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COST-BENEFIT BETWEEN RIBBED SLABS AND SOLID SLABS

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SUMMARY: This study aims to compare the ribbed slab and the conventional solid slab, analyzing the advantages and disadvantages of each type of slab to assist in choosing the most appropriate model for different situations, always considering the search for solutions that balance safety and cost-benefit. Through a bibliographic review of previous works, it was possible to evaluate the performance of both types of slab in different conditions, identifying which one presents the best cost-benefit in each scenario. The results indicate that the ribbed slab is more advantageous in medium to large-scale projects, due to its better performance in terms of cost and structural efficiency. However, in small-scale projects, the use of the ribbed slab is not justified, since the high cost of labor can make the system less advantageous.

Keywords:slab, ribbed, solid, conventional, cost-benefit.

ABSTRACT: This study aims to compare ribbed slabs and conventional solid slabs, analyzing the advantages and disadvantages of each type to assist in choosing the most suitable model for different situations, always considering the pursuit of solutions that balance safety and costeffectiveness. Through a bibliographic review of previous works, it was possible to evaluate the performance of both types of slabs under various conditions, identifying which provides the best cost-benefit in each scenario. The results indicate that ribbed slabs are more advantageous in medium to large-scale projects due to their better performance in terms of cost and structural efficiency. However, in small-scale projects, using ribbed slabs is not justified, as the high labor costs can make the system less advantageous.

Keywords: slab, ribbed, large, conventional, cost-effectiveness**.**

1. INTRODUCTION

Civil construction is always evolving and this evolution is becoming more pronounced over the years. New materials and new construction techniques are emerging in search of improvements in the performance and safety of constructions, together with the search for cost reduction. (SILVA, 2010).

These new techniques have not always replaced old techniques, as Pilotto Neto (2018) makes clear, although the methods and materials used in construction change over time, many of the old principles applied in construction remain active in the contemporary scenario.

Concrete slabs are widely used in civil construction, and due to this widespread use, methods for their execution have been developed. The slabs' function is basically to receive all the loads present on the floor and transfer them to the supports so that the integrity of the structure is maintained. (PINHEIRO, 2003).

The ribbed slab is a technique considered innovative in comparison to the solid slab, being indicated as more advantageous in several aspects, mainly for reducing the weight of the structure and having better thermal and acoustic insulation (CUNHA, 1998). However, solid slabs also have their advantages, pointed out by Carvalho and Pinheiro (2009), such as the minimization of efforts and little deformation.

This paper will present a comparison between the conventional solid slab and the ribbed slab. This comparison is of great importance for choosing the method that will be implemented in the construction. Both slab construction methods have advantages and disadvantages, but the intention of this paper is to highlight which method offers the greatest benefit in terms of cost-benefit and efficiency.

2. THEORETICAL FRAMEWORK

2.1 Importance of solid slab

Solid slabs are those in which the entire thickness is formed by concrete, with reinforcements longitudinal and, occasionally, transverse reinforcements. They are supported on beams or walls along the edges, and variations with free edges can be considered specific cases of this slab model. In Brazil, it is common to refer to any slab supported on the edges as a solid slab, although types such as the mushroom slab, which transfers the loads directly to the columns, also fit into this concept. Araújo (2003) defines the solid slab as a plate of uniform thickness, with support along its edges, and these structures are generally used in residential buildings with smaller spans. However, it is important to emphasize that, in addition to residential buildings, solid slabs can also be applied in commercial and industrial constructions, given their robustness and flexibility.

According to Silva (2010), solid concrete slabs have been used since the first construction, and are appreciated for their simplicity of execution and the safety they offer. These slabs are formed by fixed-thickness reinforced concrete plates. According to Bastos (2015), this type of slab is supported by beams or walls along the edges, and its thickness is entirely composed of concrete, with longitudinal flexural reinforcement and, occasionally, transverse reinforcement.

Large-scale projects often use solid concrete slabs, such as bridges and multi-story buildings, as well as other large-scale projects, such as schools, hospitals and industries. For residential and small-scale buildings, however, prefabricated ribbed slabs stand out for their advantages in terms of cost and ease of construction (Carvalho; Figueiredo, 2014).

The main function of solid slabs is to distribute the floor loads throughout the structure. According to Guimarães et al. (2017), these slabs are composed entirely of concrete, with longitudinal flexural reinforcement and, in some situations, transverse reinforcement. They are supported at the edges by beams or walls, and when they have free edges, they are considered a variation of this structural model. Compared to beams, solid slabs have a favorable structural behavior, as they undergo smaller deformations and are subject to lower intensity forces (Carvalho; Pinheiro, 2009).

The thickness of solid concrete slabs generally ranges from 7 to 15 cm, and is suitable for large buildings, such as commercial buildings, schools, hospitals and factories. Although they are also used in small-scale constructions, such as residences, they are not recommended for very large spans. In these cases, prefabricated ribbed slabs cast on site offer greater advantages, especially with regard to cost and ease of execution. The choice between a unidirectional or bidirectional slab depends on the ratio between the spans. If the largest span is more than twice the size of the smallest, the slab will be reinforced in one direction (unidirectional). If the ratio between the spans is less than or equal to 2, the slab will be reinforced in two directions (bidirectional), as explained by Carvalho and Figueiredo (2014).

2.2 Importance of the ribbed slab

Ribbed slabs are structures designed to optimize the use of concrete, distributing it more evenly and forming the ribs that characterize this type of slab. According to Pinheiro (2003), ribbed slabs are a structural system that seeks to move the concrete away from the neutral axis of the cross section, increasing the height of the slab and, consequently, the lever arm. This results in the formation of a set of ribs that can be arranged in one or two directions, with uniform spacing between them, which provides greater structural efficiency.

The Brazilian Association of Technical Standards (ABNT) in NBR 6118 (2014) defines ribbed slabs as those molded on site or with pre-molded ribs, whose tensile zones for positive moments are located in the ribs themselves, and inert material can be inserted between them. This means that ribbed slabs can be executed either on site, when the slab is molded in the final position, or in a prefabricated manner, in which the ribs are constructed in a different location of the building. In both cases, it is possible to fill the spaces between the ribs with inert materials, reducing the weight of the structure (SILVA, 2005).

These inert materials, called "filling elements", are prefabricated components made of various materials, whether solid or hollow, and their main function is to reduce the volume of concrete used, thus reducing the slab's own weight. In addition, these elements act as forms for complementary concrete, as described by ABNT. Souza and Lopes (2016) highlight that, in multi-story works, ribbed slabs cast on site are often adopted, varying between the use of filling materials, removable forms or the choice between reinforced or prestressed concrete, depending on the structural and economic requirements of the work.

The use of ribbed slabs has gained popularity due to the weight reduction they provide to the structure. When no filler material is used, ribbed slabs can be even more efficient, especially when molded with plastic molds, which are more economical and facilitate the on-site assembly of the ribs. This option represents a significantly lower cost compared to wooden molds, which were widely used in the first ribbed slab projects (SILVA, 2005).

Ribbed slabs can be designed unidirectionally, with ribs arranged in a single direction, or bidirectionally, with ribs in both directions. The choice between these two types of rib arrangement depends on the ratio between the largest and smallest span of the slab. If this ratio is less than 2, the bidirectional solution is more suitable, as it provides a more efficient distribution of loads, in addition to reducing displacements and stresses on the structure (CARVALHO; PINHEIRO, 2013).

Ribbed slabs can be designed in a unidirectional or bidirectional manner, depending on the ratio between the largest and smallest spans of the slab. According to Carvalho and Pinheiro (2013), if the ratio between the largest and smallest spans is less than 2, it is more efficient to adopt the bidirectional solution, which results in a more uniform distribution of loads and smaller displacements and efforts. Structurally, ribbed slabs combine plate and grid elements, presenting a "T"-shaped cross-section, where the ribs, joined by the flange, offer resistance to both tensile and compressive forces. The neutral axis is close to the flange, which means that the lower part of the slab has a less relevant role in compressive strength, serving more to ensure adhesion between the concrete and the steel (Araújo, 2008). In addition, the lower part of the slab can be filled with light and inert materials, such as polystyrene plates or ceramic elements, to further reduce the weight of the structure.

2.3 Comparison between the ribbed and solid slab models

To make the comparison between ribbed slabs and solid slabs, several studies were evaluated, where they made the same comparison in different situations, making it possible to extract extremely relevant information. Since there are different situations, some method will stand out in relation to another, but this will not always be the case.

Souza; Lopes (2016) states that the ribbed slab makes better use of the materials used in reinforced concrete, which is essentially made from steel and concrete. Therefore, using the ribbed slab reduces the structures' own weight. When using the ribbed slab together with prestressed concrete, these slabs can cover larger spans using more slender structures, presenting an advantage over the solid reinforced concrete slab.

Cunha, Andrade and Salomão (2020) state that the use of prestressed concrete combined with the lower self-weight of ribbed slabs made it possible to overcome larger spans, resulting in an advantage over conventional solid slabs. With the reduction of the self-weight of slabs through the use of ribbed slabs, it is possible to build slimmer buildings,

According to the study by Guimarães et al. (2017), the use of three types of slabs in a building was analyzed. Using the solid reinforced concrete slab, ribbed slab with plastic tubs and ribbed slab with precast reinforced concrete lattice joist and EPS blocks. Three structural projects for the same plant were used for analysis, one for each type of slab. The comparison focused on understanding the behavior of the structure, indicating the values of loads on the foundation, quantity of materials required and costs, and then being able to make the best choice. When analyzing the behavior of the structure, the solid and ribbed slabs with plastic tubs demonstrated better results, the slab with joists and EPS presented a lower total material consumption index in kg/m³. Thus, in the foundation load, the ribbed slab with plastic tubs presents the lowest value, while in the total costs, the best result is the slab with joists and EPS.

Lira and Teixeira (2022) considered that, since they are reinforced concrete slabs, each structural type has different characteristics, mainly in relation to the type of execution, materials used, quantity of materials used, costs and execution time. Analyzing whether the ribbed slab has any advantage over the solid slab structural model, in order to verify which of the slabs has the best cost-benefit ratio. Concluding that the ribbed slab model built at the Court of Auditors of the State of Maranhão was the best option, as it is more economical than the solid slab model, as it presents a better cost-benefit ratio.

Falcão (2020) compared the two types of slabs in a large-scale project, one of which was a residential building with 25 (twenty-five) floors, in order to choose the best way to execute slabs in the city of Rio Verde - GO. Cost analyses were made of the materials needed to develop the project, as provided for in the structural projects. After this, it was seen that the ribbed slab has the lowest cost compared to the solid slab,

For Oliveira and Macedo (2020), the solid slab has a high consumption of steel and concrete, compared to the ribbed slab, having a steel area of approximately

72% greater and a quantity of concrete approximately 51% greater than the ribbed slab. Because it has voids and ribs, ribbed slabs have a lower self-weight than solid slabs, and adding permanent and variable loads, it presents a lower load, containing a smaller steel area in relation to the solid slab.

The Grid Theory is very important, as it allows the analysis of the deflections and stresses in the slabs, considered fundamental by Cunha, Andrade and Salomão (2020). From this analysis, it was possible to verify the safety of the building in which the authors made their comparisons. It was observed that ribbed slabs overcome larger spans, but this system is not always the best option for small buildings, as labor costs are a burden.

Lira and Teixeira (2022) analyzed that ribbed slabs are recommended when the project requires the need to overcome large spans, and are also an excellent option in the case of large loads acting on elevated garages that need to support the load of vehicles. However, in small spans and for small loads, this structural type may not be the most economical. The authors do not recommend the use of ribbed slabs for parts of cantilevered slabs, because ribbed slabs can cause the inversion of bending moments, since where the ribs are located (lower part) does not have compressive strength as in solid slabs.

3. MATERIAL AND METHOD

This study aims to compare ribbed slabs and conventional solid slabs, focusing on the structural, economic and execution characteristics of both types of slabs. The methodological approach adopted consists of a comparative analysis of data from technical literature, bibliographic reviews and case analyses applied to different types of works. The materials and methods used to carry out this study are described below:

- The first stage of the study involved a detailed bibliographic review, with a survey of technical articles, dissertations, standards and specialized publications on the two types of slabs. Several studies on ribbed slabs (prefabricated and cast in situ) and solid slabs (unidirectional and bidirectional) were analyzed, seeking to understand the specificities, advantages and disadvantages of each type.

- The analysis of the characteristics of the two types of slab was based on the definitions of ribbed and solid slabs, according to the physical and structural properties of each. The solid slab was approached as a solid and continuous structure, while the ribbed slab was analyzed focusing on its lightened structure, composed of ribs that provide greater lightness and material reduction. The thickness, type of reinforcement (longitudinal and transverse), structural behavior, cost and efficiency of each type were the comparison parameters.

- Case studies of real projects where both types of slabs were implemented. These studies were selected based on the type of building (residential, commercial and industrial), the size of the project and the specificities of the project. From this study, the total costs, execution time and structural behavior of the two types of slabs in each scenario were observed.

4. RESULTS AND DISCUSSION

The study showed the concept of the types of slabs and how they work, in order to clarify any doubts regarding execution, and from there, it was possible to compare the ribbed slab and the conventional solid slab, showing their advantages and disadvantages regarding execution in different situations.

To carry out this work, a bibliographic review of some scientific works was carried out that focus on comparing the types of slabs, with issue dates between 2015 and 2024. Through the experiences of these researchers, it was possible to synthesize a better result.

Each project has different execution conditions and the choice of slab is no different. The choice of the type of slab execution prioritizes the safety and quality of the structure, however the cost of execution together with the labor is a major differential when choosing the type of slab to be executed.

With the evaluation of the results obtained in the publications, in relation to materials, the type of slab that presents a better evaluation in relation to cost-benefit was the ribbed slab, as it uses a smaller quantity of materials, its own weight is lower compared to the conventional solid slab, making it possible to make a less robust foundation.

However, in relation to labor, the ribbed slab requires specialized labor, thus making the labor required to execute the ribbed slab superior compared to the conventional solid slab.

Therefore, it was found that due to the high labor cost, the ribbed slab is more suitable for medium and large-scale constructions, while for small-scale constructions, the use of the conventional solid slab is more suitable.

Another aspect to be considered is the safety and quality of the structures, as depending on the type of slab, it is not suitable for slabs that will serve as a floor or base for loads in large spans, which may put the safety of the building at risk or compromise its functionality.

The ribbed slab has an advantage over the solid slab, as it requires less material and its performance in terms of deformation is better, as it does not require a more robust foundation due to its lower weight. However, another factor that is just as important as the cost of materials is labor, and calculating the labor cost is a complex activity when it comes to building a ribbed slab, as it requires specialized labor. Therefore, the cost assessment and comparison with the savings in materials when using the ribbed slab can be a topic that should be further explored in relation to labor costs.

5. FINAL CONSIDERATIONS

From everything that has been studied, it is understood that each construction has specific characteristics of options for placing slabs, which gives engineering the responsibility of calculating the function of the work and the load capacity to avoid wasting material and not compromising the safety of the building.

Therefore, it is concluded that this study contributes to the modernization and expansion of knowledge, as it demonstrates that civil engineering is evolving and its

Professionals promote different possibilities of renewing knowledge based on searches and research carried out on innovative subjects.

However, it is important to recognize that the planning of a slab system cannot be carried out only with analyses of theoretical bases; it is necessary to have publications of assertive experiences and practices that reinforce planning techniques, in order to facilitate the presentation of activities and calculations that allow adequate choices of slab systems.

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