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## Architecture-Structure Conception in the Design and Performance Analysis of the CCBB Building in Brasilia

### Concepção Arquitetura-Estrutura no Projeto e Análise de Desempenho do Edifício CCBB em Brasília

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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. In addition to the analysis, several pathological manifestations in the building's structures are presented, as discovered in a 2008 survey. All the recommendations for structure repair are made. After 15 years, the building was revisited to assess the quality, durability, and behavior of the repaired structural parts, which showed good performance.

**Keywords:** architecture; structure; niemeyer; structural system; CCBB;

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## RESUMO

O edifício Presidente Tancredo Neves, que abriga o Centro Cultural Banco do Brasil, em Brasília, desde 2000, é uma das obras icônicas do arquiteto Oscar Niemeyer, projetada em 1992. Na arquitetura do edifício destacam-se as fachadas compostas por longas paredes longitudinais em concreto armado com grandes aberturas que permitem ventilação e iluminação natural dos andares superiores. Estas estruturas, com espessura mínima em comparação com suas dimensões grandiosas, têm a aparência de vigas de *vierendeel*, embora o sistema estrutural não funcione como tal. Este trabalho apresenta uma análise do projeto estrutural do edifício, buscando mostrar ao projetista elementos de criatividade para equilibrar a estrutura, mantendo as características formais proporcionadas pela arquitetura. Uma análise numérica da solução estrutural é feita com as ferramentas computacionais disponíveis, descrevendo o sistema estrutural adotado. Além da análise, são apresentadas diversas manifestações patológicas nas estruturas do edifício, descobertas em levantamento de 2008. Todas as recomendações para reparo da estrutura são feitas. Após 15 anos, o prédio foi revisitado para avaliar a qualidade, durabilidade e comportamento das peças estruturais reparadas, que apresentaram bom desempenho.

**Palavras-chave:** arquitetura; estrutura; Niemeyer; sistema estrutural; CCBB;

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## INTRODUÇÃO

The Presidente Tancredo Neves building (Fig. 1) was initially designed by architect Oscar Niemeyer to be the Training Center for staff training units and the Professional Training Center of Banco do Brasil (INOJOSA, 2019). 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 (CRUZ, 2021).

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 external wall of the Tancredo Neves building showing the openings and the columns, shaped as pyramid trunks.



Source: Authors' Collection

## 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 6745m<sup>2</sup>. 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.

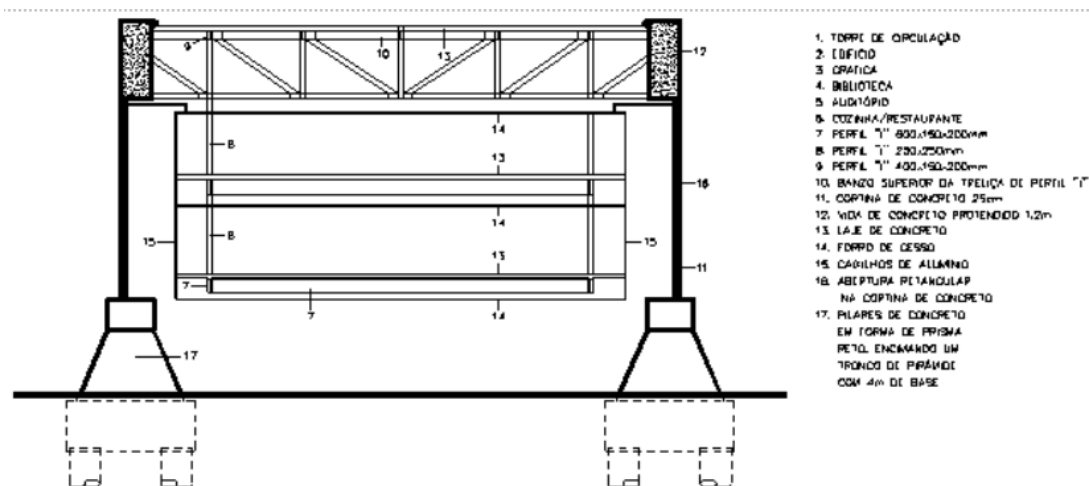
The hollow wall of wire concrete that makes up the façade is in total 11.4m high with a series of rectangular openings with rounded edges, intended for the illumination of the upper floors. Transversely the structure is hung on trusses made of I profile parts approximate spans of 20.2m with a height 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



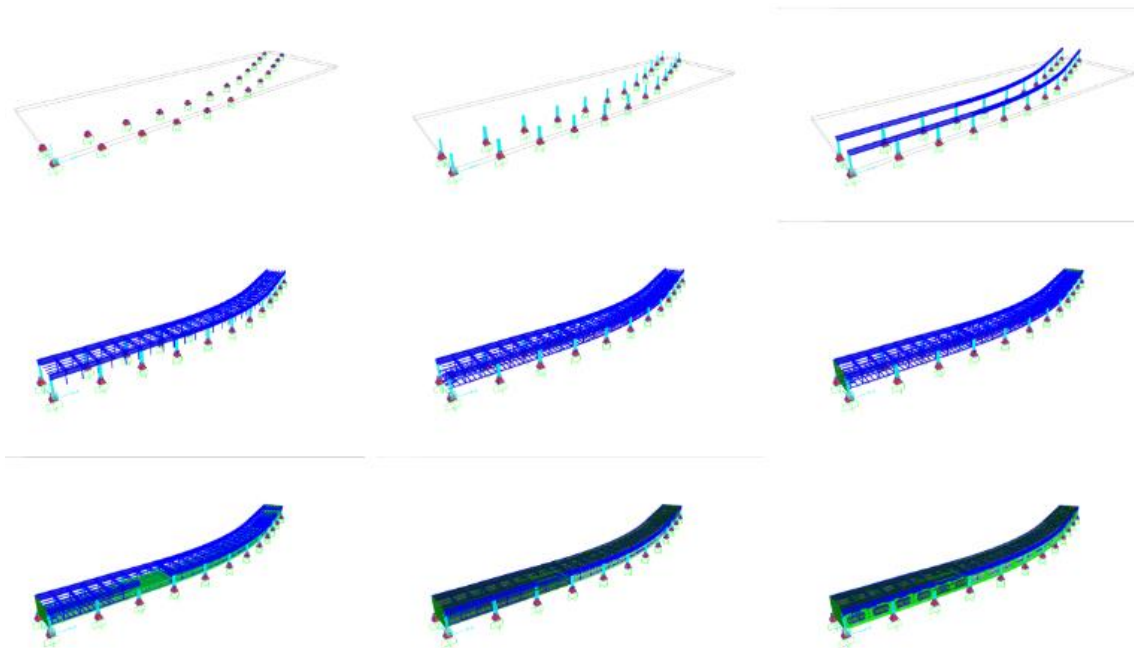
Source: Dias, Luís Andrade Matos (1999)

## Modeling

The images in Fig. 3 show the modeling process for the structural elements in the SAP-2000 software. Copies of the original structural 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 are organized in Table 1.

Following the guidelines of the NBR 6120/80 standard, (ABNT, 1980) accidental loading (LIVE – L) of 500Kgf/m<sup>2</sup> was applied on the slabs of the exhibition and museum areas and 100Kgf/m<sup>2</sup> 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).

**Figure 3** – Modeling process for the structural elements in the SAP-2000.



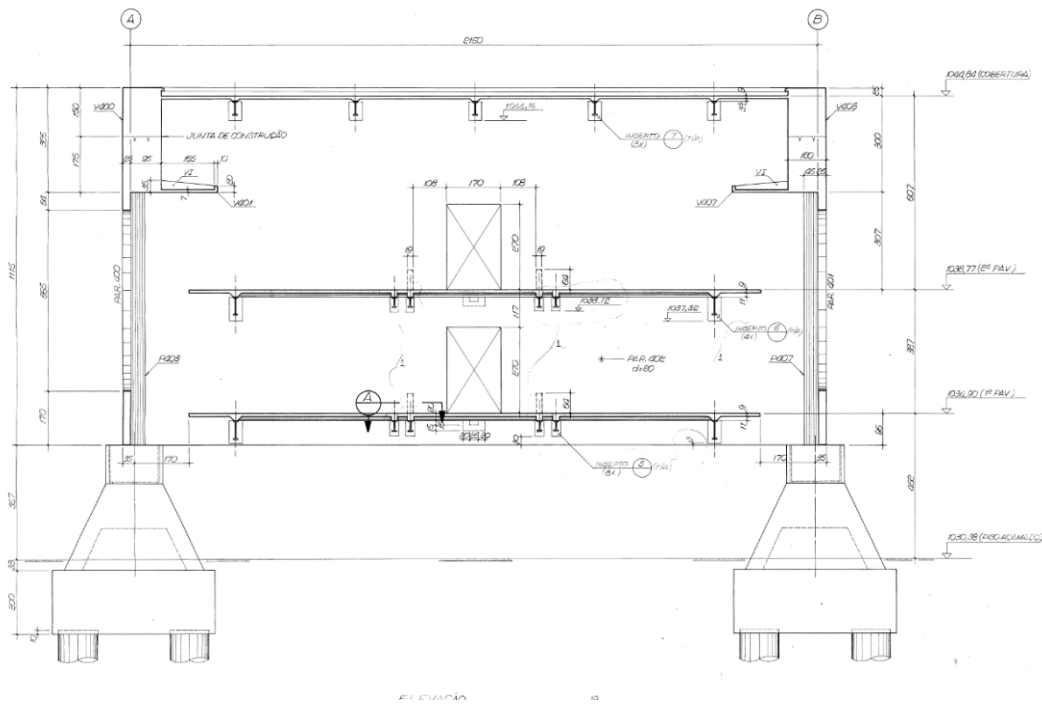
Source: Authors' Design, SAP 2000 Software.

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

Columns				Metallic Tie Rods			
Element	Type	Dimensions (m)	Color	Element	Type	Profile	Color
Base column pyramid trunk	frame	base 4x4, topo 1,8x1,8, h=2,8	Red	Floors Tie Rods	frame	CS 250x90	Orange
Base columns square prism	frame	1,8 x 1,8, h=1,2m	Yellow	Horizontal Tie Rods	frame	Tubular D=114mm	Light Orange
Columns internal to the walls	shell	1,8 x 0,7, h= 8,1	Blue				
Walls				Metallic Trusses			
Element	Type	Dimensions (m)	Color	Element	Type	Profile	Color
Concrete Curtains	shell	0,25	Green	Perfil I 250x40	frame	CS 250x40	Light Green
End walls	shell	0,2	Dark Green	Perfil I 250x52	frame	CS 250x52	Purple
				Perfil I 300x149	frame	CS 300x149	Light Blue
				Perfil I 300x167	frame	CS 300x167	Light Green
				Perfil I 350x161	frame	CS 350x161	Pink
Concrete Beams and Slabs				Floors and Roof Metallic Beams			
Element	Type	Dimensions (m)	Color	Element	Type	Profile	Color
Master Beams	shell	1,2 x 3	Dark Blue	Perfil I 300x33	frame	CS 300x33	Light Blue
Slabs (floors and roof)	shell	0,09	Light Green	Perfil I 400x49	frame	CS 400x49	Yellow
				Perfil I 600x69	frame	CS 600x69	Red
				Perfil I 600x86	frame	CS 600x86	Light Blue
				Perfil I 700x126	frame	CS 700x126	Pink

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

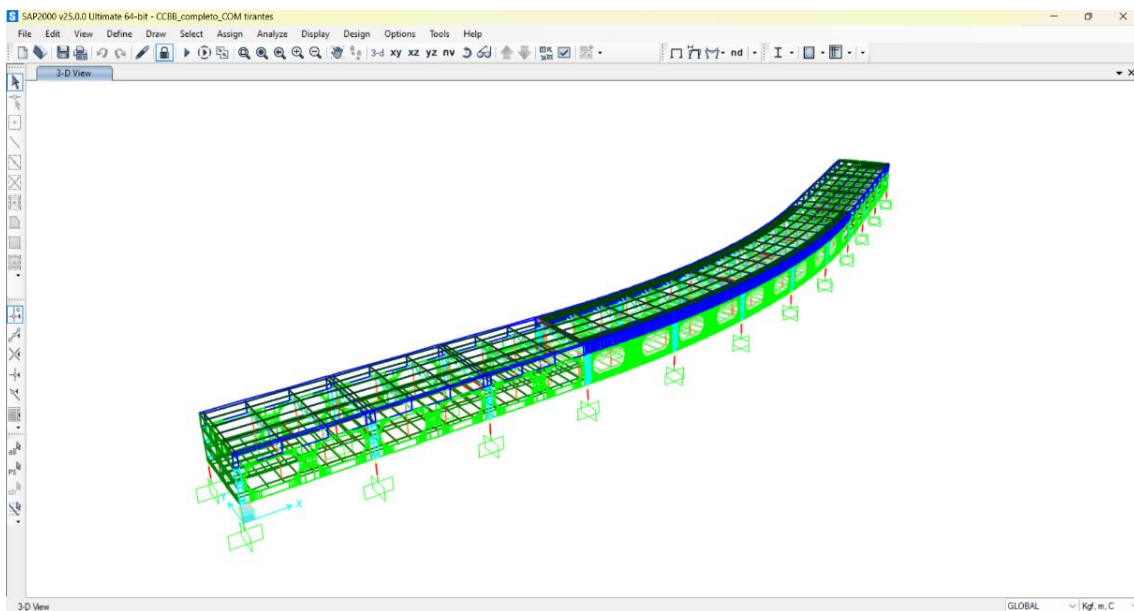
**Figure 4** – Drawings from the original Structural Design.



Source: 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.



Source: Authors' Design, SAP 2000 Software.

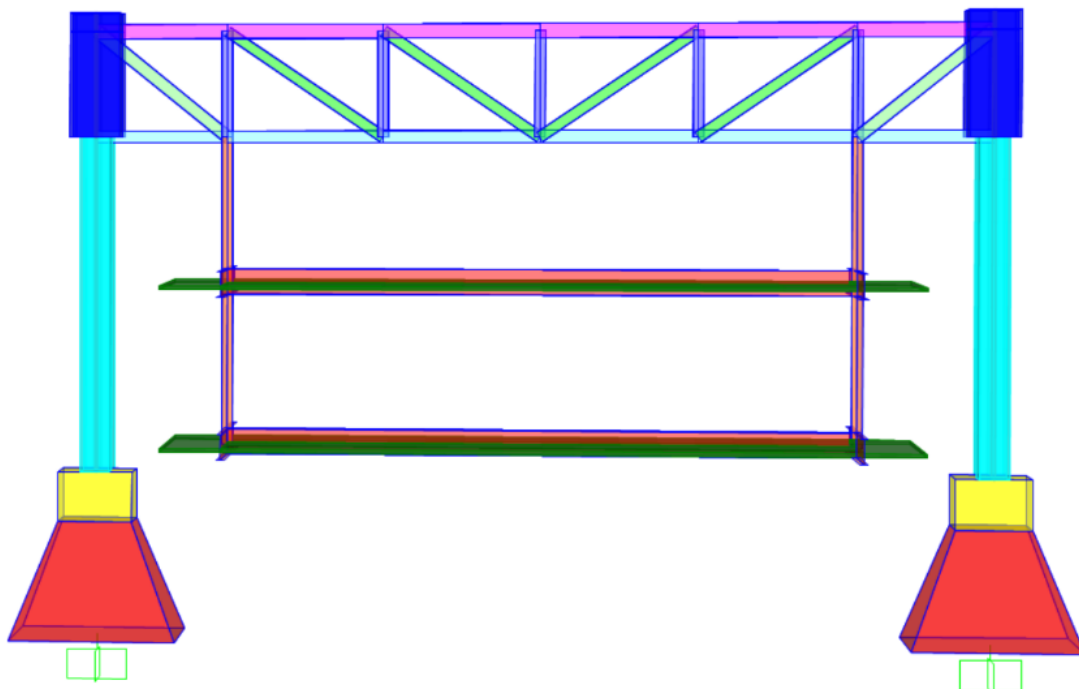
## STRUCTURAL ANALYSIS

### Porticos

Figure 6 shows in section the portico, with emphasis on the metal truss that supports the floors of the building by means of 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.



Source: Authors' Design, SAP 2000 Software.

### Concrete Walls

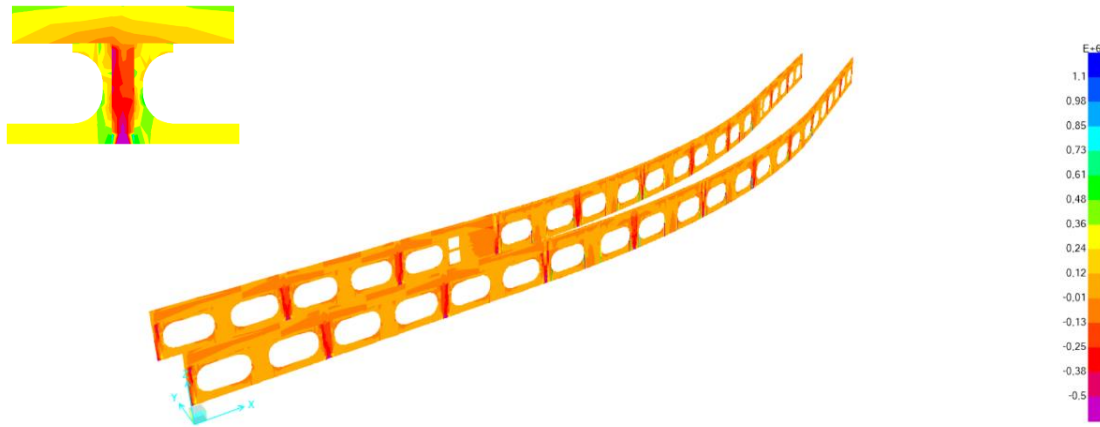
Seeking to emphasize the structural behavior of the walls of the facades and the columns of the porticoes, can be observed in Fig. 7 the concentration of compression efforts in these columns next to the supports.

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 beams and the columns are detailed to absorb the main efforts.

**Figure 7** – Diagram showing the vertical axial force at the concrete walls at CCBB building façades.



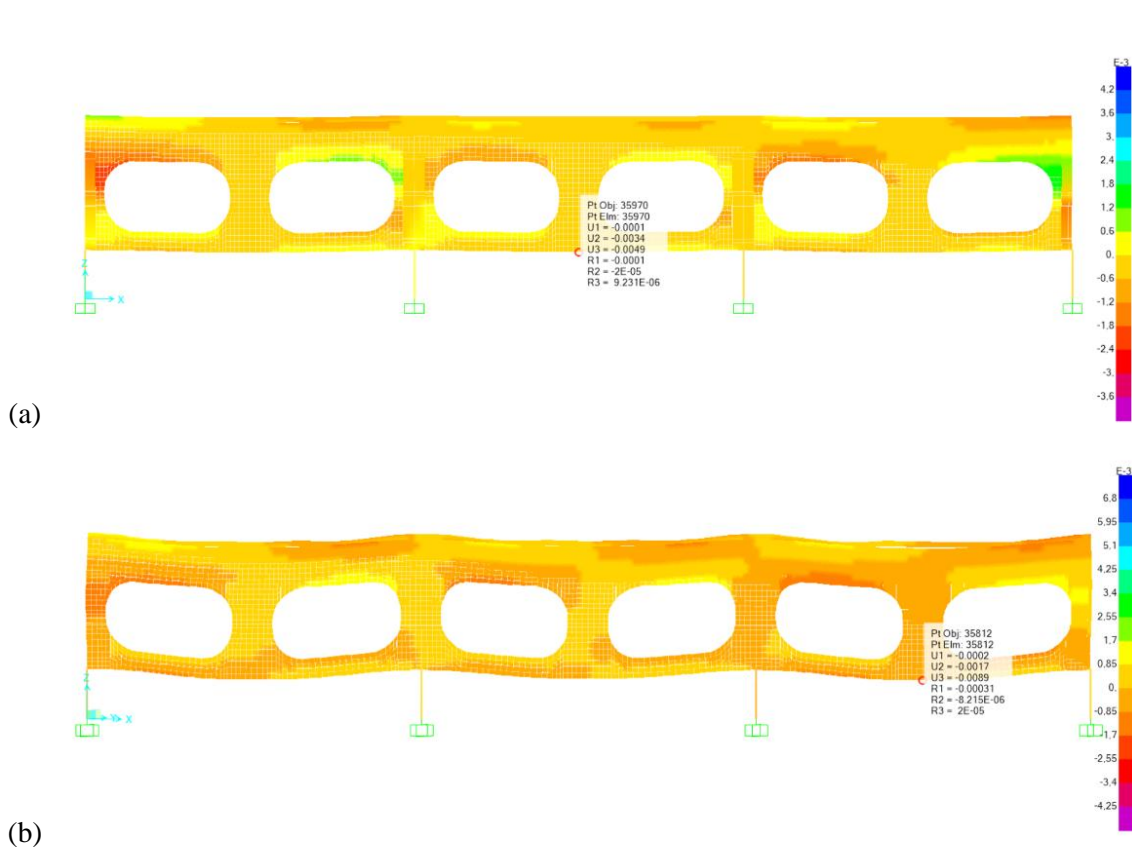
Source: Authors' Design, SAP 2000 Software.

### 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.

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.

**Figure 8** – Diagrams showing the comparison between the vertical displacement at the concrete walls at CCBB building façades as built (a) and as a vierendeel beam (b).



Source: Authors' Design, SAP 2000 Software.

## PATHOLOGICAL MANIFESTATIONS

In 2008, after a visit for a visual inspection of the building, several pathological manifestations were identified in the structure, especially in the columns of the ground floor. Some of these pathologies were visible and quite present in the columns of the main structure.

The columns mostly had characteristic cracks of the order of 1 mm in the center line of the section. This type of crack must be repaired to avoid possible contamination of the reinforcement and trigger a corrosive process that may compromise the strength function of this structural part. Other pathological manifestations, such as leaching in the concrete, corrosion, crushing of the concrete section, and corrosion in the connecting plate of the bracings were identified in almost the entire extension of the building.

This survey, carried out by the company Dual Engenharia, generated a Technical Report with a description of the findings and indications for repair and recovery of the structure of the building (DUAL, 2008). All pathologies found were treated and recovered according to these indications.

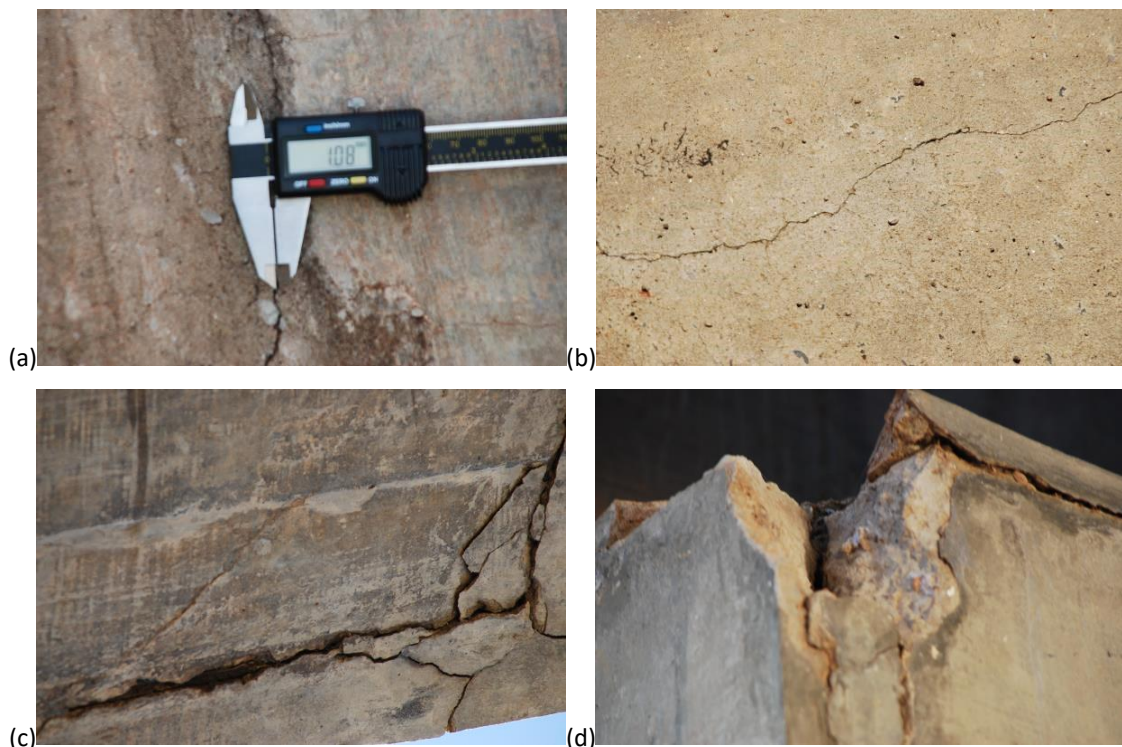
Subsequently, further visits were made to the building, after about 15 years of carrying out the repairs, in order to investigate the useful life, durability, and behavior of the recovered structural parts.

## Findings

The most recurrent pathological manifestations found in the analyzed building were fissures, exposed reinforcement, corrosion of reinforcement, detachment of concrete plate – in some points in an advanced state, carbonation of the concrete, in addition to interferences with the piping system for small drainage, runoff and stains on the surface of the concrete and the corrosion of structural elements of steel that makes up the structure.

Figure 9 shows two examples of cracks located in columns (a) and (b), which presented different advances and openings. We also see examples of concrete plate detachments that occur due to the absence of reinforcement or even low tensile strength of the concrete, causing it to begin to disaggregate and cause detachment in relation to the main structure. These manifestations were identified in several elements, such as (c) and (d).

**Figure 9** – Examples of cracks and detachments, identified in columns (a) P1B and (b) P4A, (c) P6A and (d) P6B.

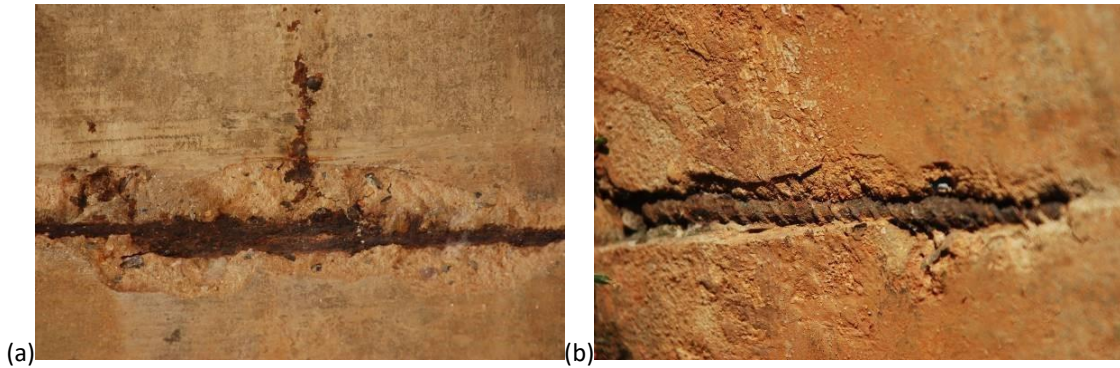


Source: Authors' Collection

Another recurrent pathological manifestation in the building was the corrosion of armor, which usually occurs due to inadequate coverage of the reinforcement for sections of exposed

concrete or concrete with high porosity or even from poor execution of the structural piece (INOJOSA, 2022). Figure 10 shows examples of this pathology.

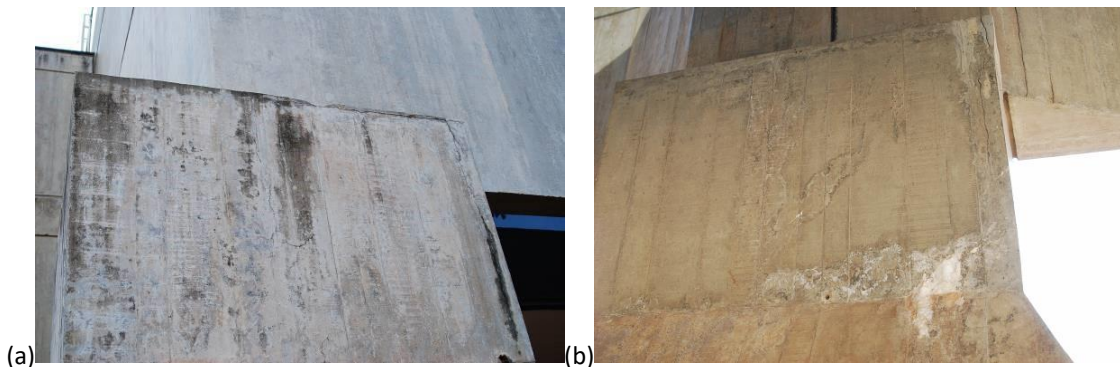
**Figure 10** – Examples of corrosion in the reinforcements – (a) pillar P1A and (b) external box 1. Author's photos



Source: Authors' Collection

Superficial damage to the concrete structure of the building was also recurrent, these manifestations may occur due to inadequate dosage, exaggerated dimensions of the large aggregate, improper casting and densification, or even excessive rate of armor. Figure 11 shows examples of these superficial pathological manifestations, such as patches (a) or carbonation of the concrete (b).

**Figure 11** – Superficial spots found in the building – (a) P1B and (b).



Source: Authors' Collection

Other pathological manifestations found to result from the inadequate relationship between construction systems, such as the presence of drainage pipes passing through the columns, causing runoff of aggressive material near their surfaces or the oxidation of the support plates of the bracing rods of the other floors of the building, as observed in several.

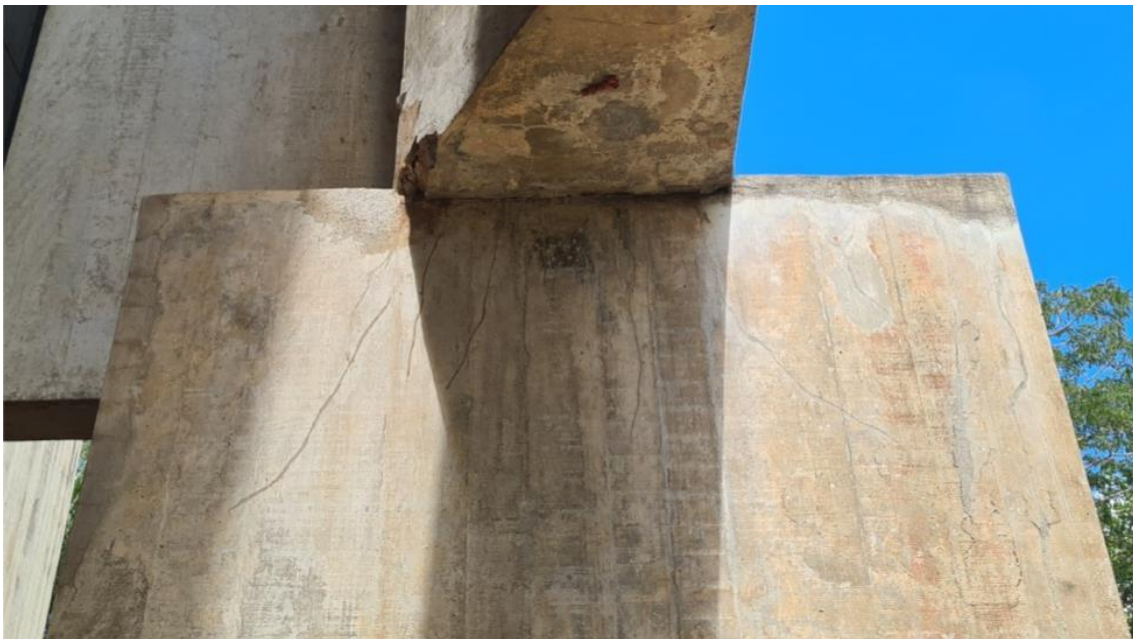
### Indicated Treatments and Actual State of the Building

The treatments recommended and executed for the main pathologies found in the studied building's structure are presented below, along with necessary measures to prevent the formation of new pathologies. The treatments are designed keeping in mind the causes that led to the identified problems, with the aim of minimizing the elements that cause pathologies and adopting preventive measures to increase the effectiveness of repairs (THOMAZ, 2006).

For treating cracks, it was recommended to apply epoxy-based grout. Cracks with openings smaller than 1.0mm require the application of grout every 5cm, while those with openings between 1.0 and 10.0mm need it every 30cm (HELENE, 2001).

The current state of repair to the P1A column is depicted in Figure 12, which was captured during an April 2023 visit.

**Figure 12** – Treatment of cracks performed in the P1A pillar, after 15 years of execution.  
Author's photo

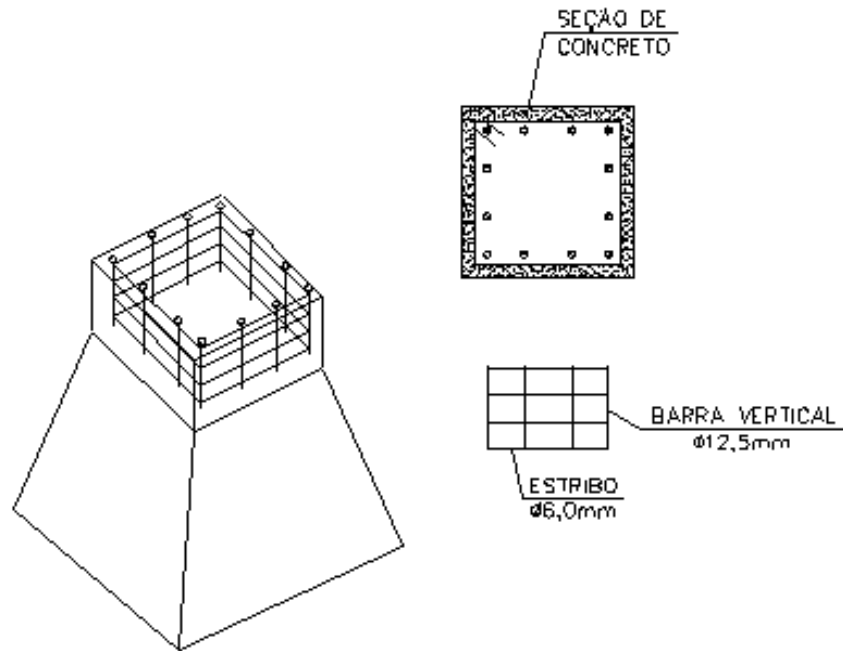


Source: Authors' Collection

In cases of concrete plate detachment, the recommended solution was to use 35MPa cement-based grout with extra reinforcement. Before applying the grout, the damaged concrete should be removed using appropriate equipment. A steel cage with vertical reinforcement was designed, forming a concrete jacket, using steel bars with dimensions that match the depth and length of the repair. The maximum coverage should be 4.0cm, and the minimum should be 2.5cm. Once the reinforcement is in place, the surface can be recomposed using concrete that matches the existing material in the structure. Figure 13 provides an illustration of the steel cage design.

Figure 14 displays the P4A column, which has been reinforced with a concrete jacket and remains in good condition 15 years later.

**Figure 13** – Pillar design with concrete recomposition due to plate detachment.



Source: Authors' design, AutoCAD software.

**Figure 14** – Recovery and reinforcement carried out in the P4A pillar, after 15 years of execution.



Source: Authors' Collection

To address reinforcement corrosion, it is advised to remove the concrete around the bars, leaving at least 2.5 cm clearance. The armor should be cleaned, and any corrosion products should be removed with sandblasting or iron sandpaper and steel brushes. Debris should be cleared with compressed air, and the surface should be carefully hydro jetted. Applying a zinc-rich primer on the armor is recommended, followed by 30 minutes of drying time. Next, apply the epoxy adhesive on the concrete surface to create a barrier against contaminated concrete and to form an adhesion bridge. Finally, apply the mortar densifying well, ensuring that the maximum thicknesses for each material are adhered to.

Despite the difference in color and texture still apparent between the original concrete and the material used in the repair, observed 15 years later, the solution adopted proved to be efficient and durable.

To ensure that the unique texture of Oscar Niemeyer's concrete works was preserved, it was recommended to start the restoration with a pilot test on a small area of the facade. This was to confirm the quality of the repair and prevent any visible markings on the surface. Once the pilot test was deemed equivalent to the existing concrete, the restoration was authorized for the rest of the structure.

## CONCLUSIONS

Oscar Niemeyer believed that architecture and structure were inseparable elements of construction, as evidenced by his works and creative process. His engineering team developed innovative structural solutions to support Niemeyer's imaginative designs (INOJOSA, 2011).

One of Niemeyer's most impressive works, the Tancredo Neves Building, was completed in 1992 and houses the CCBB Cultural Centre. It presented significant structural challenges that were tackled by engineer Bruno Contarini.

Using data from the Banco do Brasil engineering team, we analyzed the building's structure using computational tools such as SAP 2000 software. The software helped us identify the significance of the concrete walls on the façade, which not only added to the building's visual appeal but also functioned as beams supported by a sequence of portico systems.

Through this work, it has been demonstrated that structures may develop pathological manifestations over time, due to the materials used, environment, and other characteristics. However, regular inspections throughout the lifespan of the structure

allowed for the identification and treatment of any issues. All damages were repaired using technical interventions to ensure long-lasting durability. A recent technical visit, conducted fifteen years after the restoration, confirmed the success of the repairs and improved the overall protection of the structure.

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