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TYPOLOGICAL OPTIMIZATION FOR REAL ESTATE DEVELOPMENTS: 8-9 STORY MASS-TIMBER BUILDINGS FOR SEISMIC ZONES.

Juan José Ugarte Á.[1], Gerardo Armanet[2], Juan José Ugarte G.[3], Andrés Sierra[4], Jorge Romero[5], Sebastián Cárcamo[6], María Jesús González[7], Fernando Marcone[8].

ABSTRACT: In recent decades, different types of mass timber construction have been developed. These can be grouped according to materials -all timber, timber-concrete, timber-steel, timber-concrete-steel- and types -panels, posts-beams, and 3D modules-. After a process based on research and specific projects developed by the authors of this work, through the design with the post-and-beam typology, CLT slabs, and reinforced concrete cores and a methodology that included interviews with different real estate developers, this work resulted in a building of between 8 and 9 floors that is efficient from the point of view of the industry, that responds to seismic, cost and architectural program requirements.

KEYWORDS: Timber Buildings, Structural Typologies, Real Estate Developments.

1 – INTRODUCTION

1.1. BACKGROUND

Chile is characterized by high seismic activity, which strongly conditions its structural regulations, especially for mid- and high-rise buildings. Although timber has favorable seismic properties—such as a good strength-to-weight ratio and controlled deformation capacity—design must carefully consider connections and the integration of cores that provide rigidity and ductility to the structural system.

Chilean regulations also require an F-120 fire resistance rating for structural elements in buildings of this height. This requirement can be met through appropriate cross-sections of mass timber, but it also influences the choice of the construction system and typology.

From a market perspective, real estate developers prioritize factors such as cost per square meter, spatial flexibility, durability, regulatory compliance, and end-user acceptance. Therefore, any alternative construction system must demonstrate not only technical performance but also commercial viability.

The proposed typological design for 8–9 story buildings in seismic zones is based on international trends, where hybrid systems of wood and concrete have proven to be viable solutions. As Salvadori [1] notes in his review of timber buildings over five stories tall, material combinations optimize structural performance without compromising architectural flexibility (Fig. 1).

Several recent projects show that hybrid strategies—combining glulam frames with reinforced concrete cores—can effectively address the challenges of mid-rise construction, particularly in seismic zones. A notable case is the academic building described by Fierro et al., which employs mixed solutions to optimize both structural performance and construction feasibility [2]. Another example is the Tamango Building in Chile [3].

[1] Juan José Ugarte Á., Pontificia Universidad Católica de Chile, Santiago, Chile, jsugarte@uc.cl.

[2] Gerardo Armanet, Centro Nacional de Excelencia para la Industria de la Madera (CENAMAD) - ANID BASAL FB210015, Pontificia Universidad Católica de Chile, Santiago, Chile, garmanet@uc.cl, ORCID: 0009-0000-5783-5955

[3] Juan José Ugarte G., Centro Nacional de Excelencia para la Industria de la Madera (CENAMAD) - ANID BASAL FB210015, Pontificia Universidad Católica de Chile, Santiago, Chile, jugarte@uc.cl, ORCID: 0009-0003-1626-6911

[4] Andrés Sierra, Centro Nacional de Excelencia para la Industria de la Madera (CENAMAD) - ANID BASAL FB210015, Pontificia Universidad Católica de Chile, Santiago, Chile, agsierra@uc.cl, ORCID: 0009-0000-0589-9535.

[5] Jorge Romero, Facultad de Arquitectura y Diseño, Universidad Finis Terrae, Santiago, Chile, jromeror1@uft.edu.

[6] Sebastián Cárcamo, Centro Nacional de Excelencia para la Industria de la Madera (CENAMAD) - ANID BASAL FB210015, Pontificia Universidad Católica de Chile, Santiago, Chile, secarcamo@uc.cl, ORCID: 0009-0004-2685-5311

[7] María Jesús González, Pontificia Universidad Católica de Chile, Santiago, Chile, mjgonzalez9@uc.cl.

[8] Fernando Marcone, Arauco, Santiago, Chile, fernando.marcone@arauco.com.

1.2. HYPOTHESIS

This study is based on the hypothesis that typological adaptation should focus on buildings between 8 and 9 stories. This height range—from 6 to 9 stories—represents an optimal opportunity for implementing timber structural solutions, as it allows the use of section sizes and connectors that conform to current market standards. At this scale, mass timber construction offers key technical advantages: due to the size of its elements, fire performance is superior to that of traditional light-frame timber construction, allowing compliance with F-120 regulations without the need for additional systems.

Furthermore, from a programmatic and regulatory standpoint, buildings of this size can accommodate approximately 250 people, while maintaining the possibility of operating with a single evacuation stair and without requiring a rooftop escape terrace [4]. This range also allows for flexible program configurations that combine housing with commercial or service uses, a strategy validated by international case studies confirming its technical and construction feasibility [5].

Conversely, for buildings up to five stories, other systems such as platform frame may be more advantageous in both technical and economic terms. On the other hand, projects exceeding ten stories require specialized connectors and larger structural sections, which reduces timber's competitiveness compared to conventional steel or concrete solutions, increasing construction costs and limiting feasibility in local markets.

1.3. INPUTS AND CRITERIA

To develop a proposal aligned with both market needs and local conditions, the following input matrix was defined:

- Planned architectural program
- Target user profile
- Overall area and room dimensions
- Reference structural grid
- Bay widths
- Technical requirements of the system

Based on these parameters, the design process was oriented toward a structural typology that maximizes the use of engineered wood, complies with Chilean building codes, and adapts to local seismic conditions. As a result, the following were defined:

- An optimized construction sequence suitable for prefabrication
- Preliminary quantity take-offs and cost estimates for the structure
- A general technical description with best practices for mass timber design, including strategies for acoustic, thermal, fire, and chemical protection.

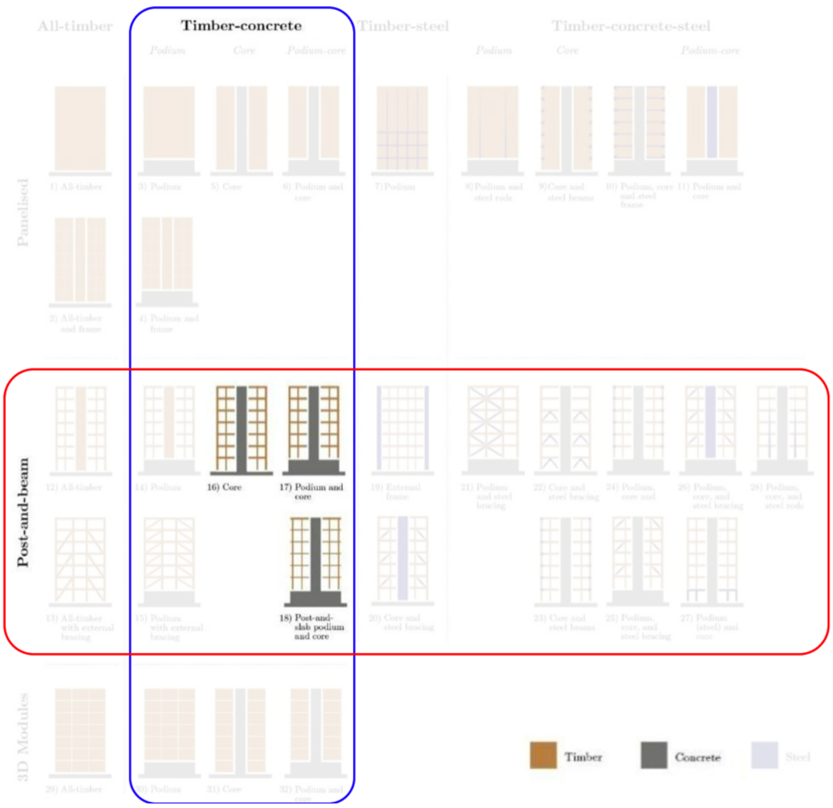

Figure 1. Selection from 20 Years of Multi-Storey Timber-Based Buildings. Vittorio Salvadori.

2 – METHODOLOGY AND SURVEY

2.1 METHODOLOGY

The research was structured around three main components:

- Literature review: Focused on international case studies of timber buildings with five or more stories.
- Interviews with seven real estate companies: All active in the Chilean market and with an interest in innovation and sustainability. The interviews addressed topics such as program types, perceptions of timber, costs, barriers, and opportunities.
- Design and structural modeling: Of a mixed-use building (retail, office, and residential), assuming a typical site with firm or dense soil and real dimensions based on preliminary design projects.

2.2 SURVEY RESULTS

The interviews revealed a clear trend for 9-story buildings: between 1 and 2 levels allocated to commercial uses, between 1 and 3 to offices, up to 1 level for storage, and between 5 and 8 levels for housing. The interviews also identified key perceptions regarding sustainability attributes that influence investment decisions.

Key questions addressed in the interviews:

- What program type is considered most attractive for the market?
- What regions of the country are considered priority for implementation?
- What additional area would be allocated to basements?
- What unit sizes are most in demand for residential apartments?
- What interior room and kitchen dimensions are considered appropriate?
- What areas are managed for offices and retail? What is the required clear height?
- What structural bay spacing is considered optimal for open-plan floors?
- How is the sustainability value of the project assessed, both from the developer's and end user's perspective?

Value attributes associated with timber construction, according to respondents:

- Use of renewable materials and low carbon footprint
- Aesthetic value of exposed timber
- Healthy indoor environments (biophilia)
- Quiet construction sites with low environmental impact
- Reduced construction waste
- Better control of schedules and costs
- Faster construction due to prefabrication
- Precise assembly
- Reduced on-site labor needs
- Suitability for poor soil conditions due to light structural weight

2.3. SYNTHESIS

The interviewed developers showed a clear preference for projects located in consolidated urban areas, with a mixed program that combines commercial, service, and residential uses. There is demand for apartments slightly larger than those defined by social housing standards, suggesting a market segment willing to pay for greater comfort without sacrificing efficiency. The most common housing typology is two bedrooms and two bathrooms, with an average floor area of around 65 m^2, aimed at small families, young couples, or elderly residents.

From a sustainability perspective, there is a widespread commitment to environmental, construction, and functional criteria. The proposed design aims not only to meet technical standards, but also to contribute to urban development through buildings that reduce environmental impact, improve energy efficiency, and optimize indoor comfort. This comprehensive approach ensures that the building is not only structurally viable, but also a tangible contribution to a more sustainable city.

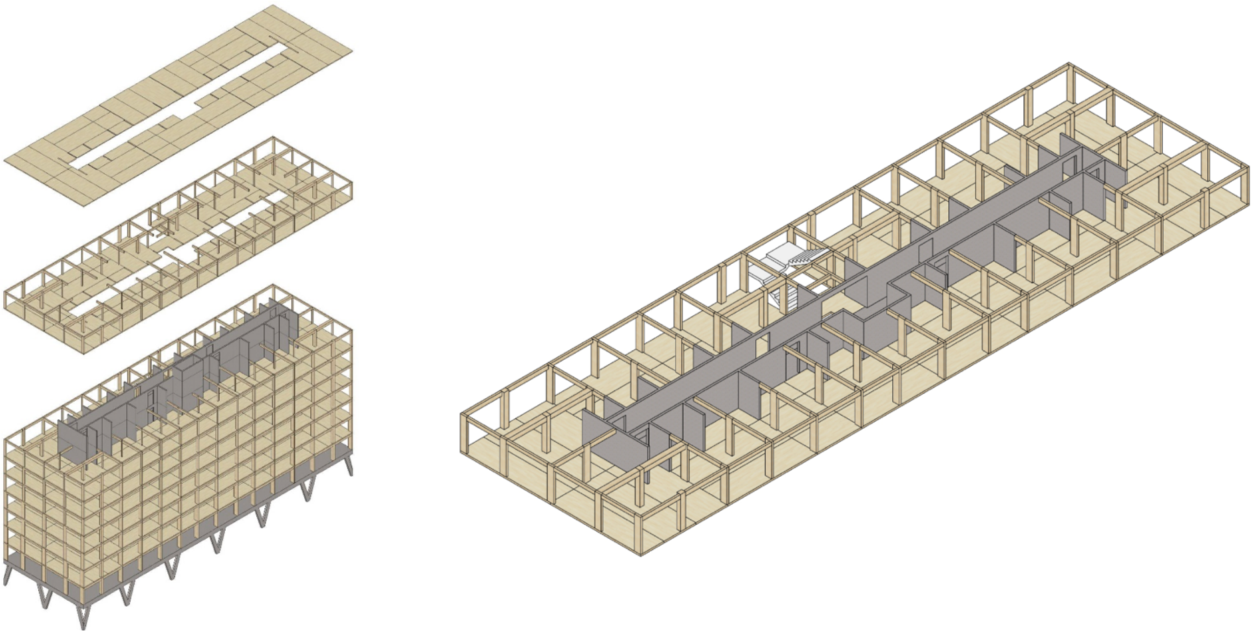

Figure 2 Hybrid structural system proposed.

3 – DESIGN PROCESS: A MIXED-USE BUILDING

3.1. LOCATION AND FLOOR AREA

Based on the preferred locations identified in the interviews and aiming for seismic design versatility, the structural analysis assumed a site with "firm or dense soil" in accordance with Chilean regulations. Based on previous studies and market demand, the standard site dimensions were defined as 14.25 x 47.65 meters, which translates to approximately 655 m² of usable area per floor.

3.2. CONSTRUCTION SYSTEM

A hybrid structural system was proposed (Fig.2), consisting of:

- A linear and open reinforced concrete core
- Glued laminated timber (glulam) columns and beams, modulated for residential use
- CLT (cross-laminated timber) floor panels
- Steel connectors
- Reinforced concrete basements and ground floor with a differentiated layout for parking

Each component was dimensioned and structurally modeled to maximize performance and explore innovations that enhance timber's competitiveness over traditional materials.

3.3. STRUCTURAL MODEL

The nine-story building was conceived with an optimized structural system that combines stability, seismic resistance, and efficiency. The model includes:

- Shear walls symmetrically distributed in both directions to absorb horizontal forces
- CLT slabs used across all nine levels, acting as rigid diaphragms in conjunction with the beams
- Beams designed to efficiently transfer loads to columns and walls
- Vertically aligned columns to ensure structural continuity and good seismic performance

All these elements were incorporated into a structural analysis model in accordance with current codes, assessing both individual and combined behavior to ensure feasibility and stability under high seismic demands (Fig. 3).

3.4. MIXED USE PROGRAM

Based on the market study and structural analysis, a mixed-use program was defined with the following configuration:

- Reinforced concrete basements for parking, storage, and technical rooms
- Ground floor (first level) in reinforced concrete for commercial or office use
- Floors 2 through 9 dedicated to residential use

This layout enabled the implementation of two differentiated structural grids: an 8-meter grid in the basements and a grid of 3.0 to 3.5 meters on the upper floors. The transition between grids is resolved at the ground floor using diagonal reinforced concrete elements, ensuring both structural continuity and architectural expressiveness.

3.5. HOUSING UNITS

In line with the structural grid and interview findings, the residential layout was based on three apartment typologies, varying in size and programmatic configuration:

Apartment A – 2 bedrooms, 2 bathrooms

Floor area: 89.94m². The largest unit, targeted at families needing more space or a more complete layout. Four units per floor.

Apartment B – 2 bedrooms, 1 bathroom

Floor area: 58.94m² A mid-sized option suitable for couples or small families. Four units per floor.

Apartment C – 1 bedroom, 1 bathroom

Floor area: 50.37 m². The most compact type, ideal for individuals or young couples prioritizing affordability and efficiency. Two units per floor.

This combination allows for a total of 10 residential units per floor, accommodating different user profiles while optimizing the floor plan's efficiency. The programmatic variety is achieved without compromising construction repeatability or structural efficiency.

3.6. QUANTITY SURVEY OF STRUCTURAL ELEMENTS

The structural design includes a total of 528 glulam columns and 784 glulam beams, totaling approximately 867 m³ of timber used throughout the building. The floors are composed of 424 CLT panels of varying thicknesses, adding up to approximately 665 m³.

This volumetric distribution enabled a progressive optimization exercise, reducing the cross-sections of vertical elements in the upper levels without compromising structural performance. For example, while the second floor uses approximately 115 m³ of timber, the ninth floor uses about 91 m³.

This optimization not only meets structural strength and stability requirements but also responds to material and cost efficiency criteria, using, for example, a structural efficiency index [6]. In this case, the building achieves a value of 0.166 m³ of timber per square meter of built area, placing it within competitive ranges for this type of construction.

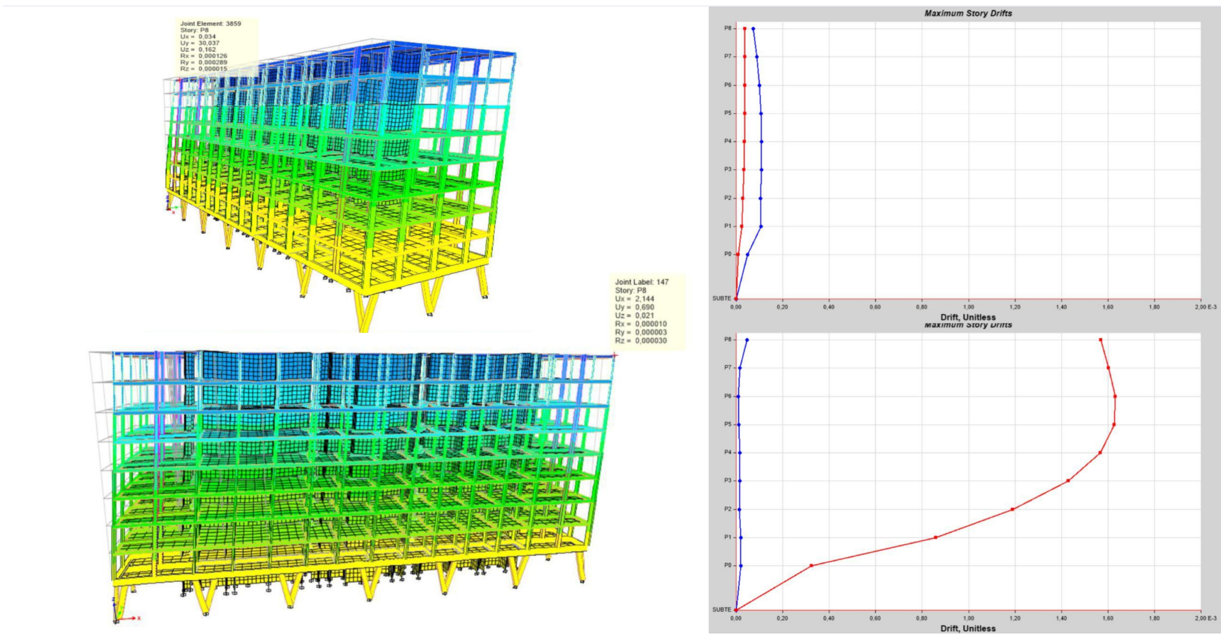

Figure 3. Structural Analysis

4 – RESULTS AND REFLECTIONS

4.1. GENERAL ASPECTS OF THE TYPOLOGY

The building designed in this study considers:

- Usable area per floor: 655 m² (14.25 x 47.65 m)
- Flexible program distribution: between 1 and 2 commercial floors, 1 to 3 office floors, and 5 to 8 residential floors
- Post-and-beam structure in glulam with spans ranging from 3 to 3.5 meters
- Intermediate floors made of CLT
- Linear and open reinforced concrete core
- Reinforced concrete basements with an 8-meter grid for parking
- Structural transition resolved using reinforced concrete diagonals (Fig. 4).

Complementary architectural elements such as terraces, overhangs, and metal balconies were also incorporated to enhance user experience and habitability. From a structural perspective, the use of timber and connectors was optimized while remaining within the usual cost range for this building type in Chile. Moreover, a wood grid was established for the upper floors—compatible with housing programs—and another for the basements—suitable for parking—connected through a solution that is both formally and structurally efficient.

4.2. ENVIRONMENTAL IMPACT AND EMISSIONS BALANCE

Considering the recent financial incentives from banks for sustainable buildings, the study included a comparative environmental impact assessment between an entirely concrete structure and the proposed hybrid solution. A full reinforced concrete version would generate approximately 2,788.65 tons of CO_2 equivalent. In contrast, the proposed hybrid design—with 891 m³ of timber (CLT and glulam) and 400 m³ of concrete—would allow for:

- Capture of 721.74 tons of CO_2 thanks to the timber
- Emission of only 864 tons of CO_2 due to concrete use
- A total reduction of 2,648.39 tons of CO_2 equivalent

4.3. ECONOMIC BENEFITS OF SUSTAINABILITY

Various national and international studies support the economic benefits of incorporating sustainability criteria. Key findings include:

- Increase in sales value of up to 30% for projects with sustainable attributes [7]
- Rent increases of up to 17%, especially in commercial buildings
- Occupancy rate improvements of up to 21.3%, which stabilizes cash flow for investors
- Approximate reductions of 30% in energy consumption and 40% in water use, significantly lowering operational costs [8]

Finally, sustainable buildings have been shown to improve occupant wllbeing. In work environments, this translates into productivity increases of up to 25% [9], generating additionalalue for both employers and users.

Figure 4. Project structure and Façade

5 – CONCLUSIONS

The study demonstrates that it is possible to optimize structural sections while remaining within market parameters, achieving an appropriate balance between efficiency, technical feasibility, and economic competitiveness. The proposed system allows for open-plan floors adaptable to different architectural programs and defines a differentiated structural grid—with spans between 3 and 3.5 meters on the upper floors and 8 meters in the basements—providing functional efficiency without compromising the design.

Structural simulations confirm that lateral displacements remain within code limits, and the estimated building cost is competitive compared to mid-to-high standard conventional concrete solutions.

The proposed system overcomes the limitations of "all-timber" solutions by integrating a reinforced concrete core, which improves seismic performance and helps control overall deformability. Compared to hybrid wood–steel alternatives, this solution offers advantages in terms of simpler connections and reduced assembly time.

Developers particularly valued the functional flexibility of the building, the potential for certification under international standards, and the commercial differentiation associated with the visible use of timber as a structural element.

Structural optimization enabled a solution that is efficient from an industrial standpoint and aligned with real estate market demands. Additionally, the design incorporated innovative elements such as metal terraces, programmatic overhangs, and a mixed-use layout based on open-plan floors, enhancing the project's adaptability.

For future stages, the following are recommended:

- Structural validation through prototype testing
- Development of pilot projects to refine real cost estimates
- User perception and acceptance studies

Figure 5.Section with architectural program.

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