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DEVELOPMENT OF AN ENGINEERED WOOD PRODUCT BASED ON A MARKET STUDY

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ABSTRACT: Mass timber products offer benefits related to sustainability, prefabrication, cost efficiency, and flexibility in construction planning and execution. However, in Brazil, when compared to other market solutions, they still tend to be more expensive. The engineered product that utilizes the largest volume of cubic meters per square meter is the slab, which has three main solutions: CLT (Cross-Laminated Timber), NLT (Nail-Laminated Timber), and the hybrid structured panel (wall panel). The hybrid structured panel, being a simpler solution, is more financially accessible, with a lower cost per square meter. However, it often does not meet the aesthetic requirements of architecture, necessitating an additional finishing layer (ceiling). In this context, this study aimed to develop a product that is both structurally and financially viable for mass timber structures, thereby making it competitive with other materials in the market. To achieve this, four experimental investigations were conducted: NLT with metal nails, NLT with wooden nails, NLT with cement board, and GLMP (Glued Laminated Mixed Panel). All proposed panels were subjected to bending tests. The results indicated that it is possible to develop a product capable of meeting structural demands for intended uses while also providing added architectural and aesthetic value.

KEYWORDS: mass timber products, NLT, wall panel

1 – INTRODUCTION

Various sectors of society are debating the concept of sustainable development, which has become a goal for many countries, particularly in terms of reducing greenhouse gas emissions and conserving energy. However, the industry that drives the development and growth of cities is the construction sector, which demands high energy consumption and generates significant pollution in the production of conventional materials such as steel and concrete. Therefore, it is necessary to explore alternative construction methods that align with sustainability [1].

Wood is a renewable, bio-based construction material and has been used in buildings and bridges in many countries, promoting the reduction of carbon production while also being capable of storing carbon within structures. This is particularly relevant given that the construction industry is responsible for 37% of carbon emissions [2]. Additionally, timber construction has grown due to the material's capacity and performance, especially in terms of strength-to-weight ratio.

Mass timber products are sustainable and offer benefits related to prefabrication, cost efficiency, and flexibility in construction planning and execution [3]. However, when compared to other market solutions, they tend to be more expensive, particularly in slab solutions such as Cross-Laminated Timber (CLT) and Nail-Laminated Timber (NLT).

The latter product is obtained by mechanically nailing together laminated wood strips, with a structural plywood or OSB (Oriented Strand Board) panel fixed to one face, creating a solid, stable element that enhances shear capacity. The configuration of NLT allows for the design

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of monolithic slabs, resulting in diverse application opportunities [4].

Nail-Laminated Timber (NLT) is considered an ancient construction method that offers various application opportunities, such as floors, roofs, walls, and slabs. Initial research on this product dates back to the 1990s and focused on bending behavior. As a result, research related to NLT remains limited [1], and there is a lack of standardized methods and normative documents describing testing parameters and quality control for this product.

In Brazil, two-story engineered wood constructions typically use hybrid structured panels (HSP) as slab solutions. These panels consist of a core filled with laminated or sawn wood, sandwiched between two cementitious boards made of CRFS (Cement Reinforced with Synthetic Fiber) and pressed. These panels are commercially known as "wall panels" and have a lower cost compared to engineered wood slab solutions that require higher m³/m² consumption.

However, hybrid structured panels (HSP) do not meet aesthetic requirements, necessitating an additional finishing system, similar to conventional concrete slabs. This highlights the need for a product that can address aesthetic concerns while maintaining the structural performance of hybrid structured panels. Wood is known to meet both aesthetic and structural requirements, and engineered wood configurations can optimize material use while providing a finished product.

This study aimed to develop a product based on market research, seeking financial viability combined with structural performance comparable to hybrid structured panels, but with enhanced aesthetics, eliminating the need for an additional finishing system (ceiling).

2 – BACKGROUND

Since the hybrid structured panel (HSP) already provides a structural solution capable of meeting the financial demands of the construction market, an experimental investigation was conducted to develop an engineered wood product with lower m³/m² consumption that could meet the same structural requirements while adding aesthetic and architectural appeal.

Among engineered wood products, Nail-Laminated Timber (NLT) has a lower manufacturing cost and is used in slab systems. It is capable of eliminating the need for an additional finishing system and has the potential to match the performance of hybrid structured panels (HSP), while enhancing aesthetic value and offering financial competitiveness.

The market study was based on projects developed by Rewood – Engineered Wood Structural Solutions, a company responsible for the design, manufacturing, and assembly of structures. Rewood offers pre-sales consulting, structural analysis, construction planning, production, logistics, and assembly services. During the design process, the company guides development to ensure architectural configurations and financial feasibility of the project.

Figure 1 shows a project executed using eucalyptus, with a projected area of 210 m² and 22 m³ of NLT. The project included NLT slabs with a width of 500 mm and a length of 10,000 mm, using laminates of 20 mm (width) x 120 mm (height). Additionally, the project incorporated inverted beams and Glued-Laminated Timber (GLT) joists.

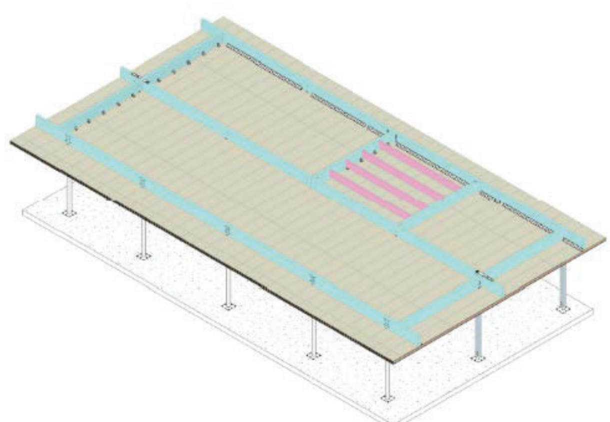

Figure 1. Project details

The slab layout was designed to optimize the use and arrangement of full panels. The design and configuration of NLT panels executed by Rewood served as the basis for the experimental planning of the panels developed in this research. Figure 2 illustrates the executed project.

Figure 2. Project executed by Rewood

Through the analysis of completed projects, particularly two-story buildings with GLT elements and Cross-Laminated Timber (CLT) slabs, it was identified that the slab system accounted for the highest consumption (m^3/m^2). This highlighted the need to reduce cubic meter consumption by adapting an engineered wood product to a market-absorbed product (hybrid structured panel) that has a lower cost and a load-bearing capacity compatible with its intended applications. Some experiences developed by the company to date are presented in the following sections.

2.1 WOODEN BUILDING

Rewood executed a three-story building structured with Glued-Laminated Timber (GLT) columns and beams and a Cross-Laminated Timber (CLT) slab system, totaling 230 m^3 of engineered wood. Of this total, 90 m^3 represented GLT and 140 m^3 represented CLT, which accounted for 70% of the engineered wood used. This indicates that the CLT slab system has a high m^3/m^2 consumption and, consequently, a higher construction cost.

This comparison was also made through solutions implemented with hybrid structured panels (HSP), which enabled financial feasibility in various two-story projects. This positions HSP as the primary slab solution for timber structures in Brazil, offering better technical and financial feasibility compared to CLT and NLT. Figure 3 presents a structural solution executed by Rewood, featuring three stories and 563 m^2 of floor area.

Figure 3. Case Rewood

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Through observations and analyses of structural solutions, a product was conceptualized to offer a cost-benefit advantage, competing aesthetically, structurally, and financially with CLT while being comparable to hybrid structured panels.

2.2 EXPERIMENTAL INVESTIGATION 1

The study was based on a construction solution for a commercial building in the United States, where engineered wood was used for both the structure and interior. The building, named T3 – Timber, Transit, Technology, has seven stories and is composed of Glued-Laminated Timber (GLT) beams and over 1,100 Nail-Laminated Timber (NLT) panels. The timber structure was erected and completed in just 2.5 months, averaging 9 days per floor. The total amount of wood used in the structure will sequester approximately 700 tons of carbon over the building's lifespan (Think Wood, 2024). Figure 4 presents the T3 case study, showcasing the use of wood in both the structure and interior. The NLT panels are visible as slabs, fulfilling both structural and aesthetic functions.

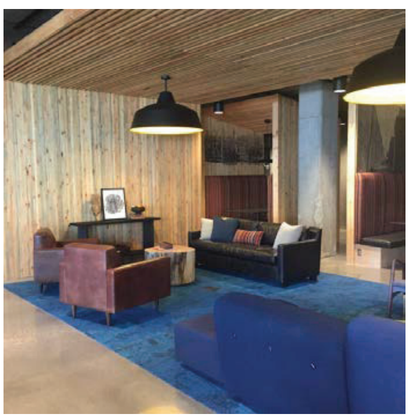


Figure 4. T3 case study. Source: Think Wood (2024).

The experimental investigation began with the development of two NLT panels made of Pinus taeda with metal nails. These panels exhibit good mechanical performance, meet aesthetic requirements, and have low production costs, requiring minimal control and specialized labor. However, they do not allow for on-site cutting to accommodate layout adjustments, and despite their lower cost compared to other engineered wood products, they do not match the cost of hybrid structured panels (HSP).

2.3 EXPERIMENTAL INVESTIGATION 2

The second phase involved the development of an NLT panel with wooden nails to overcome the limitation of necessary cuts during panel installation. The goal was to compare its performance to that of panels with metal nails. Figure 5 shows the wooden nail and its connection to the wood, which is achieved through lignin.

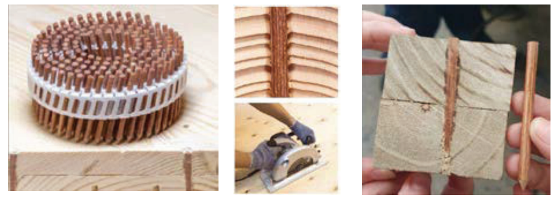


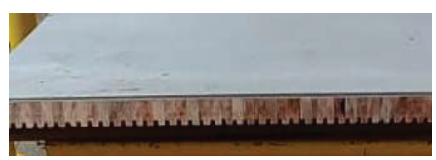
Figure 5. Wooden nail. Source: Lignoloc

The results demonstrated satisfactory performance, and the wooden nails allowed for cutting. However, the cost of materials would be higher, as wooden nails are more expensive than metal nails, making it unfeasible to develop a product capable of competing with hybrid structured panels (HSP).

2.4 EXPERIMENTAL INVESTIGATION 3

An NLT panel made of eucalyptus was developed, following the same configuration as the commercially available hybrid structured panel manufactured in Brazil. This panel consisted of NLT with a cementitious board on the top face, with a slightly greater thickness due to the need for metal nails to connect the laminates. Figure 6 illustrates the panel configuration.

a) Section of NLT panel with cementitious board.



b) Section of hybrid structured panel.

Figura 6. Section of the panels.

The panels were subjected to bending tests. The performance of the NLT panel with the cementitious board was superior, but in terms of financial competitiveness, it did not align with the hybrid structured panel. Additionally, it still faced limitations regarding on-site cutting. After testing, it was observed that it is possible to develop a panel with lower mechanical performance, i.e., compatible with the hybrid structured panel.

The possibility of reducing the thickness of the NLT panel was noted, given the superior results obtained and the mechanical performance of the hybrid structured panel, which serves as the benchmark for mechanical strength. This is because the hybrid structured panel meets market demands and the intended use.

2.5 EXPERIMENTAL INVESTIGATION 4

Since the resistance obtained in Experimental Investigation 3 was significantly higher, the goal was to develop a panel with the same commercial thickness as the hybrid structured panel (40 mm). However, maintaining the configuration of Nail-Laminated Timber (NLT) with nails does not allow for thickness reduction. Therefore, a Glued-Laminated Timber (GLT) panel with a stabilizing element—a cementitious board on the top face—was conceptualized. This led to the development of a Glued-Laminated Timber (GLT) panel with the same configuration as the hybrid structured panel, named GLMP – Glued-Laminated Mixed Panel.

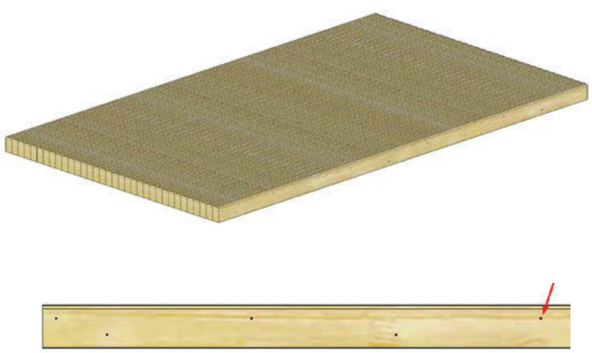
3 – PROJECT DESCRIPTION

3.1 PROJECT 1 - NLT WITH METAL NAILS AND WOODEN NAILS

Two nail-laminated panels were fabricated: one with staggered nail arrangement (Figure 7a) and the other with a continuous arrangement (Figure 7b). The panels consisted of 34 Pinus taeda laminates nailed together using 2.7 x 80 mm ring-shank nails.

The sawn timber panels, nailed side by side, were made of Pinus ssp. laminates, and a second panel of OSB (Oriented Strand Board) was fixed to one face, with dimensions of 11.1 x 1200 x 2400 (mm), providing stability during handling (Figure 8).

a) NLT panel with staggered nails



b) NLT panel with continuous nails.

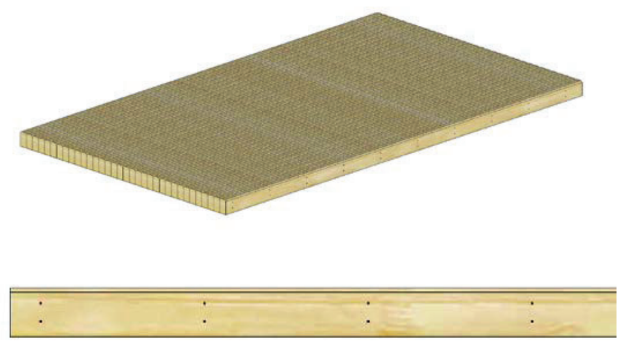


Figura 7. Configuration of panels with metal nails.

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Figure 8. Nail-laminated panel

The production and testing arrangement for the panels with wooden nails followed the same configurations as those with metal ring-shank nails. Wooden nails with a diameter of 5 mm and a length of 74 mm, manufactured by Lignoloc, were applied using a Beck machine (Figure 9).

Figura 9. Beck machine. Source: Lignoloc.

PROJECT 2 - HYBRID STRUCTURED PANEL

The hybrid structured panel used had commercial dimensions of 2500 x 1200 x 40 (mm) (Figure 10). According to the manufacturer, the panel can support up to 500 kg/m² of uniformly distributed loads with spans of up to 1.25 m. This panel consists of a core of sawn laminated wood, sandwiched between two cementitious boards made of CRFS (Cement Reinforced with Synthetic Fiber) and pressed. The central laminates are oriented transversely to the cementitious boards.

Figure 10. Hybrid structured panel. Source: Decorlit.

PROJECT 3 - NLT WITH CEMENTITIOUS BOARD

Two NLT panels made of eucalyptus wood with a cementitious board on the top face were developed. The first panel had dimensions of 2380 mm (length) x 1174 mm (width) x 51 mm (thickness). The second panel measured 2491 mm (length) x 1160 mm (width) x 46 mm (thickness). Figure 11 shows the panel configuration prepared for the bending test.

Figure 11. NLT panel with cementitious board during bending test.

PROJECT 4 - GLMP (GLUED-LAMINATED MIXED PANEL)

The Glued-Laminated Mixed Panel (PMLC) involved gluing laminates with dimensions and thickness similar to the hybrid structured panel, with a cementitious board fixed to the top face. After gluing, the panel was machined using CNC (Computer Numeric Control) for finishing, as shown in Figure 12.

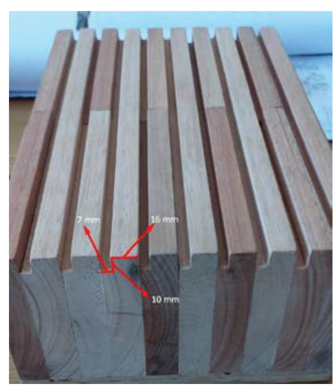

Figura 12. Machining detail of the panel.

4 – EXPERIMENTAL SETUP

The panels developed in the experimental investigations were subjected to bending tests according to the methodology described by Pereira (2014), which was based on the ASTM PRG 320 standard. The configuration used for the bending test with a concentrated load at mid-span is shown in Figure 13.

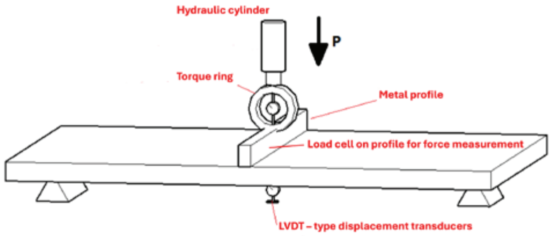

Figure 13. Bending test configuration. Source: Adapted from Pereira (2014).

The bending tests were conducted at the Wood and Timber Structures Laboratory (LaMEM) of the Department of Structural Engineering (SET) at the São Carlos School of Engineering (EESC), University of São Paulo (USP).

The panels were positioned with the laminates oriented in the same direction as the span (L). For load application, a tubular steel beam was placed at the central axis of the panel, aligning the center of the hydraulic cylinder with the center of the panel face (Figure 14a). A displacement transducer (LVDT) with a maximum range of 100 mm was then positioned at the bottom of the panel, transverse to the steel beam and aligned with the cylinder axis (Figures 14b and 14c). The load was measured using a load cell with a capacity of 250 tons.

a) Load application at the center of the panel.

b) Positioning of the LVDT transducer at the bottom of the panel.

c) Positioning of the transducer on the panel axis.

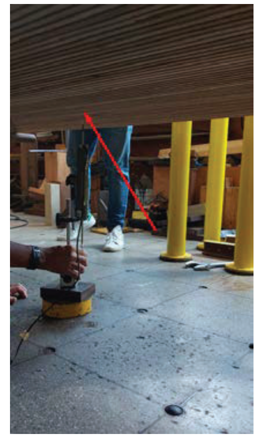

Figure 14. Details of the bending test and instrumentation.

The load was applied gradually until the limit of L/200 (where L is the free span between supports) was reached for each tested panel. Once this displacement limit was achieved, the load was relieved, and a second loading cycle was applied up to approximately 70% of the failure load. At this point, the strain gauges were removed, and the loading was continued until the panels failed. Force and displacement data were recorded using an external data acquisition system with four channels: one for force measurement and the others for displacement measurements from each transducer. Using this data, the modulus of rupture (MOR) was calculated, as shown in Equation 1:

$$MOR = \frac{P.g.L}{48.W} \tag{1}$$

Where:

MOR = modulus of rupture in bending for the tested panels (MPa);

P = force measured by the hydraulic cylinder;

g = acceleration due to gravity;

L = free span between supports of the specimen;

W = section modulus of the cross-section.

5 – RESULTS

Based on the preliminary results from the bending tests, the behavior of the panels was observed through force versus displacement data, indicating elastic behavior within a maximum deformation range of 8 mm. The

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panels with wooden nails exhibited similar behavior. The tables present the results for density (kg/m³), failure load (kgf), modulus of rupture (MPa), and modulus of elasticity (MOE). Table 1 shows the results for panels with metal nails and wooden nails.

Table 1: Results of panels with metal nails and wooden nails.

Panels	Measured properties			
	Density (kg/m³)	***Failure Load (kgf)***	***Modulus of Rupture (MPa)***	***Modulus of Elasticity (MPa)***
NLT with metal nails - 1	570.5	9327	34	8721
NLT with metal nails - 2	580.1	9081	33	9061
NLT with wooden nails - 1	483.1	8805	32	8142
NLT with wooden nails - 2	463.8	8518	31	8.581

The modulus of rupture for Panel 1 of NLT with metal nails was 34 MPa, and for Panel 2, it was 33 MPa. For NLT with wooden nails, the modulus of rupture for Panel 1 was 32 MPa and for Panel 2, it was 31 MPa. Failure occurred due to tension in the lower fibers for all panels.

Comparing the results between NLT panels with different fastening materials, it was observed that the failure resistance with wooden nails was 7% lower. However, this reduction still justifies the replacement of metal nails with wooden nails, as it was not significant. Additionally, the fastening provided by wooden nails allows for panel cutting during installation. Nevertheless, the cost of wooden nails is higher than that of metal nails, indicating that this solution is not viable for developing a product competitive with hybrid structured panels.

Table 2 presents the results for the hybrid structured panel, which served as the benchmark for evaluating the performance of the other panels, such as NLT with cementitious board and the Glued-Laminated Mixed Panel (GLMP).

Table 2: Results of the hybrid structured panel and NLT with cementitious board.

Panels	Measured properties			
	Density (kg/m³)	***Failure Load(kgf)***	***Modulus of Rupture (MPa)***	***Modulus of Elasticity (MPa)***
Hybrid structured panel - 1	774.4	1052	16	8888
Hybrid structured panel - 2	766.7	1053	16	9644
NLT with cementitious board - 1	645.6	3889	36	7428
NLT with cementitious board - 2	677.1	3833	47	12156

The failure load for the NLT panels with cementitious board was 36 MPa (Panel 1) and 47 MPa (Panel 2). The predominant failure mode for these panels was tension in the lower fibers of the eucalyptus laminates (Figure 15).

Figure 15. Panel failure due to tension in the lower fibers of the wood laminates.

The hybrid structured panel exhibited a modulus of rupture of 16 MPa. It was observed that the failure load of the NLT panels was three times higher than that of the hybrid structured panel, demonstrating the capacity of engineered wood to meet similar or even superior structural demands. Figure 16 shows the predominant failure in the panel, characterized by tension in the lower part accompanied by detachment of the cementitious board.

Figure 16. Failure of the hybrid structured panel.

The superior performance of the NLT panels demonstrated their potential to compete with hybrid structured panels. However, they did not meet the financial parameters of the latter. Nevertheless, the results indicated the possibility of reducing the thickness to align with the configurations of the hybrid structured panel. Therefore, the bending behavior of the Glued-Laminated Mixed Panel (GLMP) was tested, and the results are presented in Table 3.

Table 3: Results of the Glued-Laminated Mixed Panel (GLMP)

Panels	Measured properties			
	Density (kg/m³)	*Failure Load (kgf)*	*Modulus of Rupture (MPa)*	*Modulus of Elasticity (MPa)*
GLMP - 1	617.0	958	22	5158
GLMP - 2	586.9	1240	25	4772

The average modulus of rupture for the PMLC panels was 23.5 MPa, representing a 46.8% increase compared to the hybrid structured panel (16 MPa). This demonstrates that the laminated panel achieved higher strength with the same configurations and added aesthetic value, making it a competitive product capable of meeting the market demands for which it is intended. The Figure 17 displays the sample of the product proposed by this study.

Figura 17. Sample of the GLMP (Glued-Laminated Mixed Panel).

6 – CONCLUSION

The proposed product developed in this study aimed to achieve physical and mechanical characteristics equivalent to those of the hybrid structured panel (wall panel), while offering high aesthetic value and financial competitiveness. This would enable larger-scale timber construction projects, expanding and optimizing the use of wood. Based on the results obtained and the product configurations achieved, it can be concluded that the proposed product performed within the parameters of the hybrid structured panel currently available in Brazil, making it competitive. In other words, it was possible to develop a financially viable product with added architectural and aesthetic value, thereby promoting the use of wood in construction.

7 – REFERENCES

[1] L., Zheng; F., Wei; H., Minjuan; C., Fei; S., Xiaofeng. “Bending performance of nail laminated timber: experimental, analytical and numerical analyses”. In: Construction and Building Materials, v. 389, p. 131766, (2023). Elsevier BV. http://dx.doi.org/10.1016/j.conbuildmat.2023.131766.

[2] R., Mehdi; O., Philip. “The embodied carbon of mass timber and concrete buildings in Australia: an uncertainty analysis”. Building and Environment, [S.L.], v. 214, p. 108944, abr. 2022. Elsevier BV. http://dx.doi.org/10.1016/j.buildenv.2022.108944.

[3] S., Maryam; L., William; R., Adam. “Effects of moisture ingress and egress on the performance and service life of mass timber products in buildings: a review”. Construction and Building Materials, [S.L.], v. 290, p. 123176, jul. 2021. Elsevier BV. http://dx.doi.org/10.1016/j.conbuildmat.2021.123176.

[4] H., Rebecca; Perkins+Will; L, Tanya; Fast+Epp; D., Carla. (2017) “Nail Laminated Timber: u.s. design & construction guide” v 1.0. Binational Softwood Lumber Council. EUA. 142 p.

[5] W., Think. T3: Timber, Transit, Technology. Disponível em: https://www.thinkwood.com/construction-projects/t3-timber-transit-technology. Acesso em: 18 ago. 2024.

[6] C. M. P., Marcos. “Methodology for studying the structural characterization of Cross-Laminated Timber panels”. Advisor: Prof. Dr. Carlito Calil Junior. 2015. Thesis (Master's in Sciences and Materials Engineering) – São Carlos School of Engineering, São Carlos, 2015. Available at: https://www.teses.usp.br/teses/disponiveis/18/18158/tde-07052015-084252/publico/Dissertacao.pdf.

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