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Comparative Analysis of the Structural Dimensioning Of a Reservoir through a Computational Software and Manual Calculation

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ABSTRACT : There is a tendency in the increase of investments in technology in civil construction. It is clear the development of several areas, among them the structures. Currently there is a lot of discussion about the positives and negatives points about manual calculation methods and computational tools, to what extent is there interference of the engineer in the design and analysis of a structural design by software. The objective of this article was to perform a comparison between the two calculations methods cited in the elaboration of a structural design of a high reservoir in reinforced concrete. This analysis was performed by determining its steel areas and by analyzing how the structure behaves in each adopted methodology. The results of the study showed greater efficiency in the use of software because it takes into account countless variables that are not considered in the manual calculation. In the manual calculations, the model of calculation of the isolated elements is used, restricting its analysis to the element itself, without transmitting effects to the neighboring elements, which does not normally occur in a conventional structure. On the other hand, with a computational tool there is a greater efficiency and precision in the results, including by the interaction of all the structural elements.

KEYWORDS Structural Dimensioning.Comparative Study.Steel Area.

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I. INTRODUCTION

With the technological advancement of civil engineering, the market is increasingly developing to guarantee in a simplified way the 3 pillars of engineering: economy, functionality and safety.

Prior to the consolidation of structural calculation software, structural designs were done manually, using only calculators. It took a long time to complete, because besides the calculations, the projects and their detailing required a lot of work to be elaborated. Nowadays structural projects are elaborated with the aid of computational tools. In addition to saving time and economy, the project becomes more accurate, simulating the structure with a model closer to what happens in reality, if compared to more simplified methods [1-2].

Dynamism is also an important point to consider in this software, as the program can test various forms of structure until it finds the ideal situation to become an economical, functional and secure project. To perform these tests by manual calculation would require more work and time [3].

It should be noted that even with all these advantages, the responsibility of the project lies with the engineer. He must analyze all the outputs of the program, so theoretical and practical knowledge is essential, because the software is nothing but an aid to the execution of a structure. The lack of theoretical knowledge generates the blind use of software [4].

Given the above, this article aims to make a comparison between the method of manual calculation and commercial software in the elaboration of a structural design of an elevated reservoir in reinforced concrete.

II. LITERATURE REVIEW AND FUNDAMENTAL CONCEPTS

Reservoirs

Reservoirs, structurally, are all structures that have the function of storing liquids. According to Maiola[5], the reservoirs can be classified according to their position in relation to the soil, the shape of the average surfaces of the tanks and the volume of stored water. Regarding the first type of classification, the reservoirs may be:

- Elevated reservoirs: are used when water pressure is required. Elevated reservoirs can be separated according to their supporting structure, composed by the stem tower, supported by pillars or having their support in structures already built, such as buildings and residences. Figure 1 shows an example of elevated reservoir.

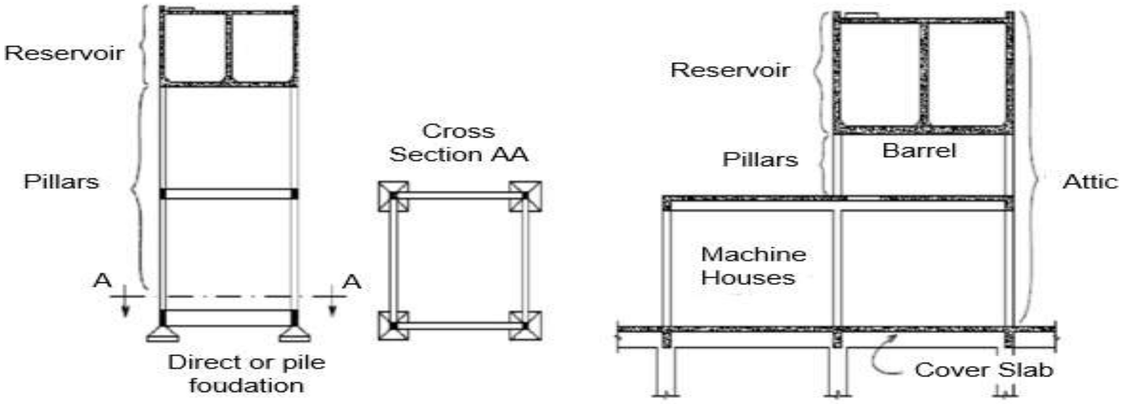

Fig. 1. Types of structures in elevated reservoirs [5].

- Supported reservoirs: These reservoirs are less common to be made of reinforced concrete because they occupy large areas. They are characterized by having the bottom slab resting directly on the ground.
- Buried or semi-buried reservoirs: These are the most economical structures, also known as cisterns. They are adopted in buildings when the pressure available in the public distribution network is not sufficient to raise water to the upper reservoir. Fig. 2 shows an example of buried reservoir.

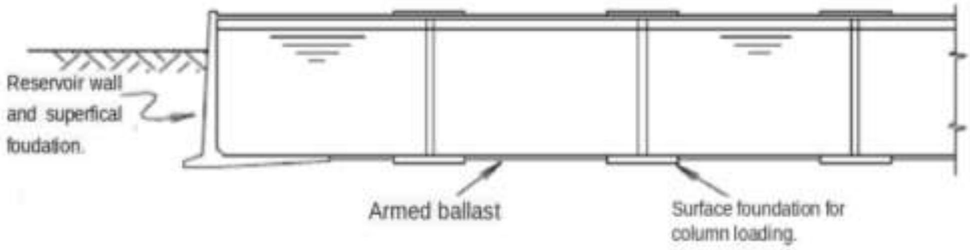

Fig. 2. Type of structure in buried reservoirs [5].

In principle, there should be a lowerreservoir(usually buried), supplied directly by the public network, and an upper (elevated) reservoir, supplied by booster pumps from the building itself. These are usually made up of at least two independent cells, so that cleaning can be done without prejudice to the water supply.

Still regarding the constructive dispositions, once the volume of water to be stored in the upper reservoir is defined and considering the necessary clearance for the installation of buoys and the safety discharge piping, the reservoir dimensions are determined, being usually limited height at about 2.0 to 2.5 meters. This height should not be exceeded to avoid overstressed slabs, even if this requires arrangements where part of the reservoir is in balance with respect to the pillars. Figure 3 shows an elevated reservoir model [6].

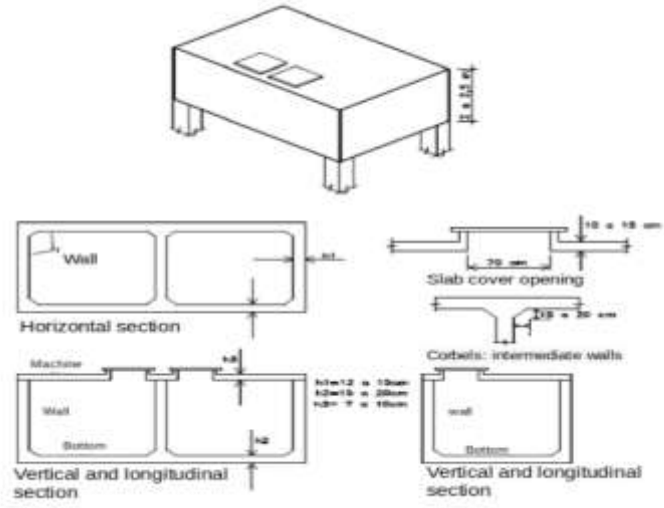

Fig.3. Elevated Reservoir Model [5].

Computational Tools

According to Kimura [7], it is currently possible to classify the computer systems intended for the elaboration of structural projects in the following types:

- Analysis software that is used to calculate the stresses and displacements of a structure. It does not perform the sizing of the reinforcement nor does it generate the final plans;
- Drawing software that serves to generate generic drawings, not directed exclusively to Civil Engineering.
- Isolated element sizing/verification software that serves to dimension an element (beam, pillar or slab) in isolation from the structure. Ideal for quick checks;
- Integrated system that covers all stages of the project. Calculates the structure, sizes and details the reinforcement, generating the final drawings. It is the type of software most used to design concrete buildings.

According to Stramandinoli [8], in the late 60's and early 70's the first programmable electronic machines began to appear. There were four or five programmable machine models and brands, including a Sharp 14 programmable Basic language model using magnetic cards. The calculation of continuous beams was done in two steps (two magnetic cards) and subsequently made the diameters of bending moments and shear forces by hand. The calculation of vertical loads in buildings, taking into account the effect of wind, was also done in two steps (two magnetic cards): first the moment due to wind on each floor was calculated and then this effect was summed with the load of each pillar on each floor.

There is currently a huge variety of reinforced concrete structural calculation software in the Brazilian market, being the most cited by professionals in the field because TQS, AltoQi Eberick and CypeCAD are most prominent.

III. METHODOLOGY

The object of the study is an elevated reservoir of a school located in the city of Simão Dias, SE, Brazil. The reservoir of this project aims to store 38.54 m³ of water. As an object of study to be compared, the calculation of the slabs and walls of the reservoir was performed. It was necessary to launch the same project in the structural design software EBERICK.

After the manual sizing was completedin accordance with the procedures of ABNT NBR 6118 [9], the structural elements were pre-dimensioned to finally size each structural part of the reservoir in the software. This step was important to obtain results and to be able to compare them with the manual calculation. For the structural sizing, the following design data were used:

- Environmental Aggressiveness Class II [9];
- Concrete with resistance of 25 MPa and specific weight of 25 kN/m³;
- 3.0 cm cover for slabs and walls;
- Height of water depth of 2.60 meters;
- Walls 15 cm thick;
- 10 cm cover slab and 15 cm bottom slab;

- Counterweight with an average thickness of 2.5 cm, made with cement and sand mortar with a specific weight of 20 kN/m³;
- 10 kN/m³ for the specific weight of water;
- Background and wall waterproofing 0.50 kN/m²;
- Accidental loads of 0.50 kN/m² for coverage.

The project was designed using AltoQi's EberickV10 framework software. Fig. 4 shows the 3D image of the structural design of the study.

Fig.3. 3D image of structural study design.

IV. RESULTS AND DISCUSSION

With the data mentioned in the methodology, it was possible to dimension the reservoir, both in the manual calculation and in the software. Table 1 shows the comparison of the steel area values by each method.

Table 1: Results obtained from the reservoir steel area calculated manually and in the software.

Structural Element Name	Direction	Steel area– manual calculation (cm²/m)	Steel area– Eberick calculation (cm²/m)	ΔSteel area (%)
L01	X	5.19	4.42	-14.84%
	Y	5.19	4.00	-22.93%
L02	X	1.61	1.53	-4.97%
	Y	1.61	1.76	9.32%
PAR 01	X	1.50	1.51	0.67%
	Y	1.50	1.51	0.67%
PAR 02	X	1.50	1.51	0.67%
	Y	1.50	1.51	0.67%
PAR 03	X	1.50	1.51	0.67%
	Y	1.50	1.51	0.67%
PAR 04	X	1.50	1.51	0.67%
	Y	1.50	1.51	0.67%
Bottom/PAR 01	Continuity	7.30	8.49	16.30%
Bottom/PAR 02	Continuity	7.30	8.49	16.30%
Bottom/PAR 03	Continuity	7.30	8.49	16.30%
Bottom/PAR 04	Continuity	7.30	8.49	16.30%
Bottom/PAR03	Continuity	2.93	2.25	-23.21%
Bottom/PAR04	Continuity	2.93	2.25	-23.21%
Bottom/PAR03	Continuity	2.93	2.25	-23.21%
PAR02/PAR03	Continuity	2.93	2.25	-23.21%
Total		**66.52**	**66.75**	**0.35%**

With the results of table 1, it is possible to observe the comparison and the variation of the results obtained in the calculations in the steel area of the structural elements of the calculated reservoir. Results varied with some larger manual calculation values and others with larger software calculation. These variations were limited to less than 25% and, if analyzed the real steel area, the values varied slightly because they were relatively small, thus making a minimal variation a slightly high value. In the final result, with the considerations of manual and software calculations, the difference was only 0.35%.

Regarding variations, they happen because of the methods used in the calculations. While the simplified method is used in the manual calculation using the Bares' table [10], the software performs its calculations using the grid method. In the simplified method, the slabs and walls have their supports considered as rigid, that is, the supports are deformable. In contrast, the software adopts the deformable structure and considers the walls together with the slabs to analyze the entire assembly as a flat grid. Slabs and walls are therefore a single structure [11].

The different behavior of the structures in both methods is one of the points that influences the calculated moments and consequently in their steel areas. Another important point to mention is that in the method of manual calculation some specific considerations are made, as for example, in balancing the moments there is only a positive moment increase where it needs to be added and does not remove where it decreases, in favor of safety.

V. CONCLUSION

It can be concluded that the steel area in the Eberick software was slightly higher in the reservoir as a whole. Already observing by isolated elements, there are situations of larger and smaller steel area, depending directly on the considerations and methods used in each of the calculations.

It is necessary to understand that the calculation methods used for the manual and software structural sizing are different, and in view of this, it is foreseeable the variation in the obtained values. While the manual calculation is performed by the isolated element method, the software uses the whole set in its analysis.

Thus, it can be stated that despite the small difference in the overall result between the two calculation methods, the use of the software is the closest to the ideal. Through this method it is possible to check with greater precision what are the influences of each design decision in the structure because it is analyzed globally, considering the interaction between all its elements.

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