Comparative analysis of the structural systems of blocks A and B of the architectural set of the Attorney General of the Republic of Brazil, Brasília, DF

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Abstract: Oscar Niemeyer's work, recognized in the landscape of international architecture, has always attracted the attention of architects and engineers to discover the dichotomy and paradigm that exists between structure and architecture. Among the Works of Oscar Niemeyer of the 2000´s, symbol of the juridical order and the democratic regime, the "Attorney General's Office" stands out for being constituted by an architectural complex of six buildings. The geometric forms of this complex are defining a monumental space represented by two main buildings, realized by two constructive technologies and different structural solutions. The block "A", supported by a cable-stayed system, and the block "B", supported by reinforced concrete pillars, demonstrates how the structure is strongly linked to the design of architectural morphology. Through a structural analysis carried out by the SAP2000 program, it was possible to identify the structural models that constitute the Attorney´s project to obtain numerical data that represent the innovation of constructing the same architectural object through two antithetical conceptions. This study of the work in question allowed to understand the patterns that characterize the formal aspects of the structural technology used by the genius of the Brazilian architect and the relative constructive methods adopted.

Keywords: Structure, Architecture, Oscar Niemeyer, Attorney General's Office.

1 Introduction

Niemeyer's architecture, which stands out from conventional standards due to the plasticity and sinuosity of its curves, is considered a true symbiosis between resistant structure and forms. It is extremely important to remember that the resistant structure of an Oscar-winning work of architecture is not only determined by notions of statics or physics, but also by reasons of symbolic origin and the intention to surprise the observer's eye. The object to be considered in the structural analysis of this work, the Attorney General's Office (PGR), one of the main symbols of Brazilian legal power, is contained in an architectural work by the architect Oscar Niemeyer, located in Brasília, DF, designed in 1996.

2 The architectural complex

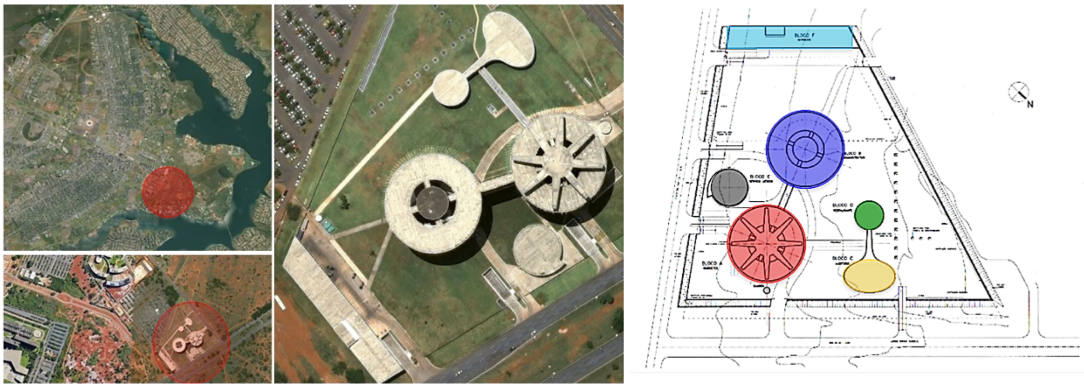

Figure 1 - Location of the Architectural Complex of the Attorney General's Office.

The architectural complex of the PGR consists of five volumes of reinforced concrete, interconnected through concrete walkways and an additional linear building (block F), headquarters of the inspection of engineering and architecture. The Block A, characterized by having a cylindrical volume and a monumental appearance, is crowned by an eight-pointed prestressed concrete "star". The lower connection, at the mezzanine level, is guaranteed by a reinforced concrete walkway, supported by concrete pillars due to the length of the span to be bridged. Vertical circulation is made possible through the rigid central core of block A which, in addition to containing elevators and stairwells, supports the load of the entire building.

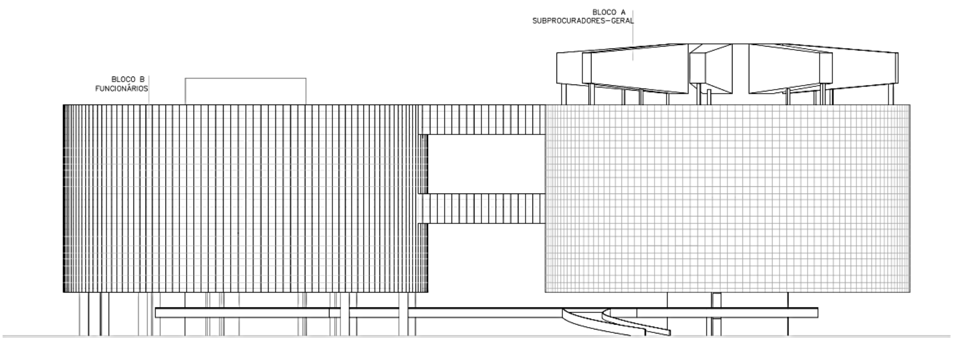

Figure 2 - Facade of blocks A to B.

The Block B, which has the same volume as A, consists of a glass cylinder with a diameter of 50 meters.

The only formal feature that differentiates it from block A is represented by the lack of structural beams crowning the top of the cylinder and by the conventional structural system with pillars.

3 Structural system's comparative analysis of block A - B

The normal efforts of block A are typically tensile instead of the stresses acting on the structure of block B, which are compression. By discretizing the T1 tie and the P1 pillar, it turns out that the path of the forces and loads incident on the structure of the two buildings are in opposite directions. the coverage. In the case of column P1, the forces increase in intensity downwards from the roof to the level of the foundations.

The structural balance of building A, guaranteed by means of the main beams of variable section, the steel ties, and the central rigid core, is made possible thanks to the prestressing system.

In the first combination (1.4G +1.4Q) there is a maximum effort of 2137 tf in the external tie, representing almost twice the effort submitted only with the structure's own weight (1450 tf). The external ties, more requested due to the larger contribution area of the slab than the internal ones, are subjected to a maximum normal stress of 1416 tf. In this trussed structural model, the efforts in the steel ties are transferred to the roof beams, from these to the rigid core. The rigid core is subjected to great compressive stresses. Maximum compression values reach 3490 tf at the top of the core.

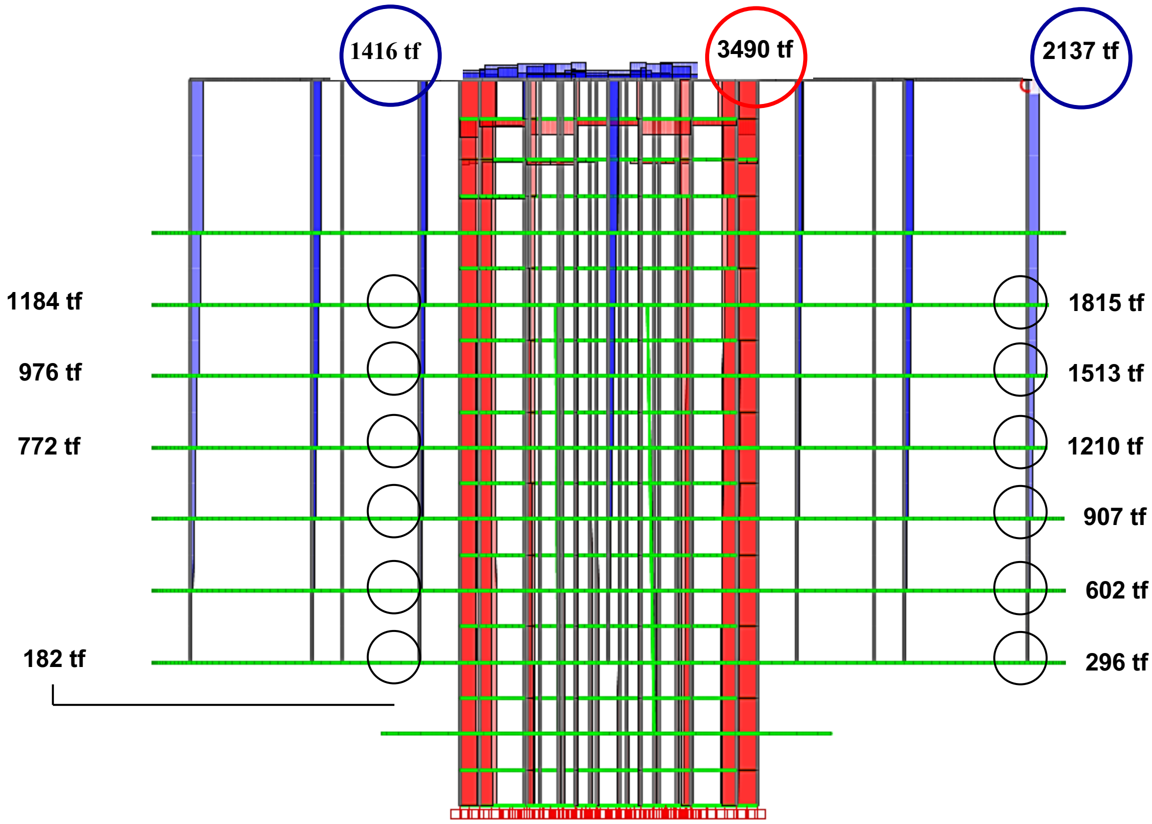

Figure 3 - Diagram of Normal Forces in Combination 1 (1.4G+1.4Q). Source: SAP 2000, author's drawing.

For the "B" block, in the first combination (1.4G +1.4Q) an effort of 2247 tf is shown, representing practically twice the effort maintained only with the structure's own weight. The external pillars have a larger slab contribution area compared to the internal pillars, which suffer a normal stress of 1734 tf. The main difference observed with the A-block model is the fact that the workers will have to climb through the protected steel rods and then descend through the central rigid core.

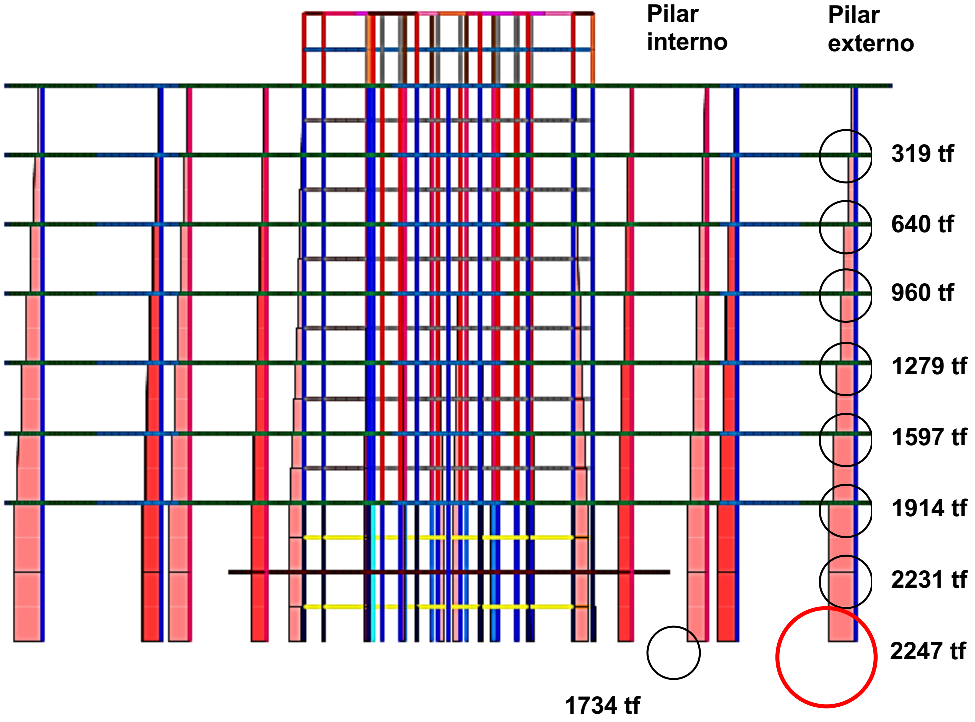

Figure 4 - Diagram of Normal Forces in Combination 1 (1.4G+1.4Q). Source: SAP 2000, author's drawing.

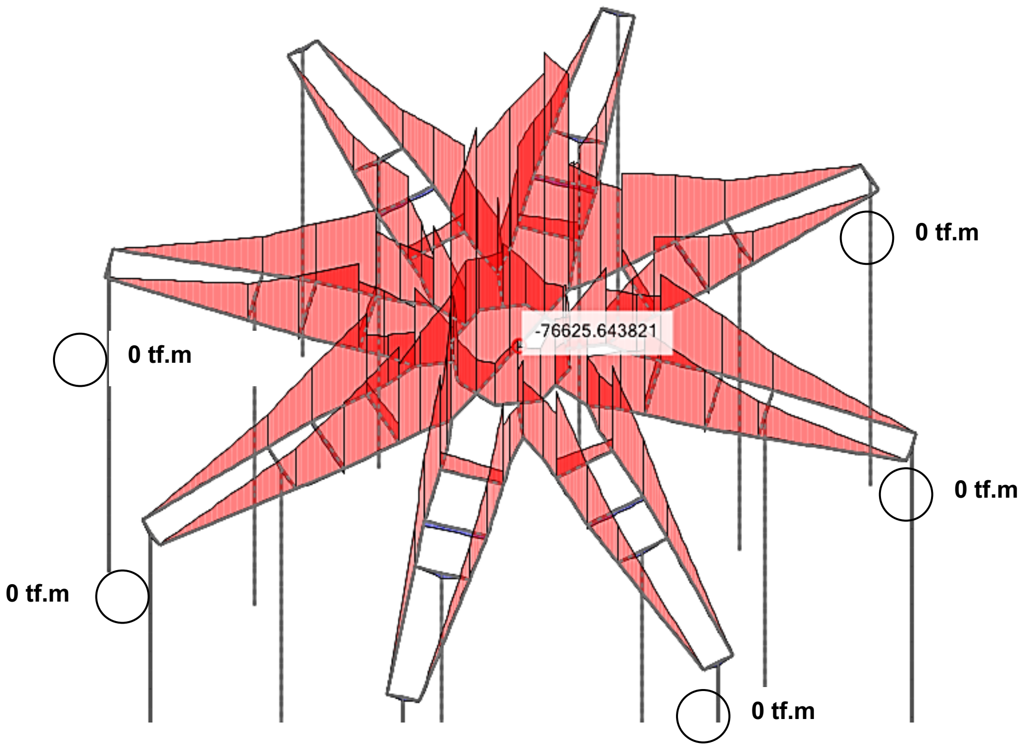

Figure 5 - Diagram in perspective of the Bending Moment of the roof beams, block A, PGR. Source: SAP 2000 program, author's drawing.

For analysis of the bending moment, figure 5 shows the bending efforts developed in the main roof beams, and in the central core the maximum value is -76,824 tf.m.

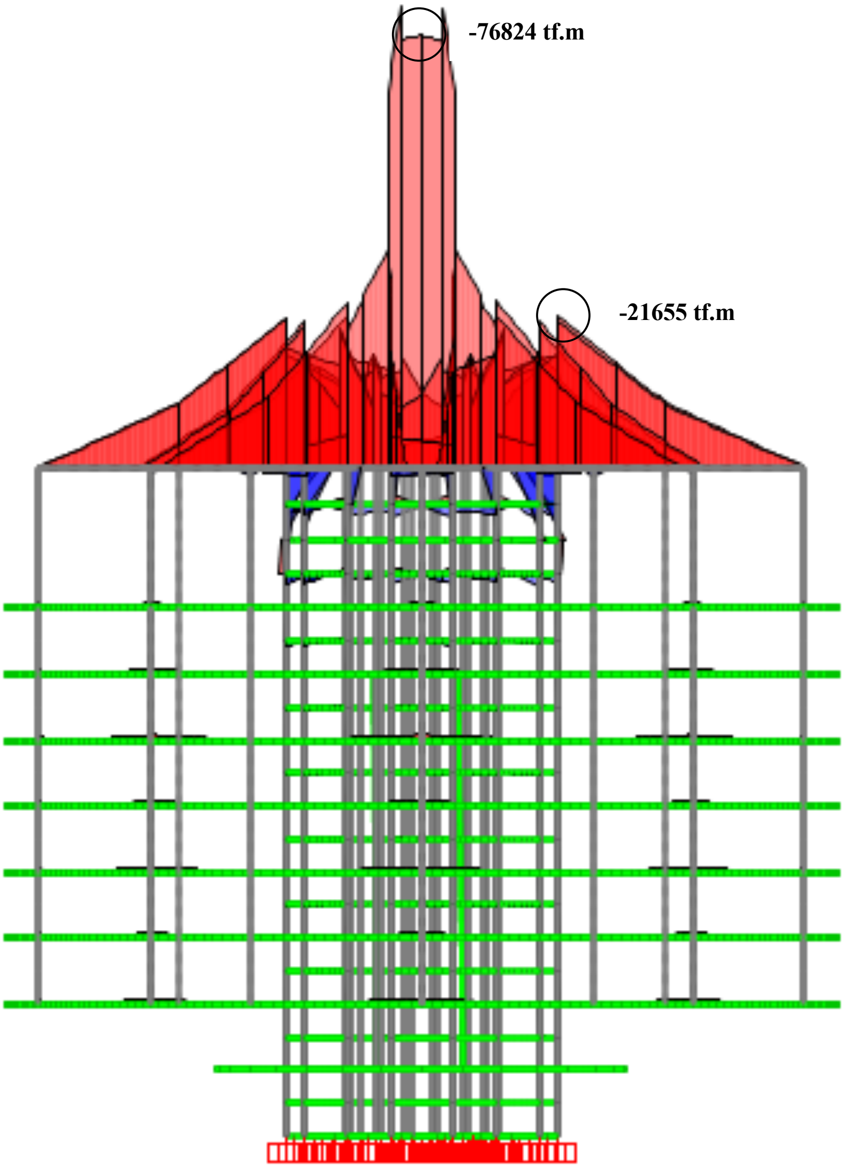

Figure 6 - Bending Moment Diagram of the beams, block A, PGR. Source: SAP 2000 program, author's drawing.

It is shown in the conventional model, as in figures, the bending moment in the enclosed beams of building B. The moments mainly close to the supports and in the beam – column connection, generated with a value of -117 tf for the beam – encounter external column and with a value of -390 tf connection in the beam – internal column connection.

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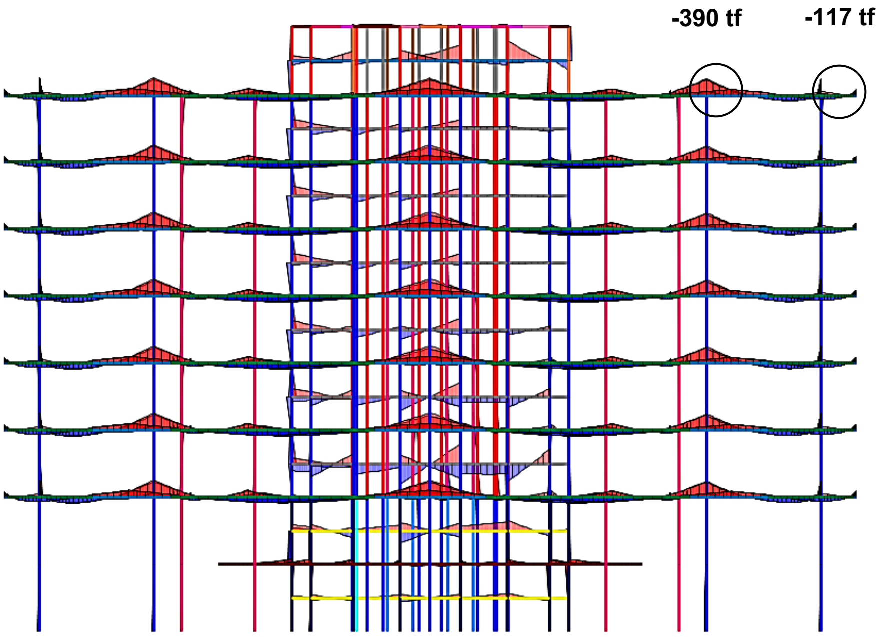

Figura 6 - Diagrama de Momento Fletor das vigas, bloco B, PGR.
Fonte: Programa SAP 2000, desenho do autor.

The structural balance of the conventional building, building B, obeys the gravity forces that impose the forwarding of the requesting loads in the direction of the foundations. Analyzing the typical resistance of the materials (steel and concrete) constituting the two structural systems, which are an inverse function of each other, it is shown:

$$\boldsymbol{R_t} = \emptyset\left(\boldsymbol{P_1}, \boldsymbol{P_2}, \ldots \boldsymbol{P_n}, \boldsymbol{F_y}\right)$$

The tensile strength of concrete elements is normally a linear function, where P1, P2, Pn are geometric properties and Fy is the yield strength of prestressing or reinforced steel.

$$\boldsymbol{R_n} = \emptyset\ (\boldsymbol{P_1}, \boldsymbol{P_2}, \ldots, \boldsymbol{P_n}, \boldsymbol{f_{ck}})$$

The compressive strength of concrete elements is usually a function where P1, P2, Pn are geometric properties and fck represents the strength of the material. In the main roof beams of block A, the preponderant effort is exerted by the bending moment and in the case of the ties, it is the traction. In the case of building A, the preponderant effort takes place in the columns and is mainly compression.

Analyzing from an economic point of view, the technological solution adopted in the cable-stayed building is more expensive in terms of the amount of steel and skilled labor. The Block B, conventional, adopts less daring technological solutions, allowing savings in terms of the volume of material mainly used (concrete).

4 Conclusions

In Oscar Niemeyer's production, one can appreciate something that, in addition to being decisive for the quality of his architecture, has important repercussions for the teaching and practice of other architects: in most of his projects it is difficult to separate the resistant structure from its formal structure, one merges with the other.
That is, formal and resistant structure are solved at the same time and not in a Cartesian way, as is common in the professional practice of the architect.
The set of the General Attorney's Office demonstrates the ability of the architect from Rio de Janeiro to produce two buildings of equal volume, proportion and geometry, through two different structural systems. This characteristic that has always determined Oscar's architectural conception reflects the will to show how architecture is not simply concrete and steel, pillars and beams, straight lines and curves. Architecture is fed by dichotomous paradigms, organic plasticity, empty and full, illusion and certainty, unusual and formal. In the period that coincided with the conception of Brasilia, the dominant theme of the approaches adopted by Niemeyer, especially in buildings of monumental value, was based on meeting plastic issues, on perfect conciseness between form and structure. The prestressing of the main beams, conceived during the creative process of the mind of Oscar Niemeyer and engineer José Carlos Süssekind, allowed the displacement of the structure to be combated and, consequently, the architectural structural balance of this work to be guaranteed. The Block A, born conventional, supported by temporary metallic pillars, rose from the ground to reach a divine symbolic dimension, marked by a structural lightness typical of nature's typologies. Antithetically, block B, conventional, suffers great compression efforts in the high-performance reinforced concrete pillars, determining reasonable displacements in the slabs of the floors participating in the architectural complex. The two buildings were born the same, they were similar, they developed the same behavior throughout the construction phases, but one evolved in a different, unexpected way.

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5 References

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