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NUMERICAL MODELING FOR THE STRUCTURAL ANALYSIS OF THE UNBUILT PRAÇA MAIOR DESIGN BY OSCAR NIEMEYER FOR THE UNIVERSITY OF BRASÍLIA

MODELAGEM NUMÉRICA PARA ANÁLISE ESTRUTURAL DO PROJETO PRAÇA MAIOR NÃO CONSTRUÍDA DE OSCAR NIEMEYER PARA A UNIVERSIDADE DE BRASÍLIA

MODELADO NUMÉRICO PARA EL ANÁLISIS ESTRUCTURAL DE LA PRAÇA MAIOR NO CONSTRUIDA DISEÑO DE OSCAR NIEMEYER PARA LA UNIVERSIDAD DE BRASILIA

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ABSTRACT

Many established architectural works follow the structural component as a guiding parameter of the project. The architectural works of Oscar Niemeyer are renowned for their seamless integration of structure and design – "once the structure is finished, architecture is already present, simple and beautiful" (NIEMEYER, 2002)[1]. The structural elements are deliberately showcased, adding to the overall aesthetic of the building. Niemeyer was responsible for Brasilia's most significant public buildings, including the National Congress, the Metropolitan Cathedral, and the Planalto Palace. However, there are numerous unrealized projects, preserved in history through sketches and even detailed plans. One such project is 1962 Niemeyer's design for the Main Square of the University of Brasilia, which featured a distinguished architectural complex composed of four blocks - Auditorium, Museum, Library, and Rectory. In this article, we explore the relationship between structures and architectural engineering by modeling structural systems and conducting numerical analysis using the software SAP2000. The main objective of this investigation is to determine how the structural system played a key role in the architectural conception of Oscar Niemeyer for this iconic project. The study aims to offer an analysis of the relationship between form and function, with a focus on how the structural elements of the project influenced its overall design and aesthetic result.

Keywords: Structural Analysis. Modern Architecture. Oscar Niemeyer.

RESUMO

Muitas obras arquitetônicas consagradas seguem o componente estrutural como parâmetro norteador do projeto. As obras arquitetônicas de Oscar Niemeyer são reconhecidas pela integração perfeita entre estrutura e design – "uma vez concluída a estrutura, a arquitetura já está presente, simples e bela" (NIEMEYER, 2002)[1]. Os elementos estruturais são deliberadamente destacados, contribuindo para a estética geral do edifício. Niemeyer foi

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responsável pelos edifícios públicos mais significativos de Brasília, incluindo o Congresso Nacional, a Catedral Metropolitana e o Palácio do Planalto. No entanto, existem inúmeros projetos não realizados, preservados na história por meio de esboços e até mesmo plantas detalhadas. Um desses projetos é o projeto de Niemeyer de 1962 para a Praça Principal da Universidade de Brasília, que apresentava um complexo arquitetônico distinto composto por quatro blocos – Auditório, Museu, Biblioteca e Reitoria. Neste artigo, exploramos a relação entre estruturas e engenharia arquitetônica por meio da modelagem de sistemas estruturais e da realização de análises numéricas com o software SAP2000. O principal objetivo desta investigação é determinar como o sistema estrutural desempenhou um papel fundamental na concepção arquitetônica de Oscar Niemeyer para este projeto icônico. O estudo visa oferecer uma análise da relação entre forma e função, com foco em como os elementos estruturais do projeto influenciaram seu design geral e seu resultado estético.

Palavras-chave: Análise Estrutural. Arquitetura Moderna. Oscar Niemeyer.

RESUMEN
Muchas obras arquitectónicas consolidadas siguen el componente estructural como parámetro rector del proyecto. Las obras arquitectónicas de Oscar Niemeyer son reconocidas por su perfecta integración de estructura y diseño: «Una vez terminada la estructura, la arquitectura ya está presente, simple y hermosa» (NIEMEYER, 2002)[1]. Los elementos estructurales se destacan deliberadamente, contribuyendo a la estética general del edificio. Niemeyer fue responsable de los edificios públicos más importantes de Brasilia, como el Congreso Nacional, la Catedral Metropolitana y el Palacio de Planalto. Sin embargo, existen numerosos proyectos no realizados, preservados en la historia a través de bocetos e incluso planos detallados. Uno de estos proyectos es el diseño de Niemeyer de 1962 para la Plaza Principal de la Universidad de Brasilia, que incluía un distinguido complejo arquitectónico compuesto por cuatro bloques: Auditorio, Museo, Biblioteca y Rectoría. En este artículo, exploramos la relación entre las estructuras y la ingeniería arquitectónica mediante el modelado de sistemas estructurales y el análisis numérico con el software SAP2000. El objetivo principal de esta investigación es determinar cómo el sistema estructural jugó un papel clave en la concepción arquitectónica de Oscar Niemeyer para este emblemático proyecto. El estudio busca ofrecer un análisis de la relación entre forma y función, centrándose en cómo los elementos estructurales del proyecto influyeron en su diseño general y su resultado estético.

Palabras clave: Análisis Estructural. Arquitectura Moderna. Oscar Niemeyer.

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1 INTRODUCTION

The city of Brasilia, Brazil's capital since 1960, is a remarkable example of modern architecture and urban planning. At the center of Brasilia's grand design lies the University of Brasilia (UnB), whose master plan was envisioned by Lucio Costa in 1962. As part of Lucio Costa's vision for the University of Brasilia layout, Oscar Niemeyer's design for the main square, known as the Praça Maior, featured a distinguished architectural complex composed of four key structures - an Auditorium, a Museum, a Library, and the Rectory. [2]

This unrealized project, preserved through plans and sketches, offers a unique opportunity to explore the relationship between Niemeyer's architectural vision and the structural systems that would have supported it.

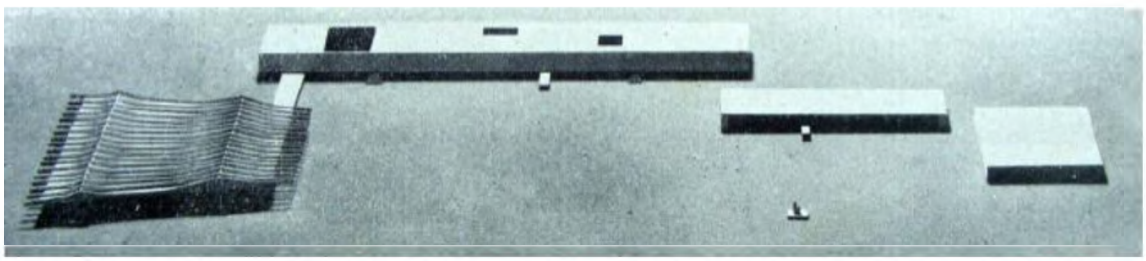
The close connection between structure and architecture is a defining characteristic of Niemeyer's work. His buildings often showcase the structural elements as a fundamental part of the aesthetic, rather than concealing them. This approach is exemplified in his iconic designs for the National Congress, the Metropolitan Cathedral, and the Planalto Palace in Brasilia.[3]

As Niemeyer himself stated, "Once the structure is finished, architecture is already present, simple and beautiful" [1] The unrealized projects of Niemeyer, where the architectural vision is preserved through plans and sketches, provide a compelling canvas to delve deeper into this ethos of integrating structure and form.[4]

This paper aims to perform numerical modeling and structural analysis of Niemeyer's Praça Maior design for the University of Brasilia (Fig. 1), in order to elucidate the interplay between structural systems and architectural aesthetics in the early stages of the architect's design process. The analysis will focus on the key components of the complex - the Auditorium, Museum, Library, and Rectory buildings - and how their structural systems were conceived to support and enhance the overall architectural expression.

Figure 1

Photo of the scale model for the Praça Maior



Source: Módulo Magazine, p. 7 [9].

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2 METHODOLOGY

This study utilizes the SAP2000 software to create a numerical model of the Praça Maior complex and conduct a structural analysis of the proposed design. The analysis will focus on the following key aspects:

Architecture Characterization: Detailed documentation of the architectural features and design intent of each of the main structures, based on the available plans and sketches.

Structural System: The identification and modeling of the primary structural elements.

Structural Analysis: Numerical simulation of the structural behavior to assess the viability of the proposed system.

Architectural-Structural Integration: An examination of how the structural system influenced and was integrated with the overall architectural design.

To support this analysis, the study will draw from relevant literature on Niemeyer's architectural philosophy and the integration of structure and form in his work, including sources that discuss the psychosocial aspects of his architecture [5] and the structural analysis of his iconic works as in[1][3][6]. The examination of the Praça Maior design, depicted in the article "A Praça Maior da UnB"[7] will be contextualized within the broader body of Niemeyer's projects, offering insights into the architect's evolving approach to merging structure and aesthetics.

By combining the architectural documentation with the numerical structural modeling and analysis, this paper aims to offer a comprehensive understanding of how Niemeyer's vision for the Praça Maior complex was expressed through the interplay of structure and form.

Praça Maior at UnB - Unbuilt Design

The Praça Maior (Main Square) of the University of Brasilia, designed by Oscar Niemeyer in 1962, was an unrealized project that would have been a significant addition to the university's architectural landscape. The design featured a unified complex composed of four distinct structures - an Auditorium, a Museum, a Library, and the Rectory.[7]

As an unbuilt project, the Praça Maior has different versions and iterations preserved through sketches, plans, and other documentary evidence.

Schlee and Ficher provide a detailed account of three different designs. The author describes 3 sets of drawings, referred to as the "UNB Series" - drawings published by the University of Brasilia in May of 1962; the Módulo Series - drawings and photos of models of the Main Square published in Módulo magazine, July of the same year; and the Original

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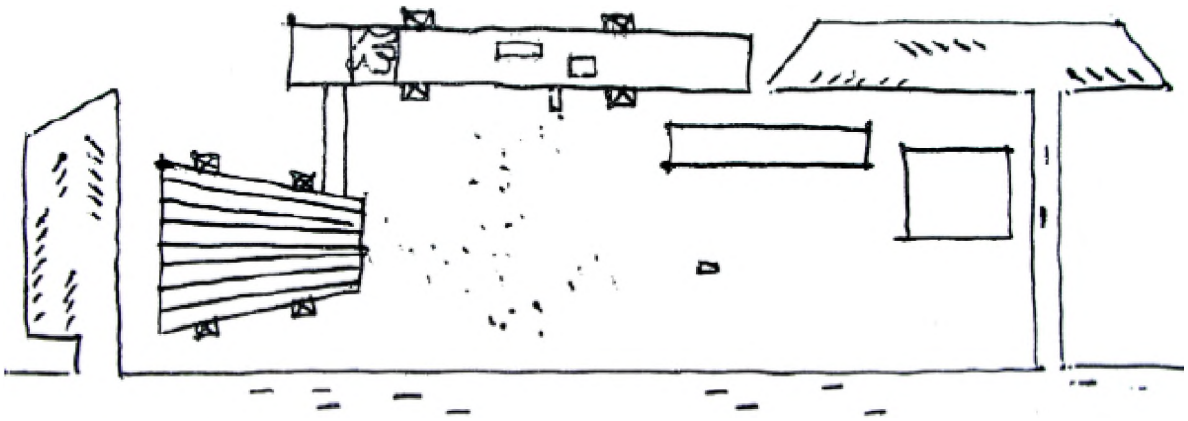
Series - original drawings of the Main Square project filed in the Documentation Centre of the University of Brasilia[7] and published in the Darcy magazine in November 2009[1].

These various sources reveal a consistent architectural language that Niemeyer sought to achieve through the Praça Maior complex. The four structures were envisioned as unified through their shared formal and material expression, with an emphasis on the interplay between solid volumes and open spaces. As seen in the sketches such as the one shown in Fig. 2, the complex for the Praça Maior can be described as a "distinguished architectural ensemble" that was envisaged to be the "central element of the university campus".[7]

Figure 2

Oscar Niemeyer´s sketches for the implantation of the Praça Maior



Source: Módulo Magazine, p. 8 [9].

The significance of the Praça Maior design is underscored by the fact that its drawings are displayed on the walls of the former home of the Centro de Planejamento Oscar Niemeyer, located in the Pavilhão de Serviços Gerais 10 at the University of Brasília. This preservation and display at this influential center, now a space dedicated to the history of UnB, highlights the importance of this unbuilt project within the broader context of the architect's body of work. [8]

The analysis in this paper will focus on the most detailed and comprehensive design, considering the structural systems. This version was published in June of 1962 by the magazine Modulo [9]. Modulo was a journal focused on architecture, design, and urbanism published by Niemeyer during the 1950s and 60s that played a key role in documenting and disseminating of Brazilian Modern Architecture.

The Praça Maior complex was envisioned as a harmonious integration of the four main

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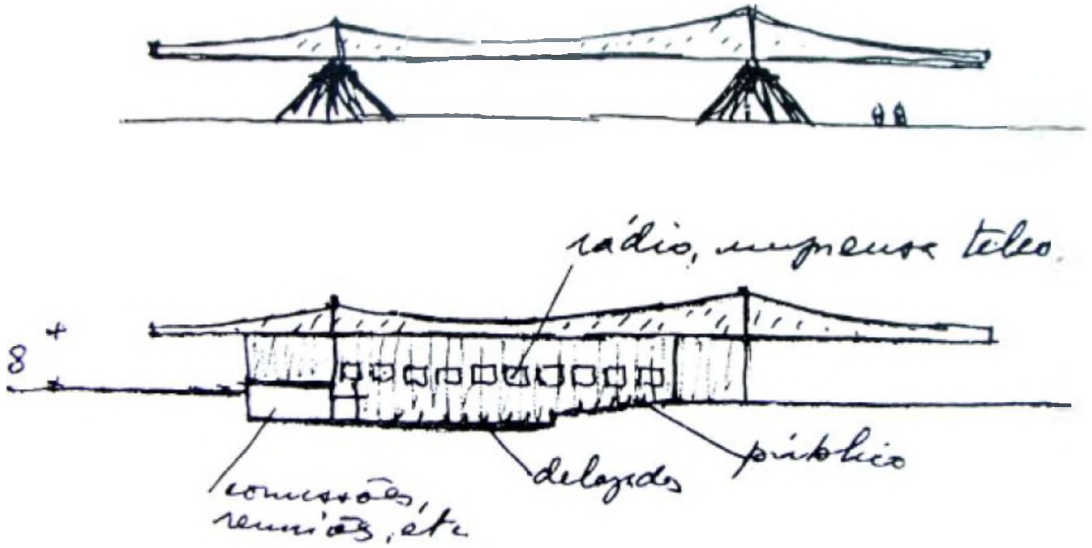
buildings, arranged around a central public plaza.

The Auditorium building was conceived as a striking sculptural form, featuring a dramatic curved roof with a structural exoskeleton raised 8 m from the ground level that would have provided a commanding presence within the square. The roof beams were 100 m long with 50 m spans and cantilever spans of 30 m and 50 m (Fig. 3). This design approach was similar to the roof of the Touring Club in Brasília, now the SESI LAB Museum, also designed by Oscar Niemeyer.

Figure 3

Oscar Niemeyer´s sketches for the sections of the Auditorium



Source: Módulo Magazine, p. 7 [9].

The Library and Rectory buildings were characterized by orthogonal forms, clean lines, and geometric volumes. The Rectory building, is a three-story structure measuring 10 by 25 meters, featured an concrete frame supported by four columns at its vertices and a glazed facade that would have visually connected the interior spaces with the exterior plaza. In contrast, the library building was a simple three-story structure with a 50 by 50 square footprint, without further detailed design elaboration. [9]

The Museum building, seen on the sketches of Fig. 4, presented a long, monolithic appearance, measuring approximately 140 m in length, 25 m in width, and 10 m in height. This imposing structure was supported on four pyramidal bases, forming 4 m tall pilotis, and crowned by a monumental roof that would have marked the entrance to the University.[7]

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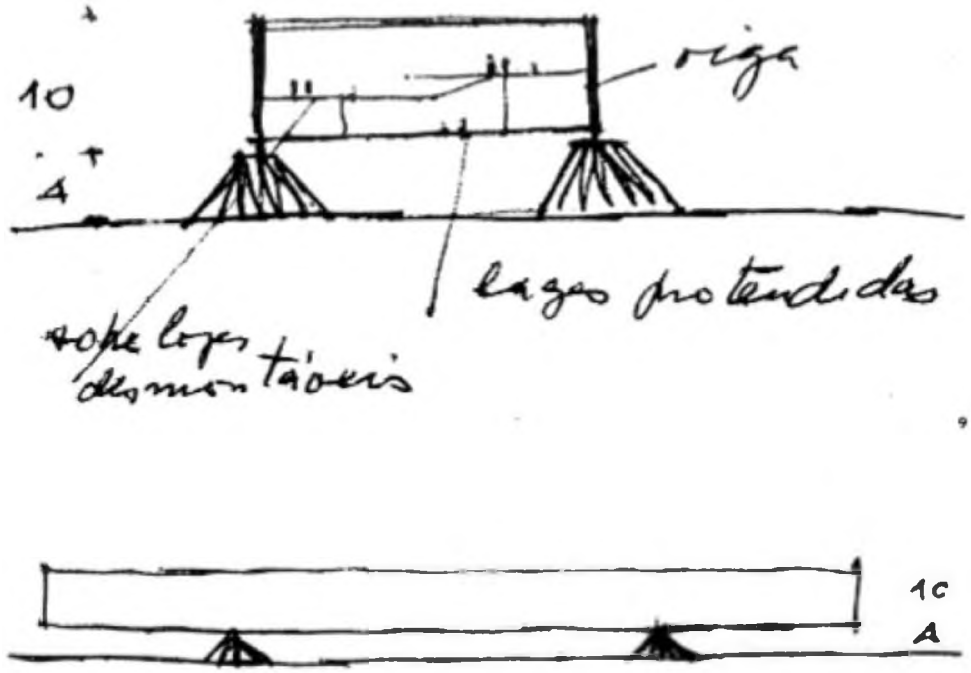
Figure 4

Oscar Niemeyer´s sketches for the Museum



Source: Módulo Magazine, p. 7 [9].

Oscar Niemeyer's 1962 design for the Praça Maior at the University of Brasilia was never realized. The military coup disrupted the university's plans as conceived by its founder, Dracy Ribeiro, and Niemeyer who served as the director of the Planning Center at UnB (CEPLAN). Following the coup, approximately 90% of the university's faculty, including Niemeyer, were dismissed. Without his leadership, many CEPLAN projects were suspended. The striking architectural ensemble of the Praça Maior, with its bold forms and innovative integration of structure and design, remained an unrealized dream for Niemeyer and the University of Brasilia.[10]

During the 1970s, only the Rectory and the Library would be built, but with distinct projects designed by architect Paulo Zimbres in 1972 and by architects José Gaubinsky and Miguel Pereira in 1968, respectively. The formal unity and integration envisioned by Niemeyer for the Praça Maior complex were not realized in these subsequent works. However, it is possible to note the influence of the original project on the formation of the Central Plaza - as it is currently called - and how Lúcio Costa's initial conception for UnB and Oscar Niemeyer's projects for the Praça Maior impacted the development of the space, even with the subsequent modifications, highlighting the plaza as the stage for historical events at important moments in UnB's history.[11]

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3 NUMERICAL MODELING AND STRUCTURAL ANALYSIS

The numerical modeling and structural analysis of Oscar Niemeyer's Praça Maior design for the University of Brasilia reveal a remarkable integration of architecture and structural engineering, reflecting the architect's defining philosophy of showcasing the structural elements as a fundamental part of the aesthetic expression in early stages of Niemeyer´s design process. This article provides an examination of the structural systems of key components of the Praça Maior complex - the Auditorium with its concrete roof structure and the Museum´s main solid volume, with its 140 m beam walls.

3.1 AUDITORIUM CONCRETE ROOF STRUCTURE

The auditorium building was designed with a dramatic, sculptural curved concrete roof.[5] The roof structure features a concrete exoskeleton supporting a suspended reinforced concrete slab, characteristic of Niemeyer's signature aesthetic approach.

The roof structure is designed as a series of 9 reinforced concrete ribs-like beams, 100 m long with 50 m spans and cantilever spans of 30 m and 50 m as shown before in Fig. 3. These beams are supported by pyramidal columns that elevate the structure 8 m from the floor and transversal beams. The dimensions of the structural elements used in the SAP 2000 model (Fig.5) are organized in Table 1 and were referenced in the proportions of the drawings and models proposed by Oscar Niemeyer in 1962.

Table 1

Structural element´s dimensions for the Auditorium

Element	Sections Dimensions	
Columns	Base: 13 x 13 m	Top: 2,5 x 2,5 m
Longitudinal Beams	Base: 0,7 m	Height: from 1,6 to 6 m
Transversal Beam 1	Base: 0,7	Height: 4 m
Transversal Beam 2	Base: 0,7	Height: 6 m

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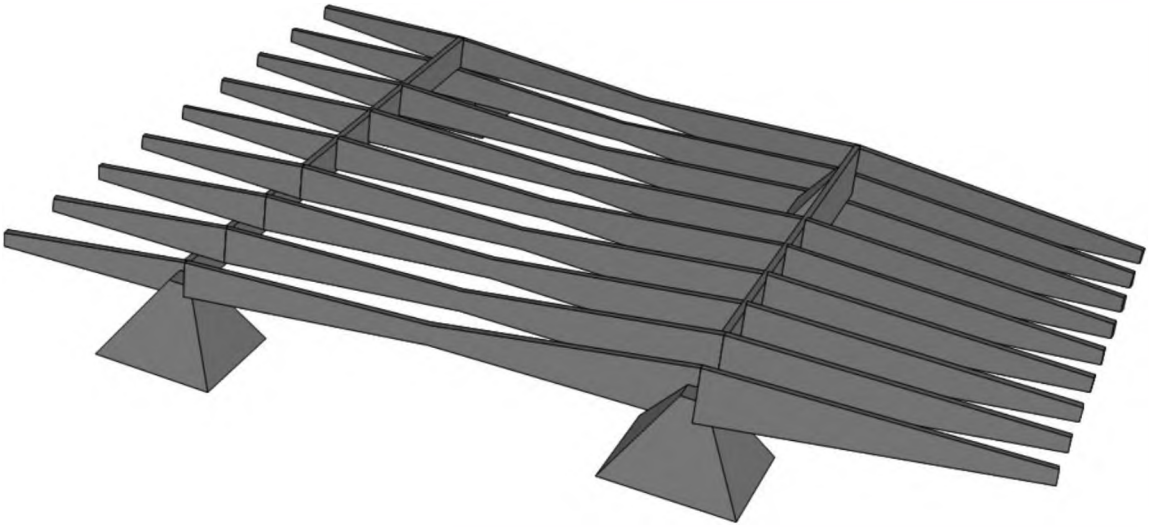
Figure 5

Model of the Auditorium

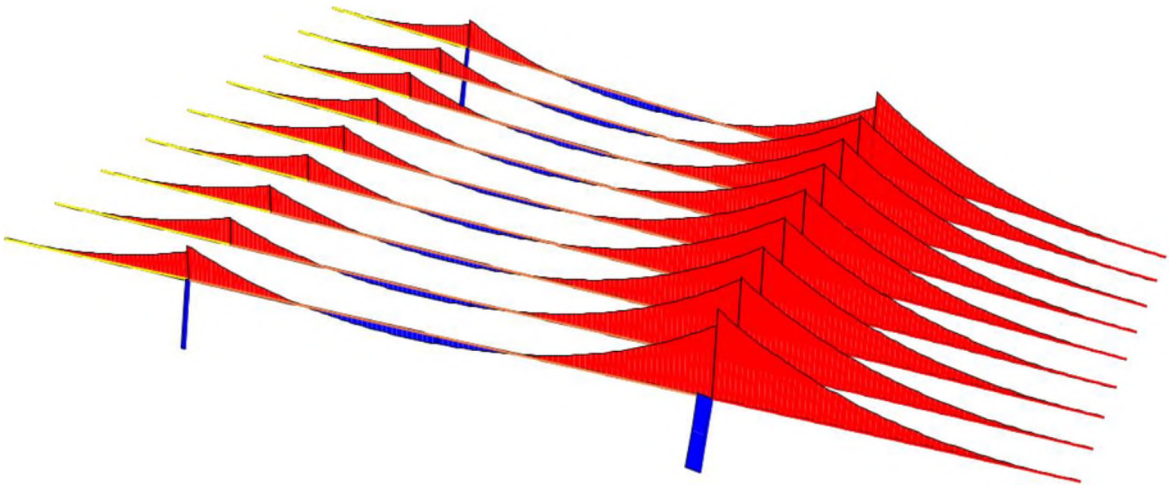


Source: Authors Design SAP 2000.

Figure 6 illustrates the vertical moment diagram, displaying how the beam's design anticipated the diagram's layout by employing larger sections in areas where the element would be subjected to greater stress.

Figure 6

Vertical moment diagram of the Auditorium



Source: Authors Design SAP 2000.

This engineering solution was instrumental in achieving Niemeyer's desired architectural expression, emphasizing the dynamic sculptural form of the auditorium.

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3.2 MUSEUM'S MAIN SOLID VOLUME

The Museum building is characterized by its long, monolithic volume measuring approximately 140 m in length, 25 m in width, and 10 m in height. This imposing structure is supported on four pyramidal concrete bases, forming 4 m tall pilotis. The structure dimensions specified in Table 2 were enabled by the proportions in the sketches and models published in Modulo magazine, aiding the modeling in the software SAP 2000 (Fig. 7).

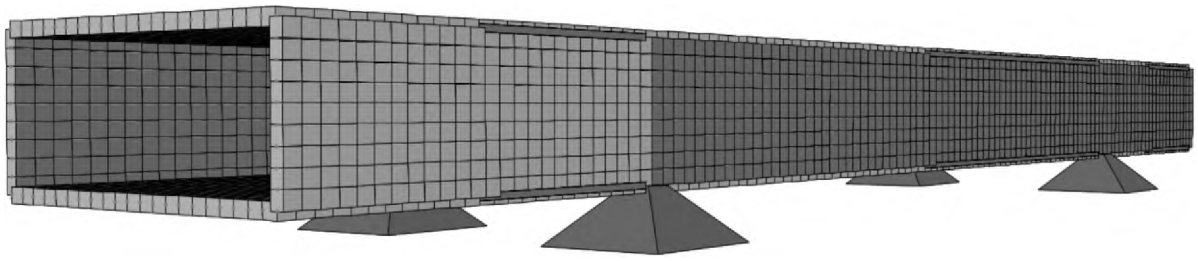
Table 2

Structural element´s dimensions for the Museum

Element	Sections Dimensions	
Columns	Base: 10 x 10 m	Top: 2 x 2 m
Longitudinal Beams	Base: 1 m	Height: 10 m
Slabs		Height: 1 m

Figure 7

Numerical Model of the Museum



Source: Authors Design SAP 2000.

The main structural system of the Museum is a reinforced concrete frame composed of columns and beam walls, which support the floor slabs and the roof above. The beam walls span the full length of the building, providing the necessary strength and rigidity to support the building's massive scale and vertical loads.

In Figure 8, the diagram illustrates the displacements of the structure, with the scale indicating values in centimeters. The displacements in the model are less than 4 cm in the most crucial positions, demonstrating that the architectural design has resulted in a functional structure, an intention described by Oscar Niemeyer in Modulo Magazine in 1962. – "In the Museum building such voids and overhangs are quite astounding – 80 and 30 m – and yet an examination of the plans shows how easy it was for the engineer to calculate them, transforming the longitudinal walls into beams 10m high." [9]

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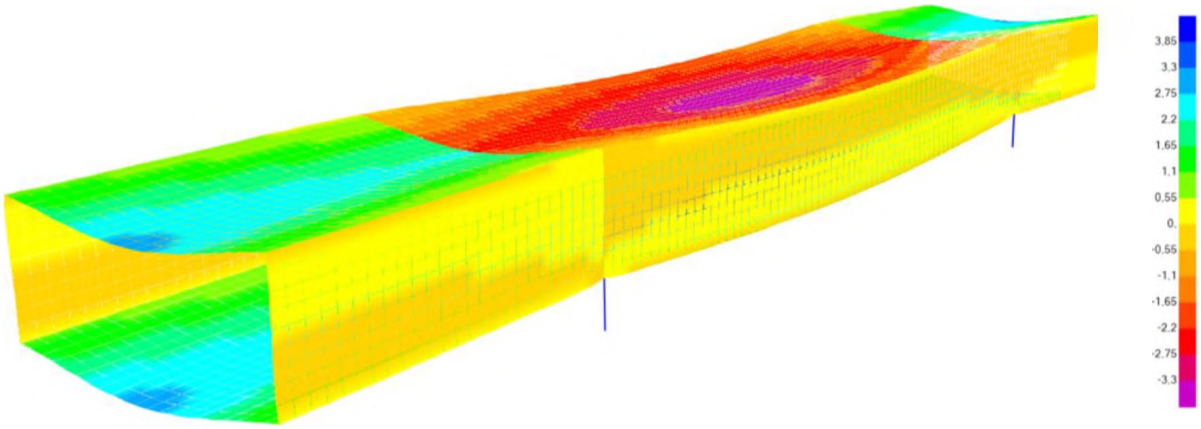
Figure 8

Displacement diagram of the Museum



Source: Authors Design SAP 2000.

The integration of architecture and structural engineering in Oscar Niemeyer's Praça Maior design for the University of Brasilia is evident in the innovative solutions developed for the Auditorium's curved roof, the Museum's monumental volume, and the Rectory's flat slab roof.

4 CONCLUSIONS

Oscar Niemeyer's 1962 design for the Praça Maior at the University of Brasilia exemplifies his pioneering approach to the integration of architectural aesthetics and structural engineering.

The structural systems of the Auditorium, Museum, and Rectory buildings were conceived as an integral part of the architectural composition, rather than as merely functional elements.

In the Auditorium, the curved concrete roof structure with its arched ribs and suspended slab, was a key driver of the sculptural form. The Museum's monolithic volume, supported on four pyramidal bases, demonstrated Niemeyer's mastery of reinforced concrete construction at a grand scale. The flat concrete slab roof of the Rectory building complemented the simple, geometric volume of the structure.

These architectural and structural solutions can be seen in other notable Niemeyer projects. The Touring Club in Brasília features a roof structure similar to the Praça Maior Auditorium, with its curved concrete form. The STJ – Superior Tribunal de Justiça building in Brasília employs concrete pyramidal columns akin to the Museum's design. In the palaces of

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Brasília, Niemeyer utilized a flat concrete slab roof, protecting a glazed façade, much like the Rectory building.

Niemeyer's innovative use of reinforced concrete enabled him to create dynamic, sculptural forms that pushed the boundaries of architecture and structure, showcasing his ability to seamlessly integrate structural considerations with his distinctive architectural language. His works stand as enduring examples of the potential for architecture to elevate the role of structural systems as a fundamental aspect of aesthetic expression.

Despite the Praça Maior complex remaining unbuilt, the numerical modeling and structural analysis of its key components provide valuable insight into Niemeyer's design process and his enduring legacy as a master of reinforced concrete architecture.

This article brings light to the creative and technical contribution of Oscar Niemeyer to the development of Brazilian modernist architecture through the lens of his unrealized Praça Maior design for the University of Brasilia, revealing the profound integration of form, structure, and aesthetics that characterized his works.

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