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ANALYSIS OF CONTEMPORARY BUILDING BEAMS COMPARING DIFFERENT METHODS OF STRUCTURAL ANALYSIS THROUGH COMPUTER PROGRAMS

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ABSTRACT

Structural analysis ensures the safety and efficiency of reinforced concrete structures, but different computational methods can generate variations in the results. This study compares the SAP2000 and Eberick software in beam analysis, evaluating its accuracy and reliability based on an architectural design and the ABNT NBR 6118:2023 and NBR 15575:2021 standards. Both met the criteria of the service limit state (ELS), while in the ultimate limit state (ELU), the differences in efforts were minimal. The Eberick proved to be more practical for structural design, while the SAP2000 showed greater precision. The study highlights the importance of technical knowledge and regulatory compliance in interpreting the results. Future research should explore different structural configurations in addition to alternative materials.

Keywords: Structural Analysis. Beam. Computer Programs.

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Revista ARACÊ
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INTRODUCTION

Since the earliest civilizations, civil engineering has stood out as one of the most essential professions, ranging from the planning and conception of projects to the execution of works, to ensure quality of life for society and drive innovations in materials and construction techniques.

This area is responsible for the conception, design, construction, and maintenance of structures such as buildings, bridges, roads, and dams. According to Queiroz (2008), civil engineering is crucial for the safety and functionality of built spaces and is considered "social engineering", given its direct influence on life in society.

Among the main construction materials, concrete stands out, being used in various ways, such as reinforced, prestressed, or sprayed concrete. Despite having advantages such as fire resistance, durability, and the possibility of precasting, concrete also faces challenges, such as the high cost of formwork and shoring, high weight, and complexity in renovations or demolitions. Arezoumandi et al. (2015) point out that concrete is one of the main solid wastes of civil construction, due to the large volume generated.

Structural analysis is crucial to ensure that all elements of a building meet current standards, respecting the Service Boundary States (SLE) and the Ultimate Boundary State (ULS). NBR 6118 (2023) defines ELU as the state in which structural collapse occurs, making the use of the structure unfeasible, while ELS refers to the comfort, durability, and good use of buildings.

Structural projects are fundamental in any work, as they consider aspects such as the characteristics of the terrain, the acting loads, and the weather conditions. Beams, for example, are essential horizontal elements to support and distribute loads to columns or support walls, ensuring stability and preventing excessive deformation (SPENGLER, 2023).

With technological advancement, computer programs have made structural analyses more accurate and efficient. However, professionals must possess not only mastery of these programs but also solid theoretical knowledge and mastery of traditional methods, which are essential to validate the results and assess their technical-economic feasibility.

This work compares different methods of structural analysis of beams using the SAP2000 (CSI Portugal) and EBERICK (AltoQi) software, considering a single-family residence project. The evaluation takes into account geometric aspects, loadings, and

Revista ARACÊ
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material properties to determine which method is the most accurate and reliable. The methodology adopted is based on the use of the finite element method, one of the most modern and widely used structural analysis tools. The dimensioning carried out by each software will be compared, taking into account calculation methods, materials and costs. The results will be evaluated in the ELU and ELS, according to the technical standards.

Structural analysis of beams is critical to ensure that the loads and stresses supported do not compromise the safety of the structure. Choosing the proper method directly affects the accuracy of the results and the efficiency of the construction. Therefore, the comparison between different computational approaches contributes to the advancement of civil engineering, by identifying advantages and limitations, thus improving the choice of structural analysis methods.

LITERATURE REVIEW

The review in question focuses on the analysis of the beam with the highest load demands of a reinforced concrete structure of a medium-sized building, through the use of *software*. It is necessary to emphasize that there are situations in which structures may not fit the structural models described in this work, and it is necessary to use *appropriate software* for each case, giving importance to safety standards, particularities, and complexities of each structure.

SYSTEMS AND STRUCTURAL ELEMENTS

Structural systems are composed of interconnected components that work in an integrated manner to provide stability and strength to the structures. These systems include elements that play a key role in receiving and transmitting loads to the ground. These elements can be horizontal, which directly supports gravitational forces, or vertical, which transfers the charges coming from the horizontal elements to the ground.

The preparation of a structural project can be simplified into stages, which include the design, structural analysis, dimensioning, detailing of the elements, and the launch of the project drawings. Based on these items, the type of structural system, the materials to be used, and the actions to be considered are appropriately chosen, taking into account the functionality of the building and the characteristics of the site (SILVA, 2020).

Revista ARACÊ
ISSN: 2358-2472

Porticoes

Gantry systems are three-dimensional structures composed of interconnected pillars and beams, forming a rigid grid. They support vertical and horizontal loads efficiently and are widely used in various constructions such as buildings, bridges, and industrial structures. Frames are defined as structures formed by bars, which connect to form frames. There are four fundamental types of flat isostatic frames, which, when combined, in the same way that single beams combine to form composite beams, result in so-called composite frames (SUSSEKIND, 1981).

According to Kimura (2007), the flat frame model is capable of simulating the global behavior of a building, and not just of a floor, allowing the application of both vertical and horizontal loads. In this model, the beams and pillars aligned in a portico of the building are represented by bars arranged in the same plane, that is, in two dimensions.

The spatial portico, in turn, is a more complete structural model, which represents the structure more faithfully. It allows you to determine bending and torsional moments, as well as shear and normal forces of all elements. This model is particularly suitable for the analysis of horizontal and vertical loads, including asymmetric situations (CORRÊA, 1991).

Beams

A beam is defined as a linear element whose main purpose is to transmit the loads it receives to the columns, columns, or supports. It can have different shapes, sizes, and materials, but its fundamental function is to support vertical loads and distribute them appropriately to the structure as a whole. They are generally used as support for slabs, or for other beams that are not supported by columns (ADÃO, HEMERLY, 2010).

Beams are "linear elements in which bending is preponderant" (NBR 6118/141, item 14.4.1.1). Also according to NBR 6118 (ABNT, 2023), for the cross-section of the beams, minimum values of 12 cm are established, except for wall beams, which have a minimum of 15 cm. In exceptional cases, it is possible to reach 10 cm, provided that certain conditions are mandatorily met:

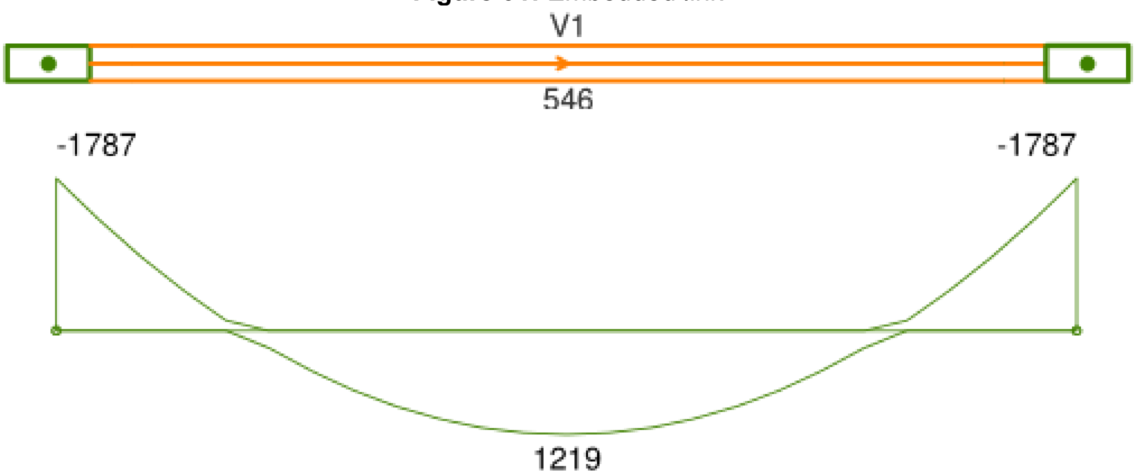
a) accommodation of the reinforcements and their interference with the reinforcements of other structural elements, respecting the spacing and coverings established in the Standard;
b) launching and vibration of concrete according to ABNT NBR 14931.

Revista ARACÊ
ISSN: 2358-2472

The definition of beam connections in a project is extremely relevant, as it has a direct impact on the forces, displacements, and overall stability of the structure (ALTOQI, 2020):

- Crimping link: ensures that there are no rotations between the beam and the column at the support node. Both elements will have the same rotation at that point, that is, a transfer of moments from the beam to the column.

Figure 01: Embedded link



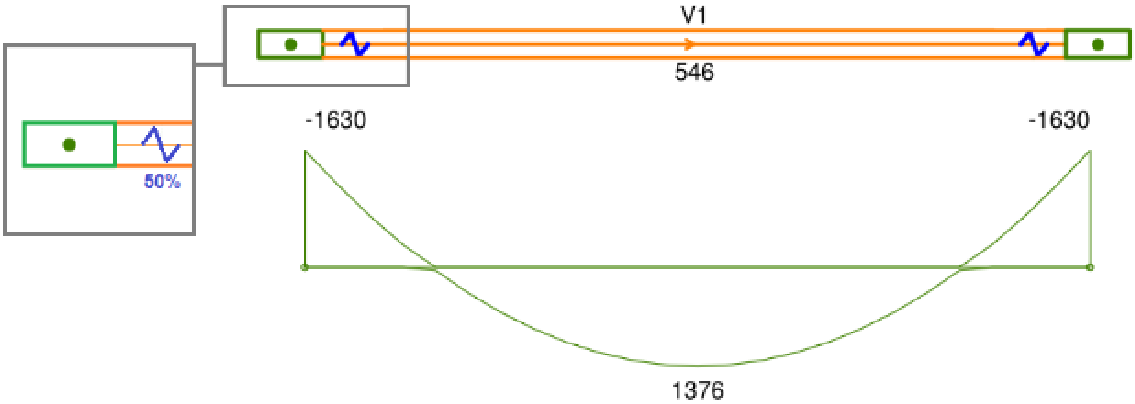
Source: AltoQi (2020).

Since there is continuity of rotation, the stiffness of the column contributes to the stiffness of the beam, decreasing its displacement values and its positive moments. However, this can increase the need for reinforcement in the columns due to higher bending moments, compared to semi-rigid or labeled links.

- Semi-rigid bond: in a structure after construction, the total rigidity of the connections between elements is not guaranteed, causing deformation and cracking. Therefore, there may be a redistribution of efforts due to this effect. In the example below, a 50% redistribution was made.

Revista ARACÊ
ISSN: 2358-2472

Figure 02: Semi-rigid bond

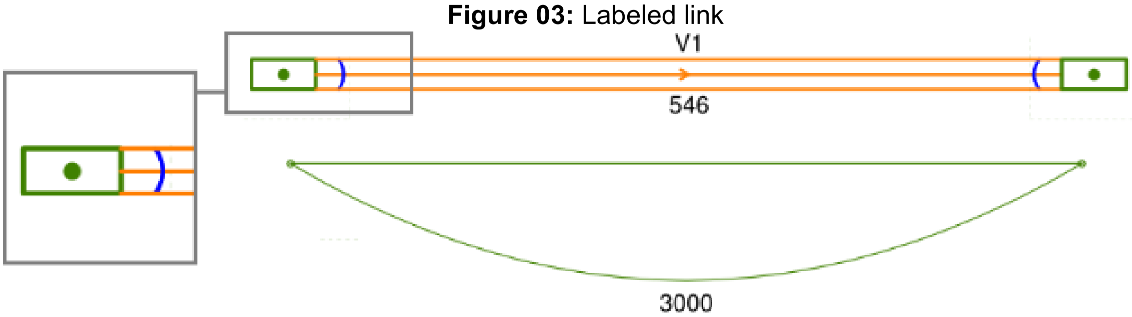


Source: AltoQi (2020).

Compared to the previous model, there is a decrease in the negative moment and a slight increase in the positive moment of the beam. The reduction of the bending moment at the connection of the beam with the column may not have much impact on the design of the beam, but on the design of the column, because a lower bending moment implies a lower reinforcement rate.

- Labeled link: these are the most flexible of the three options, with zero momentum transmission from the beam to the column. This makes the column sizing less robust due to smaller moments. However, the release of rotation at the beam supports results in greater displacements and positive moments. The loss of rigidity in the frames formed by these beams can directly affect the overall stability of the building.

Figure 03: Labeled link



Source: AltoQi (2020).

ACTIONS ACTING ON THE STRUCTURE

The actions acting on structures are the causes that cause efforts or deformations. Usually, the forces and deformations imposed by actions are considered as if they were the

Revista ARACÊ
ISSN: 2358-2472

actions themselves. Forces are designated by direct actions and deformations imposed by indirect actions (ARAÚJO, 2010).

Permanent Loads

They refer to the loads or forces that constantly act on a structure throughout its useful life. The calculation and dimensioning of these actions consider their most unfavorable representative values aiming at safety, to maintain the stability and integrity of the structure.

Permanent actions are divided into direct and indirect actions. Direct permanent actions include the self-weight of the structure, coatings, fixed elements, permanent installations, and permanent thrusts, while indirect permanent actions are made up of deformations imposed by concrete shrinkage and creep, support displacements, geometric imperfections, and prestressing (SILVA, 2020).

Variable Loads

Variable actions consist of loads or forces that act on the structure occasionally or intermittently or that can vary significantly over time. During the design and dimensioning of structures, it is essential to contemplate both permanent and variable actions to ensure that the structure can safely withstand all possible conditions throughout its useful life.

The direct variable actions defined by ABNT NBR 6118:2023 are the accidental loads foreseen for the use of the construction, such as vertical loads, moving loads, side impact, longitudinal braking or acceleration force, and centrifugal force. And, indirect variable actions are divided into uniform temperature variations, non-uniform temperature variations, and dynamic actions (SILVA, 2020).

Exceptional loads

Exceptional loads refer to unusual situations or events that can affect a structure and are generally not foreseen in conventional structural design.

Some examples of these actions are: temporary overloads, natural disasters, and accidental impacts.

Revista ARACÊ
ISSN: 2358-2472

STRUCTURAL ANALYSIS AND MODELS

As provided for in NBR 6118:2023, structural analysis can be carried out through: linear analysis, linear analysis with redistribution, plastic analysis, nonlinear analysis, and analysis through physical models.

Structural analysis is one of the phases of structural design in which the surveys of the internal and external forces of the structure are carried out in the face of the imposed actions based on a structural model. The idealization of the behavior of the structure in this stage of the project is of fundamental importance because, at the end of this analysis, the results of corresponding forces, displacements, and deformations in the structure under study are obtained (MARTHA, 2010).

Structural analysis requires a model that is fit for purpose in the analysis, which can consist of fundamental structural elements combined to form a resilient system. This allows the forces applied to the structure to be transmitted clearly to the support points. Therefore, for this work, the Finite Element Method (FEM) will be used through the SAP2000 *software*, as well as the Grid Model, used by the *Eberick* software.

USE OF *SOFTWARE* AS RESOURCES FOR PROJECT DEVELOPMENT

Better known as a "computer program", *software* is a set of logical information. It is the mechanism that, combined with the computer, is capable of performing several pre-programmed functions using a database and an already determined operational structure (MIRANDA, SILVA, 2022).

The use of *software* in civil construction has become increasingly necessary. These technological tools play a crucial role in all phases of a project, from initial planning to completion and maintenance. For Miranda and Silva (2022), due to the enormous productivity and efficiency required by the market, the use of a specific computer system for the preparation of structural projects is practically essential. There is no more room for structures to be calculated entirely manually.

The use of *software* in civil construction not only increases the efficiency and accuracy of processes, but also contributes to reducing costs, minimizing errors, and improving safety on the construction site.

Revista ARACÊ
ISSN: 2358-2472

SAP2000

SAP2000 is a structural design and analysis software developed by CSI (Computer and Structure, Inc.). It uses the Finite Element technique and has a three-dimensional graphical interface. The *software* is capable of performing the modeling, analysis, and design of a wide variety of structures in an integrated way, making it an essential tool for engineers in the field of civil construction.

Known for its flexibility in terms of the type of structures it allows to analyze, for its calculation power and the reliability of results, SAP2000 is the daily work tool for countless engineers. The versatility of modeling structures allows its use in the design of bridges, buildings, stadiums, dams, industrial structures, maritime structures, and any other type of infrastructure that needs to be analyzed and dimensioned (SILVA, 2020).

Finite Element Method (FEM)

The Finite Element Method (FEM) is a mathematical analysis technique that discretizes a continuous medium into small elements while maintaining the properties of the original material. These elements are described by differential equations and solved by mathematical models, to obtain the desired results (LOTTI et al., 2006).

When designing a structure, it is essential to perform a continuous analysis of the state of stress and strain, as well as consider changes in properties throughout this process. The FEM is particularly suited to provide an effective response in this context.

The application of FEM depends on the specific characteristics of each type of problem. Before performing a structural analysis with the FEM, it is necessary to consider aspects such as dynamic or static, linear or nonlinear analysis, in addition to the type of structure (AZEVEDO, 2003).

Finite elements can be one-dimensional, two-dimensional, or three-dimensional, with varying shapes, different numbers of knots on their sides and faces, and different numbers of degrees of freedom. The choice of the shape of the element to be used depends on the domain to be discretized. To ensure the interaction between these domains, finite elements use interpolating functions, which are directly related to the nodal parameters, the shape of the element, and the convergence criteria of the method (SORIANO, 2009).

Revista ARACÊ
ISSN: 2358-2472

AltoQi Eberick

Eberick is a civil engineering software widely used for structural analysis and building design. It offers advanced features for structural design calculations, taking into account specific technical standards. The Eberick system verifies the elements for the Ultimate Limit State (ELU) and the Service Limit State (ELS), according to Brazilian standards (SILVA, 2020).

AltoQi Eberick has several configurations that allow the user to customize the design process of reinforced concrete structural elements. The design is carried out by the program by the normative instructions, but there are several variable design parameters during this design process, and it is the responsibility of the designer to define the values adopted for such configurations (ALTOQI, 2018).

To facilitate the launch of the structure, the Eberick software allows the import of files in DXF and DWG format, which allows the user to import the architectural design and launch the structure on top of it. Although the *software* has the basic tools for manipulating the drawing, the creation of the architectural project is not the objective of the program, so it is advisable to use a specific CAD software for the preparation of this before importing it into Eberick (SOUZA, MEDEIROS, 2017).

METHODOLOGY

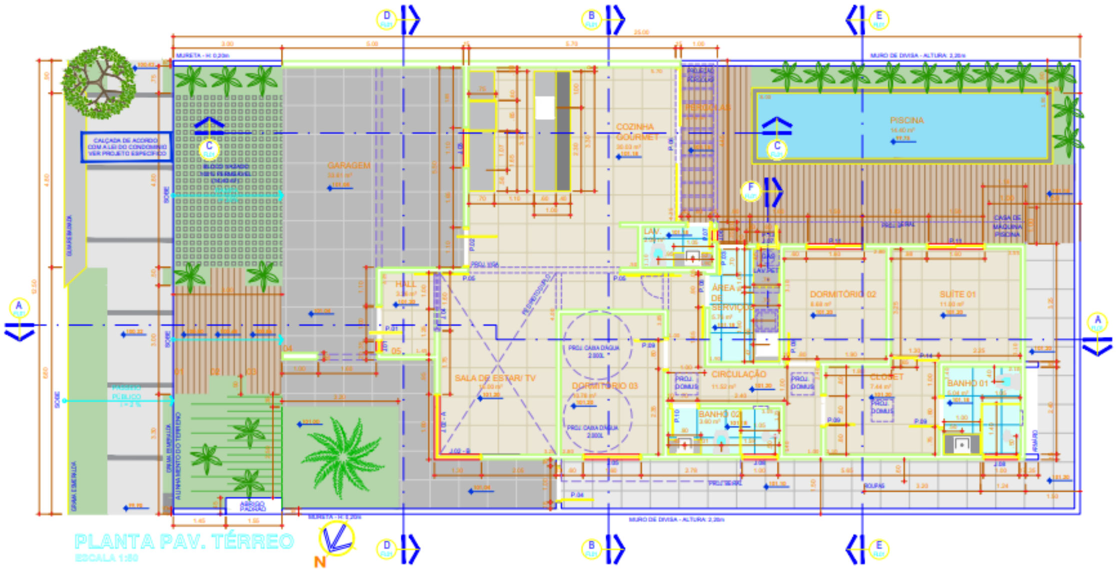
This study used an architectural project provided by a local Civil Engineering company, available in a DWG digital file, as a basis for the comparative analysis between the Eberick and SAP2000 programs. The work was divided into the following stages:

- Preliminary study of computer programs (national and international) and their respective calculation methods;
- Modeling of the structure composed of pillars, slabs, and beams;
- Design of the beam to be studied in each of the programs;
- Comparative analysis of the results.

The model used for the structural modeling includes the levels, floor heights, and floor plans, as illustrated in Figures 04 (ground floor floor plan), and 05 (floor plan.

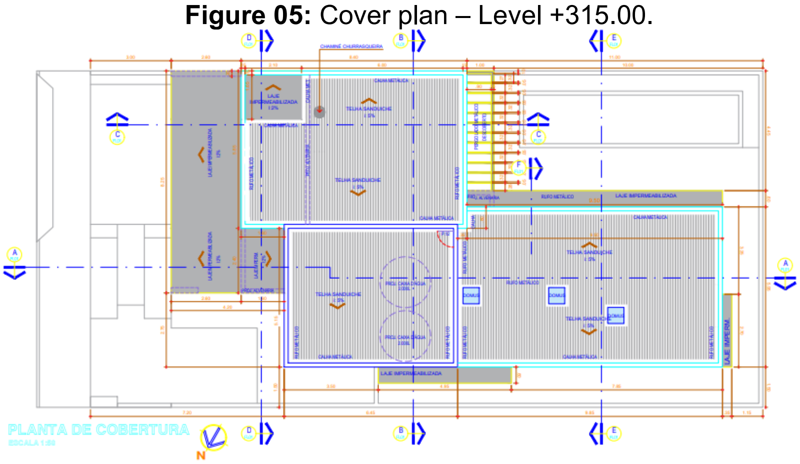
Revista ARACÊ
ISSN: 2358-2472

Figure 04: Ground floor plan - Level +0.00.



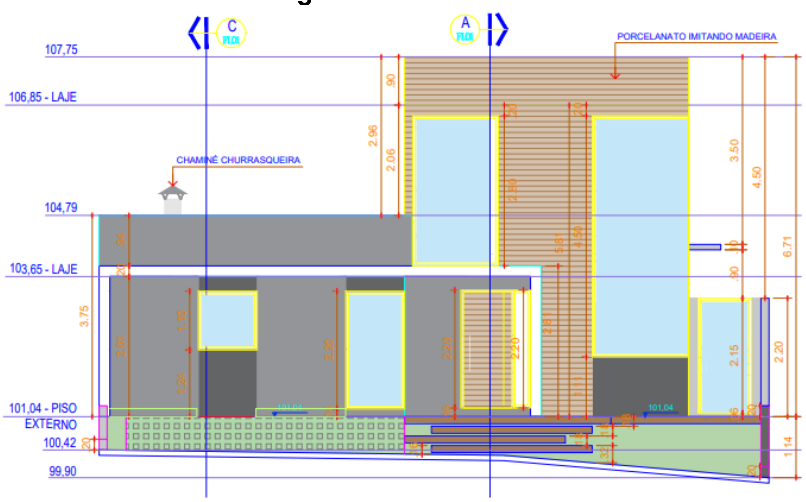
Source: Local Engineering Company (2023).

Figure 05: Cover plan – Level +315.00.



Source: Local Engineering Company (2023).

Figure 06: Front Elevation

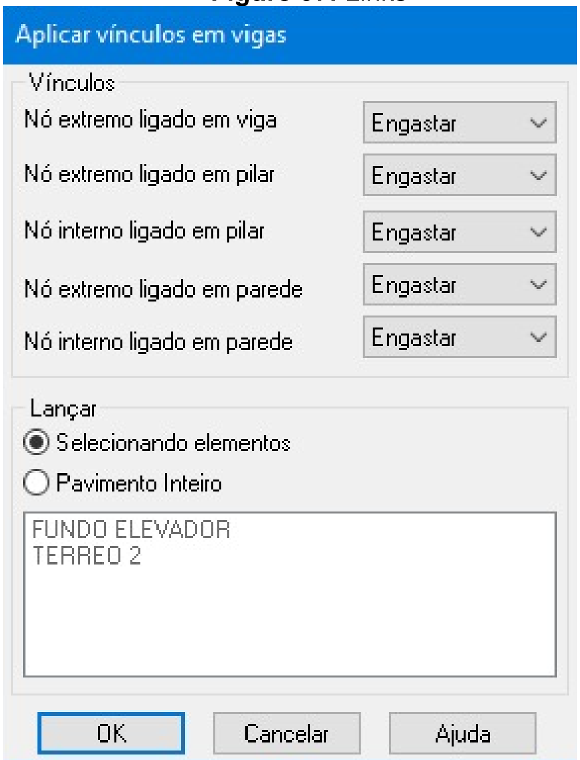


Source: Local Engineering Company (2023).

ISSN: 2358-2472

The structural design was elaborated for reinforced concrete and the connections of the structural elements by Figure 07.

Figure 07: Links



Source: Authors (2023).

STRUCTURAL DESIGN IN THE EBERICK (NATIONAL) AND SAP2000 (INTERNATIONAL) COMPUTER PROGRAMS

To give fullness to the structural model, the concept of foundation with piles was used, however, it is important to emphasize that the analysis of the infrastructure will not be contemplated in this study. Table 01 contains the data adopted for the project in both *software*.

After the preliminary configuration, the launch of the structure began on all levels, starting with the pillars, followed by the beams and, finally, the slabs. To make the analysis viable, the columns on the ground floor were treated as foundation pillars, based on piles. Then, the wall loads were applied to the beams and slabs, and, finally, the reservoir load was incorporated. The connections between the beams were established, considering them as crimping beams.

Figure 08 (Eberick) and Figure 10 (SAP2000) show the 3D frame with the structural design completed in both programs.

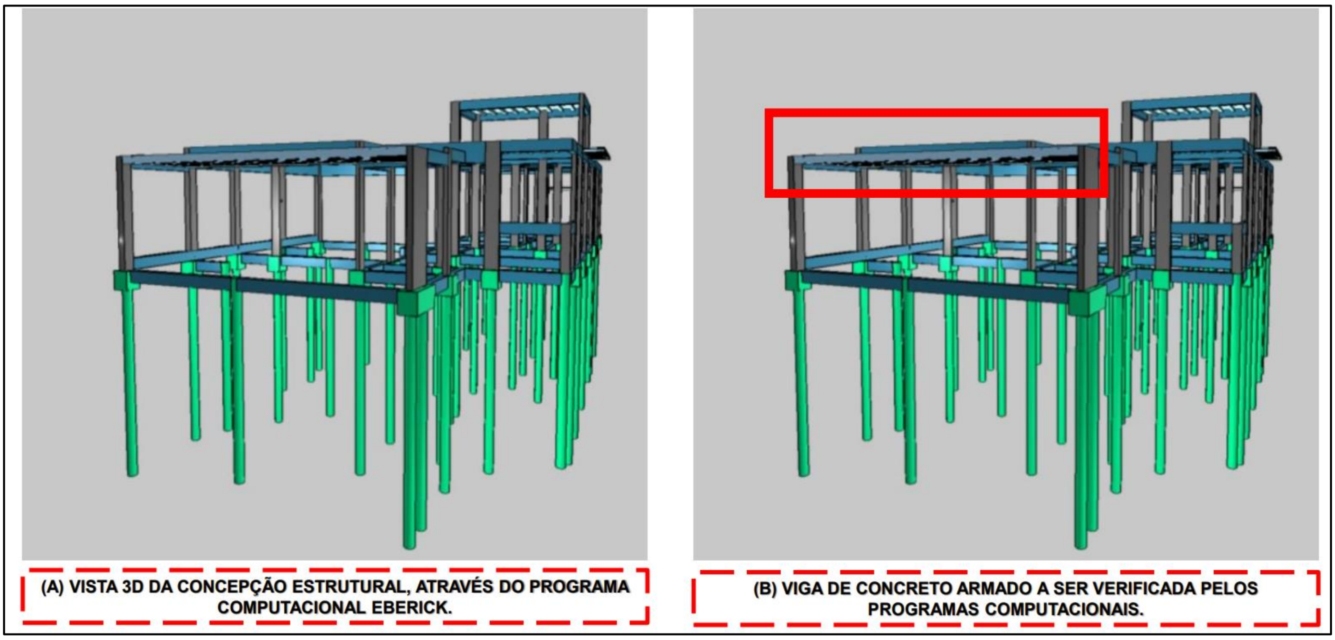
Revista ARACÊ
ISSN: 2358-2472

Table 01: Project data.

General Features for Structural Design			
Structure type	Reinforced concrete		
Concrete	Fck = 25 MPa		
Steel	CA50 and CA60		
Coverings	Slabs		2cm
	Beams	Internal	2cm
		External	2cm
		In contact with the ground	2cm
	Pillars	Internal	2.5cm
		External	2.5cm
Foundation	Stakes		

Source: Authors (2023).

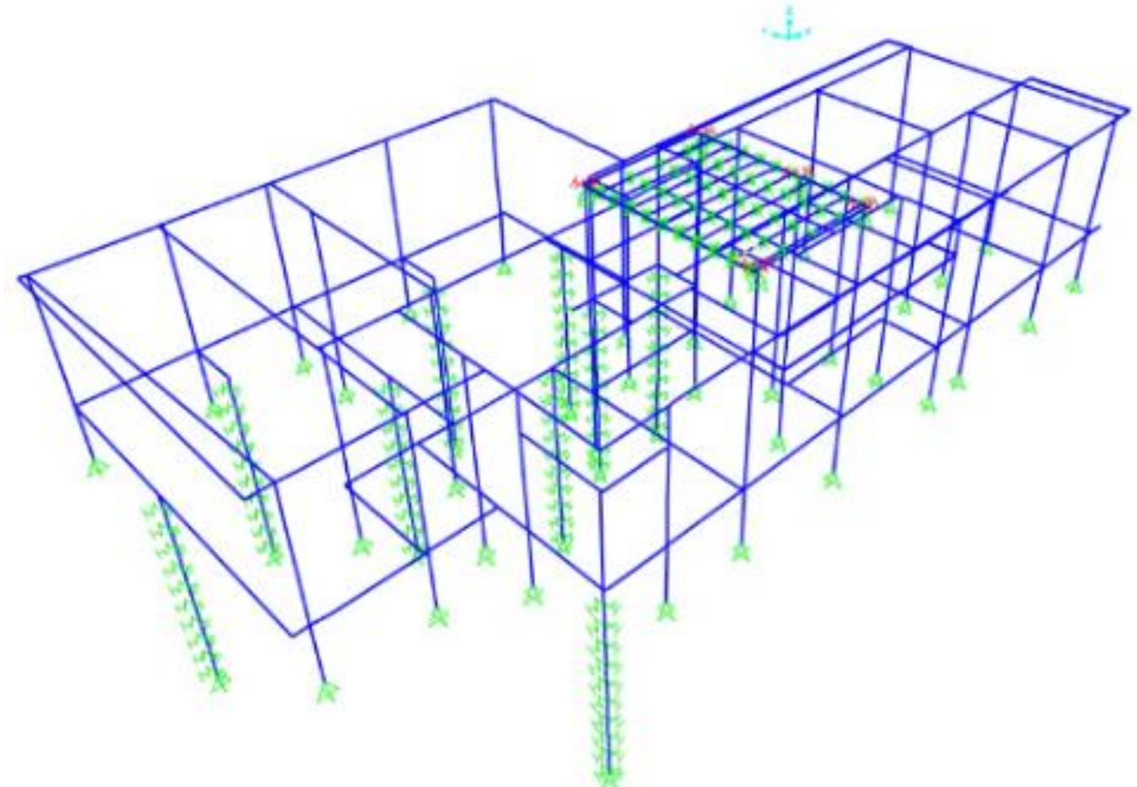
Figure 08: 3D gantry at Eberick



Source: Authors (2023).

Revista ARACÊ
ISSN: 2358-2472

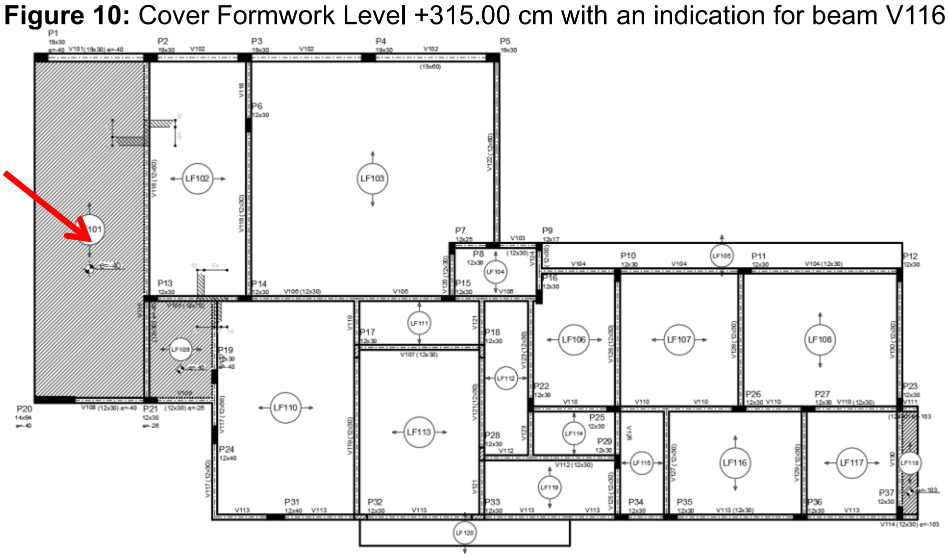
Figure 09: 3D gantry at the SAP2000



Source: Authors (2023).

The dimensions of the beams and columns were defined by the Eberick program, which has an integrated CAD environment, facilitating the modeling of the elements and allowing them to be exported to a DWG digital file. Figure 10 shows the floor plan at level +315.00 m, with the analyzed beam highlighted by the red arrow. The beam region was enlarged in Figure 11 for better visualization.

Figure 10: Cover Formwork Level +315.00 cm with an indication for beam V116.



Source: Authors (2023).

Revista ARACÊ
ISSN: 2358-2472

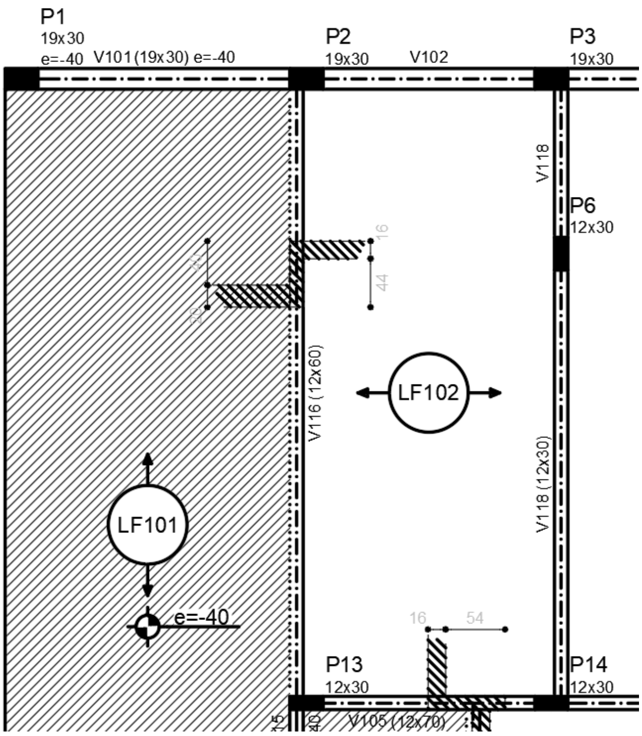
ANALYSIS OF THE REINFORCED CONCRETE BEAM

For the comparative analysis, Figures 12 and 13 present, respectively, the beam "V116" in the floor plan and three-dimensional visualization in the Eberick program.

With the results obtained, the analysis of the most requested beam (V116 12x60) was carried out. Following the load combinations established by item 10.4 of ABNT NBR 6118:2023 as criteria related to user comfort, durability, appearance, and good use of the structure.

The NBR 15575 (ABNT, 2021) performance standard has distinctive characteristics when contrasting with pre-existing standards. According to NBR 6118 (ABNT, 2023), the cross-section of pillars and solid wall pillars, regardless of their shape, cannot have dimensions smaller than 19 cm. On the other hand, NBR 15575 (ABNT, 2021) argues that single-story houses and townhouses with a total height of up to 6.0 m (measured from the lowest level of the foundation to the top of the roof) are exempt from the need to comply with the minimum dimensions established for structural components in specific structural design standards, as long as there is a guarantee of the overall stability of the structure.

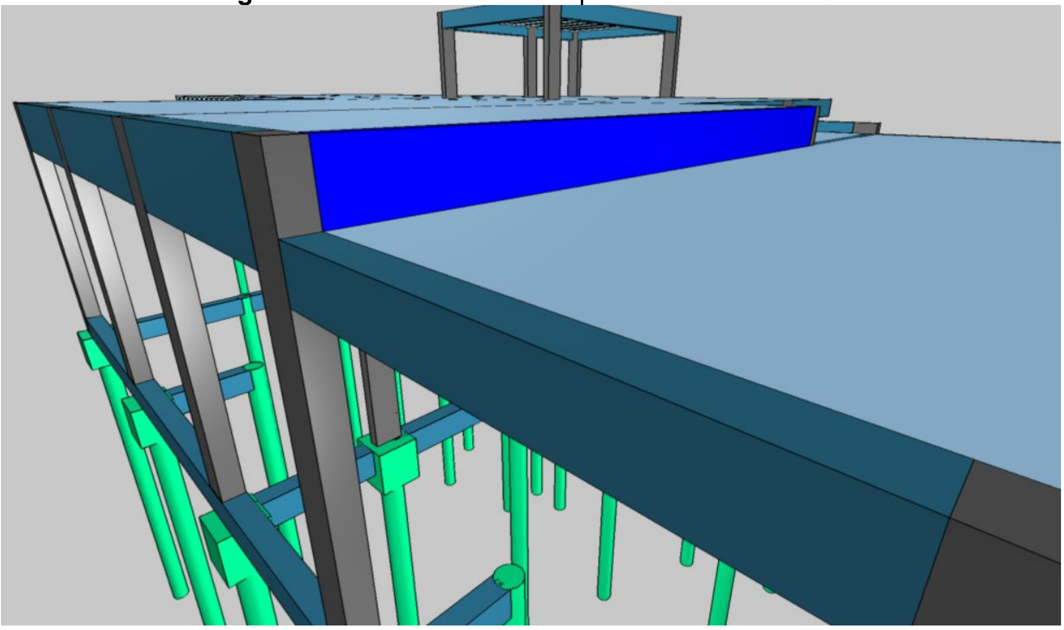
Figure 11: Enlargement of the formwork plan of Figure 11, representation of beam "V116"



Source: Authors (2023).

Revista ARACÊ
ISSN: 2358-2472

Figure 12: "Blue check" corresponds to beam "V116".



Source: Authors (2023).

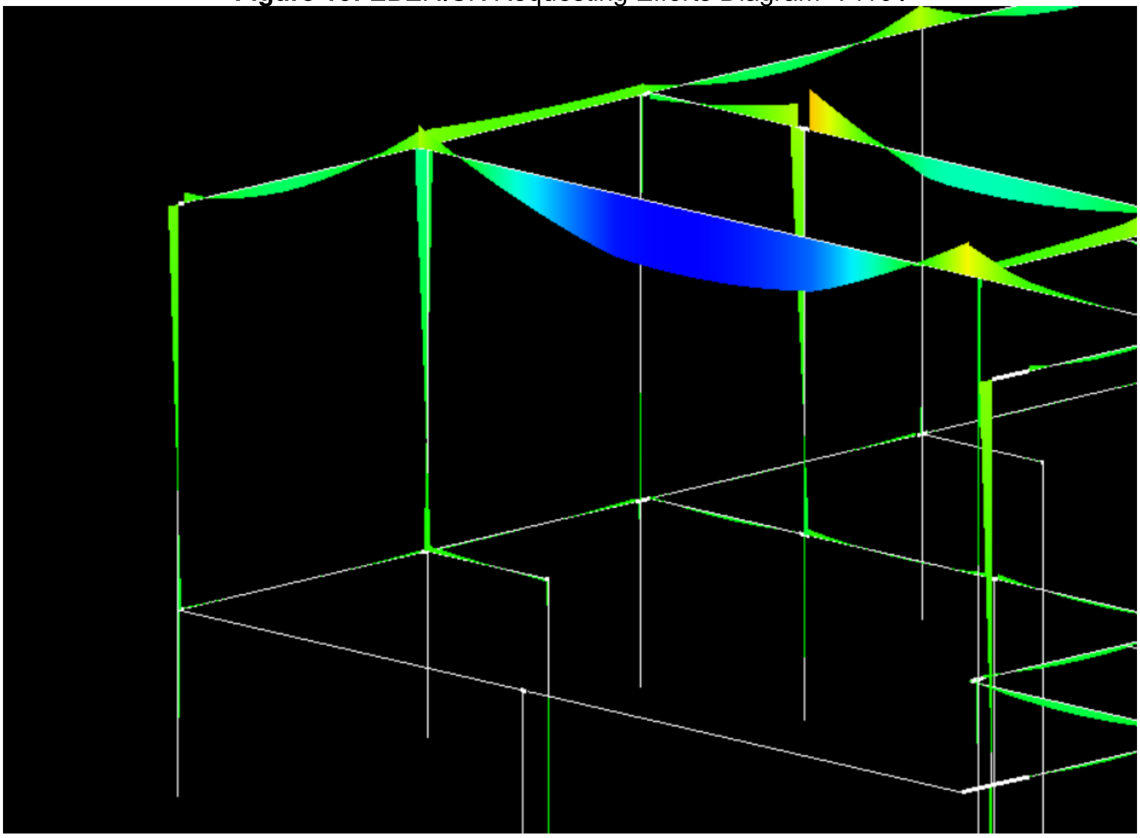
Since Eberick uses national standards, for the SAP2000 the values established in it were adopted, being governed by the following normative premises, focusing on *Eurocode* 90, below:

1. **ACI 318**: This is the standard published by the American Concrete Institute and is often used in the United States and other countries that follow American standards.
2. **Eurocode 2 (EN 1992):** It is a European standard applied to reinforced concrete structures in the European Union and other countries that have adopted it.
3. **CAN/CSA A23.3**: In Canada, reinforced concrete is regulated by the CSA (Canadian Standards Association) through the CAN/CSA A23.3 standard.
4. **BS 8110**: In the United Kingdom, the British Standards (BS) has published the BS 8110 standard for reinforced concrete structures.

To ensure a standard structure and an accurate comparative analysis of the results obtained, Figures 13 and 14 present, respectively, the single-line frame and the diagram of the requesting forces for the Eberick and the SAP2000, highlighting the beam "V116" with the highest stress

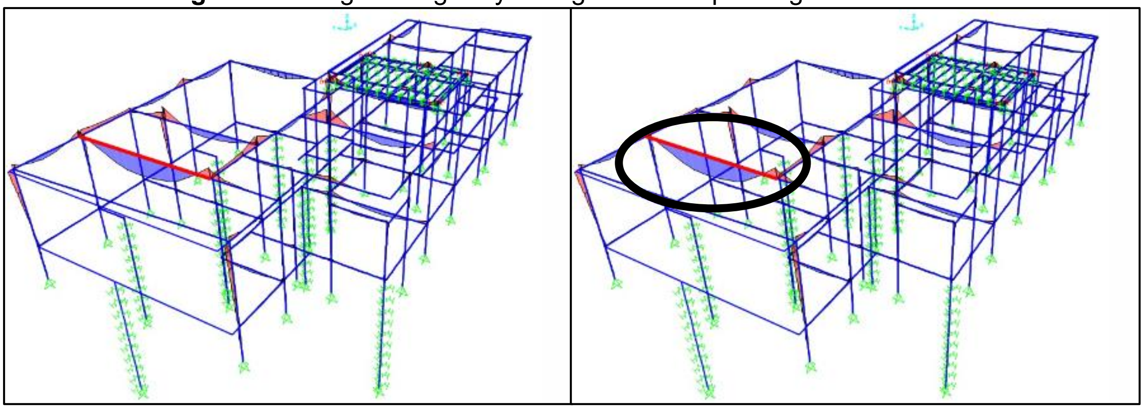
Revista ARACÊ
ISSN: 2358-2472

Figure 13: EBERICK Requesting Efforts Diagram 'V116'.



Source: Authors (2023).

Figure 14: Single-line gantry - Diagram of Requesting Forces SAP2000



Source: Authors (2023).

RESULTS AND DISCUSSIONS

With the results obtained in this project, the loads on the beam (V116) were separated, the bending moment forces were studied, the displacement was evaluated and a comparative analysis of the results generated by the two softwares.

Torsion moments will not be represented due to the result having an irrelevant/minimal value.

Revista ARACÊ
ISSN: 2358-2472

LOAD DISTRIBUTION ON THE ANALYZED BEAM

The vertical loads thrown on this beam were added with the self-weight, additional loads, accidental loads and loads of the areas of influence of the slabs. They were distributed by types of shipments in Table 02.

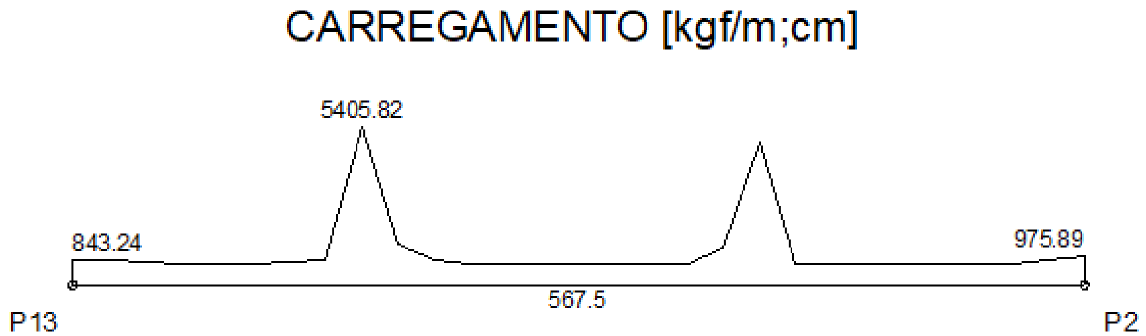
Table 02: Distribution of vertical loads by type of loading

Data						
Pillar Stretch	LengthSupport 1 and 1o(cm)	Bar Width (cm)	Distributed Load - Beam		Distributed load - Slabs (*)	
			Perm.	ACID.	Perm.	ACID.
			(kgf/m)	(kgf/m)	(kgf/m)	(kgf/m)
P13		12.00				
1	567.50	552.00	180.00	0.00	847.94	95.40
P2		19.00				

Source: Authors (2023).

Figure 15 shows the graphic distribution of the vertical loads on the beam under analysis in Eberick.

Figure 15: Graphical representation of vertical load distribution in Eberick



Source: Authors (2023).

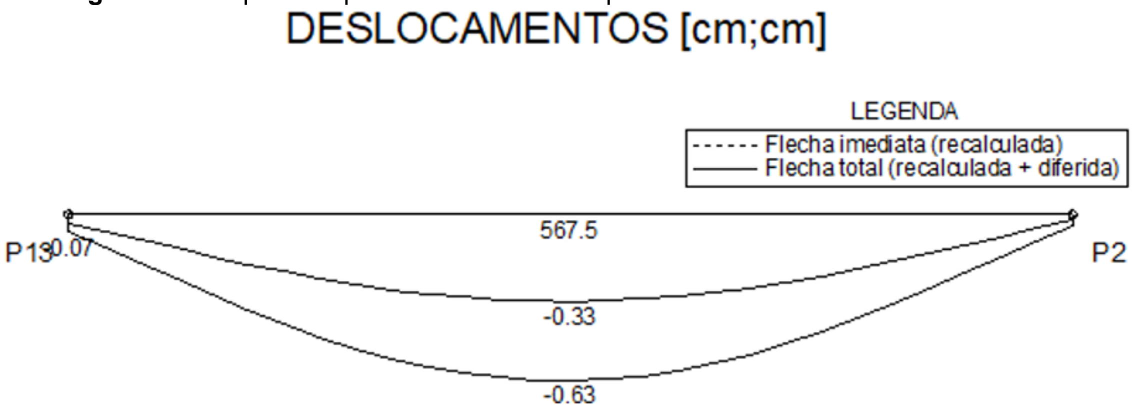
The distributed load from the slabs presented in the report is an average of the reactions of the grating bars connected to the section, and is not used by the program in the design of the beam. For the design, the program uses the efforts obtained from the analysis of the structure.

Revista ARACÊ
ISSN: 2358-2472

MAXIMUM DISPLACEMENTS

The displacement generated in the beam using the combination for the ELS is graphically illustrated by the Eberick (in centimeters) and SAP2000 (in meters) software, respectively represented in Figures 16 and 17.

Figure 16: Graphical representation of the displacement of the V116 beam in the Eberick



Source: Authors (2023).

Tables 03 and 04: Eberick wraps

Wrap	**Go 1**		
	Node I	**Bay**	**Node F**
Gross Cross-Section Inertia (m4 E-4)	21.60	21.60	21.60
Fissured inertia (m4 E-4)	3.42	4.76	3.42
Cracking moment (kgf.m)	2770	2770	2770
Moment in service (kgf.m)	-1384	3435	-1321
Sub-section length (cm)	45.41	475.10	46.99
Equivalent inertia (m4 E-4)	14.90		
Total arrow multiplier	1.97		

Wrap	**Go 1**	
	Value	**Position**
Immediate Arrow (cm)	-0.30	283.8
Immediate Arrow (Recalculated) (cm)	-0.32	283.8
Deferred Deflection (cm)	-0.30	283.8
Total Arrow (cm)	-0.62	283.8

Source: Authors (2023).

Revista ARACÊ
ISSN: 2358-2472

Figure 17: Graphical representation of the displacement of the V116 beam in the SAP2000

Source: Authors (2023).

Table 05 manually filled in the results of the maximum displacements.

Table 05: Maximum Displacements on Beam V116

Displacements (cm):							
Pavement	**Beam**	**Section (cm)**	**Deflection Limit according to ABNT NBR 6118 (L/250)**	**SAP2000 (cm)**	**Eberick (cm)**	**Percentage difference (%)**	**Situation**
Superior	V116	20x60	567.5/250=2.27	0,68	0,63	7,9	OK

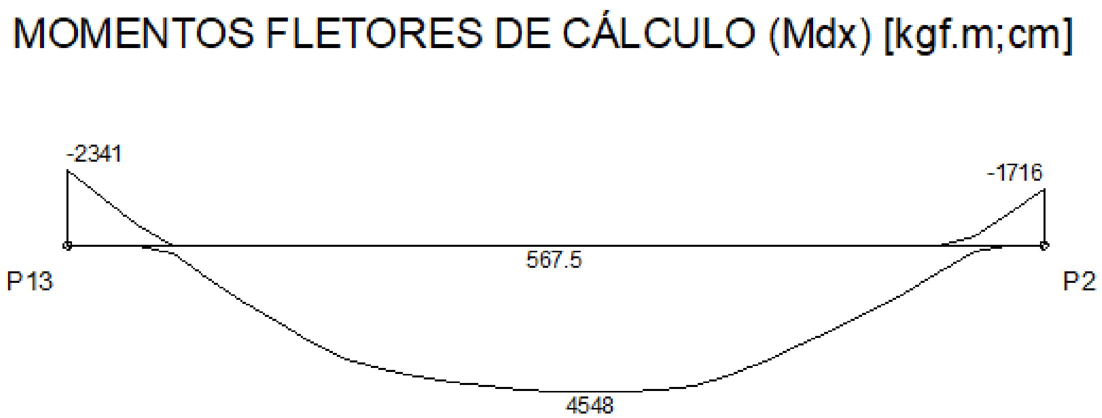
Source: Authors (2023).

For the excessive deflections found, a solution would be to increase the beam section and/or perform deflections to combat immediate displacements, reducing the maximum displacement of this structural element. Therefore, the case-by-case study would be necessary to find the best solution.

BENDING MOMENTS

To prevent collapses in the structure, the combination in the ultimate limit state (ELU) is used, the graphs of maximum vertical moments (MyMax) are represented in Figures 20, 21 and 22, by the Eberick software, as well as SAP2000.

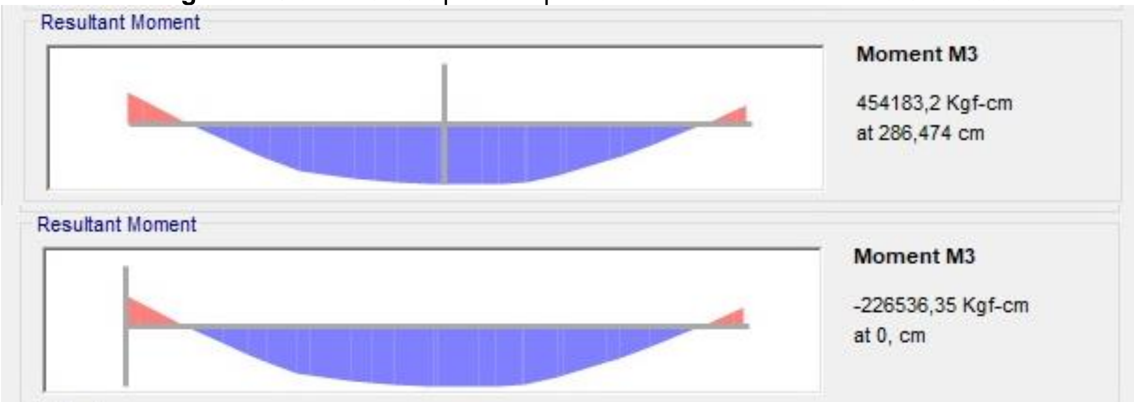
Figure 18: Graphical representation of moment in Eberick



Source: Author (2023).

Revista ARACÊ
ISSN: 2358-2472

Figures 19 and 20: Graphical representation of moment in the SAP2000



Source: Author (2023).

Table 06 compares the results of the moments for the ELU load combination.

Table 06: Maximum Bending Moments on beam V116.

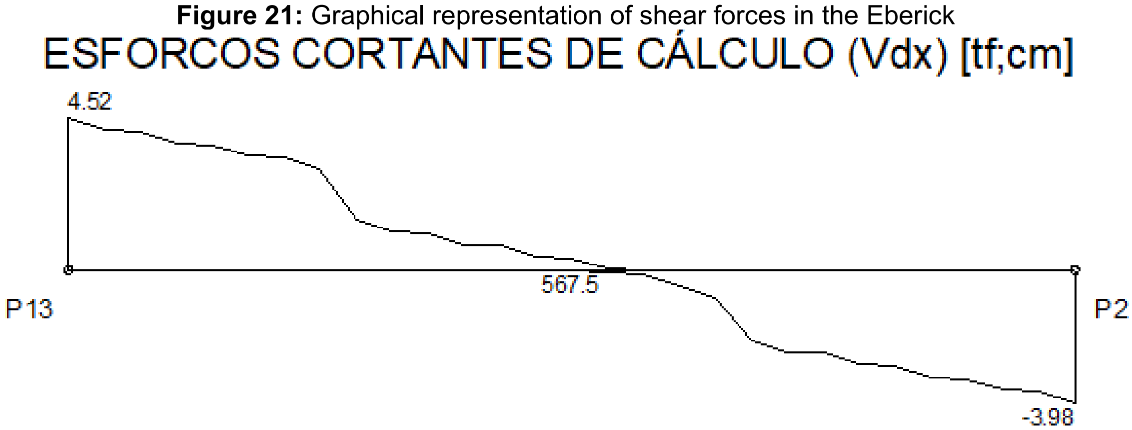
Moments	SAP2000(kN.m/m)	Eberick (kN.m/m)	Percentage difference (%)
MMmax	4.541,83	4.548,00	0,001
Negative Mmax	2.265,36	2.341,00	0,033

Source: Author (2023).

SHEAR FORCES

Figures 21 and 22 show the graphs of shear forces using the Eberick and SAP2000 software.

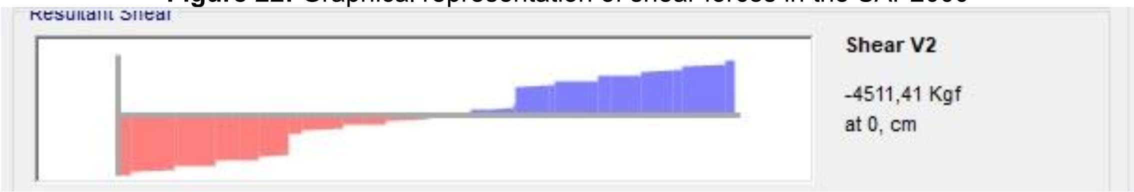
Figure 21: Graphical representation of shear forces in the Eberick



Source: Author (2023).

Revista ARACÊ
ISSN: 2358-2472

Figure 22: Graphical representation of shear forces in the SAP2000



Source: Author (2023).

Table 07 compares the results of shear efforts.

Table 07: Shear forces on beam V116.

Sharp	SAP2000(TF; cm)	Eberick (tf;cm)	Percentage difference (%)
VDx	4,51	4,52	0,002

Source: Author (2023).

CONCLUSION

During the performance of this work, the relevance of theoretical knowledge related to reinforced concrete structures was highlighted, as well as the importance of mastering the ABNT NBR 6118:2023 standard in the execution of structural projects. As for the use of computer programs, it is crucial to highlight that they do not have the capacity for autonomous reasoning, and the intervention of an engineer is essential to provide accurate and cohesive information, in addition to interpreting the results obtained.

It is also noteworthy that a preliminary study of any structure, covering the architecture, functionality, definition of the structural system and choice of materials, is essential for the effective elaboration of a structural project. This applies regardless of the computational tool used throughout the process, since this initial analysis prevents failures in the structural design and simplifies subsequent modeling and analysis through the software.

The Eberick program is primarily aimed at the modeling of buildings in reinforced concrete, providing notable advantages in the definition of the structural model and the application of loads. It is important to note that this software is widely known for its usability and for providing results that, in various scenarios, meet the requirements of civil engineering projects.

The SAP2000 program takes a fairly comprehensive approach to structural analysis. It is worth noting that the results obtained with SAP2000 tend to be more accurate due to

Revista ARACÊ
ISSN: 2358-2472

its refined methodology, which involves the use of a mesh with a larger number of elements.

Regarding the Service Limit State (SLA), visual sensory acceptability was analyzed. The observed beam showed an arrow lower than the limit established by the NBR 6118:2023 standard, both in Eberick and SAP2000, indicating that there is no need for changes in the sections or the implementation of counter-deflections to combat immediate displacements. It is important to note that, in numerical terms, the arrow in the SAP2000 software presented a higher value compared to the Eberick, with a difference of 7.9%. Such variation can be attributed to several causes, such as the calculation method used by the software, the way the loads are distributed among the structural elements in each model, and even the rounding in mathematical operations.

In the context of the Ultimate Limit State (ULS), the maximum moments and the shear forces were analyzed, observing a percentage difference of 0.033% for the negative maximum moment and a difference of only 0.002% in the shear forces. Based on these results, it is reasonable to conclude that the values generated by the Eberick software are satisfactory in its grid + space gantry model, when compared to the SAP2000. Given the similarity between the values presented and Eberick's reputation for security, the results tend to ensure the security of the project.

It is important to note that, in this work, some essential checks that must be carried out in a real project were not included, such as the analysis of the action of the wind. In addition, the results provided by the chosen software should not be passively accepted , and it is essential that the professional performs a careful verification of the data presented.

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Revista ARACÊ
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