PROCEDURES FOR BIM MODELING OF REINFORCED CONCRETE RIBBED SLABS IN BUILDINGS

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Glauco José de Oliveira Rodrigues[1], Danielle Malvaris Ribeiro[2].

ABSTRACT

It is impossible not to admit that commercial computational tools for structural analysis and detailing have become indispensable in the various applications of Structural Engineering nowadays. The importance of these tools equipped with graphical interfaces based on the BIM (*Building Information Modeling*) environment is mainly due to the flexibility and ease in making common corrections and changes during the elaboration stage, as well as the proposition of different structural conceptions, not always innovative, but almost always bold, as in the case of reinforced concrete ribbed slabs.

The use of ribbed slabs in reinforced concrete is an old practice in Structural Engineering, which has encouraged the adaptation of commercial computational tools, both in the development of structurally consistent mathematical formulations, as well as in the development of specific databases, equipped with information from mold manufacturers and materials intended for the execution of this type of slabs.

It is highly efficient in building structures in which there are numerous problems of interference of structural elements with elements of installations, such as large-diameter pipes for wastewater, sewage, gas, fire, and even air conditioning ducts, exhaust and architectural elements.

This efficiency is mainly due to the fact that large beams are not considered in their supports, making the lower face of the slab practically without obstacles to the building pipes, and is also due to the low average thickness of concrete used in the pavement compared to conventional rectangular supported slabs and flat mushroom slabs.

However, it is not always possible to obtain an optimal final result, even with all the adaptations previously described, mainly due to executive and computational modeling problems.

This work intends to present a possible structural modeling methodology, which provides results within the limits of the feasibility of the slab, both in the construction aspect of the computational structural model, as well as the possibility of using materials from manufacturers and labor, using a commercial computational tool for structural analysis and detailing.

Keywords: BIM, Reinforced concrete ribbed slab.

[1] State University of Rio de Janeiro
Email: glauco.grengenharia@gmail.com
[2] Veiga de Almeida University
E-mail: daniellemalvaris@hotmail.com

INTRODUCTION

As is well known, the thickness of a reinforced concrete slab depends, in addition to the overload for which it is intended, on the span to be overcome.

This thickness must be sufficient to avoid major deformations or undesirable vibrations.

However, in the case of large spans, solid slabs can reach such great thicknesses that most of their strength would be used to combat the stresses due to their own weight, which can cause a costly practice, from an economic point of view.

In this way, the alternative of reducing the structure's own weight was started, suppressing the part of the concrete that does not work, that is, using only the sufficient amount of concrete, in order to envelop the reinforcements in the tensile areas.

The traction regions with armor concentrated in bands are called ribs. In the space between the ribs, low self-weight materials are usually placed, with the ability to simultaneously allow a flat finish of the roof and serve as forms for the ribs.

The total savings are a function not only of the relief of self-weight, but also of the difference in costs (including execution) between the concrete and the inert material that has the function of replacing it.

Ribbed slabs have their application in residential or commercial buildings, especially in floors intended for garages, which usually require large spans and higher overloads.

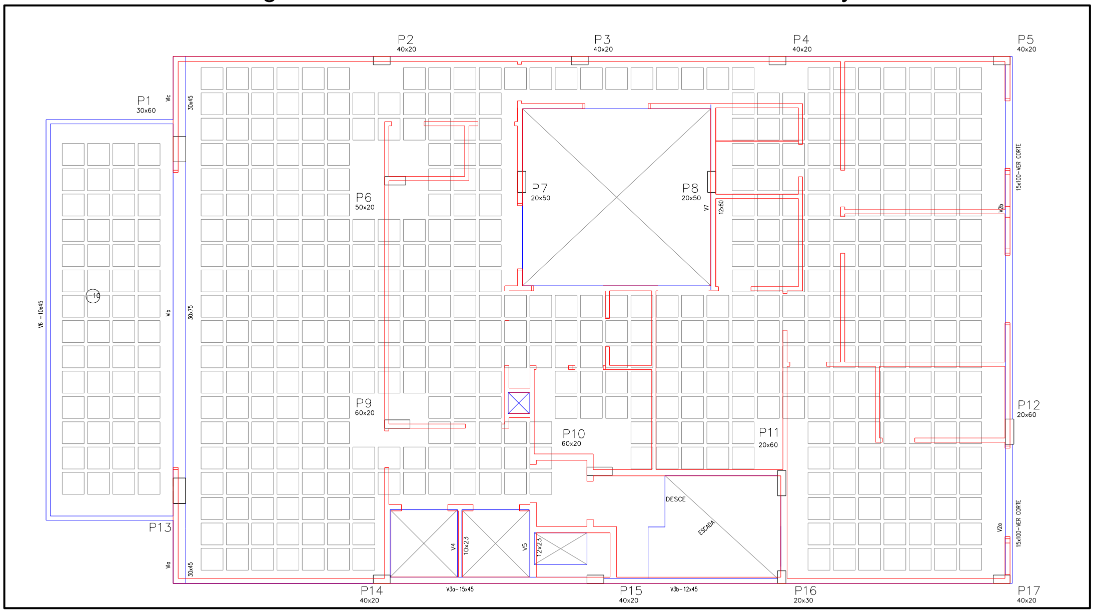
For the execution of the ribs, reusable forms of polypropylene are usually used, as shown in Figure 1.

Figure 1 – Cuvette that serves as the shape of the ribs of the Atex slab

STRUCTURAL MODEL PROJECT DATA

In order to have an idea of how to design a ribbed slab in reinforced concrete with the Cypecad software [1], let's take as an example the formwork plan shown in Figure 2. It is a structure with only one roof, equipped with capitals on the pillars and thickening in the regions where it was not possible to place the forms due to geometric limitations. The use of capitals in the columns is justified by combating the efforts of punching the columns on the slabs when they are devoid of beams in these regions.

Figure 2 – Formwork Plan / Location of the masonry



As can be seen, the plan of forms shown in Figure 2 above already has the masonry of the architectural project positioned. To facilitate modeling, the columns and beams are already pre-dimensioned. In this way, we can devote our attention only to the design of the ribbed slab.

For the launch of the structure, several characteristics of the project are defined, such as: fck of concrete (adopted 25MPa), steel grade (adopted 50A), utilization overload (adopted 200 kg/m2) and coating (adopted 150 kg/m2). The contour beams are rectangular in section and at some ends no beams were arranged, leaving the support due to the thickening of the slab in these regions. The self-weight will depend on the value informed by the manufacturer in its catalog, as will be seen in Figure 4, and will be automatically generated in the structure.

BIM MODELING

The structure is modeled exactly like a solid slab structure. The difference arises when we choose the type of slab that will fill the empty panels, as shown in Figure 3. There is the option of automatic generation of the massive regions, in space around the pillars, in order to mitigate the effects due to the punching.

Figure 3 – Structure modeled in Cypecad 3D before filling the panels

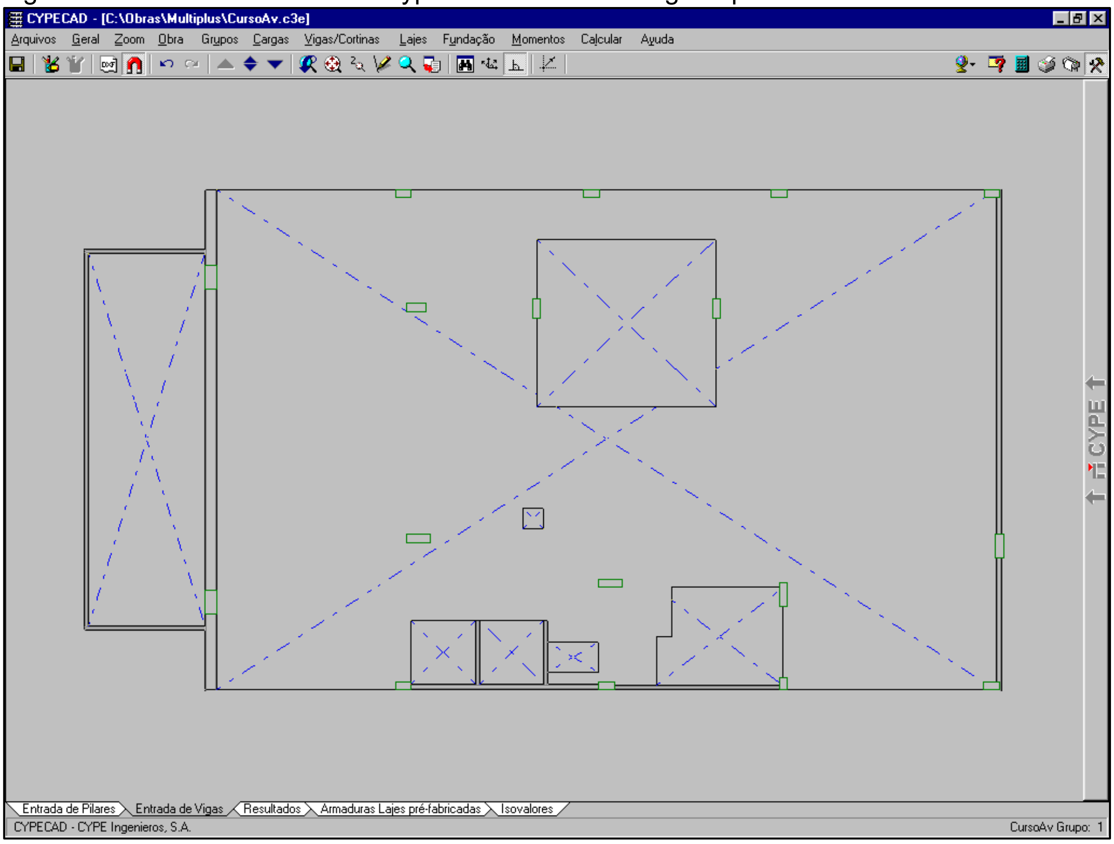
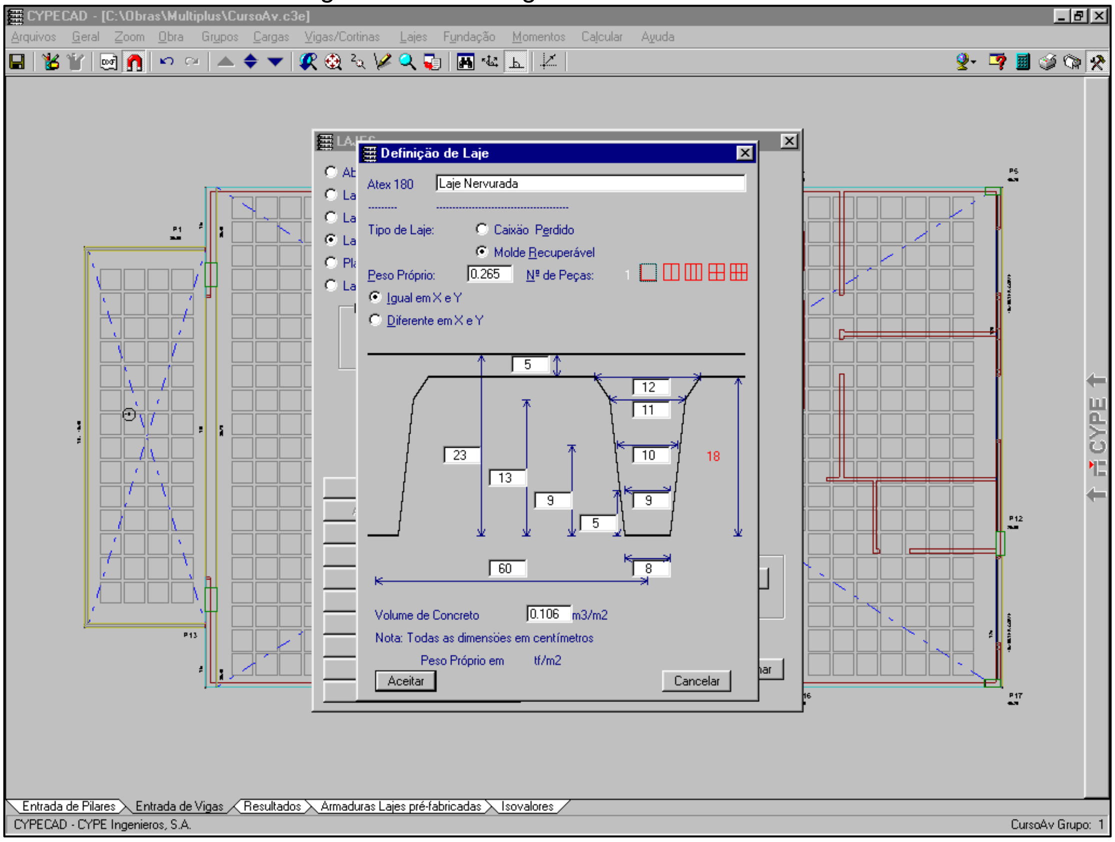


Figure 4 – Providing data for the ribbed slab



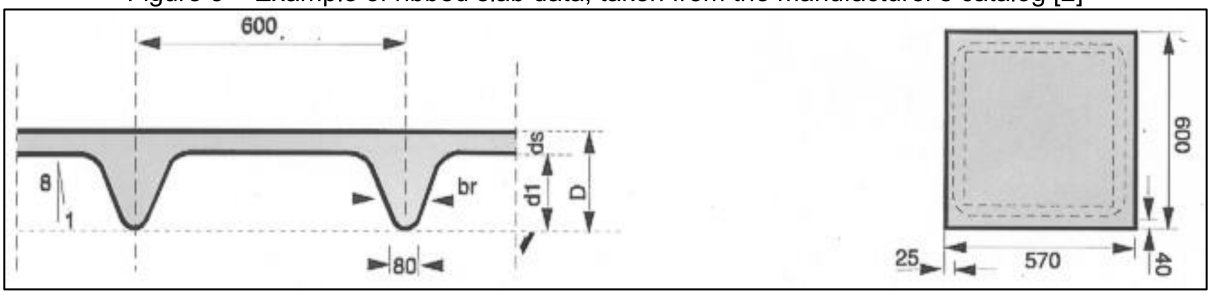
Therefore, it is necessary to create patterns of ribbed slabs with its mechanical characteristics, such as geometric data, between rib axes, self-weight of the slab, as shown in Figure 4

As can be seen in figure 4 above, it is enough to collect data on the properties of the slabs, taking as a reference the catalog of a manufacturer, which in this particular case is that of the company Atex.

It should be noted that the number of elements into which the ribbed slab bowl is divided is variable, from one element per bowl to 6 elements per bowl. Due to the computational effort required for a very large number of elements, it is very reasonable in vats of up to 1.00m of interaxis, the use of only 1 element per tub

These data are taken from the tables provided by the mold manufacturers [2], as shown in Figure 5.

Figure 5 – Example of ribbed slab data, taken from the manufacturer's catalog [2]



USE OF WELDED MESH REINFORCEMENT

In order to obtain a more homogeneous result of the reinforcements during the execution of the work, it is advisable to use a base reinforcement for the ribs (positive reinforcement). To do this, it is enough that the reinforcement table that will be used in the calculation is equipped with these meshes and that they are assigned before the calculation as shown in Figure 6.

It is customary to use superior mesh reinforcement in the ribs and masses of 4.2mm, in order to combat minimal (negligible) moments and that induce the software to make reinforcement reinforcement in these regions, despite the little need, and therefore discard it from the final detailing.

The final detail of the reinforcement in a ribbed slab (typical) can be observed, for example, in Figure 7, shown below.

In some cases, it is interesting to calculate the same structure with different base reinforcements and check the list of quantities of the work that provides the lowest reinforcement rate per m3 of concrete. It is important to remember to consider the additional weight of the mesh considered in each round, as it is not considered in the list of quantities of the work by the software.

After the calculation with the configuration that is understood as optimal (both from the point of view of structural safety and from the economic point of view), it is enough to make the final optimizations in the reinforcement, punching and shear reinforcement of the ribs, so that the definitive reinforcement drawings can be generated.

Figure 6 – Reinforcement table for positive reinforcement in the ribs [3]

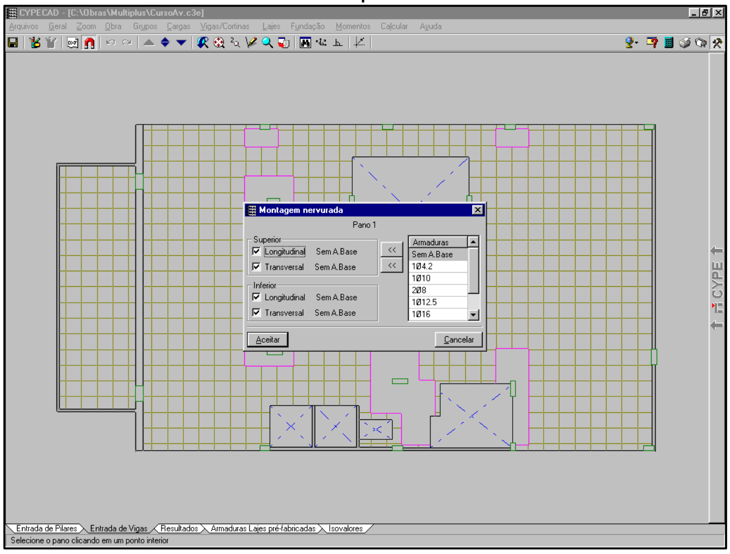
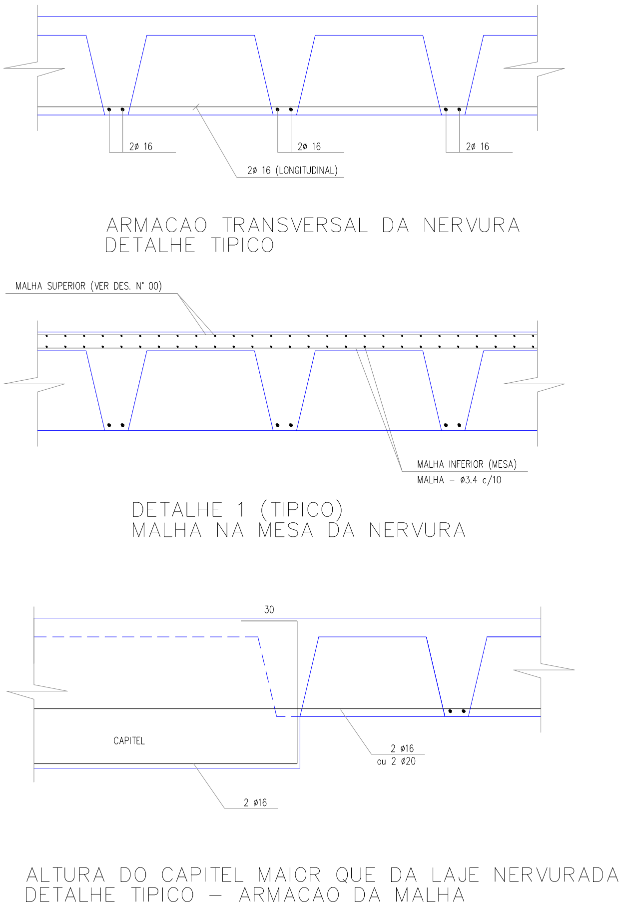


Figure 7 – Detailing of the reinforcements of the ribs



CONCLUSIONS

The advent of the BIM methodology in structural projects with the use of software such as Cypecad [1], has enabled the calculation engineer to innovate his design criteria in order to design increasingly economical structures, taking full advantage of the properties of the materials used (concrete and steel).

At the same time, suppliers such as Atex [2] presented their system that, constructively, meets the economic requirements mentioned above.

In this way, project engineering moves simultaneously with the development of construction techniques, in order to obtain final results with increasingly better quality.

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