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THE TECHNICAL-ECONOMIC OPTION FOR THE USE OF THE NERVURED SLAB IN A RESIDENTIAL-COMMERCIAL BUILDING: CASE STUDY

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ABSTRACT

It is noticed that civil engineering is still a very empirical science compared to other engineering. Still predominates in construction sites in Brazil, constructive methods very similar or equal to those practiced for centuries. However, increasing competition in the construction industry has made to seek more effective techniques and options with better money. As an example we have the ribbed slab, which is a relatively old constructive methodology, but is gaining popularity in the construction sector. In this article we tried to discuss the technical and economic choice of ribbed slab in the enterprise Prime Green Candeias located in Vitória da Conquista, Bahia. To obtain proper results, a literature review was conducted with relevant sources, beyond to interviews with various professionals responsible for the work. Based on these results it was found that, in fact, the main driver of choice for ribbed slab was able to meet larger spans, and verify that there is a cost savings from the elimination of concrete down the line neutral slab. However, because of the ribbed slab having a large thickness due to the ribs, this generates an increase in the ceiling height of the work, which eventually caused an extra charge.

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INTRODUCTION

There is an increasing search for perfecting the productive processes. In general, all branches of industry invest in innovation and continuous improvement of the management process and production. Also in civil construction, new technologies reach the market every year, making it increasingly necessary to qualify the workforce and increasing the mechanization and control of each phase of an enterprise.

Among these technologies, is the ribbed slab, a structural system formed by a set of ribs, and can be distributed in one or two directions, with regular spacings between them, interconnected by a cover or table of concrete compression, resulting from the elimination of concrete below the neutral line. The ribbed slabs provide a decrease in the weight itself and a better use of steel and concrete. According to Pinheiro and Razente (2003), it is in the ribs that the tensile strength is concentrated, and the filling materials have as their only function the replacement of the concrete, with no contribution to the resistance.

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These reductions provide savings in materials, labor and forms, thus increasing the viability of the construction system. In addition, the use of ribbed slabs simplifies the execution and allows the industrialization, with reduction of losses and increase of the productivity, rationalizing the construction. (PINHEIRO and RAZENTE, 2003).

The increased competition in the construction industry has instilled both the designers of reinforced concrete structures as well as the builders in a constant search for solutions that, in addition to being simple and effective, bring savings, speed, versatility in the applications or that still provide a increased cost-benefit ratio (SCHWETZ, 2005). Thus, the ribbed slab can fit this need. The use of ribbed slabs is very widespread in the United States and Europe since in these places construction is much more industrialized using technology widely in its processes. In Brazil, despite the predominant use of the conventional method in the construction of reinforced concrete structures, there is a growth in the use of this new constructive methodology (SCHWETZ, 2011). This is justified by some advantages in relation to the solid slab, such as the lower consumption of concrete and steel; the lowest index of forms, due to the use of inert elements, or of industrialized forms,

which decreases in the labor force, directly interfering in the cost; the greater ease in the distribution of the loads, by the possibility of the desired placement of the ribs, through the systems of forms and structures for ribbed slabs, using plastic buckets, available in the market; smaller deformations, due to good flexion, the stiffness of the slab being able to respond to larger spans, as well as cleaner works, as they require fewer forms (TENÓRIO *et al*., 2009). The complexity of this structural system has motivated the growing research on the subject. It is seen, however, that the knowledge about sizing criteria, on the behavior of the ribbed slabs of reinforced concrete is still quite scarce. In this sense, it is necessary to develop procedures and norms that guide the use of this type of construction system, since the current Brazilian standard NBR 6118 - Concrete Structures Project (ABNT, 2014) refers to it very succinctly, once which suggests the use of simplified calculation methods (SCHWETZ, 2011). It is known that the main parameters for choosing any constructive methodology is to meet the very specific characteristics of each project. Therefore, the research aims to verify that the main characteristic that defines the use of the ribbed slab is the possibility of overcoming larger spans compared to the solid slab of reinforced concrete. Thus, the criteria that civil engineers take into account in choosing the ribbed slab were analyzed. For this, we sought to identify the advantages and disadvantages of the same in relation to the others; present the executive process of this slab; demonstrate what kind of work is most used, and verify its history of use.

MATERIALS AND METHODS

The present analysis was carried out from January to May 2015 in the city of Vitória da Conquista, through the case study. The qualitative study was adopted in a work located in the neighborhood Candeias, in Vitória da Conquista. The company responsible for executing the project is PRIME, which carries out its first work in the city. The company has its administrative office located in Salvador - Bahia. Initially, bibliographical researches on the ribbed slabs were carried out, in order to obtain scientific knowledge of the subject to understand the possible reasons for choosing this technology. Then the authorization of the responsible engineer was required to carry out this research, since it was informed that the data obtained would be disclosed together with the company name and site of the work. The work analyzed was *Prime Green Candeias*, a residential building that contains eight floors with 32 apartments, a floor with 7 stores and two basements of garages. As a tool for collecting research data, a small interview was applied to those responsible for the work, such as: the structural engineer, the engineer with technical responsibility for the work, the master of works, etc., basically containing questions about the advantages of ribbed slab and the reasons that led to the choice of ribbed slab in the project. Prior to the application of the interview, the subjects of the research signed the Term of Free and Informed Consent - TFIC. The interview was preceded by an explanation of the reasons that determine the accomplishment of the research and the importance of the answers so that the objectives are reached. The interview questions were as clear and precise as possible, having language accessible to the understanding, facilitating interpretation and avoiding ambiguities. After the interviews ended, the signed TFICs were printed and collected under the responsibility of the authors, and filed by the researchers.

RESULTS AND DISCUSSION

According to the answers obtained in the applied questionnaires, it was generally verified, in the analysis of the questionnaires, that the first care of the ribbed slab is the compatibilization of projects (architectural, structural, electrical and hydraulic). In the execution of the slab, care must be taken in the execution of the shape, placing the cumbucas aligned according to the design, to make a perfect concreting. It is necessary to verify the shortenings, observing the locking of the cumbucas so as not to happen problems of displacement. Another recommendation is to check the spacing of the steel and concrete the entire slab at a single time to avoid joints. The shoring must be compatible since this slab has a greater ease of deformation. Regarding the type of project in which the ribbed slab is used, it has been found useful to use it in residential, commercial buildings, garages and places where larger spans are needed because the ribbed slab facilitates the marking of block masonry once that there are no beams that can be wiped out. Another advantage is that the installations are made after concreting, avoiding rework in case of wrong marking. According to the interviewees, the choice of ribbed slab was due to the compatibility of the architectural design with the structural design. A study requested by the company was carried out to verify the best slab alternative for the enterprise. The main advantage of the ribbed slab identified in the research is the saving of concrete and steel in relation to the massive slab, increase of spans between pillars, decrease in the number of pillars, greater productivity according to the project due to not having too much grinding and cutting of beams. It can also be emphasized that with the use of ribbed slabs there was a decrease in the time of removal of the shoring, optimizing the progress of the work. Since the company did not provide the feasibility study that was used in the choice of slab type; for the purposes of the present research, a simple comparison was made between the volumes of concrete expended in each type of slab, maintaining the same characteristics of the ribbed one, excluding, however, costs with labor and indirect costs. In this comparison, it was necessary to estimate the slab thickness. This calculation was performed according to the method described by Professor Bastos (2015), which consists in determining, first, the useful height of the slab, taking into account the dimensions of the piece and the number of set sides; then the total height resulting from the sum of the useful height, the half of the thickness of the reinforcement (gauge) and the covering of the reinforcement specific for this type of slab, as recommended by NBR 6118 (ABNT, 2014), is determined. As a result of this estimation, it was verified that a massive slab, to attend to the same span would have to present a total height of 26cm. The volume and cost comparisons with concrete that were practically used in the project, and the volume and cost that would be spent had the solid slab been chosen, are described in the following tables. It is noticed that the updating of the conventional slab would cause a significant increase in the cost with concrete. However, in the ribbed slab, bathroom drains can not be drilled in any position, only in regions where there are no ribs and no capital. In addition, there is an increase in the right foot of the work, often due to the lowering of plaster that is normally done in each floor below the slabs so that the various circuits of the work are installed, since there is this impossibility of if you stick the ribbed slab anywhere. As a consequence there is an increase in the cost of construction in other items such as masonry, slabs, plaster and gypsum. The ribbed slab has the additional cost of

cumbuca that ends up being compensated with the decrease of the cost of the manufacture of the beams.

Table 1. Comparison of the concrete volume of a slab of the Prime Green Candeias

Type of slab	Concrete volume (m3)	Unitary value*	Amount
Massive	92,56	R$ 305	R$ 28.230,80
Ribbed	50	R$ 305	R$ 15.250,00
Difference	42,56		R$ 12.980,8

Source: Department of Engineering of Prime Empreendimentos, 2015.
Note: * The unit value considered is related only to the cost of the material.

Table 2. Comparison of the concrete volume of all eight slabs of the project Prime Green Candeias

8	Concrete volume (m^3)	Unitary value*	Amount
Massive	740,48	R$ 305	R$ 225.846,40
Ribbed	400	R$ 305	R$ 122.000,00
Difference	340,48		R$ 103.846,40

Source: Department of Engineering of Prime Empreendimentos, 2015.
Note: * The unit value considered is related only to the cost of the material.

After this, we observed the entire executive process of technology being recorded through photos and explanations of each method. The first step to start this type of structure, according to the other types is the location of the pillars, through the axes that were used in the location of the work from an established landmark that was the post. From this, the frame of the pillars was positioned in the proper position according to Figure 1. The next step was to place the forms on the pillars for their proper concreting according to figure 2. Concrete was used with fck 35Mpa with slump 10 +/- 2.

Source: Authors' collection.

Figure 1. Mounting of the pillars rising from the foundation in the basement of the building

Source: Authors' collection.

Figure 2. Forms of the Pillars to be concreted

In order to have a greater reliability and inspection of concrete a company was hired to do its technological control. This company was responsible for collecting from each concrete truck three test specimens according to Figure 3 to perform tests in laboratories to verify the strength of each test body at 7, 21 and 28 days, as well as to verify the Slump Test of each truck, as Figure 4.

Source: Authors' collection.

Figure 3. Preparation of three test specimens for compressive strength test

Source: Authors' collection.

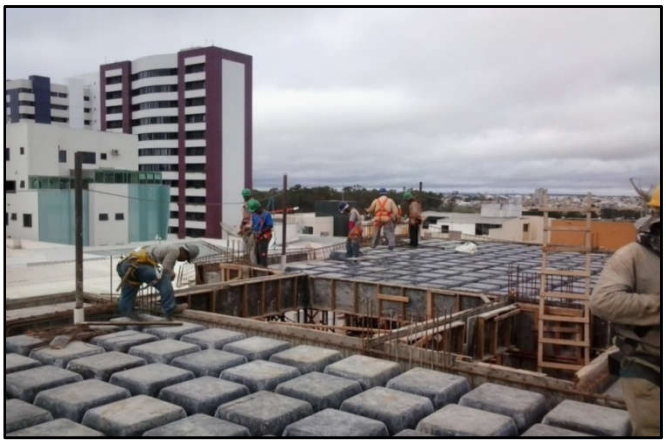
Figura 4. Slump test

After the concreting of the pillars, it is necessary to anchor the slab to position the buckets according to the project, as shown in Figure 5. A mini crane was used to lift the hardware of the slabs, beams and pillars in order to meet the schedule of the work to make a slab every week.

Source: Authors' collection.

Figure 5. Shoring of slabs for placement of cuvettes

A release agent was applied to avoid damaging the polypropylene shapes. After this, the beams frame was positioned properly for the concreting, according to figure 6.



Source: Authors' collection.

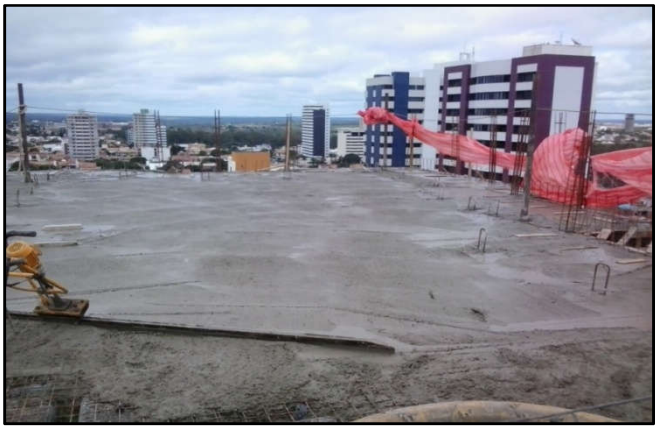
Figure 6. Positioning of the Positive Frame on the slabs of the slabs

After that, the positive frame of the ribbed slab was placed in the X and Y positions. After this, the Q113 screen was placed over the cuvettes with the 3 cm chair type spacer, according to the design, as shown in Figure 7.

Source: Authors' collection.

Figure 7. Positioning of the positive reinforcement in the two directions of the slab

The concreting of the slabs and beams were carried out on Fridays to facilitate the cure of the concrete, being used about 82 m³ of concrete. A vibrator was used to avoid voids in the concrete, according to Figure 8.



Source: Authors' collection.

Figure 8. Concrete detail of the Ribbed Slab

After the concreting, it is necessary to wait about 3 (three) days to unform, since it is necessary the concrete to have a minimum resistance. The struts should be removed gradually as shown in figure 9, being removed completely after 15 days of concreting.

Source: Authors' collection.

Figure 9. Ribbed slab after removal of forms

The ribbed slab utilizes materials that can be reusable like the cumbucas and anchors, being beneficial for the environment, because it diminishes the use of wood. The culture of the massive slab in medium and large-sized residential buildings is still noticeably predominant in the country, with the ribbed slab being a technology still in the know by the companies, especially in the interior of the country. It could be observed, in the case of the work analyzed that in the city there is no construction company specialized in this type of technology, in front of this it became necessary to hire a contractor of Salvador-BA to carry out this service. The need to disseminate the use of this type of slab is then verified, so that the companies start to explore these new technologies, aiming to offer economic and technical advantages to the client. In choosing this constructive method in a work one must study the project, check if it is necessary to use it, hire a designer with experience in the area and a company that specializes in the service. In addition, in order to choose the ribbed slab, it is advisable to carry out a study to verify the viability of its use in relation to other technologies, and if its characteristics meet the needs of the client. Finally, with the realization of the research, it was possible to perceive that the main reason for the choice of the ribbed slab of the building was the possibility of attending to larger spans, since the economy coming from the elimination of the concrete below the neutral line is compensated by the increase of the foot right of the work, making possible the choice of the ribbed slab.

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