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Cross-laminated timber made of Hungarian raw materials

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Cross-laminated timber made of Hungarian raw materials

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Abstract. Cross-laminated timber (CLT), generally made out of softwood, enjoys increasing popularity throughout Europe. This material offers a versatile, eco-friendly technology to create strong, lightweight and energy-efficient buildings. Unfortunately, the sites and climatic conditions in Hungary are not suitable for growing high-quality coniferous trees. Transporting raw materials from other countries (sometimes thousands of kilometres away) negates the environmental advantages of wood-based construction. Local options are definitely preferable from an ecological aspect.

Poplar wood (populus spp.) is of great economic importance in Hungary. There are several relatively high density, high strength varieties growing in large quantities in Hungary, that may be used as alternatives to softwood, with comparable properties. There is an increasing interest in using poplar as a construction material, especially in regions were there is a shortage of traditional construction timber.

This paper presents the results of a preliminary investigation to create CLT using poplar lumber. Laboratory-scale CLT specimens were created in a hot press, and tested for their loadbearing capacity. The MOR values of poplar CLT are comparable to, albeit somewhat lowerthan those of softwood CLT. Further investigations are required to establish the economic viability and technological conditions for the commercial production of poplar CLT.

1. Introduction

Lightweight residential construction is gaining in popularity all over Europe, especially due to the increasingly stringent regulations that is pushing for near-zero emission buildings. Lightframe houses are especially suitable for this purpose, due to their superior thermal insulation, and low embodied energy. In the meantime, they have been criticized because of their low heat storage capacity [1], and also regarding the potentially unhealthy living environment that may arise depending on the type of ventilation system used [2]. Solid wood wall structures (e.g. log houses) present a healthier alternative, with improved heat storage, but also pose certain technical challenges.

A new type of wood-based construction material, Cross-Laminated Timber (CLT) was first proposed in the mid-1990s in Austria. It was developed at the Graz University of Technology, Austria [3]. The basic idea behind the new material is creating a strong, dimensionally stable, solid wood material, similar to plywood in structure (i.e. composed of layers of alternating, perpendicular grain direction), but made out of lumber, rather than wood veneer. The resulting panels (typically composed of 3-9 layers, but may be as many as 17 layers) are strong, dimensionally stable, versatile, easily tailored to create any kind of wall, ceiling, or roof surfaces. They have a relatively large mass to facilitate heat storage, provide a healthy living environment if left exposed (due to wood's excellent humidity control capacity), and pleasant in appearance.

There are several facilities that produce CLT in Central-Europe. The raw material is typically coniferous lumber, with a strength grade of C16 or higher (according to EN 14081-1, [4]). Recently it also become increasingly popular in the US [5], and in Canada [6]. However, in regions without significant softwood forests (e.g. in Hungary), the production, and also the utilisation of CLT is limited or nonexistent.

Even though CLT was first developed in Europe, there is currently no European standard governing the production and requirements of CLT. A draft standard was published in 2011, but is not in effect to date. In North America, APA – the Engineered Wood Association published a standard for performance-rated CLT panels [8], which contains reference values for the required performance of CLT.

Poplar wood (Populus spp.) has relatively low density. It is typically used for manufacturing wood veneer, and various simple wood products like matches, crates, pellets, etc. Poplar's mechanical characteristics are similar to those of some coniferous species, and are, in fact, classified together with softwoods according to the European Standards [4]. There are some successful examples of using poplar in structural products like LVL [9], and even in glulam [10]. However, it has not been considered for manufacturing CLT until recently, when our study, and a parallel study by Kramer [3] both focused on this potential raw material.

The purpose of the research project described in this study was to manufacture Cross-Laminated Timber made of poplar wood, and assess its properties to compare it to softwood CLT, and to existing industrial standards.

2. Materials and methods

The raw material chosen for the experiments was a hybrid poplar (Populus × euramericana cv. 'I-214'). This poplar hybrid is very popular in Hungary, due to it relatively fast growth rate and uniform structure. The resin was a structural grade polyurethane adhesive (Jowapur 686.60).

Several 3 m long logs were obtained, and cut up in a sawmill into lumber of varying width, 45 mm in thickness. The logs were green at the time of sawmilling (63% MC). After sawmilling, the lumber was cross-cut into lengths of 2.03 m and 0.97 m, and edged using a bandsaw. After this, the lumber was kiln-dried using a gentle drying schedule for two weeks, until it reached a moisture content of 12±2 %. After drying, the lumber was left to cool and equalize for one week in an indoor climate. The dried lumber was planed down to 33 mm in thickness, and various widths.

Before creating the layup for the CLT panel, the lamellae were stress-graded nondestructively, according to the standard EN 338-2003 [11]. The measurement is based on measuring the density and the longitudinal vibration frequency of the lamellae. The measurement has been carried out by the Portable Lumber Grader equipment that has been certified for grading lumber according to the European Norm [12]. All of the lamellae were graded. Low grade long lamellae were cut up into shorter pieces to be used in the core, while higher grade material was used in the face layer. The moisture content of the lamellae was also verified using a resistance moisture meter.

After preparing the lamellae, one 3-layer CLT panel (2m×1m×0.1m) was created according to the following procedure:

- Laying out two face layers and one core layer using the lamellae. The lamellae were laid out in such a manner that any curvature was facing outwards from the centre (see figure 1).
- Clamping each layer laterally, so as to eliminate any gaps between the lamellae.
- Adhesive application by pouring the amount of resin specified in the technical guidelines of the adhesive onto the layup, and distributing it using serrated spatulas.
- Placing the layers on top of one another, and transferring the final layup into the press (while maintaining lateral clamping, see figure 2)
- Closing the press, applying 0.4 N/mm^2 pressure, for 12 hrs (no heat application.)
- Opening the press and removing the CLT panel.

After removing, the panel was cut up along its length into 3 pieces of 300 mm wide bending specimens, and tested on a large scale structural testing machine in 4-point bending, according to EN

408:2010 [13], using a video-extensometer to measure the centerpoint deflection (figure 3). Load and deflection data were recorded using a data acquisition frequency of 10/s. The beams were tested to failure, and the failure mode observed.

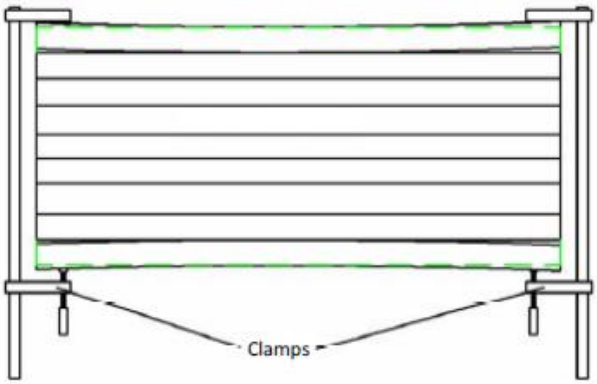

Figure 1. Laying up and clamping the lamellae so that they curve outward

Figure 2. The final layup placed in the press while maintaining lateral pressure

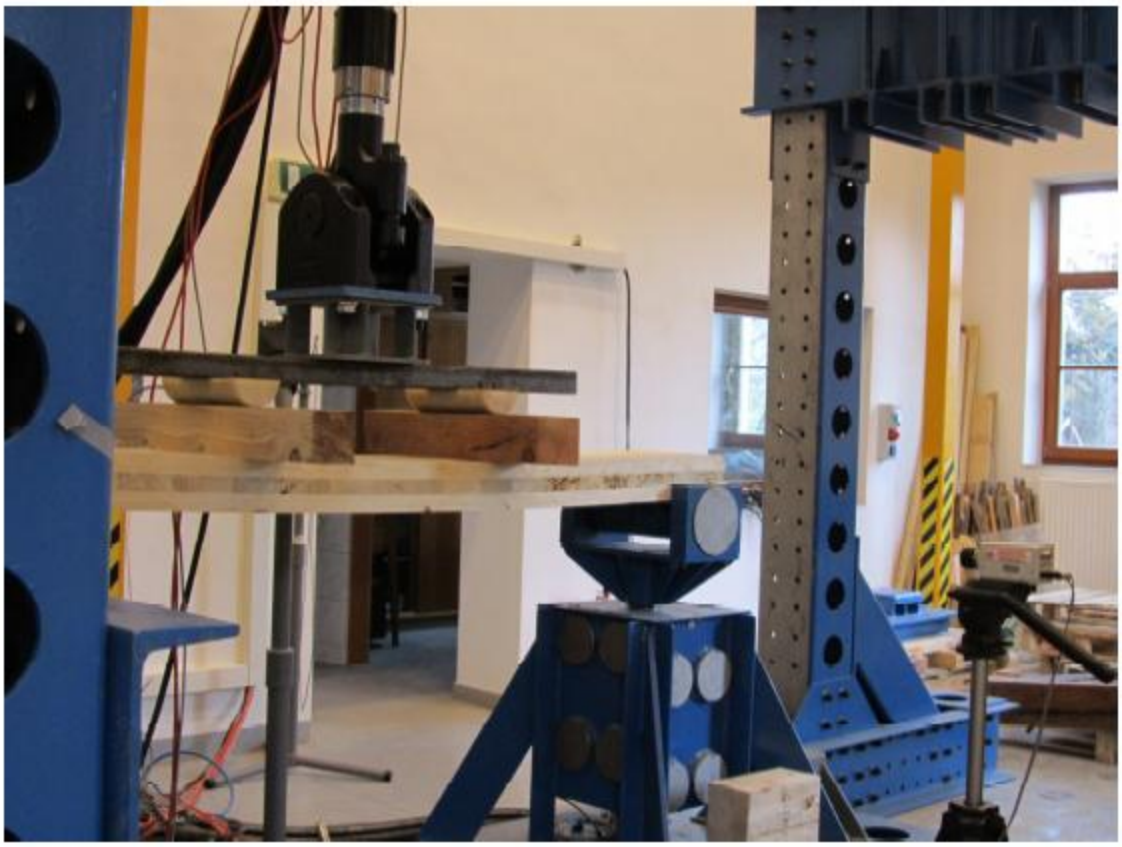

Figure 3. Testing the CLT specimen to failure using a 4-point bending setup. Deflection is measured using a video-extensometer

3. Results and discussion

Figure 4 shows the lamella strength classes determined by nondestructive testing. Generally, the strength classes were higher than expected. This allowed all of the face layers to contain lamellea of strength classes C18 or above. This is close to fulfilling the technical requirements set forth by the German Institute of Building Technology [14], which stipulates that at least 90% and 30% of the individual boards running parallel and perpendicular to the longitudinal direction of the element, respectively, shall correspond to strength class C24 or higher, and the rest should be at least C16, according to EN 338.

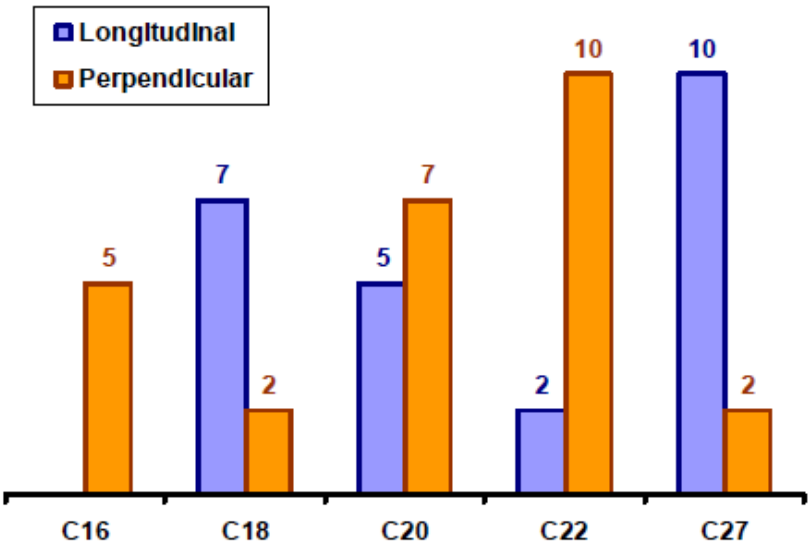

Figure 4. Non-destructively measured Strength classes of the face and core layer (longitudinal and perpendicular) poplar lamellae

Figure 5 displays the failure modes of the three tested specimens. The failure was typically a combination of bending and rolling shear, the latter usually occurring close to the glueline. Glueline failure occurring in specimen nr. 1 is probably due to the imperfection of the manual adhesive application process, which could be remedied by using industrial glue applicators. The combined failure mode is similar to that found in a parallel study [3].

Figure 5. Failure modes of the tested specimens

Table 1. Measured MOR and MOE values, and design values based on ANSI/APA PRG 320 [8]

	MOR (N/mm^2)	MOE (N/mm^2)
Specimen #1	34.0	7,552
Specimen #2	46.9	8,354
Specimen #3	48.8	7,787
Average	**43.2**	**7,898**
Design values [8]	***12.7 … 28.2***	***8,270 …11,720***

Table 1 contains the measured MOR and MOE values of the three specimens. The table also shows the design values belonging to various CLT grades, according to the American standard APA PRG 320. Our study was not extensive enough to calculate design values for poplar CLT, but if measured values are indicative of the typical MOR values to be expected of this product, poplar LVL can probably fulfill the requirements of at least the lower grade CLT. On the other hand, MOE values were markedly lower than those specified in the American standard. These findings are consistent with a parallel, larger scale study undertaken at the Oregon State University [3], which also found poplar LVL sufficiently strong, but somewhat falling behind requirements in terms of MOE.

4. Summary and conclusions

A small-scale study of the viability of poplar wood to produce Cross-Laminated Timber elements led to the following results and conclusions:

- Hybrid poplar, as a raw material, can yield lumber of sufficiently high strength grade to produce commercially viable CLT.
- The CLT specimens manufactured and tested in this study yielded relatively high bending strength values, but low MOE. These findings are consistent with a parallel study by Kramer [3].
- Despite the relatively low MOE values, poplar may be a viable raw material for CLT, either by selecting and using high-grade lumber only (through non-destructive testing), or using poplar as a mix-in species along with softwood lumber.

The above results show that poplar lumber, while not automatically suitable for this purpose has the potential to be used in CLT manufacturing, either by choosing premium grade material, or as a mix-in species, in conjunction with softwood material.

Acknowledgements

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