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THE GRADING OF THE MODULUS OF ELASTICITY OF WOOD FOR THE MANUFACTURING OF GLULAM BEAMS TO MEET ARCHITECTURAL CONFIGURATIONS

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ABSTRACT: Wood grading enables the selection and positioning of each lamella within the structural element's cross-section according to its strength class. Through evaluation of the modulus of elasticity and visual grading, it is possible to manufacture components with identical cross-sections but varying mechanical resistance capacities, as determined by structural design calculations. This study aimed to demonstrate how the wood grading method based on modulus of elasticity facilitated the architectural configuration of beams with identical cross-sections spanning different lengths (7.50-meter modular spans and a maximum 12.56-meter span), while maintaining a uniform 0.12 m × 0.45 m cross-section for all beams, thereby optimizing costs and the built environment. The findings confirm that preliminary grading ensures proper physical and mechanical characterization of the material, allows for its maximum utilization, and enhances wood efficiency in the manufacturing process.

KEYWORDS: *wood, MTG, modulus of elasticity,* mass timber products.

1 – INTRODUCTION

Mass timber products, particularly glued laminated timber (GLT), allow for preliminary estimation of most key mechanical properties through analytical and numerical models for structural design applications. The assignment of mechanical properties to wood is crucial for its use as a structural material and is achieved through visual or mechanical grading, which must comply with technical standards [1].

According to Sandak et al. [2], GLT manufacturing follows guidelines specified in national or European codes that establish predefined strength classes. The appropriate class is determined by both the wood's inherent strength and its position within the cross-section. Strength and stiffness values for each resistance class are established according to current standards.

The assignment of mechanical properties to wood is essential for structural applications, obtained through visual or mechanical grading performed in compliance with regulations [3]. The Brazilian standard NBR 7190 [4] specifies that lamellas must be classified into strength categories through both visual and mechanical grading based on modulus of elasticity. This process generates data that characterizes and evaluates each lamella for component design purposes.

Through lamella grading, structural elements can be manufactured according to load demands and capacity requirements specified in the structural design, with positioning based on their visual and mechanical classification. This enables production of components with identical cross-sections but varying mechanical resistance capacities.

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This study demonstrates how the modulus of elasticity grading method, obtained through non-destructive testing, was applied in the planning and manufacturing of components for a high-end residential project by Rewood - structural timber solutions. This approach enabled longer spans with increased slenderness ratios while facilitating architectural configuration and cost optimization.

2 – BACKGROUND

The project was executed in Angra dos Reis, Rio de Janeiro (Figure 1). The architectural design was developed by Jacobsen Architecture, with a total projected area of 1,160 m² using 110 m³ of glued laminated timber (GLT). The GLT elements were designed, manufactured, and installed by Rewood, a structural solutions company. The wood species used was pine (Pinus spp.) with an average density of 550 kg/m³.

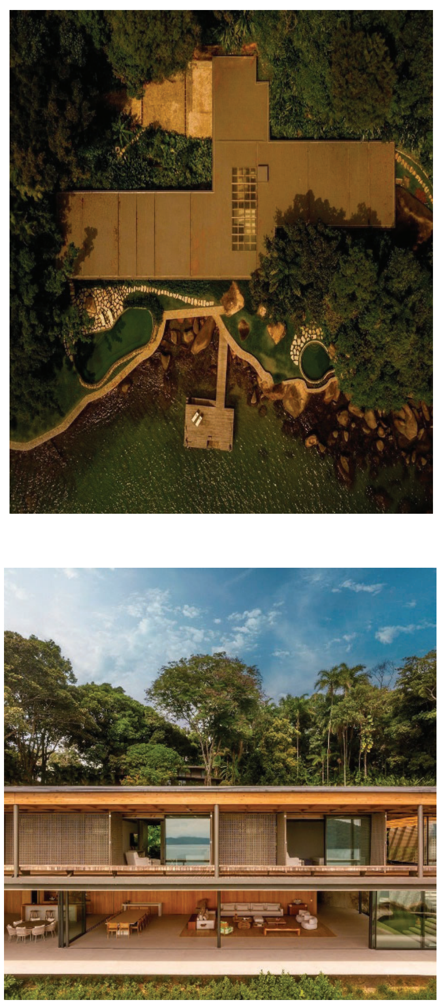

Figure 1. The project. Source: Jacobsen Architecture (2024).

As the company responsible for the design (Figure 2), fabrication, and assembly of engineered timber structures, Rewood guides the development process during the architectural design phase to achieve both the desired architectural configurations and associated financial objectives.

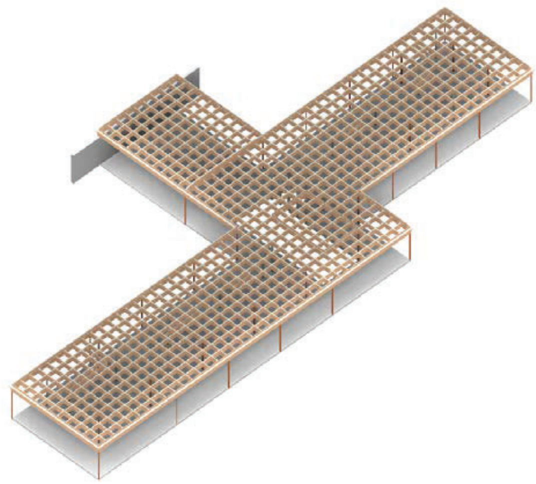

Figure 2. Three-dimensional representation of the case study

The service portfolio encompasses pre-sale consulting, structural analysis, construction planning, production, logistics, transportation, assembly, installation, warranty, and post-installation support throughout Brazil. Each project undergoes specific logistics analysis, as the company monitors and guarantees the entire material delivery process to the destination site.

This case study presented complex logistics challenges for material delivery to the construction site, as maritime transport was the only viable option. Consequently, the entire process was analyzed from the design phase onward, particularly due to the inclusion of extra-long components.

The structural concept was developed to achieve modular spans of 7.50 m and a maximum span of 12.56 m while maintaining consistent cross-sections for all beams. This design constraint would not have been possible without wood grading, as it would otherwise require larger volumes with variable cross-sections based on span lengths.

The project comprised steel columns and various glued laminated timber (GLT) elements: primary, secondary, and tertiary beams, along with purlins and collar ties. To maintain uniform cross-sections while identifying components subject to higher stresses, we implemented visual grading and modulus of elasticity testing to map material properties for manufacturing, ensuring

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compliance with the project's physical and mechanical requirements.

The process employed an ergonomic LCD-display measurement device - the Timber-Grader (MTG) (Figure 3). The device is placed against the wood piece (lamella), and when the trigger button is pressed, it sends a sonic wave longitudinally through the material. The Stress Wave Detector mechanism then receives the reflected impulse and wirelessly transmits it to a computer. Finally, the Timber Grader software converts the sonic waves into measurable results.

Figure 3. Timber Grader MTG

The design of each structural element was performed in accordance with Brazilian standard NBR 7190 [4], which specifies the modulus of elasticity (E) as the key reference parameter for component assembly. The grading process requires: Upper Sublot - Boards with modulus of elasticity values exceeding the species average (E_m) and Lower Sublot - Boards with values below this E_m threshold. Figure 4 illustrates this lamella composition methodology based on elastic modulus classification.

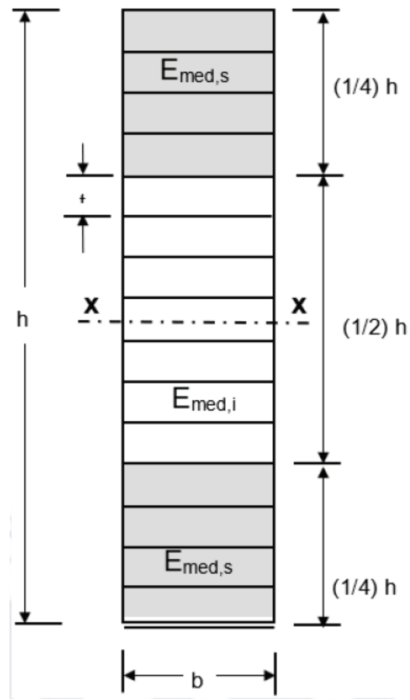

Figure 4. Composite cross-section featuring lamellae with distinct Young's moduli. Source: ABNT NBR 7190, 2022.

Lamellae from the upper sublot shall be allocated to the outermost quarter sections (farthest from the neutral axis) of the GLT member, while those from the lower sublot shall compose the central half of the cross-section.

The transformed section method was employed for flexural stiffness calculations, accounting for each lamella's modulus of elasticity within the GLT member. The beam was specifically designed with higher modulus lamellae (Class A) positioned in the bottom tension zone. Through Rewood's controlled grading and assembly process, exact lamella placement was achieved - with 25% of above-average modulus lamellae systematically placed in the bottom section.

Lamella Distribution Configuration (Figure 5): Top zone - Grade B (25%), Middle zone - Grades B+C (50%) and Bottom zone - Grade A (25%). The production batch utilized 130 m³ of raw material (0.15 m × 0.05 m × 3.00

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m boards, totaling 5,778 pieces), achieving 85% yield efficiency resulting in 110 m³ of finished GLT.

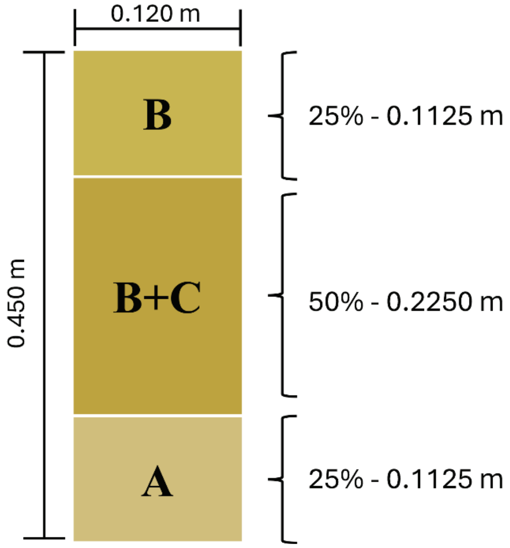

Figure 5. Graphical representation of laminate distribution versus cross-section height

5 – RESULTS AND DISCUSSION

Following lamella characterization and grading, the structural members were designed and manufactured with a uniform cross-section of 0.12 m × 0.45 m for all primary beams. This configuration achieved a clear span of 12.56 m, satisfying both: the architectural constraint prohibiting intermediate supports and the required physical and mechanical performance specifications.

From the total 110 m³ of produced glued laminated timber (GLT):

- 27.5% comprised high-modulus lamellae (Grade A).
- Strategically positioned in the bottom 0.1125 m tension zone (as illustrated in Figure 5).

Figure 6 displays the normal distribution of elastic modulus values, with:

- Maximum graded value: 16,353 MPa
- Minimum graded value: 7,546 MPa The Gaussian distribution correlates with the mechanical grading classifications (A, B, C), demonstrating the material property variation within the sample population.

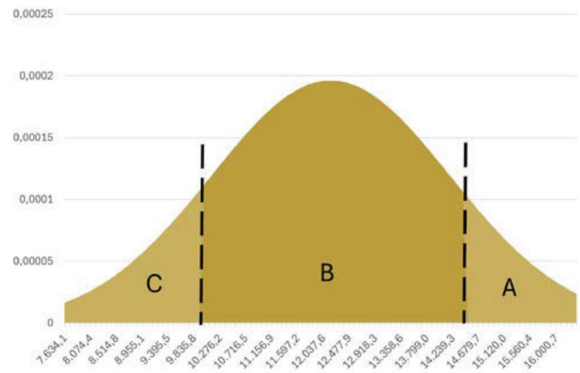

Figure 6. Normal distribution of elastic modulus

The elastic modulus considered in the input data for the structural calculation parameters in the RFEM software was 11,000 MPa, derived from laboratory tests routinely conducted to monitor the physical and mechanical properties of REWOOD's projects. The timber classification allowed for higher elastic modulus values. Comparing the maximum value obtained (16,353 MPa) through timber classification to the baseline, a percentage increase of 48.67% was observed. Figure 7 illustrates the Serviceability Limit State (SLS) deformations generated by RFEM.

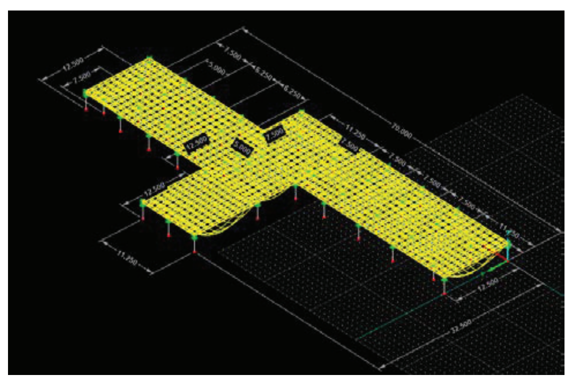

Figure 7. Analysis of structural deformations in the SLS (Serviceability Limit State)

Figure 8 illustrates the assembly sequence of the structure, beginning with the installation of the steel columns, followed by the assembly of the primary beams. Subsequently, the secondary beams were installed, then the purlins, tertiary beams, and battens.

The floor plan of the primary beams shows their modular layout, with spans ranging from 7.00 m to 12.56 m (Figure 9). All beams and purlins maintained the same cross-section throughout.

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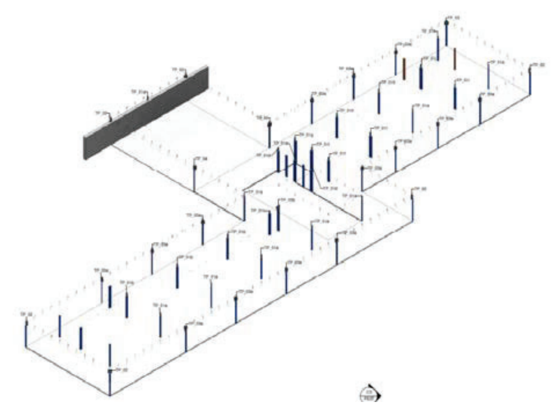
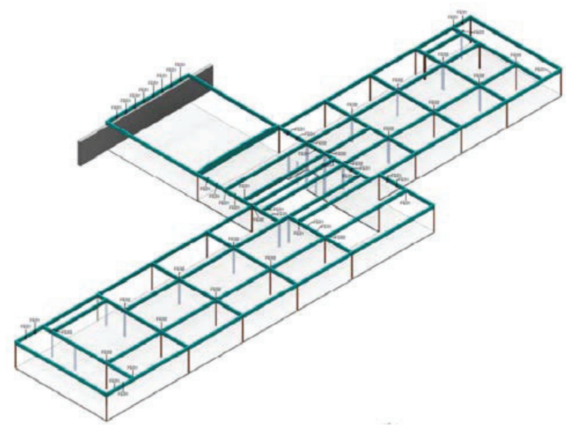
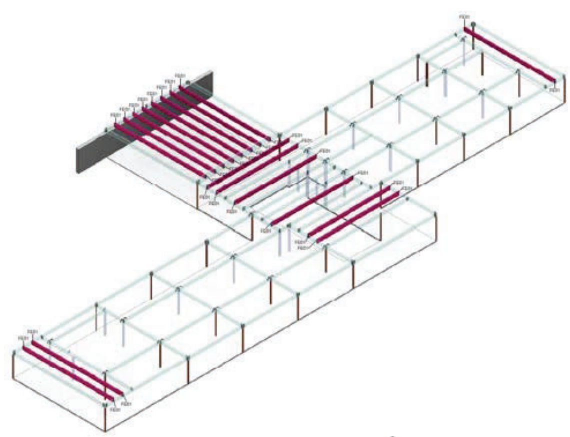
a) Steel column installation



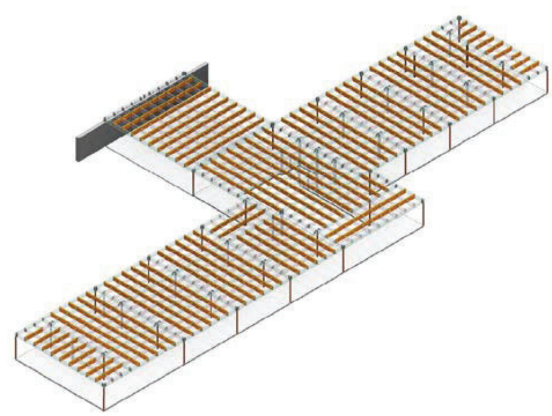
b) Primary beam assembly



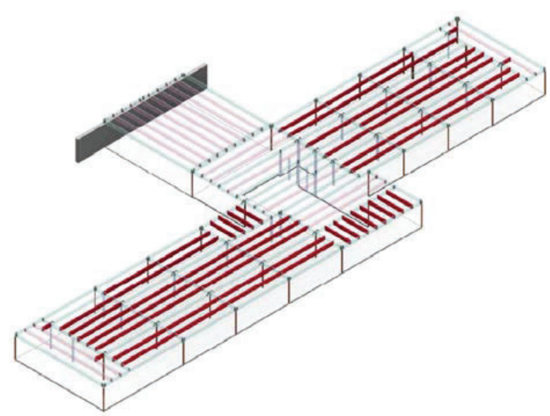
c) Secondary beam assembly



d) Purlin installation



e) Tertiary beam assembly



f) Batten installation

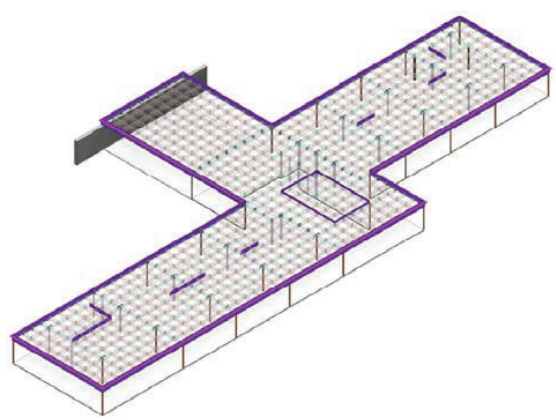


Figure 8. Assembly Sequence

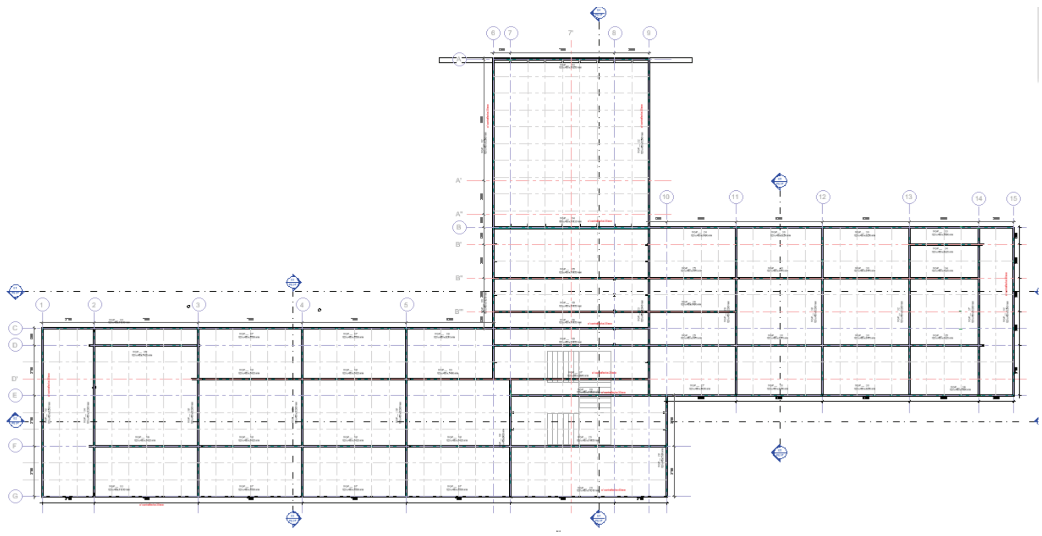


Figure 9. Floor plan of primary (main) beams

Figure 10 presents the executed project design

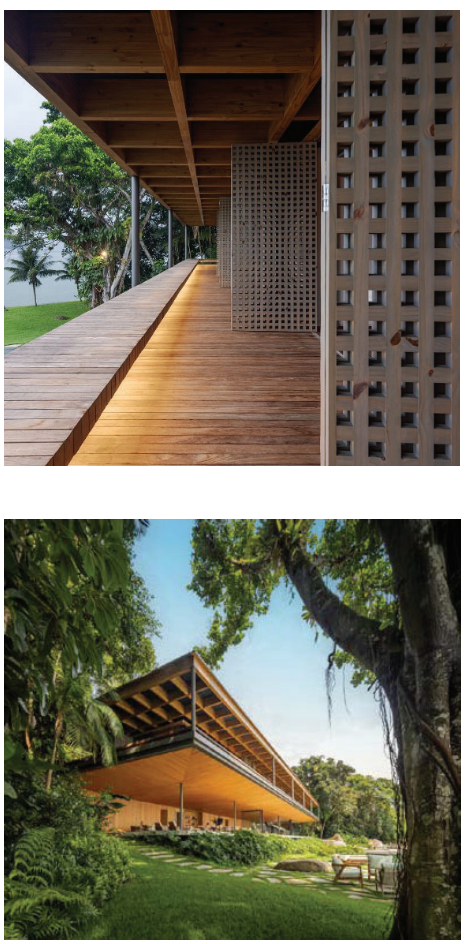


Figure 10. Executed design. Source: Jacobsen Architecture (2024).

Mechanical grading of laminates through elastic modulus and visual classification enabled the use of identical cross-sections for all project beams despite varying spans. Without preliminary grading, it would have been impossible to accommodate longer spans while maintaining the same section and cubic volume. This approach facilitated rational wood utilization by adapting and integrating its properties to the intended application - made possible through grading - achieving different structural spans simply by modifying wood processing methods.

The findings demonstrate that industrializing wood processing not only optimizes material efficiency but also accommodates diverse architectural and aesthetic configurations. Furthermore, the financial aspects highlight the significance of engineered wood in contemporary construction.

6 – CONCLUSION

Engineered wood, particularly glued laminated timber (GLT), can overcome structural barriers to meet architectural demands requiring longer clear spans while maintaining uniform cross-sections throughout the project. The timber grading method enables structural element optimization through classification and mapping based on elastic modulus and visual grading, which resulted in nearly 50% higher elastic modulus values for graded wood compared to ungraded timber parameters considered in RFEM software calculations.

The case study successfully applied these concepts to ensure appropriate physical and mechanical material properties, enabling the use of plantation-grown timber

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while maximizing material potential. The findings demonstrate that when properly graded, wood meets specific structural requirements without increasing cubic volume - simply by adapting manufacturing processes and optimizing material properties. This approach allows engineered wood to overcome technical limitations while remaining financially viable.

7 – REFERENCES

[1] M. Gonzalo, Í. Guillermo, C. Gonzalo, B. Vanesa. "Evaluation of Yield Improvements in Machine vs. Visual Strength Grading for Softwood Species." In: Forests.(2022). http://dx.doi.org/10.3390/f13122021.

[2] Sandak, Jakub; Niemz, Peter; Hänsel, Andreas; Mai, Juana; Sandak, Anna. "Feasibility of portable NIR spectrometer for quality assurance in glue-laminated timber production". In: Construction and Building Materials.v.308. (2021). Elsevier BV. http://dx.doi.org/10.1016/j.conbuildmat.2021.125026.

[3] Moltini, Gonzalo; Íñiguez-González, Guillermo; Cabrera, Gonzalo; Baño, Vanesa. "Evaluation of Yield Improvements in Machine vs. Visual Strength Grading for Softwood Species". In: Forests. v. 13, n. 12. (2022) MDPI AG. http://dx.doi.org/10.3390/f13122021.

[4] Brazilian Association of Technical Standards. NBR 7190-1: Design of wooden structures - Part 1: Design criteria. 1 edition. Rio de Janeiro: ABNT, 2022. 81 p.