Architecture-Structure Conception in the Design of the CCBB Building in Brasilia

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Abstract. The Presidente Tancredo Neves building, which has housed the Banco do Brasil Cultural Center in Brasilia since 2000, is one of the iconic works by architect Oscar Niemeyer, designed in 1992. In the architecture of the building stand out the facades composed of long longitudinal walls in reinforced concrete with large openings that allow ventilation and natural lighting of the upper floors. These structures, with minimal thickness compared to their grandiose dimensions, have the appearance of vierendeel beams, although the structural system does not function as such. This work presents a structural design analysis of the building, seeking to show the designer's elements of creativity to balance the structure, maintaining the formal characteristics provided by the architecture. A numerical analysis of the structural solution is made with the available computational tools, describing the adopted structural system.

Keywords: Architecture, Structure, Niemeyer, Structural System, CCBB.

1 Introduction

The Presidente Tancredo Neves building (Fig. 1) was designed by architect Oscar Niemeyer, initially to be the Training Center for staff training units and the Professional Training Center of Banco do Brasil. The structural project is authored by the engineers at Promon Engenharia ltda. and was executed by the construction company Serveng Civilsan in 1992.

The Centro Cultural Banco do Brasil Brasília (CCBB - Brasília) began occupying the building on October 12, 2000, after a renovation of the building's adaptation, bringing together spaces for all forms of art demonstration. The complex of buildings houses ample living spaces, café, restaurant, galleries, movie theaters, theater, multipurpose rooms, gardens and a central square for open events.

It is currently considered one of the main cultural centers of the federal capital and its structure allows great diversity of cultural activities, because in addition to the buildings that form the complex, the free area, a landscape project idealized by Alda Rabello Cunha, receives extensive outdoor events, in addition to daily visitations [1].

In the architecture of the building stand out the facades composed of long longitudinal walls in reinforced concrete with large openings that allow ventilation and natural lighting of the upper floors. These structures, with small thickness compared to their grandiose dimensions, have the appearance of vierendeel beams, although the structural system does not work as such.

Another highlight in the architecture of the building is the free floor plan - without the interference of columns, a solution much used for this type of buildings by the architect. This was possible since the two upper floors are hung by tie rods, supported by large metal beams that cross the roof transversely. The columns of the ground floor are located on the facades and have great aesthetic appeal for the architectural composition of the set, as they have a robust base formed by a combination of a rectangular prism on a cone trunk, whose base reaches 4 meters on the side.

Figure 1. View of the façade of the Tancredo Neves building, showing openings in the external wall and the columns in the form of a pyramid trunk. Author's photo

2 Building's Structure

The main structure of the building is made of exposed reinforced concrete arranged basically by two hollow facades that form the "false vierendeel beams" supported by concrete columns. The main building is 14.7m high, 22m wide and 296m long, has a ground floor over the pilotis with 6745m². Two upper floors in metal structure, set back 2 m from the sides, with a width of 18m and a length of 307m fixed in the concrete facades.

The main body of the building is structurally divided into four sectors, separated by expansion joints that pass transversely through the concrete structure. The main structure is formed by the hollow concrete curtains of 25cm thickness and enlarged in the support part forming columns with 70cm thickness, in the upper part there is a beam of 3.25m high on which are supported the metal beams of the transverse structure of roof. The roof of the building is made of reinforced concrete slab waterproofed with asphalt blanket. The ceiling height of the ground floor is 3.47m and of the two upper floors 2.6m.

The hollow wall of wire concrete that makes up the façade is in total 11.4m high with a series of rectangular openings with rounded edges, intended for the illumination of the upper floors. Transversely the structure is hung on trusses made of I profile parts approximate spans of 20.2m with a height of 2.8m and spaced of 9m that are responsible for the support of the two floors below and the roof through tie rods. These beam-trusses are supported by prestressed concrete beams, of 3.25x1.2m section, which run at the top, throughout the length of the facades of the building.

The columns are spaced every 27m with a base of 3.6m high and a geometry composed of a straight prism on a pyramid trunk with a base of 4m which gives the element a characteristic robustness of modern brutalist architecture, however, the structural designs show that such element has an internal void (Fig. 4). Next to the columns, in the region of the slabs are arranged metal structures with tubular section placed to prevent the horizontal displacement of the hanging structure.

Figure 2 shows the main cross-section of the building, in this figure you can see the trusses of the roof where it receives the two floors thrown, it is also noted that the truss is supported on the beam in prestressed concrete next to the roof that connects the structure of the columns in the regions of thickening of the wall that forms the façade. Finally, the bases of the columns that receive the loads of the whole structure and discharge into foundations are shown.

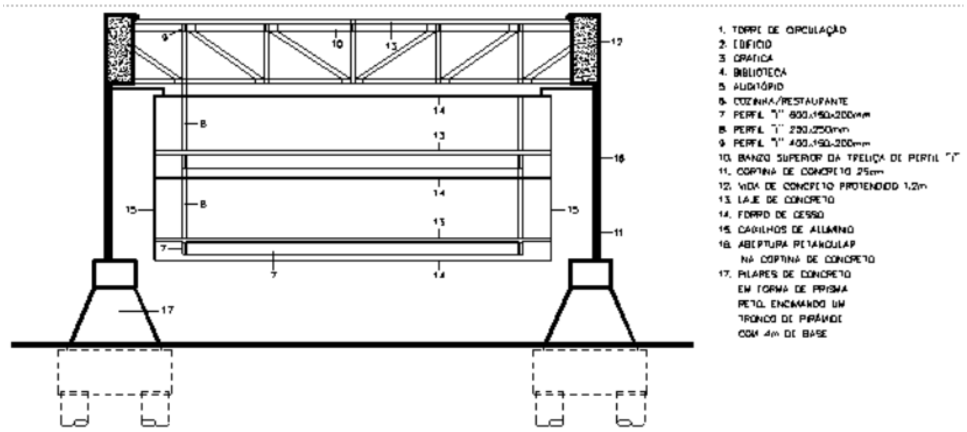

Figure 2. Cross section of the Tancredo Neves building [2]

2.1 Modeling

The images in Fig. 3 show the modeling process for the structural elements in the SAP-2000 software. Copies of the original strucutural design for the building, provided by the engineering team of the Banco do Brasil, were used as the basis for this modeling. The dimensions of the structural elements were organized in Table 1.

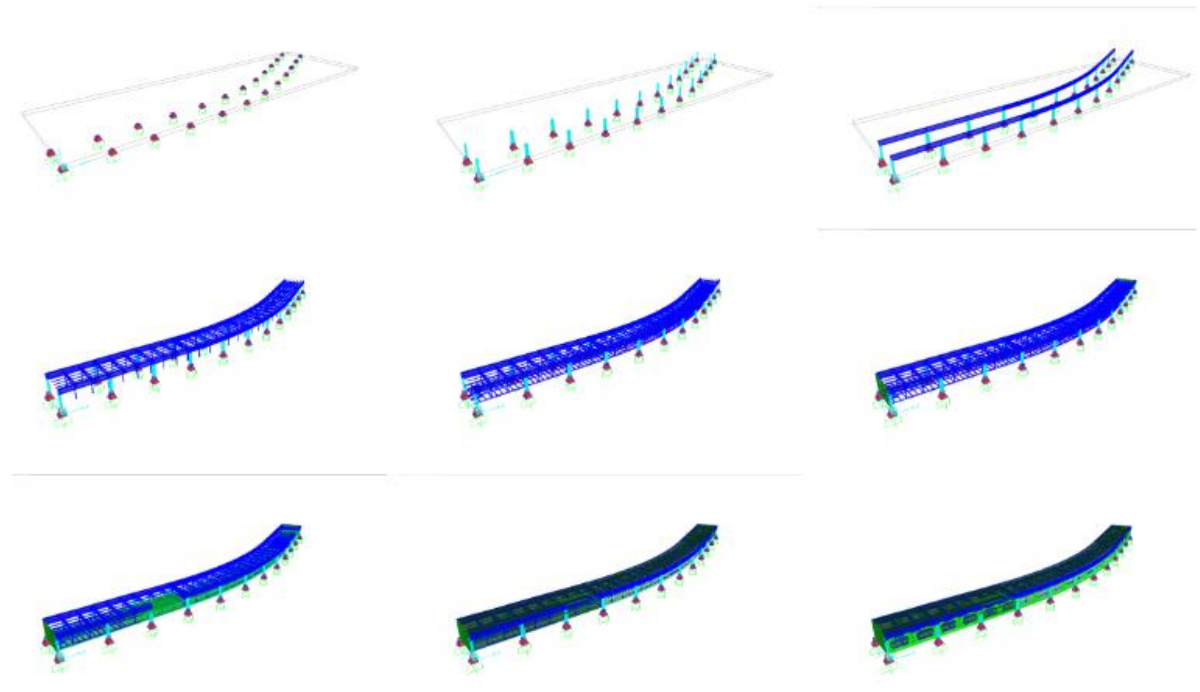

Figure 3. Modeling process for the structural elements in the SAP-2000, authors

These drawings show the details of the structural design, where we can understand the system used to suport the building, as the portico system shown on Figure 4.

Following the guidelines of the NBR 6120/80 standard, [7] accidental loading (LIVE – L) of 500Kgf/m² was applied on the slabs of the exhibition and museum areas and 100Kgf/m² on the roof, in addition to the proper weight of all the structural pieces (DEAD – D). For numerical analyses, the following load combinations were used: 1.4D + 1.4L – Ultimate Limit State (ELU) and 1.0D + 1.0L – Service Limit State (ELS).

Table 1. Dimensions of the structure of the Tancredo Neves building, raised for structural analysis.

Columns			
Element	Type	Dimensions (m)	Color
Base column pyramid trunk	frame	base 4x4, topo 1,8x1,8, h=2,8	
Base columns square prism	frame	1,8 x 1,8, h=1,2m	
Columns internal to the walls	shell	1,8 x 0,7, h= 8,1	

Walls			
Element	Type	Dimensions (m)	Color
Concrete Curtains	shell	0,25	
End walls	shell	0,2	

Concrete Beans and Slabs			
Element	Type	Dimensions (m)	Color
Master Beans	shell	1,2 x 3	
Slabs (floors and roof)	shell	0,09	

Metallic Tie Rods			
Element	Type	Profile	Color
Floors Tie Rods	frame	CS 250x90	
Horizontal Tie Rods	frame	Tubular D=114mm	

Metallic Trusses			
Element	Type	Profile	Color
Perfil I 250x40	frame	CS 250x40	
Perfil I 250x52	frame	CS 250x52	
Perfil I 300x149	frame	CS 300x149	
Perfil I 300x167	frame	CS 300x167	
Perfil I 350x161	frame	CS 350x161	

Floors and Roof Metallic Beans			
Element	Type	Profile	Color
Perfil I 300x33	frame	CS 300x33	
Perfil I 400x49	frame	CS 400x49	
Perfil I 600x69	frame	CS 600x69	
Perfil I 600x86	frame	CS 600x86	
Perfil I 700x126	frame	CS 700x126	

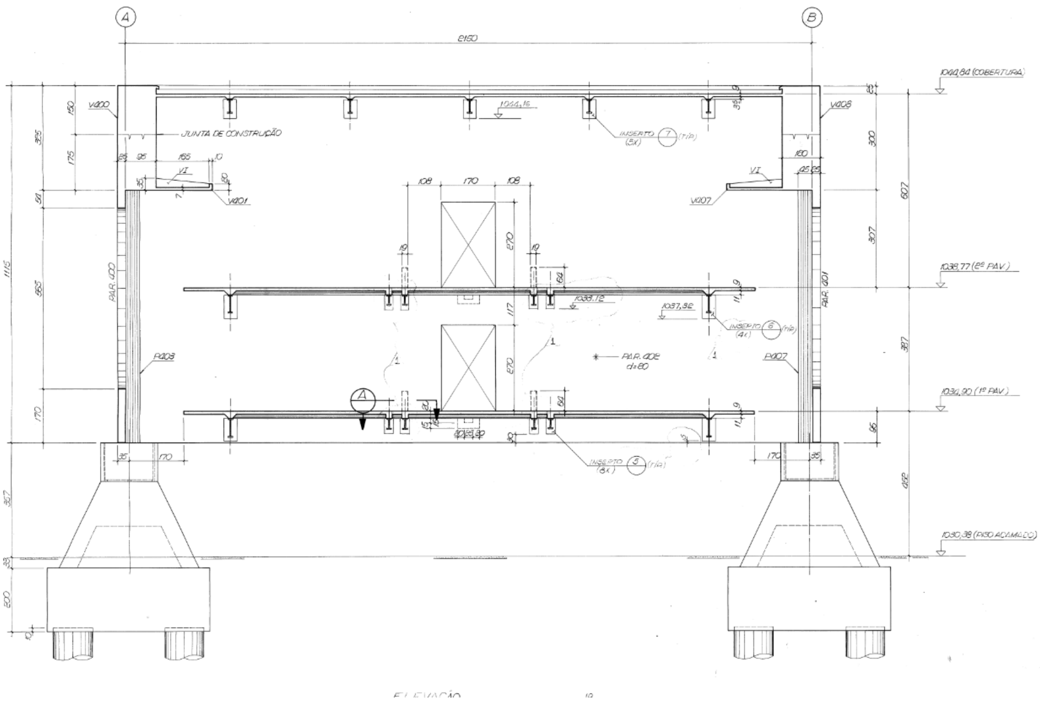

Figure 4. Drawings from the original Structural Design, provided by the engineering team of the Banco do Brasil.

For the model studied (Fig. 5), bar elements (frames) were used – for the columns and metallic beams and plates (area shells) for the slabs, concrete walls, longitudinal concrete beams and main concrete columns, along with the concrete walls, resulting in a model composed of 2,016 frames, 11,569 area shells, 15,485 points and a total of 46,283 area edges.

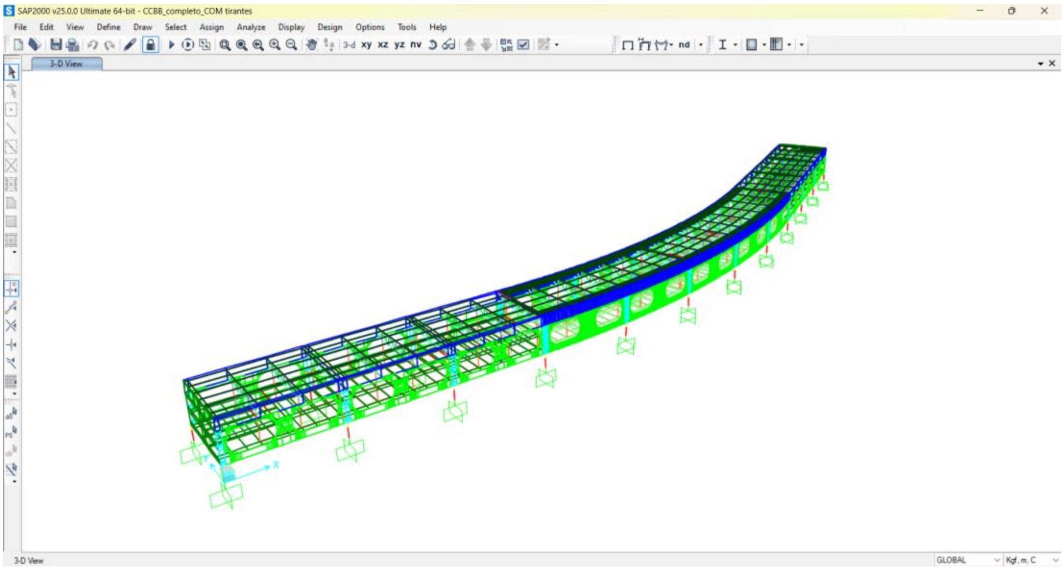

Figure 5. Model of the Tancredo Neves Building. Authors' Design, SAP 2000 Program.

3 Structural Analisis

3.1 Porticos

Figure 6 shows in section the portico, with emphasis on the metal truss that supports the floors of the building by means of also metallic tie-rods. Also noteworthy (in blue) are the prestressed master beams that accompany the building longitudinally on the two facades, next to the reinforced concrete wall. It is emphasized that it is these beams that absorb the bending efforts of the large spans of the façade.

Below the beams, the 70 cm thick pillars are shown that are disguised in the inner part of the façade wall, leading the efforts to the prismatic pillars of 4x4 m at the base. To avoid the lateral displacement of the slabs thrown to the large metal truss, horizontal bracings were placed in tubular bars connecting the slabs to the pillars.

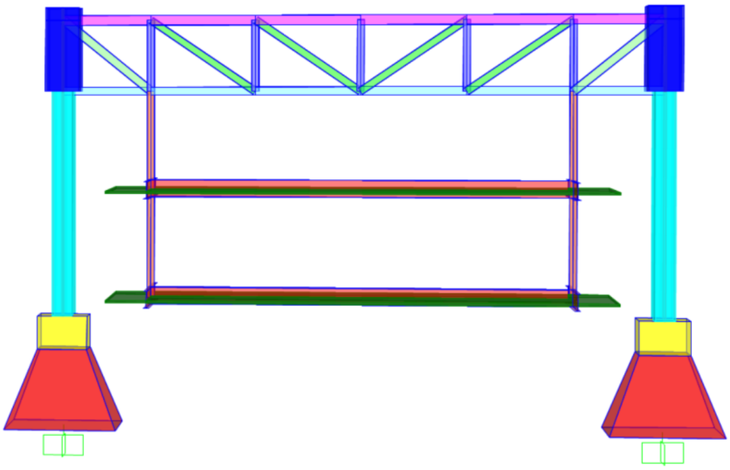

Figure 6. Portico Structure at CCBB building. Authors' Design, SAP 2000 Program.

3.2 Concrete Walls

Seeking to emphasize the structural behavior of the walls of the facades and the columns of the porticoes, it can be observed in Fig. 7 the concentration of compression efforts in these columns next to the supports.

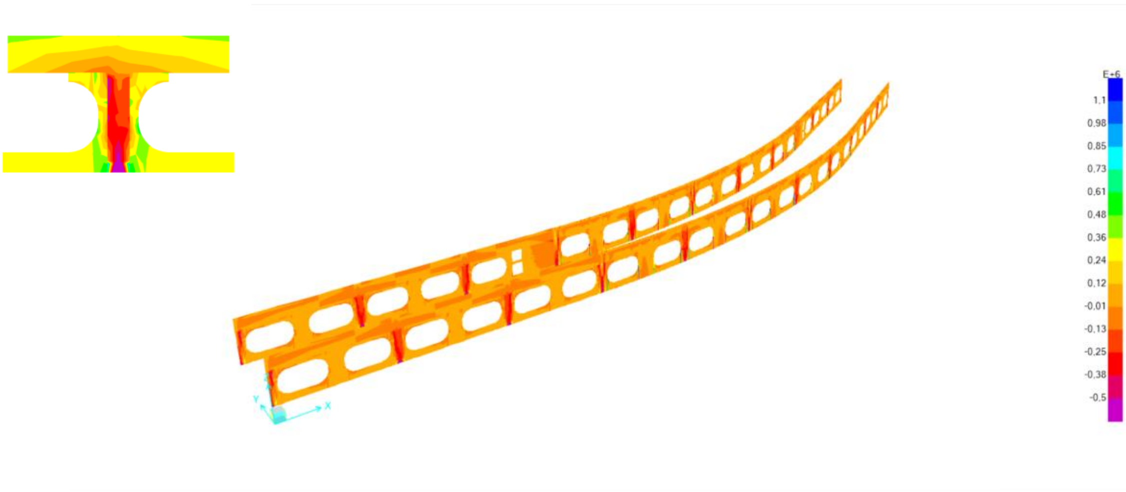

Figure 7. Diagram showing the vertical axiel force at the concrete walls at CCBB building façades. Authors' Design, SAP 2000 Program.

This analysis clearly shows that the structural system functions as a "conventional" system of porticoes, and not as large Viennedel beams as the architectural form suggests by highlighting the large concrete facades and their openings. This is also evidenced when we analyze the structural projects, where the large prestressed beans and the columns are detailed to absorb the main efforts.

3.3 Comparative analysis

When we compare models of the same building, built in SAP 2000 software, one showing the building as it was built and another using a vierendeel beam of constant thickness for the entire wall of the façade including in the region of the pillars (Fig. 8), we can see that the displacement in the center of the spans of 27 meters between the supports is about 50% lower in the solution adopted by the calculating engineer.

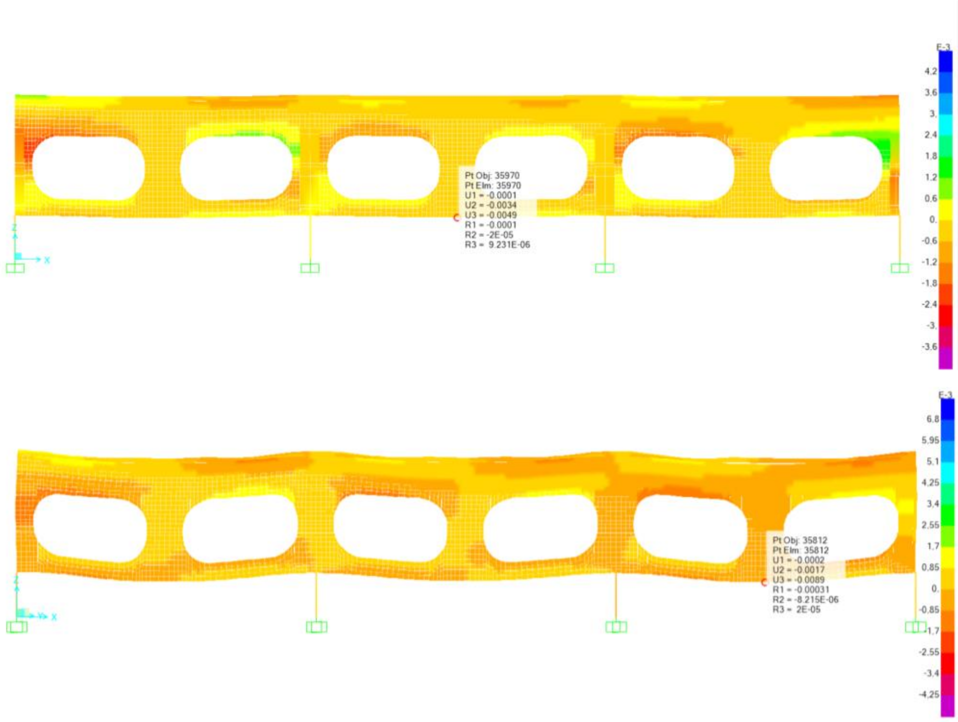

Figure 8. Diagrams showing the comparison between the vertical displacement at the concrete walls at CCBB building façades as built and as a vierendeel bean. Authors' Design, SAP 2000 Program.

Considering the minimum displacement, found in the two solutions observed, for the Limit State of Service, it can be concluded that both would meet the NBR 6118 standards. However, when one observes the efforts in the support regions, the thickening of the wall is necessary, since in the situation suggested in the study these regions would not support such efforts.

4 Conclusions

Oscar Niemeyer has always shown in his works, including in his creative process, that architecture and structure are born together, they are not distinct elements of construction. The engineers who worked with Niemeyer were responsible for structural solutions unheard of in several eras, to enable the realization of the formal inventiveness of Niemeyer's architecture [6].

The Tancredo Neves Building, house of CCBB Cultural Centre, built between 1992 is among the most striking works of Oscar Niemeyer and follows the line of the great structural challenges that the architect provided to the calculator Bruno Contarini.

Based on data collected from the Banco do Brasil engineering team, we were able to analyze this structure in several aspects with the aid of computational tools, such as the SAP 2000 program, used in this case study. Through the analyses made in the computer program, we can identify the relevance of the large concrete walls of the façade of the building, an element that visually has a great aesthetic function and have the appearance of vierendeel beams, as in fact is supported, along with the rest of the building, by a sequence of porticoes systems.

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