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Structural reinforcement for adaptation of architectural projects in buildings with pre-panels concrete moldings in Brasilia, Brazil.

Refuerzo estructural para adaptación de proyectos arquitectónicos en edificios con paneles prefabricados de hormigón en Brasilia, Brasil

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RESUMEN

El objetivo de este artículo fue analizar la estructura de un departamento ubicado en la Superquadra de Brasilia, en el Distrito Federal, donde paneles prefabricados de concreto conforman el sistema estructural. A través de la solución de rehabilitación utilizando láminas metálicas como refuerzo, se logró diseñar una nueva arquitectura, redefiniendo la distribución y ampliando los espacios disponibles. Se realizaron visitas técnicas y pruebas de esclerometría para evaluar minuciosamente el estado estructural previo a las intervenciones. Todas las etapas siguieron los estándares vigentes, garantizando la calidad y seguridad de las modificaciones. Los resultados del estudio concluyen que el refuerzo estructural es una solución eficaz que permitió crear la nueva arquitectura propuesta, aportando mayor seguridad y estabilidad, además de permitir la adaptación del apartamento a las necesidades de los residentes.

Palabras clave: refuerzo estructural, láminas metálicas, premoldeados, viabilidad arquitectónica.

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ABSTRACT

The purpose of this article was to analyze the structure of an apartment located in a traditional Brasilia's superblocks, Federal District, where precast concrete panels make up the structural system. Through the rehabilitation solution employing metal plates for reinforcement, it was possible to conceive a new architecture, redefining the layout and expanding the available spaces. Technical visits and sclerometry tests were conducted to thoroughly evaluate the structural condition prior to the interventions. All steps followed the current standards, ensuring the quality and safety of the modifications. The study results conclude that structural reinforcement is an effective solution that enabled the realization of the proposed new architecture, providing greater safety and stability, in addition to enabling the adaptation of the apartment to the needs of the residents.
Keywords: Structural Reinforcement; Sheet Metal; Precast; Architectural Feasibility.

INTRODUCTION

Brasília was conceived with an accelerated schedule, which required the application of a technique that was efficient in the construction of the city, the strategy being the use of precast concrete panels. This approach enabled the standardization and repetition of parts, generating significant results in both cost reduction and building delivery time. Precast concrete panels have thus become a practical, economical, and quick option to materialize the construction of the city (Brandão, 2018).

Choosing to use precast elements represents an excellent choice to improve the efficiency of a building's construction process. This approach contributes to more organized production, resulting in greater agility in execution, improved quality control and modular coordination (Madureira, 2017).

Figure 1 – South Superblock 407 South, South Wing, Brasilia-DF

Source: Valmor Pazos Filho, 2023.

According to Pantoja, a typical problem of topological optimization is the selection of the best possible configuration for the design of a structure. In the last decade, much attention has been dedicated to the development of methods for continuous topological optimization (Pantoja, 2023).

The Superblocks buildings were designed using this technique. The object of analysis of this article is the building M located at 407 South, which was also built following this construction method (Figure 1). According to Ferreira and Gorovitz (2009), the building consists of three floors on pilotis (columns), totaling 24 apartment units with “living room, 3 bedrooms, corridor, bathroom, kitchen, laundry area and service area”.

In this sense, when it comes to precast structures, it is essential to consider that the used parts, in addition to defining the layout, will have a structural function. Therefore, when installing a structural wall, it not only delimits the environments, but also plays the role of transmitting the building's loads. Redefining the layout of apartments that were built with structures of this type becomes an even more complex task (Madureira, 2017).

There are several reasons that require a reinforcement project to be carried out in concrete structures. The possibilities range from reconstituting its bearing capacity,

reduced due to wear and tear over time, to structural modification, such as cutting some of these elements to meet architectural needs (Moraes, 2009).

The article will address the method for enabling an architectural project in Brasilia-DF, presenting the structural reinforcement technique used to redistribute loads in a precast concrete panel structure, through the application of steel metal sheets (Figures 2 (a-b)).

Figures 2 (a-b) – Building M of 407 South: (a) View of the front facade; (b) View of the rear facade.

(a)

Source: Valmor Pazos Filho, 2023.

(b)

Source: Personal collection, 2023.

METHOD FOR DEFINING REFORM

First, a technical inspection was carried out at the location of interest with the purpose of collecting technical data and photographic records. This action aimed to carry out an analysis of the structure, as well as verify the state of conservation of building M of Superblock 407 South. Based on this information, it was possible to assess the feasibility of removing the structural walls of the apartment. The procedures were carried out considering the adequate collection of detailed data for the preparation of the technical report.

The main characteristics of the building and the structural and architectural designs were surveyed to evaluate the construction system of the typical floor. Based on

the projects provided by the owner, it was possible to verify that the construction system used for the standard floor is structural masonry in reinforced concrete panels. This type of structural system is characterized by uniformly distributing the loads on the building. This occurs because all panels are permanently interconnected, enabling the effective transfer of loads between them. In turn, the pilotis are made of a reinforced concrete structure, where load distribution occurs linearly.

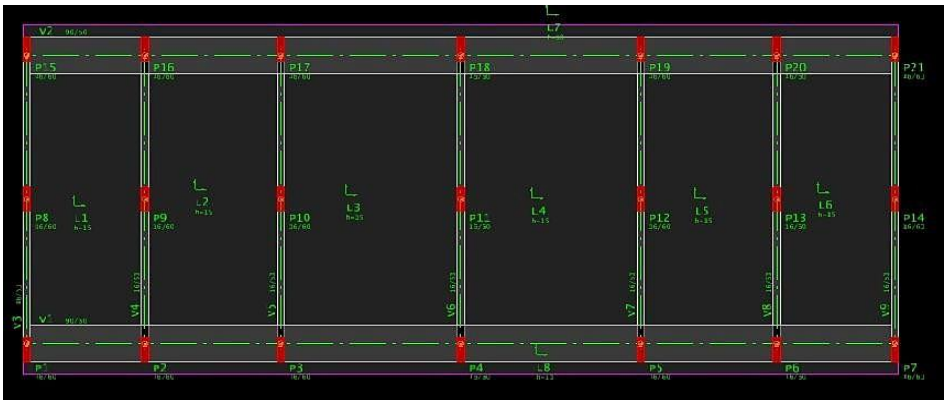
As the loads travel through the panels, they are redirected to the slabs and pilotis. Therefore, when performing a structural function, any modification to the standard pavement requires the structural elements of the pilotis to support this change, directly reflecting on the foundation. Therefore, it is essential that a structural reinforcement project is carried out before any high-impact renovation of the building to ensure the safety and stability of the structure during and after the intervention.

After all the documentary analysis, the information collected was essential to prepare the computer modeling of the building, considering the integrity of the structure and guaranteeing the modifications requested by the owner. The solution chosen and implemented in the structural reinforcement project for apartment 106 involves the removal of certain reinforced concrete panels and their replacement with steel sheets. This approach aims to ensure the economic viability of the work, preserve the durability of the structure, guarantee the safety of the building, and optimize its performance during use.

Previously, the construction system operated with distributed and linear loads; it now has a system of concentrated and linear loads. That is, the transfer of loads that were distributed across the structural walls, with the inclusion of metal profiles, now is applied at certain points on the slabs to be distributed to the building's pilotis.

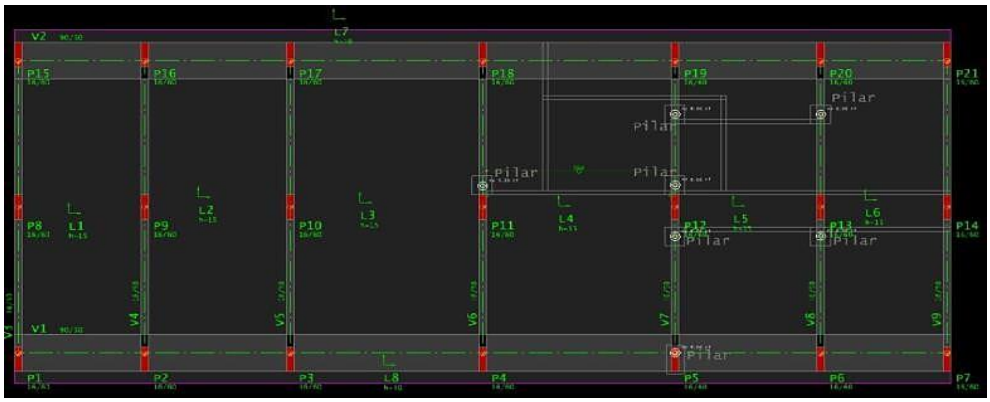
Two computational models were developed using the TQS V. 11.22.21 software. The first consists of the original configuration of the apartment, preserving the positioning of the structural masonry (Figure 3). The second simulation incorporates the new configuration with the reinforcement of steel sheets (Figure 4). The purpose of these modeling is to evaluate the Ultimate Limit States (ULS) and Service Limit States (SLS) of the pilotis, considering the new load distribution in the apartment.

Figure 3 – Original configuration with loads distributed on the pilotis slab.



Source: João da Costa Pantoja, 2023.

Figure 4 – New configuration with loads concentrated on the pilotis slab.

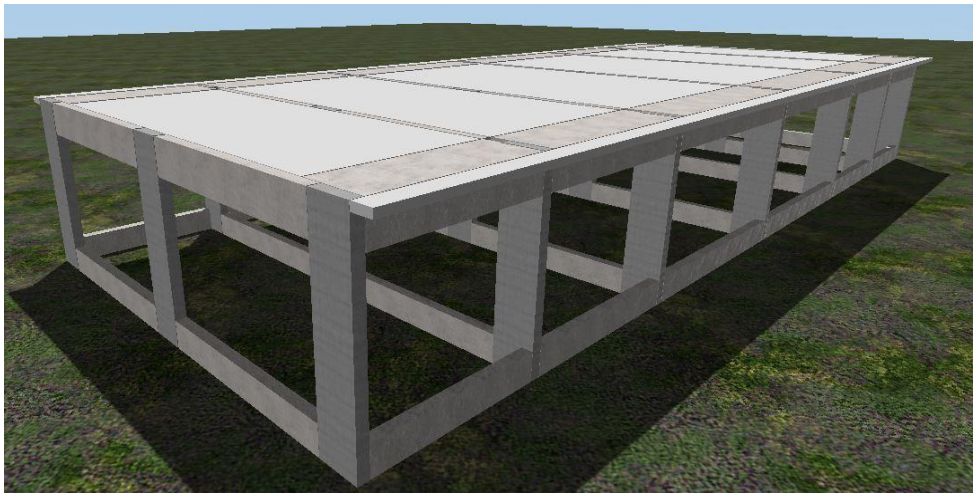


Source: João da Costa Pantoja, 2023.

ULS AND SLS are precise safety and performance guidelines required for concrete structure design. According to the Brazilian Standard ABNT NBR 6118/2014, projects must take these limit states into account to guarantee the efficiency, safety, and durability of the structure, supporting its maximum loads, without interfering with its performance over time.

After the structural survey carried out in the TQS program (Figure 5), together with the analysis report, it was possible to confirm that the new configuration of the structure complies with the ultimate limit and service states, as established by the standard. However, to guarantee safety and adequate structural performance, it is necessary that the concrete used in the pilotis pillars has a compressive strength (Fck) equal to or greater than 20 MPa (Mega Pascal measurement unit).

Figure 5 – Modeling in the TQS program of the block M pilotis.



Source: João da Costa Pantoja, 2023.

A sclerometry test was carried out to determine the strength of the concrete in the pilotis elements. The purpose of this test is to evaluate the quality of the concrete, without causing damage, by examining the homogeneity of the material in different regions of the structure's surface (Figures 6 (a-b)).

Figures 6 (a-b) – Sclerometry test carried out in January 2023

(a) (b)

Source: (a) João da Costa Pantoja, 2023; (b) Personal collection, 2023.

The procedures performed for the test followed the specifications of NBR 7584/2013. The method used is based on the “ricochet principle” which involves making

collisions on the surface of the concrete element, allowing its resistance to be assessed after the impact generated. The equipment used was the Schimidt Type N - Swiss sclerometer model, manufactured by the company SOLOTEST.

From measurements at two different points, the results obtained for the test were 42.1 MPa at point 1 and 53.7 MPa at point 2. After analyzing the structure using the sclerometry test, the lowest value of surface resistance found was considered (Tables 1 (a-b) and Table 2). It was found that the safety index is greater than 2 for the calculated load of 20 MPa. This means that the structure has a good safety margin and can withstand new loads that will be applied, making it suitable to receive these additional forces.

Tables 1 (a-b) – Average Sclerometric Indices

ENSAIO Nº 1			
Sentido de aplicação: 90°			
31	32	36	39
41	52	38	49
38	38	38	38
44	38	36	40
-10%	MÉDIA		+10%
34,4	38,2		42,0

(a)

ENSAIO Nº 2			
Sentido de aplicação: 0°			
49	49	47	49
47	46	52	42
52	46	44	46
49	51	52	44
-10%	MÉDIA		+10%
43,4	48,2		53,0

(b)

Table 2 – Measurement's Results of Concrete Surface Hardness in the tested locations.

Nº ENSAIO	INDICE ESCLEROMÉTRICO	RESISTÊNCIA SUPERFICIAL
1	38,2	42,1 MPa
2	48,2	53,7 MPa

Source: João da Costa Pantoja, 2023.

In this way, materials such as 3mm and 4.75mm ASTM A36 metal sheets were used, together with Sikadur 32 resin. This approach, in addition to reorganizing the loads on the structure, also enabled the successful execution of the renovation, meeting the requests of residents.

An interview was carried out using a question guide with the responsible manager, Civil Engineer Marcos Barros. The objective of the questionnaire applied was to collect information that described the sheet gluing process. The interview took place

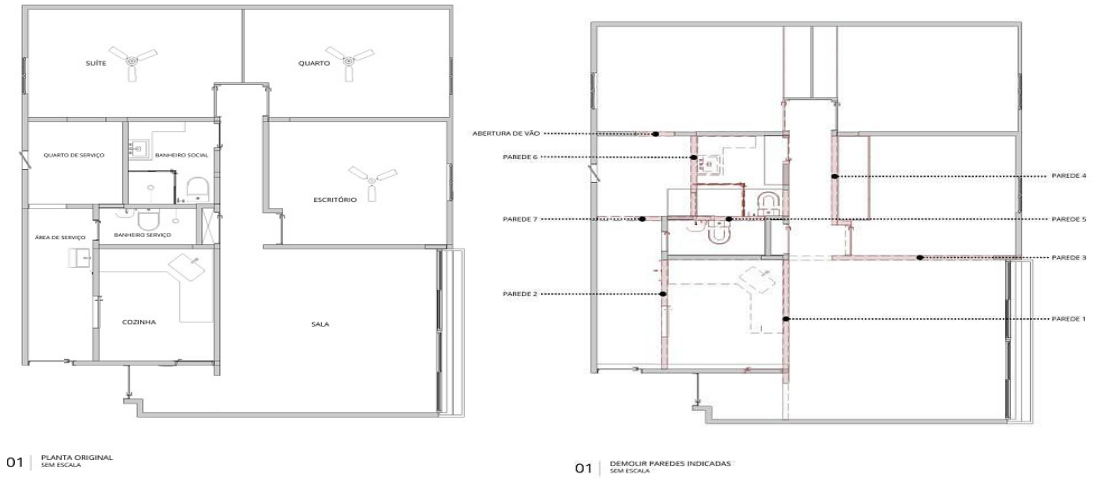
on 14/08/2023, followed by a technical visit to collect photographic records on 01/10/2023, both carried out at the construction site in Brasilia-DF. The interview with the manager brought relevance to the development of the research, as it contributed with precise information, adding quality to the study.

CASE STUDY

Brasília's superblocks are built with precast concrete structures, therefore, both the other blocks and block M of 407 South impose certain limitations on possible renovations, due to the structural functions performed by the building's internal walls. The purpose of the renovation was to make an architectural change to apartment 106, located on the first floor, enabling a wider layout configuration with integrated and comfortable environments, as requested by the owner.

In this sense, it was essential to demolish some structural walls to create openings that integrate the spaces of the new architecture and new divisions in the existing spaces. There were, in total, 7 walls: the walls arranged between the living room and the kitchen, between the kitchen and the service area; the walls between the living room and the office, between the office and the corridor leading to the bedrooms; the wall between the service bathroom and the guest bathroom; the wall between the guest bathroom and the service room; the wall between the service room and the service area and, finally, an opening between the suite and the service room (Figures 7 (a-b)).

Figures 7 (a-b) – Floor plan of Apartment 106: (a) Plan with the original configuration; (b) Plan indicating the walls to be demolished.



(a) (b)

Source: Eng. Marcos Barros, 2023.

The significant change in the apartment brought an architecture with wider spaces, which were previously interrupted by structural walls. The office and kitchen are now integrated with the living room; the service area, previously made of masonry, gained a sliding door; the service room and part of the guest bathroom were transformed into a bathroom for the suite, while the other part of the old guest bathroom, together with the old service bathroom, were resized to create the new bathroom that will provide support for the entire area. social and the second bedroom.

Thinking about a viable renovation, 3mm and 4.75mm thick metal sheets were used to structurally reinforce the precast concrete system, together with Sikadur 32 resin, applied throughout its entire length.

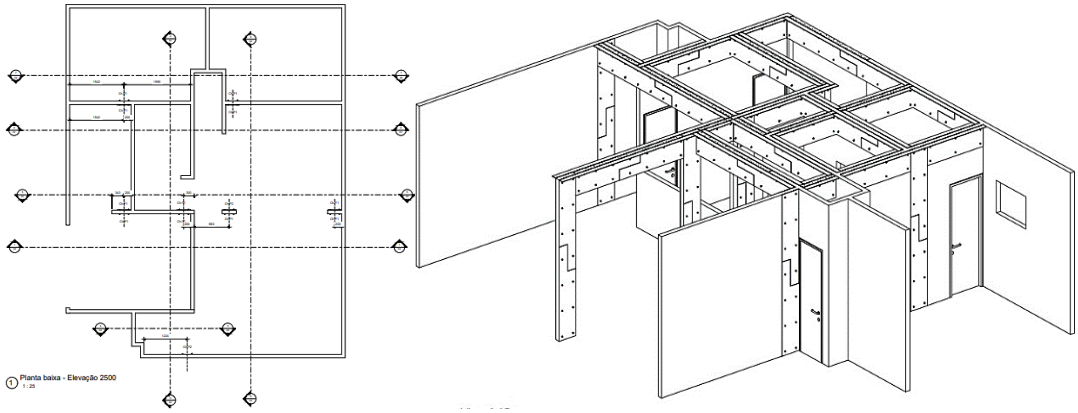
RESULTS AND DISCUSSIONS

REINFORCEMENT PROJECT

The project requires the use of ASTM A36 type metal sheets for reinforcement. These steel sheets are used because they have a combination of strength and ease of welding, making them suitable for various applications in structural components. All parts were manufactured according to project specifications. Before the assembly

process, all parts were checked to ensure that their dimensions were in accordance with the architectural design (Figures 8 (a-b)).

Figures 8 (a-b) – Structural Reinforcement Project: (a) Floor plan; (b) 3D view of the design sheet metal reinforcement.



Source: João da Costa Pantoja, 2023.

Epoxy resin Sikadur 32 was specified for adhesion. This adhesive is mainly formulated for fixing structural supports, being suitable for joining steel sheets to concrete. The implementation will be carried out on the structural walls so that the distributed loads become concentrated loads, generating efforts that will act inside the glued metal sheet pillars, so that the existing reinforced concrete structure (in this case, the pilotis) can support these efforts, safely and appropriately.

CONSTRUCTION PROCESS

The structure reinforcement process involves important steps to ensure the safety and efficiency of the intervention. First, it is necessary to prop up the structure to ensure its stability during the procedure. Next, the concrete slab is scarified, removing any previous coating, and creating an uneven surface. Next, holes are drilled in the correct measurements according to the sheet metal template. These holes are filled with chemical anchor ampoules, followed by the insertion of pins. Wait for the curing time is recommended by the manufacturer to ensure adequate adhesion.

After curing, epoxy resin is applied to the steel sheet, which is pressed against the prepared concrete face. The nuts are placed on the studs and tightened according to the manufacturer's torque specifications.

At this stage, two procedures are carried out: first, gluing the side plates and pillar plates; after that, it is required to wait for the curing time to reach the necessary resistance. Next, the walls are cut out, finishing with work on the lower face of the metal element by welding. Even with the sides glued and respecting the curing period, and with a significant increase in resistance, the struts continued to be positioned to further enhance the safety of process steps (Figures 9 (a-c)).

Figures 9 (a-c) – Work in the process of execution: (a) Plates applied and welded with struts still in position; (b) Plates applied to the suite bathroom; (c) Detail of the fixed plates.

Source: Personal collection, 2023.

For the final treatment, the sheets underwent a sanding process to remove resin excess. Then, they were waterproofed with polymer mortar. For painting, the pieces received two coats of zinc chromate, which protects the metal surface against bad weather, and the finishing was done with synthetic enamel paint. This set of steps guarantees the protection, durability, and aesthetics of the sheets, making them ready for use and with a longer useful life (Figures 10 (a-c)).

Figures 10 (a-c) – Plates in the final treatment process. (a-c) Plates finalization.

(a) (b) (c)

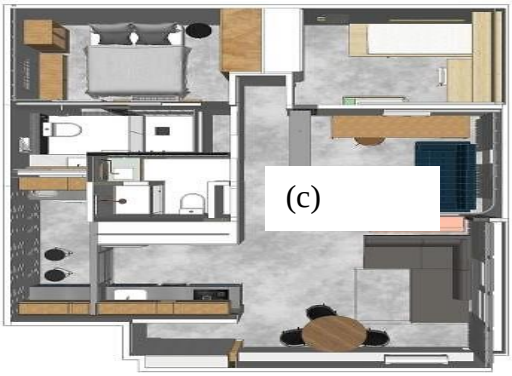
Source: Personal collection, 2023.

FINAL CONSIDERATIONS

The reinforcement project made the desired architecture design viable, allowing the planned changes and transformations to be carried out. With the implementation of structural reinforcement, it was possible to reach openings, expand spaces and create a new layout configuration for the apartment. This intervention made it possible to integrate environments and adapt spaces according to the needs and preferences of residents, bringing modernity, comfort, and functionality to the space. Furthermore, the reinforcement guaranteed the safety and durability of the structure, providing a reliable and quality environment for the apartment's occupants (Figures 11 (a-d)).

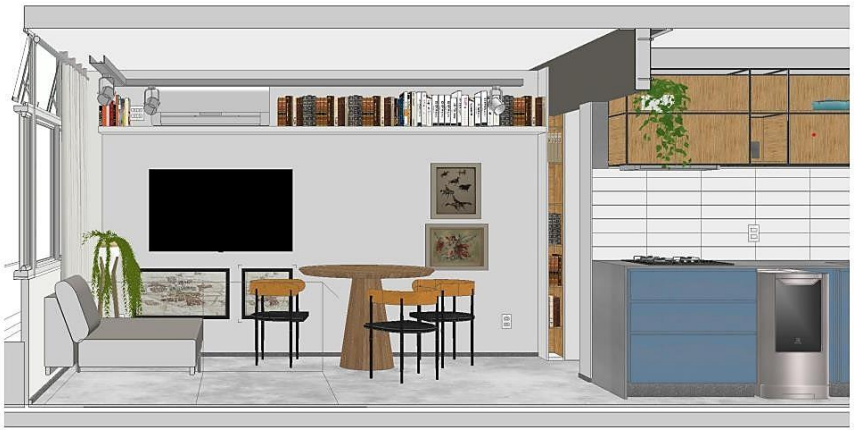
Figures 11 (a-d) – Architectural Project: (a) New layout of apartment 106; (b-d) Perspectives of renovated environments.

(a)



(b)

(c)



(d)

Source: Eng. Marcos Barros, 2023.

Before undertaking renovations in buildings that utilize precast concrete panels, the creation of a thoroughly developed structural reinforcement project is paramount. The inherent restrictions of structural masonry demand considerable consideration for modifications, and removing any walls without necessary reinforcement could jeopardize the building's structural integrity. This might lead to substantial damage and even safety hazards to the structure. Hence, it is crucial that reinforcement is meticulously planned and executed to prevent any adverse outcomes during and after the remodeling process.

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