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ORIGINAL

Alternative design for a portico system for the Municipal Palace of the Mayor's Office of Acacias Meta, in the central area of the town centre

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, located 28 km south of the city of Villavicencio and 126 km from Bogotá, capital of Colombia. It has a total area of 1.169 km², an elevation of the municipal seat of 498 meters above sea level (m.s.n.m.), and is among the most important municipalities of the department of Meta, not only for its economy and population, but also for the cultural treasure that resides there. [22]

It is estimated that the first administrative dependencies of the municipality of Acacias began to emerge in 1920, the year that marked the start of the first period denominated "corregimiento" from 1920 to 1947; after this period ended, budgets and expenditures were adopted in 9 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 not precisely known, but it is presumed to have been after 1947, during the institutional development periods, given the need of the different dependencies to have a space from which to operate. [23]

In recent years, this municipality was the scene of shocking events, where the municipal government's infrastructure suffered serious damage, due to a social protest that occurred on 2 May 2021, which resulted in damage to several municipal buildings, including the municipal government building, which caught fire, leaving extensive material damage and affecting the architectural and structural integrity of the building. As a consequence of these events, the municipal government relocated its offices and distributed them across various points in the municipality. This generated certain discontent and discomfort among the population when carrying out their respective procedures with the municipality, forcing them to move from a location to another to receive the corresponding service. [24].

Figure 1. News of the fire at the town hall

Source: Noticias Caracol, https://acortar.link/HZNNezhttps://acortar.link/HZNNez

The present degree project was carried out to assist the mayor's office of Acacias and, primarily, the community, focusing on the design of a new building for the mayor's office of Acacias, Meta, allowing the offices to be reunified in a single location.

The current municipal palace is a 3-story building constructed of concrete and brick. The floors have ceramic coverings, and each floor contains masonry partitions, most of which are modular. [25]

The design was carried out using a rigid frame system, which was selected for its optimal behavior under various loads and deformations, economic viability (reduced construction costs and time), ease of construction, and efficiency in the use of space, as it allows large spans (distance between two supports) and adaptability to different uses. [26]

The rigid frame system is an arrangement of vertical structural elements (columns or pillars) and horizontal elements (beams) rigidly connected (forming frames or rigid frames), which is capable of supporting loads through bending and shear. This structural rigidity resists deformations and displacements, ensuring the stability and safety of the structure and its occupants. [L1]

This structural design alternative was implemented in accordance with the requirements and parameters set forth in the Colombian Regulation for Earthquake-Resistant Construction (NSR-10), as it is vital for the safety and integrity of the Acacireña community.

General Objective

To propose an alternative structural design for the Municipal Palace of the municipality of Acacias, Meta, in the central zone of the urban area, unifying the offices in a single location and facilitating geographic access for the population.

METHODS

Approach, Type, and Research Design

The methodology used in the development of the design alternative for the municipality of Acacias employs a quantitative approach, as indicated in [38], since it is linked to numerical analyses and mathematical methods, representing a set of processes organized sequentially (addressed in the specific objectives of this project) to verify certain assumptions.

On the other hand, this work constitutes applied research, since it seeks to confront 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 satisfy the social, functional, regulatory, and aesthetic demands of this building of public importance.

Accordingly, an exploratory-descriptive research design was employed. The exploratory design allows an in-depth understanding of the requirements and challenges of the structural design of the municipal palace, while the descriptive design focuses on describing and analyzing the specific characteristics of the proposed design.

Data Collection Techniques and Instruments

Research Technique

Direct observation of the previous practices used for the design of the frame system in the Alcaldía de Acacías was carried out. This included reviewing the methods employed and analyzing their efficiency in relation to local construction regulations.

Data Collection Instruments

Questionnaires with closed-ended questions will be implemented to assess the satisfaction level of residents regarding the design alternative for the municipal palace. These questionnaires will be administered to a representative sample of the target population, comprising individuals over 18 years of age residing in the central zone (zone 1) of the urban core. Additionally, specialized software tools (AutoCAD, ETABS, ArcGIS, REVIT, among others) will be used for the modeling and structural analysis of the municipal palace.

Development phases

Phase 1: Research and Literature Review

In Phase 1, activities related to the study of the location of the Municipal Palace, its economic, historical, and cultural aspects, and the review of regulations and legal aspects were carried out. Data collection on the fundamental requirements of the new design, based on the current needs of the officials and other personnel who occupy the facilities, was also taken into account.

Phase 2: Preliminary diagnosis

In this phase, a preliminary design of the Municipal Palace was developed based on data collected during the first phase. Functional aspects of the building were established, considering aesthetics in relation to the urban environment, as well as the optimization and use of available space. Different structural design concepts were explored, taking into account durability and seismic safety, among other aspects. This phase involved the creation of sketches and preliminary plans, which were grounded in the BIM methodology using 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 conducted. Structural analysis software tools were used to evaluate the feasibility and stability of the design, considering static and dynamic loads, as well as overload conditions and earthquakes. Computational simulations were performed using ETABS to verify the strength and structural integrity of the Municipal Palace. The designs, calculations, and methods were carried out in accordance with the Colombian Regulation for Earthquake-Resistant Construction - NSR 10.

Phase 4: Cost estimation of the structure (shell) and completion of the architectural design

In this phase, an analysis was conducted to estimate the cost of the Municipal Palace, which included material costs for the construction of the structure without finishes. Additionally, the architectural design was adjusted according to the structural design carried out, taking into account the distribution of spaces and the optimization of the building's functionality. This also ensured that the dimensions and spaces were adequate for community and administrative services.

Phase 5: Review and final delivery

Finally, detailed plans, material descriptions, and construction budgets were prepared in accordance with the updated regional prices. In addition, a formal presentation of the final proposal was prepared; the deliverables, or annexes, included the structural report and the material costs.

RESULTS

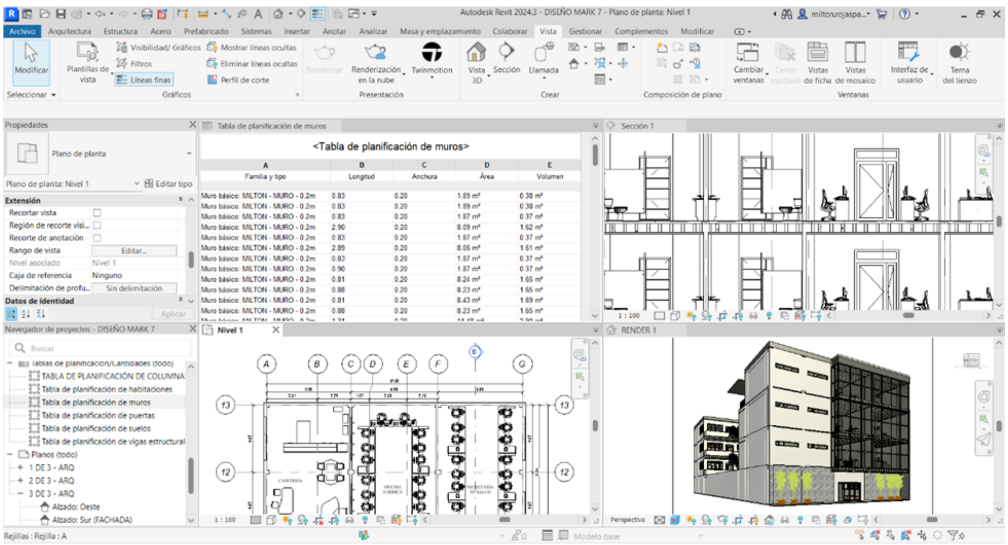
Identification of the available space in the central area for the design of the municipal palace in the municipality of Acacías using Geographic Information Systems software.

To fulfill the specific objective of identifying the available space in the central area for the design of the Municipal Palace in the municipality of Acacías, a topographic survey of the land located at Cra. 14 #13-45 (Barrio Centro) was carried out. The survey determined that the total area of the land is 409 m²; an expansion of 255.57 m² is proposed to accommodate larger offices, resulting in a total of 664.57 m² (See Annex 1).

The results show that the available space is adequate for the proposal of a new Municipal Palace, considering the functional and administrative needs identified in the design. The strategic location in the center of the urban core facilitates citizen access, promoting greater inclusion and participation in administrative procedures.

The analysis of the available area also enabled the evaluation of its configuration and geometric characteristics, which is essential for developing an efficient architectural design that integrates all administrative offices in a single location.

Figure 1. Information management with REVIT.



Source: The authors' own elaboration.

Provide a visual representation of the distribution of offices and other spaces, as well as grounding in the BIM methodology using REVIT.

In order to provide a visual representation of the distribution of the offices and other spaces required for the proper functioning of the Municipal Palace, BIM Revit software was used to prepare three-dimensional (3D) models and detailed plans. This methodology allowed the efficient integration of all the necessary architectural and structural elements, ensuring that the design complies with the functional and regulatory specifications. Similarly, REVIT made it possible to efficiently manage the project information, allowing the generation of floor plans, cut-offs and quantity tables.

In addition to this, it is important to highlight the project's participation for more than 2 years in various research seedbed meetings at both the regional and national levels.

Figure 2. Rendering of the Municipal Palace of Acacias.

NOTE: For interdisciplinary reasons, this project was supervised and approved by the architecture school of the Corporación Universitaria del Meta – UNIMETA, which provided tutoring throughout the entire process.

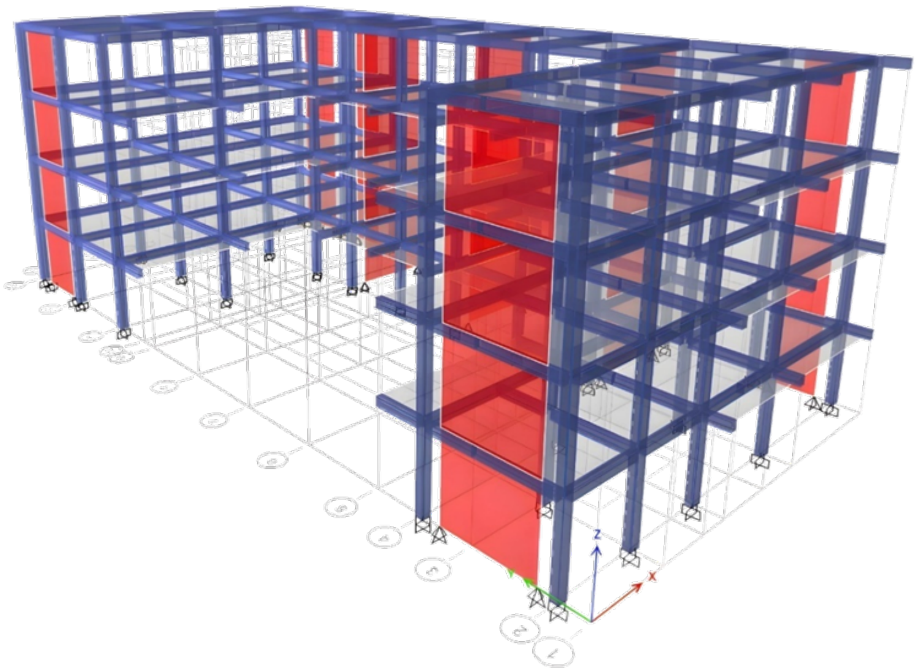
Figure 3. Rendering 2 of the Municipal Palace of Acacias.

Source: Own elaboration.

Determine the demands or effects that occur during the construction and design of the frame system.

For the design of the structure, a methodological process was developed that included structural modeling in ETABS (see Fig. 16) and verification of the designs using Excel spreadsheets.

Figure 4. Structure of the municipal palace modeled in ETABS.



Source: Own elaboration.

Among the main findings and discussions regarding the results obtained are:

General Considerations

The designed building consists of four levels with a total height of 14.5 m. A structural system of rigid frames was adopted, with one-way lightweight slab floors and a concrete slab roof. Given the project's location in a high seismic hazard zone, an importance coefficient of 1.10 was considered, corresponding to Use Group II, which conditioned the structural requirements and seismic design.

Preliminary Sizing of Structural Elements

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

Load Assessment

The applied loads were established in accordance with the current regulations:

Table 1. Loads applied to the interfloor slabs and roof slab.

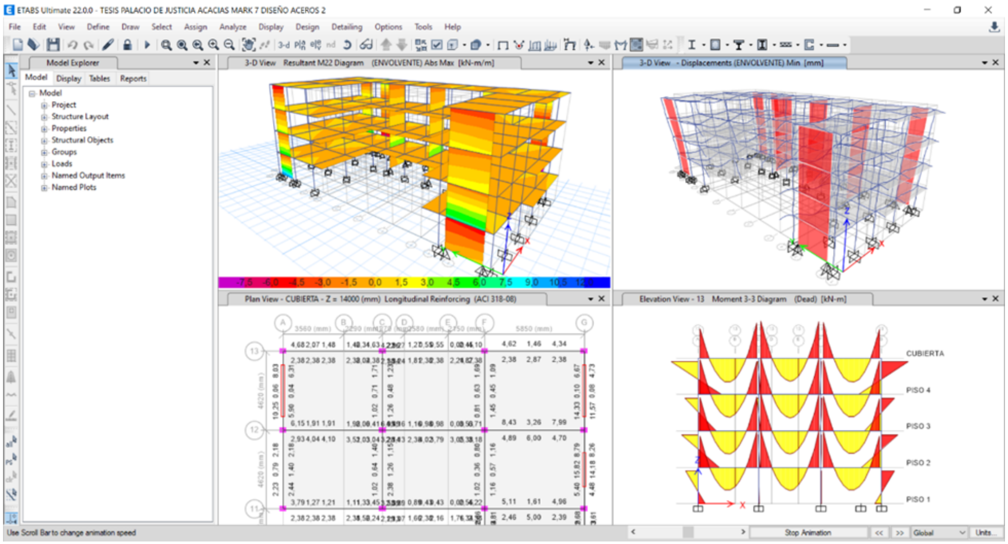
SLAB	TYPE OF LOAD		
	SUPERIMPOSED	VIVA	POOLING
For a typical floor	4.3 kN/m² for offices and corridors	2 kN/m² for offices and 5 kN/m² for corridors	No loads of that type were applied.
For cover	2.3 kN/m²	2 kN/m²	kN/m²

Source: Own elaboration.

Creation of the Mathematical Model

The structural model was developed in ETABS (see Fig. 17), 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 due to lack of redundancy were performed.

Figure 5. Structural analysis in ETABS



Source: Own elaboration.

Drift Check

The drift analysis revealed that the structure, in its initial configuration, did not comply with the limits established by NSR-10 (maximum permitted drifts of 1%). To address this, 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 adequate structural design, 17 load combinations were considered according to NSR-10 (B.2.4.2 - Basic Combinations), evaluating both gravity loads and seismic effects, which allowed for adequate sizing of the structural elements.

Design of Structural Elements

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

Table 2. Most relevant observations for structural elements

STRUCTURAL ELEMENT	MOST RELEVANT OBSERVATIONS
SLABS	Unidirectional lightweight slabs were adopted for the floors and the roof, satisfying the stiffness and strength requirements. The temperature steel (welded wire mesh) was designed, resulting in 4 mm at 12.5 x 12.5 cm.
COLUMNS	The reinforcement of 6 steel bars of 5/8” with 3/8” stirrups was determined, and its performance was confirmed through interaction diagrams evaluating the response to axial compression and bending moments.
BEAMS	The steel reinforcement was designed according to the minimum ratios obtained from ETABS.
JOISTS	They were designed according to the strength and allowable deformation requirements.
FOOTINGS	They were designed according to the type (centered, edge, or corner) and the most critical axial loads transmitted by the columns.

Source: Own elaboration.

Final Considerations

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

To view the complete calculation report, see Annex 3.

To estimate the cost of the structure in rough construction, without considering finishes, and to allow 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. Activities were classified into five major categories: preliminary works, foundations, reinforced concrete structure, masonry, and roofing, allowing for better organization and control of the budget.

Principal investment items

The activities that represented the largest investment in the project were:

a) Reinforcing steel: With a cost of $526,794,622, representing 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: With a cost of $482,764,618, which is equivalent to 33.56% of the total project cost.

Economic factors considered

To guarantee the accuracy of the budget, the Current Legal Monthly Minimum Wage (SMMLV) for 2025 was taken into account, which was set at $1'423.500, plus a transportation allowance of $200.000, giving a total of $1'623.500. Likewise, percentage factors for severance, vacations, bonus, clothing, and occupational risks were considered, adjusted according to the job position and the number of minimum wages received by each worker.

Price Updating and Cost Efficiency

Input prices were updated to 2025 values, ensuring that the budget is adjusted to current economic conditions and increasing the viability of the project. In addition, the concrete mix design made it possible to determine exact dosages according to the required strengths and considering 2.5% waste.

CONCLUSIONS

Through the use of Geographic Information Systems (SIG), the optimal area for the location of the Municipal Palace was identified, which occupied an area of 664.57 m², considering the urban, regulatory, and geographical conditions of the surroundings. This analysis guaranteed the viability of the location and its compatibility with the territorial planning of the municipality.

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

The detailed analysis of load demands allowed a comprehensive understanding of the structural behavior of the Municipal Palace. Through the evaluation of dead loads, live loads, and seismic actions, the critical demands affecting the frame system were identified.

Based on data obtained in previous studies, a frame system was designed capable of resisting the applied loads and minimizing deformations. All structural analyses and calculations were carried out under the criteria established by the Colombian Regulation for Earthquake Resistant Construction (NSR-10). This ensures that the proposed design meets the minimum safety standards.

The Building Information Modeling (BIM) methodology was applied through the use of Revit software, which allowed the generation of tridimensional models, detailed plans, and graphic representations of the project, optimizing information management in all stages of the project.

The cost estimate of the structure in rough construction provided a fundamental basis for guiding budget planning. Through the analysis of materials, work quantities, and costs associated with the construction of the frame system. The cost analysis showed that the project has a total direct cost of $1'438.438.206,13, where the main investment items focused on reinforcing steel and the demolition of the existing structure.

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