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ORIGINAL

Design Alternative of a Portico System for the Municipal Palace of the Mayor's Office of Acacias Meta, in the central zone of the urban area

Alternativa de Diseño de un Sistema de Pórtico para el Palacio Municipal de la Alcaldía de Acacias Meta, en la zona central del casco urbano

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ABSTRACT

Acacias, a key municipality in Meta, suffered a serious impact on May 2, 2021, when a fire that occurred during a social protest destroyed the mayor's office, causing great material damage and affecting the functionality of the offices. Currently, the offices are dispersed, making it difficult for the community to carry out administrative procedures. Therefore, the objective of this degree work is to design a new building for the mayor's office that unifies all the offices in a single location. To do this, the methodology used is a quantitative approach, including all the calculations required for the structural design of the building. The work was carried out in 5 phases: Research and bibliographic review, preliminary design, analysis and technical evaluation, estimation of the cost of the structure (without finishes) and finally the final delivery. The final results obtained from this work include topographic survey activities, preparation of architectural plans, structural report and budget of the work. Likewise, quantity reports, general budget and structural designs were prepared. In conclusion, the unification of the offices in a single location will resolve the current difficulties for citizens, which will improve administrative efficiency and optimize the use of resources.

Keywords: Structure; Porticos; Municipal Palace; Acacias; Design; Budget.

RESUMEN

Acacias, municipio clave en el Meta, sufrió un grave impacto el 2 de mayo de 2021, cuando un incendio ocurrido durante una protesta social destruyó la sede de la alcaldía, causando grandes daños materiales y afectando la funcionalidad de las oficinas. En la actualidad, las oficinas están dispersas, lo que dificulta a la comunidad la realización de trámites administrativos. Por tanto, el objetivo de este trabajo de grado es diseñar una nueva edificación para la alcaldía que unifique todas las oficinas en una sola ubicación. Para ello, la metodología empleada es de enfoque cuantitativo incluyendo todos los cálculos requeridos para el diseño estructural de la edificación. El trabajo se ejecutó en 5 fases: Investigación y revisión bibliográfica, diseño preliminar, análisis y evaluación técnica, estimación del costo de la estructura (sin acabados) y finalmente la entrega final. Entre los resultados finales obtenidos de este trabajo se incluyen actividades de levantamiento topográfico, elaboración de planos arquitectónicos, memoria estructural y presupuesto de la obra. Así mismo, se realizaron memorias de cantidades, presupuesto general y diseños estructurales. Como conclusión la unificación de las oficinas en una sola sede resolverá las dificultades actuales para los ciudadanos, la cual mejorará la eficiencia administrativa y optimizará el uso de recursos.

Palabras clave: Estructura; Pórticos; Palacio Municipal; Acacias; Diseño; Presupuesto.

INTRODUCTION

Acacias is located 28 km south of Villavicencio and 126 km from Bogotá, the capital of Colombia. It has a total area of 1 169 km^2 and an altitude of 498 meters above sea level (m.a.s.l.) at the municipal capital. It is one of the most important municipalities in the department of Meta, not only because of its economy and population but also because of its cultural treasure.[1,2,3,4,5,6]

It is estimated that the first administrative offices of the municipality of Acacias began to emerge in 1920, the year that marked the beginning of the first period known as the "corregimiento" (district) from 1920 to 1947. At the end of this period, budgets and expenditures were adopted in nine subsequent periods of institutional development in the Municipal Mayor's Office. However, the exact date of the construction of the Municipal Palace of Acacias is unknown. Still, it is presumed to have been after 1947, during the periods of institutional development, given the need for the different departments to have a space from which to operate.[7,8,9]

In recent years, this municipality has been the site of shocking events, where the mayor's office infrastructure suffered severe damage as a result of a social protest that took place on May 2, 2021, which resulted in damage to several municipal buildings, including the municipal mayor's office, which was set on fire, causing extensive material damage that affected the architectural and structural integrity of the building.[10,11,12,13,14] As a result of these events, the municipal government relocated its offices and distributed them throughout the municipality. This caused discontent and inconvenience among the population when carrying out their procedures with the municipal government, as they were forced to travel from one location to another to receive the corresponding service.[14,15,16,17]

Figure 1. News report on the fire at the town hall

This thesis project has been undertaken to assist the municipality of Acacias and, above all, the community. It focuses on the design of a new building for the city of Acacias, Meta, which will allow the offices to be reunited in a single location.[18,19,20,21,22]

The current municipal building is a three-story structure built of cement and brick. The floors are covered with ceramic tiles, and each floor has masonry partitions, most of which are modular.[23,24,25]

The design was based on a rigid portico system due to its optimal performance under different loads and deformations, its economic viability due to reduced construction costs and times, ease of construction, efficiency in the use of space as it allows for large spans (distance between two supports), and adaptability to different uses.[26,27,28]

The rigid frame system is a distribution of vertical (columns or pillars) and horizontal (beams) structural elements connected in a rigid manner (forming frames or porticos) that can withstand bending and shear loads. This structural rigidity resists deformation and displacement, ensuring the stability and safety of the structure and its occupants.[29,30,31,32]

This structural design alternative was carried out by the requirements and parameters contained in the Colombian Seismic Construction Regulations (NSR-10), as it is vital for the safety and integrity of the Acacireña community.[33,34,35,36,37]

METHOD

Research approach [38] the methodology used in developing the design alternative for the municipality of Acacias is quantitative. It is linked to numerical analysis and mathematical methods and represents a set of sequentially organized processes (addressed in this project's specific objectives) to verify certain assumptions.

On the other hand, this work addresses a type of applied research that sought to address a practical and specific problem: the structural design of the Municipal Palace. This choice is justified by the need to develop

concrete and viable solutions to meet the social, functional, regulatory, and aesthetic demands of this building of public importance.[39,40,41]

In this sense, an exploratory-descriptive research design was used. The exploratory design will allow for an in-depth understanding of the municipal palace's structural design requirements and challenges, while the descriptive design will focus on describing and analyzing the specific characteristics of the proposed design.

Data Collection Techniques and Instruments

Research technique

Direct observation of previous practices used in the design of the portico system at the Acacías City Hall was carried out. This included a review of the methods used and an analysis of their efficiency with local building regulations.

Data collection instruments

Implemented questionnaires with closed questions designed to obtain the level of satisfaction of residents regarding the alternative design of the municipal palace. This questionnaire will be applied to a representative sample of the target population, those over 18 years of age residing in the downtown area. In addition, specialized software tools (AutoCAD, ETABS, ArcGIS, and REVIT, among others) will be used for the modeling and structural analysis of the municipal palace.

Phase 1: Research and bibliographic review

During phase 1, activities related to studying the Municipal Palace's location, economic, historical, and cultural aspects, regulation review, and legal aspects were carried out. Data was also collected on the new design's fundamental requirements based on the current needs of the officials and other personnel who occupy the facilities.

Phase 2: Preliminary diagnosis

In this phase, a preliminary design of the Municipal Palace was developed based on the data collected during the first phase. Functional aspects of the building were established, considering aesthetics concerning the urban environment and the optimization and use of available space. Different structural design concepts were explored, considering durability and seismic safety, among other aspects. This phase involved the creation of preliminary sketches and plans, which were based on BIM methodology with the help of Revit software.

Phase 3: Technical analysis and evaluation

In this phase, a detailed analysis of the technical aspects of the proposed structural design alternative was carried out. Structural analysis software tools were used to help evaluate the feasibility and stability of the design, considering static and dynamic loads, overload, and earthquake conditions. Computer simulations were performed with the help of ETABS to verify the structural strength and integrity of the Municipal Palace. It should be noted that the designs, calculations, and methods used were carried out according to the criteria of the Colombian Seismic Construction Regulations - NSR 10.

Phase 4: Estimation of the cost of the structure (shell) and completion of the architectural design

In this phase, an analysis was carried out to estimate the cost of the Municipal Palace, including the costs of materials for constructing the structure without finishes. At the same time, the architectural design was adjusted according to the structural design, considering the distribution of spaces and the optimization of the Municipal Palace's functionality. This development also ensured that the dimensions and spaces were adequate for the community and administrative services.

Phase 5: Review and final delivery

Finally, detailed plans, a description of materials, and construction budgets (based on current prices in the region) were prepared. In addition, a formal presentation of the final proposal was prepared, and the structural report and the cost of materials were delivered as annexes.

RESULTS

Using Geographic Information Systems software, identify the space available in the downtown area for the design of the municipal palace in the municipality of Acacias.

To meet the specific objective of identifying the space available in the downtown area for the design of the Municipal Palace in Acacías, a topographic survey was conducted of the land located at Cra. 14 #13-45 (Barrio Centro). This survey determined that the total area of the land is 409 m^2, but an expansion of 255,57 m^2 is proposed to achieve more spacious offices, leaving a total of 664,57 m^2.

The results obtained show that the available space is adequate for the proposed new Municipal Palace,

considering the functional and administrative needs set out in the design. The strategic location in the center of the urban area facilitates citizens' access, promoting greater inclusion and participation in administrative procedures.

The analysis of the available area also allowed for the evaluation of its configuration and geometric characteristics, which is essential for the development of an efficient architectural design that integrates all the administrative offices in one place.

Provide a visual representation of the distribution of offices and other spaces and justification using BIM methodology with REVIT.

To provide a visual representation of the layout of the offices and other spaces required for the proper functioning of the Municipal Palace, BIM Revit software was used to create three-dimensional (3D) models and detailed plans. This methodology allowed for the efficient integration of all necessary architectural and structural elements, ensuring that the design complies with functional and regulatory specifications. Similarly, REVIT allowed for the efficient management of project information, enabling the generation of floor plans, sectional drawings, and quantity tables.

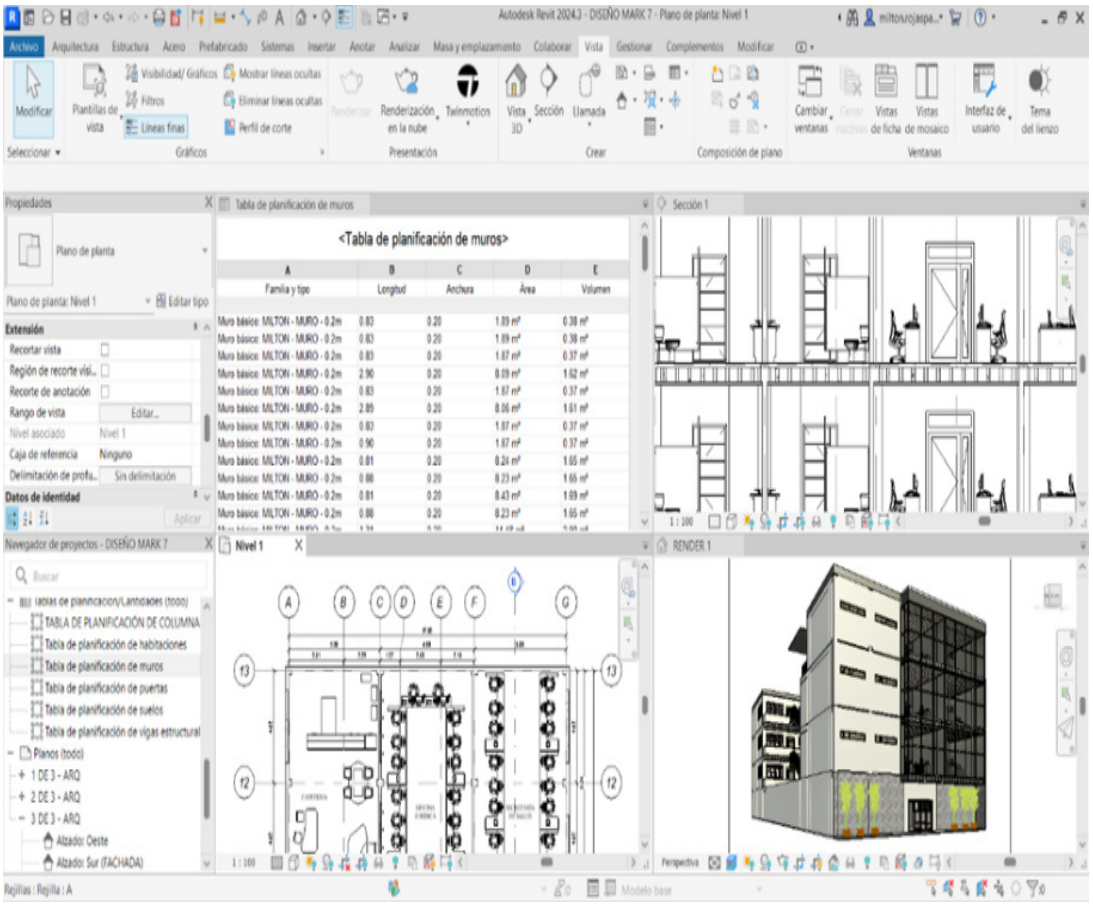

Figure 2. Information management with REVIT

Figure 3. Rendering of the Municipal Palace of Acacias

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Figure 4. Render 2 of the Municipal Palace of Acacias

Determine the stresses or effects that arise in the building and design of the frame system.

For the design of the structure, a methodological process was developed that included structural modeling in ETABS (figure 5) and verification of the designs using Excel spreadsheets.

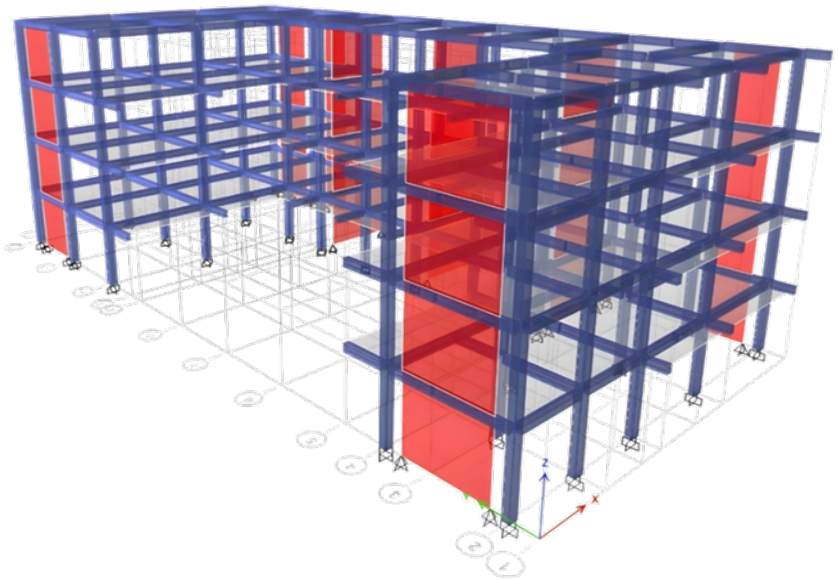

Figure 5. Structure of the municipal palace modeled in ETABS

General information

The designed building consists of four levels with a total height of 14,5 m. A rigid frame structural system was adopted, with lightweight unidirectional floor slabs and a concrete slab roof. Given the project's location in a high seismic hazard zone, an importance coefficient of 1,10, corresponding to a Use Group II, was considered, which conditioned the structural requirements and seismic design.

Preliminary Design of Structural Elements

The preliminary design of the structural elements was carried out initially according to the recommendations of NSR-10. Initially, the columns were pre-dimensioned with a section of 30x30 cm and the beams with dimensions of 25x35 cm. Subsequently, based on detailed structural analyses, the columns were adjusted to a section of 30x40 cm to improve drift control.

Load Assessment

The loads applied were established in accordance with current regulations:

Table 1. Loads applied to floor slabs and roof slabs

Losa	Load type		
	About impuesta	Viva	Empolyemption
For floor type	4,3 kN/m² for offices and corridors	2 kN/m² for offices and 5 kN/m² for corridors	No such penalties were applied.
For cover	2,3 kN/m²	2 kN/m²	0,5 kN/m².

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Creation of the Mathematical Model

The structural model was developed in ETABS (figure 6), including the assignment of materials (24 MPa concrete and 420 MPa steel), support conditions, and the established loads. Seismic analysis, determination of the base shear using the equivalent horizontal force method, and evaluation of structural irregularities in plan, elevation, and absence of redundancy were performed.

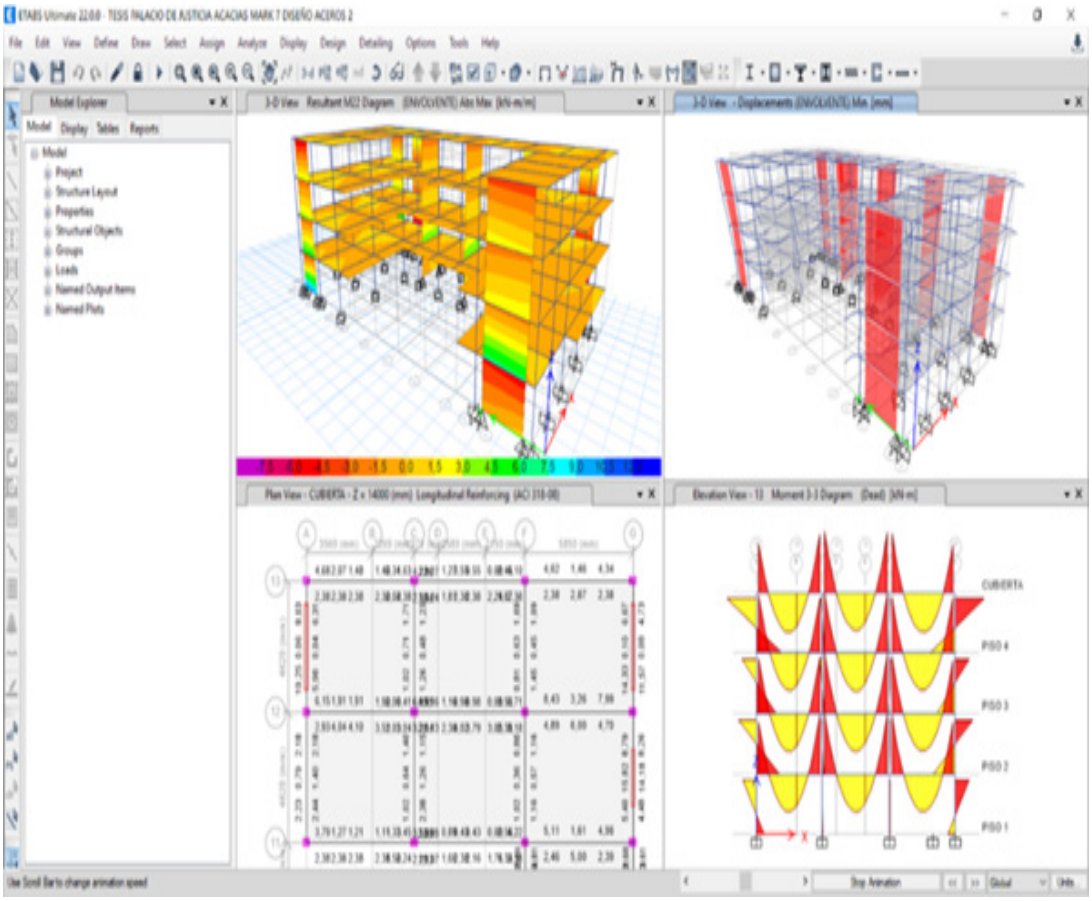

Figure 6. Structural analysis in ETABS

Drift Check

Drift analysis revealed that in its initial configuration, the structure did not comply with the limits established by NSR-10 (maximum permissible drift of 1 %). As a solution, the column section was increased from 30x30 cm to 30x40 cm in the most critical direction, achieving final drifts of 0,65 % in the X direction and 0,47 % in the Y direction.

Load Combinations for Analysis and Design

To ensure proper structural design, 17 load combinations were considered according to NSR-10 (B.2.4.2—Basic Combinations), evaluating both gravitational loads and seismic effects. This allowed for the proper dimensioning of the structural elements.

Structural Element Design

The various structural elements were designed considering the results obtained in ETABS and manual verifications in Excel.

Table 2. Most relevant observations for structural elements

Structural element	Most relevant observations
SLABS	Lightweight unidirectional slabs were adopted for floors and roofing, meeting the requirements for rigidity and strength. Similarly, the steel design was carried out according to temperature (electro-welded mesh), resulting in 4 mm of 12,5 x 12,5 cm.
COLUMNS	The reinforcement of six 5/8“ steel bars with 3/8” stirrups was determined, confirming their performance through interaction diagrams, evaluating the response to axial compression and bending moments.

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BEAMS	The steel was designed according to minimum quantities obtained from ETABS.
JOISTS	They were designed according to the requirements for strength and permissible deformation.
SHOES	They were designed according to type (central, partition, corner) and according to the most critical axial loads transmitted by the columns.

Final considerations

The structural analysis confirmed that the proposed design complies with safety, functionality, and current regulations. Adjusting the column section was a key decision to ensure drift control in its most critical direction, highlighting the importance of design iterations to achieve an efficient structural solution.

Estimate the cost of the shell structure without considering finishes, allowing for a possible evaluation of the project's economic viability and budget planning.

The cost and budget analysis for the shell construction of the Municipal Palace of Acacías, Meta, revealed a total direct cost of $ 1 438 438 206,13. The activities were classified into five broad categories: preliminary, foundation, reinforced concrete structure, masonry, and roofing, allowing for better organization and budget control.

Main investment items

The activities that represented the most significant investment in the project were:

a) Reinforcing steel: The cost of $ 526 794 622 represents 36,62 % of the total project cost. Its high impact on the budget is due to its volume in the foundation and reinforced concrete structure.

b) Demolition of the existing structure: $ 482 764 618 is equivalent to 33,56 % of the total project cost.

Economic Factors Considered

To ensure the budget's accuracy, the current legal minimum monthly wage (SMMLV) for 2025 was taken into account, which was set at $ 1 423 500, plus a transportation allowance of $ 200 000, for a total of $ 1 623 500. Likewise, percentage factors for severance pay, vacations, bonuses, allowances, and occupational hazards were considered and adjusted according to the job position and the minimum wages each worker receives.

Price updates and cost efficiency

Input prices were updated to 2025 values, ensuring the budget aligned with current economic conditions and increasing the project's viability. In addition, the concrete mix design allowed for the determination of exact dosages according to the required strengths and was considered a waste of 2,5 %.

CONCLUSIONS

Using Geographic Information Systems (GIS), the optimal area for the Municipal Palace's location was identified, which occupied an area of 664,57 m^2, taking into account the urban, regulatory, and geographical conditions of the surrounding area. This analysis ensured the viability of the location and its compatibility with the municipality's territorial planning.

An efficient distribution of administrative and operational spaces was established, ensuring proper organization and circulation within the building. The architectural proposal meets the criteria of functionality, accessibility, and comfort, guaranteeing optimal activity performance.

A detailed analysis of the load requirements provided a comprehensive understanding of the Municipal Palace's structural behavior. Through the evaluation of dead loads, live loads, and seismic actions, the critical demands on the portico system were identified.

Based on the data obtained in previous studies, a portico system was designed to withstand the applied loads and minimize deformations. All structural analyses and calculations were performed under the criteria established by the Colombian Seismic Construction Regulations (NSR-10), which ensures that the proposed design complies with minimum safety standards.

The Building Information Modeling (BIM) methodology was applied using Revit software, which allowed the generation of three-dimensional models, detailed plans, and graphs of the project, optimizing information management in all stages.

The cost estimate of the structure in rough construction provided a fundamental basis for guiding budget planning. This was done by analyzing the materials, quantities of work, and costs associated with the construction of the portico system. The cost analysis showed that the project has a total direct cost of $1,438,438,206.13, with the main investment items focused on reinforcing steel and demolishing the existing structure.

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