UNIVERSITY of SOPRON

11th Hardwood Conference

30-31 May 2024
Sopron

11TH HARDWOOD CONFERENCE PROCEEDINGS

Róbert Németh, Christian Hansmann, Holger Militz, Miklós Bak, Mátyás Báder

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Editors: Róbert Németh, Christian Hansmann, Holger Militz,
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Developing Laminated Strand Lumber (LSL) based on underutilized Hungarian wood species

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ABSTRACT

The demand for wood-based construction materials is increasing, and the current supply of softwood from Austria and Germany is likely to run out in the coming years. At the current rate of production, the supply of traditionally used softwood raw materials is unsustainable. In addition, the warming climate is making it more difficult to grow Softwood species such as pines, which are one of the most important raw materials for the wood industry. As a result, there is a need to find alternative tree species that can adapt to the changing climate, and whose technical properties are suitable for use in construction. One potential source of alternative wood is hardwood species from the Carpathian Basin. This study, which is the part of the ERDOLAB (Forest Lab) research project, aims to develop Laminated Strand Lumber (LSL) from underutilized Hungarian hardwood species for use in the construction industry. Several LSL panels were manufactured using poplar strands and MDI adhesive, with dimensions 340x340x35 mm, and 600 to 650 kg/m3 in density. Tests included bending and internal bond strength, as well as water absorption and thickness swelling.

Test results show that the experimental LSL meets most of the requirements of the standard for structural building materials, with the exception of tensile strength perpendicular to the plane, which is slightly lower than the required standard. However, all other properties of LSL meet or exceed the requirements of the standard. Therefore, LSL can be considered a suitable material for structural applications with the exception of applications where high tensile strength perpendicular to the plane is required.

INTRODUCTION

In recent years, there has been a growing interest in eco-friendly and long-lasting alternatives to conventional lumber, growing demand for large-section wood is straining traditional resources, and climate change threatens long-term viability. Traditionally, engineered wood products like LVL (Laminated Veneer Lumber) relied on softwoods like Scots pine Aro et al. (2017). However, there's increasing interest in exploring hardwoods for LVL production as well. Understanding the properties of different wood species is crucial to fully unlocking LSL's potential.

One such option is laminated strand lumber (LSL), a composite material made by bonding wood strands with adhesives. LSL's high strength-to-weight ratio and use of renewable resources make it a promising substitute.

Notably, a project at the University of Sopron in Hungary is currently investigating "The Role of Forest-Based Bioeconomy in Climate Change Mitigation through Carbon Storage and Material Substitution" European Commission (2021). This project aligns with the ongoing effort to discover innovative methods of reducing the greenhouse effect in the environment. LSL is a significant area of investigation within this project, as researchers explore ways to safeguard the environment by substituting conventional non-biodegradable structural materials with sustainable options.

LSL (Laminated Strand Lumber) is generally considered an advancement of OSB (Oriented Strand Board). However, LSL strands are differentiated by their length, measuring 12 inches (304.8 mm), which is significantly longer than those used in OSB production. Unlike OSB, LSL typically lacks distinct "hourglass" shapes or staining, making it a preferable choice for structural framing applications. When compared to PSL (Parallel Strand Lumber), glulam (glued laminated timber), and LVL (Laminated Veneer Lumber), LSL exhibits lower shear strength. This characteristic makes it more suitable for use in shorter framed structures SFS Group USA (2023).

Due to its exceptional strength, durability, and affordability, Laminated Strand Lumber (LSL) has emerged as a highly promising product, rapidly gaining popularity within the construction industry. LSL is manufactured by compressing thin strips of wood with a resin binder, resulting in the formation of a sturdy lumber with substantial thickness Liu, J., et al. (2008). This manufacturing process yields a consistently robust and uniform material, making it ideal for a wide range of building applications such as framing, beams, and columns Asdrubali, F., et al. (2017).

In Hungary, several hardwood species hold promise for laminated strand lumber (LSL) manufacture due to their desirable mechanical attributes. These species include Turkey oak, hornbeam, beech, and domestic poplars. Their advantages lie in high stiffness, strength, and dimensional stability in Hungary and other European countries Monlar Sandor (2002). This accessibility makes them a sustainable and cost-effective option for LSL production.

LSL offers several advantages over traditional hardwoods like Hungarian Turkey oak, hornbeam, beech, and even domestic poplars. Due to its consistent reliability, longevity, and performance, LSL emerges as a compelling choice for numerous construction applications.

Research has shown promising results for the mechanical, physical, thermal, and morphological properties of LSL derived from various hardwood species. This suggests that LSL has the potential to cater to the demands of diverse industries, including construction, furniture, and packaging.

Furthermore, manufacturing LSL from domestically available hardwoods could contribute to sustainable forest management practices and reduce reliance on imported wood. However, further research is necessary to fully understand the qualities of LSL made from these specific wood types and to optimize the manufacturing process.

Emphasizes LSL's potential as a sustainable and versatile resource for the timber sector and highlights the potential for economic and environmental benefits using locally sourced timber species. Hasan, KM Faridul, et al. (2023).

The study proposes a sustainable solution: Laminated Strand Lumber (LSL) made from domestic poplar trees in Hungary. While poplar itself isn't suitable for construction, LSL production can transform this abundant resource into a high-value composite lumber with properties comparable to conventional lumber. This research investigates the methodology for creating poplar-based LSL using various glue densities and assesses its potential as a sustainable alternative to traditional lumber sources.

MATERIALS AND METHODS

Materials and methods for fabricating and evaluating laminated strand lumber (LSL) panels using a combination of poplar and Scots pine strands. The primary objective is to optimize pressing parameters for LSL production using a laboratory press. This involves developing a process for creating LSL panels from pre-dried domestic wood strands with the goal of achieving optimal pressing parameters. The focus lies on establishing a method for LSL production that relies entirely on readily available domestic materials, promoting resource efficiency and potentially reducing reliance on imports.

Materials:

Strands: average dimension 120 x 30 mm, moisture content 4-5%, dominated by poplar with some Scots pine and PMDI resin and paraffin emulsion (obtained from Swiss-Krono, Vásárosnamény Hungary Kft.)**.**

Caul plates: Metal plates for even pressure distribution during pressing. Spacer rods: 30 mm thick metal rods to control panel thickness.

Process:

The process consisted of several key steps:

Strand Measurement and Mixing: Strands were measured for targeted density and then weighed.

Resin and paraffin emulsion were mixed in a lab blender while the strands were continuously agitated. To compensate for potential adhesive loss, slightly more resin (10% extra) was used.

Layup Formation: Resin-coated strands were spread in a 40x40 cm box, ensuring their long axis aligned in one direction. The forming box was then removed, a second caul plate placed on top, and the entire layup transferred to the preheated press (figure 1).

Hot Pressing: A three-stage pressing cycle (figure 2) with gradually decreasing pressure was applied to ensure uniform bonding throughout the panel.

Figure 1: LSL panel formation and the produced panel

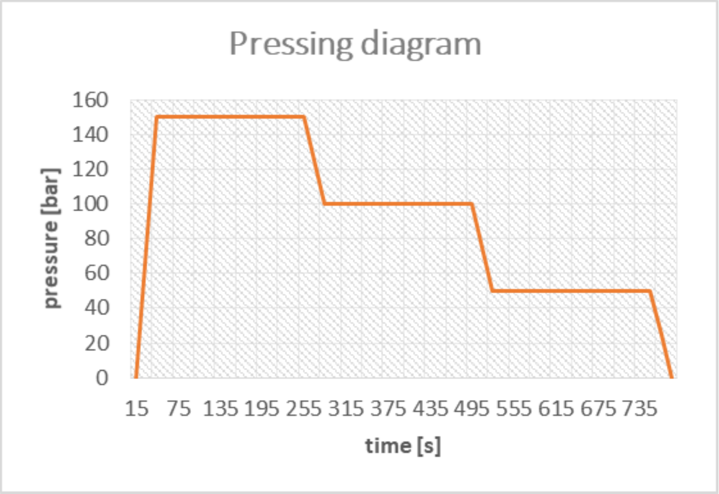


Figure 2: Pressing diagram

After establishing the appropriate pressing time, first the resin content, then the panel density was optimised. This included creating six experimental panels, as shown in Table 1.

Table 1:

Pressing parameters	LSL Panels							
	A	B	C	D	E	F	R1	R2
Temperature (°C)	200	200	200	200	200	200	200	200
Resin content (%)	2.9	3.4	3.9	3.4	3.4	3.4	3.4	3.4
Paraffin content (%)	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Tartget density (kg/m3)	600	600	600	500	550	650	600	600
Total pressing time (s)	750	750	750	750	750	750	900	900
t1 (s)	250	250	250	250	250	250	180	180
t2 (s)	250	250	250	250	250	250	180	180
t3 (s)	250	250	250	250	250	250	540	540

Cooling and Sample Preparation: After pressing, the panels cooled and trimmed to a standard size (340x340 mm) and machined into test specimens according to specific dimensions (Figure 3) for tensile strength, water absorption, and swelling tests (50x50 mm) and bending strength tests (320x15 mm).
Evaluate Specimen Conditioning: The prepared samples were conditioned at 65% relative humidity and 20°C for 72 hours before testing.

Testing Standards

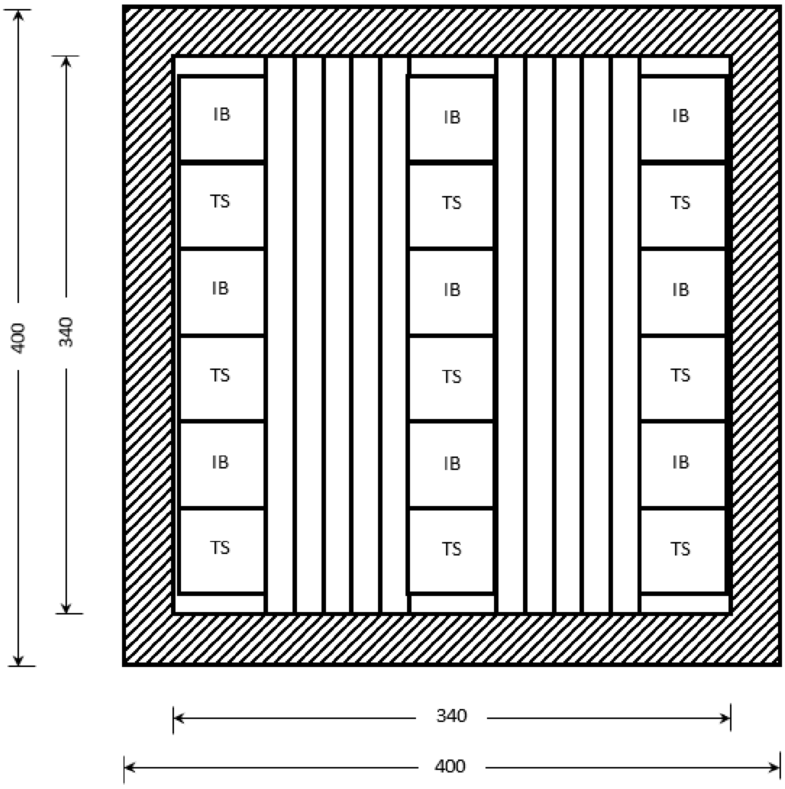
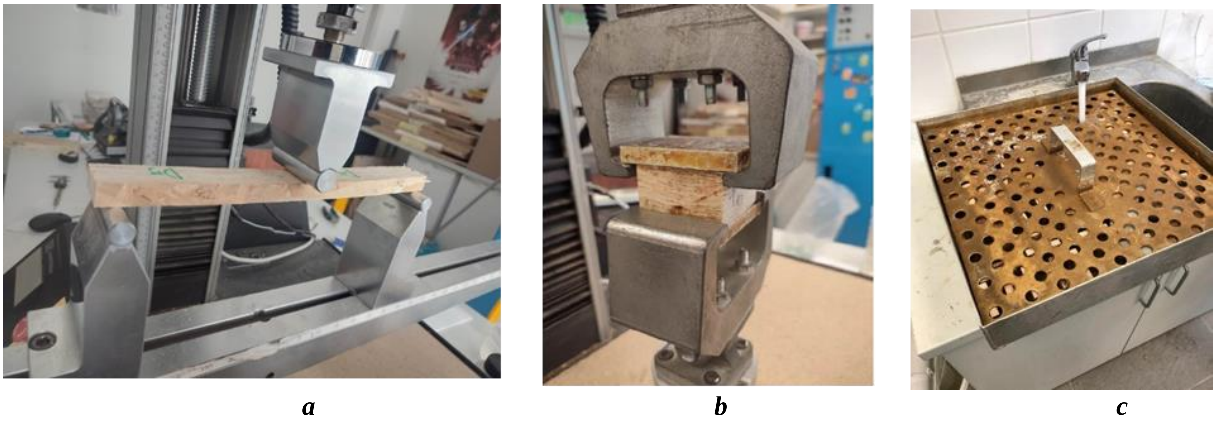


Figure 3: Cutting pattern for the Bending (long vertical strips), Internal Bond (IB) and Thickness Swelling (TS) specimens produced from the 400 x 400 mm panels

Due to a lack of specific LSL standards, testing methods followed MSZ EN standards for load-bearing wood panels suitable for dry environments (MSZ EN 310, MSZ EN 317, MSZ EN 319). An INSTRON 5566 machine used for material testing according to MSZ EN 325 specifications for wood-based panel test specimen dimensions.

Panel evaluation included measuring the bending strength (MOR) according to MSZ EN 310, Internal Bond strength (IB) according the MSZ EN 319, and water absorption/thickness swelling according to MSZ EN 317 (see Figure 4). Density also measured using the bending specimens after failure, by measuring the weight and calculating the volume based on specimen size.



a *b* *c*

Figure 4: Bending (a), Internal Bond (b) and Thickness Swelling/Water absorption (c) tests

RESULTS AND DISCUSSION

Board Strength: A positive correlation observed between board strength and both adhesive content and density. The highest MOR values achieved with a target density of 600 kg/m³ and an adhesive content of 3.4%. However, the internal bond (IB) strength remained relatively low at this level (0.16 N/mm² on average). Therefore, a target density of 650 kg/m³ was determined to be a safer option for further testing.

Moisture Resistance: Thickness swelling decreased with increasing adhesive content and surprisingly, also with increasing density. Conversely, water absorption tended to increase with both higher adhesive content and density.

Replication Experiments: The results from the replicated experiments (panels R1 & R2) were generally consistent with those of the original panel (panel F). There were slight variations: MOR values were slightly lower, while IB strength was higher in the replicated panels. Thickness swelling and water absorption were also comparable, except for panel R2, which exhibited significantly lower thickness swelling compared to panels F and R1.

Pressing Time: The replicated panels utilized a longer pressing time compared to the original panel. There were no significant improvements in panel properties observed with the increased pressing time, suggesting that the original pressing time (750 seconds) is sufficient.

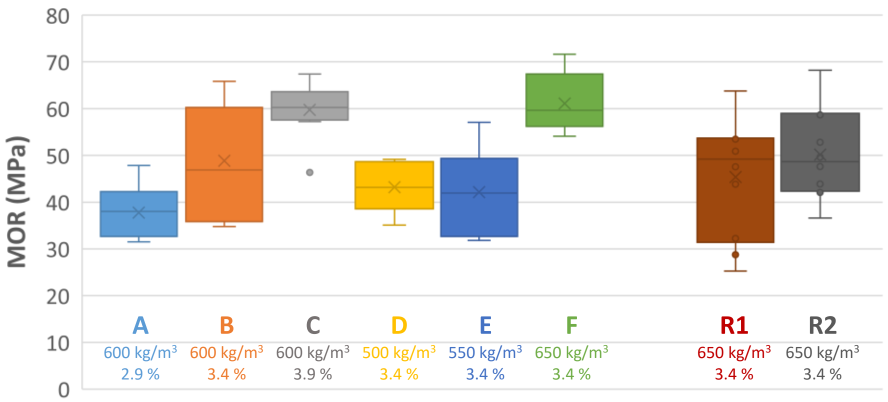


Figure 5: show the results of the MOR for all measured panels

Discussion

The target density of 650 kg/m³ (with actual densities ranging from 650 to 750 kg/m³ or higher) and an adhesive content of 3.4% identified as the most promising combination for further experimentation. However, achieving consistent density distribution throughout the panels proved challenging due to limitations of the small-scale laboratory layup process.

Industrial production methods expected to yield better results, potentially allowing for successful utilization of lower density panels.

The average Modulus of Rupture (MOR) of panels F, R1, and R2 (around 52 N/mm²) surpasses the minimum requirement for C24 solid wood structural lumber (the most common grade in Hungary). This indicates that the LSL material even at this early stage demonstrates promising qualities. Furthermore, LSL expected to outperform solid wood by an even greater margin, potentially reaching characteristic strength values as high as 40 N/mm².

The high standard deviation (11.7 N/mm²) observed in the MOR values is attributable to the challenges of maintaining consistent horizontal density distribution and strand orientation within the panels in a small-scale laboratory setting.

Industrial production anticipated to produce panels with similar average strength but with lower variation, leading to higher characteristic strength values.

CONCLUSIONS

The preliminary experiments demonstrate that panels manufactured with the established parameters for panel F (target density of 650 kg/m3 and total pressing time of 750 seconds, detailed in Table 1) exhibit very good average values for Modulus of Rupture (MOR), Internal Bond (IB) strength, Thickness Swelling, and Water Absorption. These results indicate the promising potential of poplar LSL for use in Hungary.

However, it is important to note that the laboratory experiments produced high variations in the results. This is likely due to limitations in controlling factors like density distribution and strand orientation within the smaller test panels.

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