered in structural calculations, except for certain materials that depend on specific standards. Examples of loads (TABLE 1) according to their respective occupations are presented below:

RESIDENTIAL BUILDING (bedrooms, living room, kitchen, etc.).	1.5 KN/m²
BANKS (boardrooms and management offices)	1.5 KN/m²
MACHINE ROOMS	7.5 KN/m²
GRANDSTANDS	4 kN/m²
OFFICES	2 KN/m²
GARAGES AND PARKING LOTS	3 KN/m²
SPORTS GYM	5 KN/m²

Table 1 – Accidental loads

Source: Adapted from ABNT NBR 6120 - 2014

Permanent loads (TABLE 2) are also specified by NBR 6120. These loads are determined according to each type of construction material, which may be structural materials, cladding materials, masonry, etc. Some examples of materials and their specific weights are shown below:

LIME, CEMENT, AND SAND MORTAR.	19KN/m³
CEMENT AND SAND MORTAR	21 KN/m³
SIMPLE CONCRETE	24 kN/m³
SAND	25 kN/m³

Table 2 - Permanent loads presented in NBR 6120

Source: Adapted from ABNT NBR 6120 - 2014

To support such loads, a rigid structure is required. No matter how small a building is, even the largest skyscrapers, the structure

(FIGURE 1) is the most important thing to be analyzed, without it no geometric shape can be preserved. The function of the structure is to receive its loads, whether permanent, variable, or exceptional, and transmit them to the ground (ANDRADE, 2013).

- **Slabs:** Slabs are concrete plates that receive loads perpendicular to their plane, assist in locking the structure, and distribute the loads to the beams (BASTOS, 2015);
- **Beams:** These are horizontal elements that receive vertical loads from the walls and slabs and transfer them to the supports (PINHEIRO; MUZARDO; SANTOS, 2004);
- **Pillars:** These are vertical elements that receive loads from the beams and transmit them to the lower floors or foundations (ANDRADE, 2013);
- **Foundation:** Elements that are in contact with the ground, such as blocks, footings, and piles, which receive loads from the columns and transfer them to the ground (CARDOSO; SANTOS, 2013).

Since a structure must be dimensioned to support the loads that are applied to each element, we can conclude that the heavier the structure, the larger the dimensions of its structural elements, thus consuming more concrete, steel, etc. (ARANGUIZ, 2016).

When designing the structure, the engineer must keep in mind several aspects, such as: maintaining the aesthetics and functionality

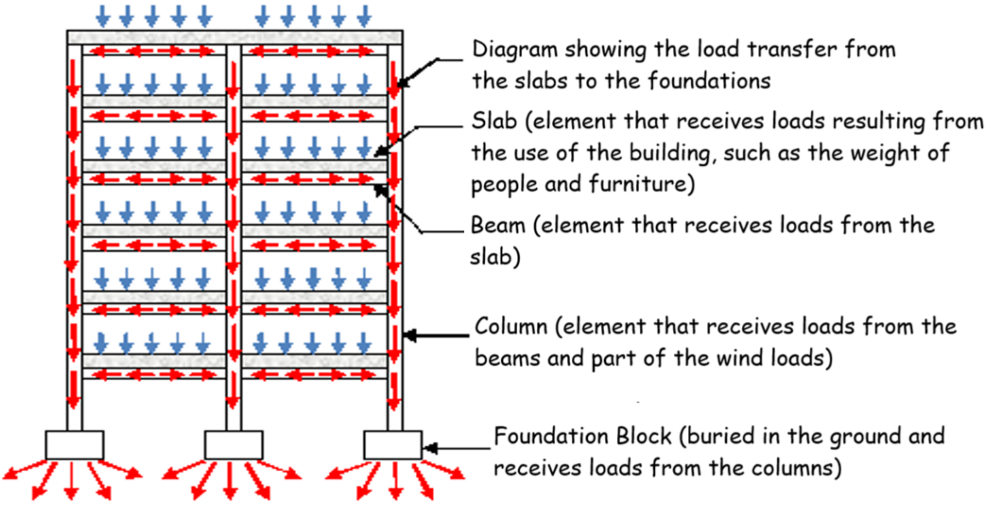

Figure 1 – Distribution of loads on structures

Source: UFAL, 2017

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of the architectural design, an approximate idea of the forces acting on the structure, construction methods, and costs. The choice of a building's structural system is generally influenced by architectural requirements, construction routines, or even the region's infrastructure. Even so, structural engineers must seek, among all possibilities, the most economical structure for their project (ALBUQUERQUE P.1, 1999).

Given that the country is undergoing an economic crisis and the civil construction sector has been greatly affected, it is extremely valuable to analyze and use materials that can contribute to savings in construction. One alternative would be to use different sealing elements in the walls, seeking alternatives with a lower specific weight, thereby reducing the loads affecting the structure (AVRELLA, 2016).

Along with the analysis of sealing materials, the structural design, individually, is also of great economic importance in the final budget of the work, as it accounts for the most significant stage in the total cost of construction (15% to 20% of the total cost). A preliminary study is therefore justified for the choice of the structural system to be adopted , as it is known that a 10% reduction in the cost of the structure can represent a 2% reduction in the total cost. In practical terms, 2% of the total cost corresponds to the execution of the entire painting stage or all earthmoving, thresholds, baseboards, window sills, and roofing services combined (ALBUQUERQUE, P.7, 1999).

METHODOLOGY

To develop this research, a bibliographic survey was first conducted using monographs, articles, and standards that addressed issues related to the factors that influence the structural design of a building.

Type of research

This research is qualitative and quantitative in nature, presenting data that was analyzed and measured to perform a comparison between structural designs.

Research location

The following research was conducted in the city of Alfenas, Minas Gerais, through a project to analyze the financial feasibility between two structures with different sealing elements.

Data collection procedure

Data collection was carried out through three companies in the city of Alfenas that sell ceramic blocks, as well as through a company that sells Sical (BCCA) blocks in the city of Alfenas and two other companies that supply the same products in large centers across the country.

Data was also collected through a structural project based on the architectural design of a five-story building, applying the masonry loads for sealing cellular concrete blocks and ceramic blocks to the structure (the weight of the load was taken from the manufacturers' manuals, which provide the specific weight of each material), analyzing the dimensions obtained in each designed structure.

Through the research and visualization service of maps and satellite images of the Earth (Google Maps), images of residences built with BCCA were obtained.

No questionnaire was administered to the professionals involved due to the complexity of analyzing each building. They volunteered to collaborate with the research project.

Data analysis

The data was analyzed after the structure was entered into the Eberick V10 computer software (a program whose settings are already updated in accordance with ABNT, NBR 6118-2014), obtaining results that demonstrate the dimensions and details of the elements, as well as the amount of materials consumed.

RESULTS AND DISCUSSION

BCCA AS A MATERIAL FOR CIVIL CONSTRUCTION IN ALFENAS.

The BCCA production and manufacturing process uses ground sand, which is produced using a mill, cement and lime, water, and additives used by the company/manufacturer. The amount of each material used varies according to the manufacturer. The block shape is obtained through greased molds where the mixture obtained in the process of mixing the materials is placed and taken to dry with the aim of reducing the moisture content. During the drying process, the material undergoes major changes, expanding almost twice its volume, a process similar to that which occurs in the fermentation of dough. This process is due to the addition of chemical additives, forming millions of tiny hydrogen gas bubbles. The additive most commonly used by manufacturers is aluminum powder, and the drying temperature of BCCA is 80°C. This process takes approximately 4 hours. After the mass has dried inside the mold, it must be demolded using a release agent (grease) to prevent adhesion between the cellular concrete mass and the metal of the mold used. Immediately after demolding, the piece is cut mechanically (MACHADO, 2012).

To improve the strength and shrinkage characteristics of the concrete, an autoclaving process is carried out, with the autoclave varying from 150 to 160°C, with a pressure of 6 to 12Kgf/cm², lasting around 5 hours (BONOTTO, 2005). According to Azevedo (2011), the autoclave temperature can reach 180°, which accelerates the hydration of the concrete and causes a second fermentation (chemical reaction), offering greater strength, dimensional stability, and rigidity. This process takes between 8 and 14 hours.

> After passing through the autoclave, quality control must be performed to ensure product conformity. Once this step is complete, the product can be packaged, stored, and palletized (DÉSIR, p. 13, 2012).

The NBRs (TABLE 7) that govern its execution, requirements, and testing methods are presented below:

According to NBR 14956 (ANBT, 2013), which governs the use of BCCA, some important points must be observed

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NBR 14956-1	**Execution of masonry without structural function**
NBR 12438	Minimum requirements for receiving autoclaved cellular concrete blocks.
NBR 12438/13	Methods for determining the dry bulk density and compressive strength of autoclaved aerated concrete blocks.

Table 7 - BCCA regulatory standards

Source: Authors

Company:	Dimensions (cm):	Price:
STORE A	60x30x15	R$12.89
	60x30x12.5	R$10.99
	60x30x10	R$8.99
	60x30x7.5	R$6.49
STORE B	60x30x12.5	$8.90
	60x30x10	R$7.90
	60x30x7.5	R$5.39

Table 6 - BCCA Dimensions

Source: Authors

Quantity	Price in R$ for the size (10 x 30 x 60)	Location	Company	Type of Sealing
1	11.64	Alfenas – MG	A	BCCA
1	8.45	São Paulo – SP	B	BCCA
1	5.60	SCO Catalog	Not applicable	BCCA

Table 8 – Economic analysis

Source: Authors

when using BCCA to avoid construction problems. For example, block laying should only begin after at least four subsequent floors have been completed and without shoring. In small buildings, walls should only be started after the entire structure has been completed, beginning with the first floor just below the roof, and provided that the entire roof structure has been completed. In order to achieve better structural reinforcement, all masonry must be fixed to the pillars with welded mesh, and this masonry must also be wedged into the beam. Walls longer than 10 meters must have reinforced concrete support pillars, and those whose height exceeds 4.5 meters must have tie straps (ABNT, NBR 14956 –2013).

ECONOMIC ANALYSIS OF BCCA

BCCA is more readily available in more populous cities where there is greater openness to new products. It is generally found in large stores and building material chains throughout the country in the following dimensions (TABLE 6):

1- Economic analysis (TABLE 8) showing the average price of the block in the dimension (10x30x60cm) in a given city, location of the company selling the BCCA, and price of the block according to the SCO catalog.

According to the table above, we can see the price difference in the city of Alfenas, Minas Gerais, compared to the prices of blocks in the city of São Paulo, São Paulo (which does not have to be exclusively in São Paulo, as the same company has stores in other cities across the country), and the SCO catalog. According to salespeople at the store in Alfenas, where we can find BCCA, the price is higher because the block is not produced in the region and, consequently, has to be purchased from outside companies, which results in freight and transportation costs.

In the Alfenas region, the smaller cities that surround it do not have BCCA in their building material stores, so when a construction project is carried out in the city using BCCA, the product must be ordered in advance, waiting for the goods to be transported from São Paulo, SP, or Alfenas, MG, to Areado, MG, for example.

When BCCA prices were quoted in the Alfenas region, it was observed that the nomenclature used in the region is different from that used by large wholesalers. In the region, BCCA is known as Bloco Sical.

After talking to professionals in the civil construction industry, they mentioned the advantages and disadvantages of working with this material and solutions to the problems encountered in construction projects using BCCA, as it used to be very difficult for engineers and construction teams. Six years ago, it was very difficult to glue the conduit to the masonry due to a lack of knowledge and materials, but today, information about the material has grown considerably, making it easier to work with AAC. If buildings had problems due to a lack of information about the material, today its application and correction of defects in homes is extremely easy.

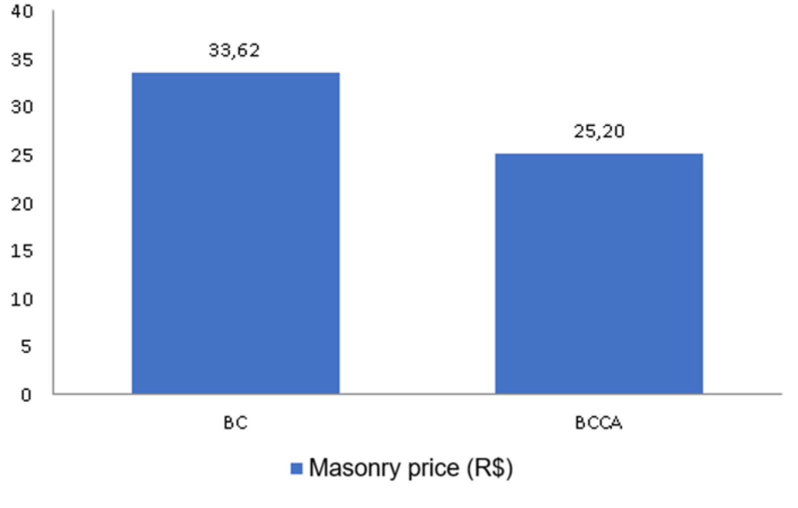
2- A comparison of total construction costs between BC and BCCA can be analyzed according to the following graphs, based on data from (TABLE 9), in which data was obtained through the SCO catalog service item composition.

With regard to the data presented in the table, the following graphs show an

MASONRY:	BCCA	Unit of Measure	Quantity	Unit Cost R$	Partial Cost R$
DESCRIP-TION:	Dimensions (10X30X60) cm	One	6.00	5.6	33.60
	Bricklayer's income	H	0.60	18.46	11.08
	Servant's Income	H	0.60	12.42	7.45
	Social Security Contributions 3%	%	1.00	18.53	0.56
	Mortar	m³	0.005	360.32	1.80
MASONRY:	**BC**				
DESCRIP-TION:	Dimensions (14X19X29) cm	One	18.00	1.40	25.20
	Bricklayer's income	H	0.94	18.46	19.15
	Servant's Income	H	1.30	12.42	17.82
	Social Security Contributions 3%	%	1.00	33.50	1.11
	Mortar	m³	0.025	355.43	9.25

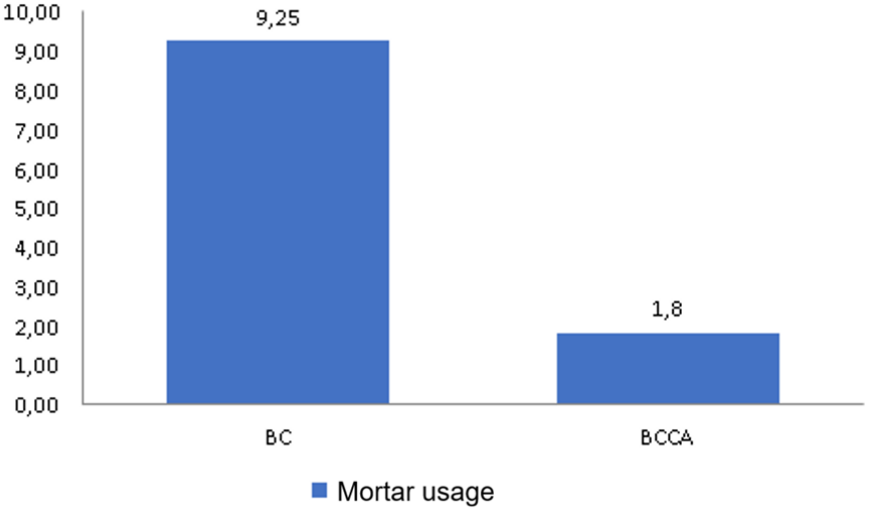
Table 9 – Data for total construction work between blocks

Source: Adapted from the SCO Catalog



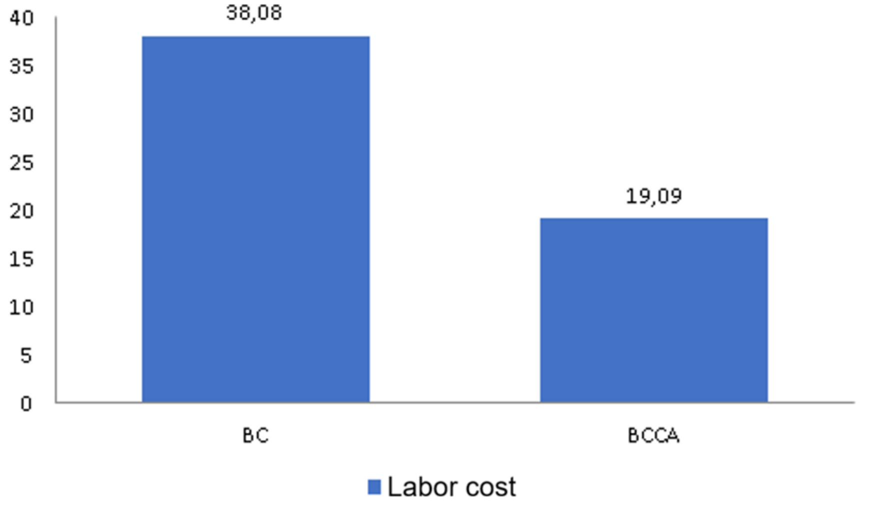
GRAPH 1 – Cost per m²

Source: Authors



GRAPH 2 – Mortar consumption per m³ for laying

Source: Authors



GRAPH 3 – Labor

Source: Authors

analysis demonstrating the efficiency of BCCA in relation to BC, based on the ratio between cost per m², mortar consumption, and labor productivity.

CHART 1 shows the relationship between the cost per m² of masonry, i.e., to build 1 m² of masonry with BCCA at a price of R$5.60/unit, the cost is R$33.62, while with BC, the cost is R$1.40/unit, generating an expense of around R$25.20, according to the (TABLE 9) Adapted from SCO, we conclude that BC is more viable than BCCA, as it offers savings of 25.04% in the cost of masonry construction per m², making BCCA less viable when comparing the cost of masonry construction.

GRAPH 2 shows the mortar consumption (m³) for laying blocks in one m² of masonry. The values are: BC R$9.25/m³ and BCCA R$1.80/m³, according to (TABLE 9) Adapted from SCO. This shows that BCCA has an 80.48% reduction in mortar consumption compared to BC, making its use more viable.

The CHART above shows the relationship between labor costs plus charges/hour, according to (TABLE 9) Adapted from SCO, with values of R$38.08 for BC and R$19.09 for BCCA, the relationship between the two blocks shows a 50.13% reduction in the amount paid for a bricklayer and an assistant to lay the blocks for one hour, i.e., BCCA has economic advantages over BC.

To calculate this total savings (GRAPH 4), all partial costs in (TABLE 9) were added up, totaling R$72.53 for the cost of construction using BC and R$54.51 for the cost of construction using BCCA. The savings generated between the two blocks is 24.85% in favor of BCCA, that is, even though the unit cost of this block is higher than the unit cost of BC, and the construction of 1m² of masonry is also higher, the final cost of BCCA is almost ¼ cheaper than BC, making it viable in this comparison.

3– Comparative analysis performed in the Eberick program, in which (TABLE 10) shows the consumption of materials such as steel, concrete, and formwork, generated by the loads of BC and BCCA masonry in the building structure.

After entering the loads for each masonry type into the Ebercik program, the results confirm that BCCA offers savings when compared to BC, since, according to (TABLE 10), the consumption of concrete, which is 116.13m³ with BC, was 108.67m³ with BCCA, providing a saving of 6.42% in the final construction cost. The use of CA-50 and CA-60 steel in masonry construction with BC is 7993.9 kg and 2153.6 kg, and when BCCA is used, its consumption generates around 5968.9 kg and 1674.1 kg, totaling a total savings with the use of BCCA of 25.33% in the consumption of CA-50 steel and 22.27% in the final consumption of CA-60 steel. Finally, the analysis of formwork consumption between one masonry and another showed a reduction of around 10.45% in favor of BCCA, since formwork consumption with the use of BC in the building is 1226.09m² and with BCCA the total consumed was 1097.98m².

The figure above shows the 3D portico of the 5-story building, demonstrating all structural elements such as foundations, footings, columns, beams, and slabs. Structure generated in the Eberick program.

Figure 6 shows the floor plan of the architectural design of the five-story building, with two apartments per floor, each with:

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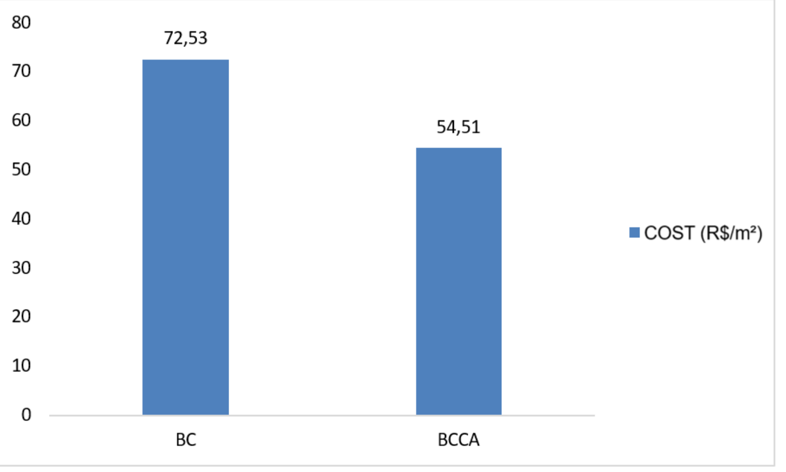

GRAPH 4 – TOTAL SAVINGS

Source: Authors

Comparison of material consumption between Sealing Blocks				
	Material	*BC Consumption*	*BCCA Consumption*	*Unit*
	Concreto	116,13	108,67	m^3
	Steel CA-50	7993,9	5968,9	Kg
	Steel CA-60	2153,6	1674,1	Kg
	Formwork	1226,09	1097,98	m^2
Total material consumption reduction of BCCA compared to BC in %				
Material				
Concrete - 6,42%				
Steel CA-50 - 25,33%				
Steel CA-60 - 22,27%				
Formwork - 10,45%				

Table 10 - List of total material consumption according to Eberick

Source: Authors

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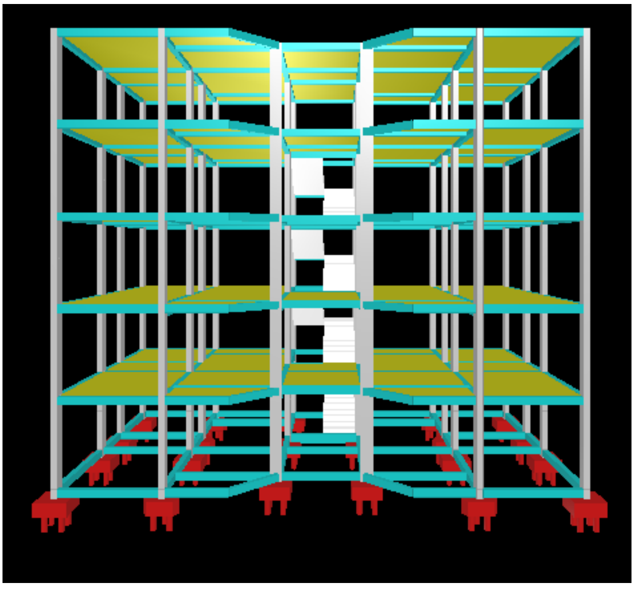

Figure 5 – Front elevation of the 3D Structural Project

Source: Authors

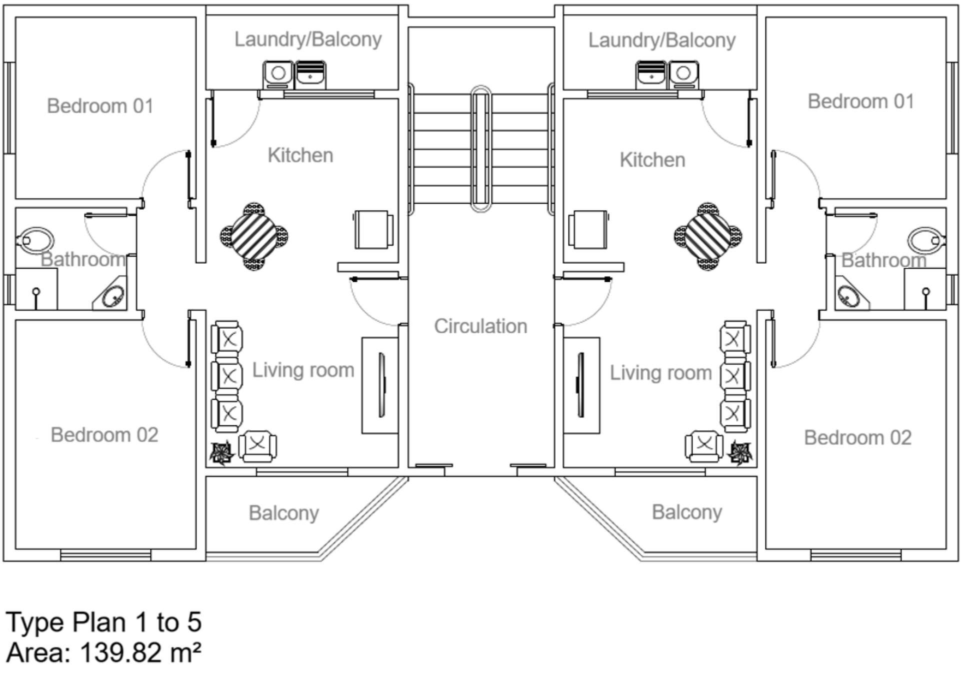

Figure 6 – Architectural design

Source: Authors

two bedrooms, kitchen, living room, laundry room, bathroom, and balcony. Total area: 139.82 m².

4- Discussion of the advantages and disadvantages of using BCCA in construction.

A major advantage of BCCA, according to (COSTA, 2016), is that during its manufacturing process, the agents cause reactions in the block, forming calcium silicates that will provide the expected compressive strength. As a result, its compressive strength is 3.2 MPa, while BC has a strength of 0.9 MPa (FERRAZ, 2011), meaning that BCCA has greater strength.

> Because they are made of lightweight material, cellular concrete blocks are usually larger than ceramic blocks [...], making it possible to reduce time and cost in the construction of walls due to labor, as well as savings in the building structure due to the reduction load on the structures and foundation. (FERRAZ, 2011, p. 22)

The productivity attributed to BCCA is justified by its high regularity and squareness, in which the coating stage ensures that the coverings are less thick. BCCA, due to its easy workability, simplifies the execution of other services such as hydraulic and electrical installations (CELUCON, 2016).

According to data from the SCO Catalog, the unit price of a BCCA is around R$5.60, making one of the biggest disadvantages of using BCCA that, in relation to its price in the city of Alfenas, it costs twice the SCO price, and it is also difficult to find it in the city of Alfenas, with only one company working with this block, and there are no other companies in the city region that work with it. This makes it difficult to build homes in the region because the product is not readily available.

The fact that this block is no longer used in the region and in the city of Alfenas is due to the disadvantage mentioned above, because according to engineers and professionals who have worked with this material, it is easy to use and finish, which is a major performance factor.

Another factor that contributes to the non-use of BCCA is the lack of knowledge about the construction price per square meter between it and BC, but according to (BIANQUINI, 2016), (DARÉ, 2016), and analysis previously carried out in the study (GRAPH 4), if the cost of labor and other services performed within a construction project are analyzed, the use of BCCA has lower costs than BC. In other words, due to a lack of knowledge, this myth ends up preventing the use of BCCA in construction.

5- Demonstration of residences (FIGURE 7) in the city of Alfenas – MG that will use BCCA as their masonry.

In the city of Alfenas, we can find some buildings using BCCA, but all of them are private, so it is not possible to obtain much information about them. An estimate of buildings in the city is very low, not reaching 10 buildings, but in the city of Alfenas there is a multinational company in the copper wire production industry, which has several shed buildings in its factory using BCCA, making this location the highest index of buildings using BCCA masonry in the region.

Figure 7 – Homes with BCCA in their masonry

Source: Authors

CONCLUSION

Based on the results presented in this last chapter, we have reached the following final conclusions for this study:

- There is little literature that discusses the influence of the load generated by masonry walls on the dimensions of structural elements, using BCCA as the study material;
- The consumption of materials in the structure using BCCA as a sealing element was lower than that of BC, but the difference was not significant, so it was not possible to conclude whether the material was economically viable or not, and an analysis of the productivity of this material is therefore necessary;
- Analyzing the costs of materials and labor, we concluded that BCCA is more viable than BC, as it generates a small saving in the structure when used, and in terms of productivity, it achieves a saving of approximately 24.85% compared to BC;
- It is important to note that in calculating the structure, some structural elements supported their loads with smaller dimensions, but with excessive deformations, which is not permitted by standard, and also taking into account the architectural constraints of the project, it was not possible to reduce the sections of various elements in the structure;

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