Chapter 63

Structural panel of lamelada wood glued crossed

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Fabricio Gomes Gonçalves
Federal University of Espírito Santo, Brazil

Yonny Martinez Lopez
Federal University of Southern and Southeastern Pará, Brazil

Izabella Luzia Silva Chaves
Federal University of Espírito Santo, Brazil

Rafael Gonçalves Espósito de Oliveira
Federal University of Espírito Santo, Brazil

Pedro Gutemberg de Alcantara Segundinho
Federal University of Espírito Santo, Brazil

Marcos César de Moraes Pereira
Amazonas National Research Institute , Brazil

1 INTRODUCTION

Engineered wood products have their commercial origin in the 19th century. Through the union of the seals with the aid of a waterproof adhesive, the system proved stronger than the lumber itself rekindling the interest in wood constructions, which declined after the period of the industrial revolution (ZMIJEWKI; WOJTOWICZ-JANKOWSKA, 2017).

For several decades, concrete has been the most used building material due to the ease of finding the materials that compose it, the simplicity of processing and transportation, as well as the possibility of being produced on site. For the first time, after a massive production of concrete in the 20th century, this material began to be considered questioned for some types of construction (DI BELLA; MITROVIC, 2020).

In recent years, traditional constructions such as modern technologies that take advantage of wood-based materials have developed. Currently industrialized wood allows to create elements of all shapes presenting high compressive and tensile strength, allowing the wooden structures to be multi-store, reaching more than six floors (ZMIJEWKI; WOJTOWICZ-JANKOWSKA, 2017; LI et al., 2019; NAVARATNAM et al., 2020).

The inherent properties of wood, such as high strength/weight ratio, durability, insulation, sustainability and availability, makes it the material that presents the best performance for structural use (PANGAVHANE; MAGARPATIL, 2020). Given the above, wood has potential for the development of manufacturing products that do not necessarily require parts of high structural classification for its manufacture (WEI et al., 2020).

Possessing an orthogonal laminar configuration, the Madeira Lamelada Colada Cruzada (MLCC) or "Cross Laminated Timber" (CLT) has become a well-known industrialized wood product being commonly applied as constituent elements of floors and walls (BRANDNER et al., 2016). Its excellent physical and mechanical properties, allowed it to be among the most interesting and innovative wood construction systems enabling the use of wood as an alternative to other systems, offering new possibilities to reduce the environmental impact caused by civil construction (DI BELLA; MITROVIC, 2020).

This structural element has received much attention in recent years due to these characteristic properties, which offers a great opportunity to use MLCC as structural elements in medium to tall buildings (LI et al., 2019; RAHMAN et al., 2020; WANG et al., 2017).

In this context, the present work aims to contribute with information about some of the characteristic principles that this product has as a way of encouraging the constructions of wood at the national level.

2 BRIEF HISTORYCO

Wood Lamelada Colada Cruzada (MLCC) is a relatively new commercially constructing system that is helping to spread and integrate the class of wood products known as engineered wood. These products aim to use the best characteristics that wood can offer in order to make products with equal or superior characteristics.

THE CLT or MLCC is a solution based on industrialized wood highly competitive to concrete, masonry and steel, being an appropriate candidate for some applications that use these materials due to records of many cases in which it exceeded the physical and mechanical properties presented by them (GAGNON et al., 2013; MOHAMMAD et al., 2012; ŻMIJEWKI; WOJTOWICZ-JANKOWSKA, 2017; PANGAVHANE; MAGARPATIL, 2020).

Initially designed and developed in Europe, it has been gaining increasing popularity in residential and non-commercial applications in several countries (GAGNON et al., 2013; Ross, ROSS, GAGNON, KEITH, 2013). Its technology had its initial development primarily in Germany, Austria and Switzerland. Currently can be found in the hundreds of PROJECTS in MLCC throughout Uropa and North America (CHERRY et al., 2019; DAVIDS et al., 2017; DI BELLA; MITROVIC, 2020; GAGNON et al., 2013; LI et al., 2019; MOHAMMAD et al., 2012; RAHMAN et al., 2020; ZMIJEWKI; WOJTOWICZ-JANKOWSKA, 2017).

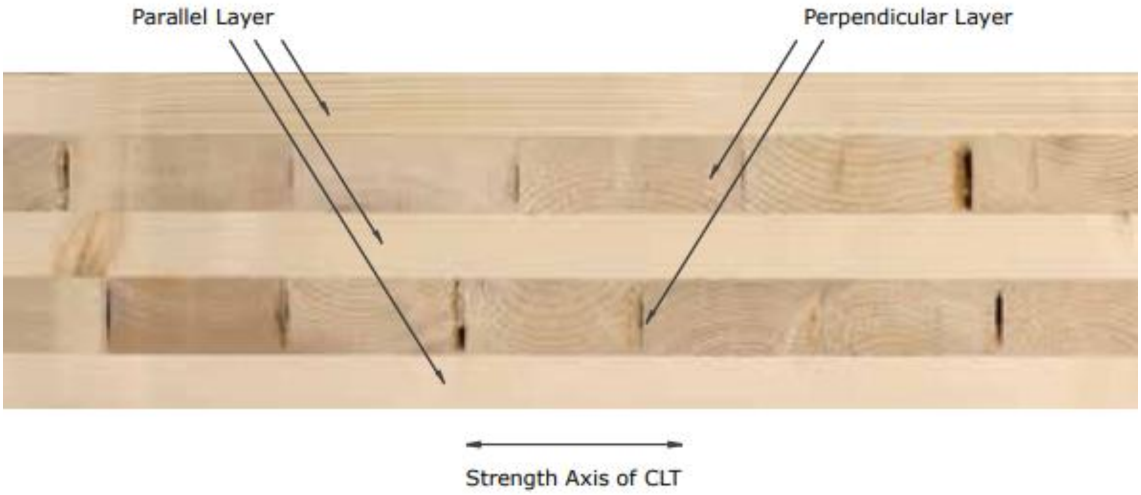
Thus, the experience of countries in North America and the European continent has shown that construction in MLCC can be competitive, being easy to handle during construction and having a high level of prefabrication. In addition to these advantages, the CONSTRUCTION SYSTEM based on MLCC facilitates the rapid completion of the project, thus showing the many advantages that this product has to offer the construction sector (DI BELLA; MITROVIC, 2020; GAGNON et al., 2013; LI et al., 2019; MOHAMMAD et al., 2012).

3 DEFINITION OF CROSS GLUED LAMED WOOD (MLCC)

Cross-glued lamellate wood (MLCC) can be defined as a prefabricated solid wood product. Its mounting configuration makes it possible to obtain a solid, straight and flat rectangular structural element, intended for roof, floor or wall applications. This arrangement confers high strength, stiffness and dimensional stability (Figure 1) (YEH; KRETSCHMANN; WANG, 2013; ZMIJEWKI; WOJTOWICZ-JANKOWSKA, 2017).

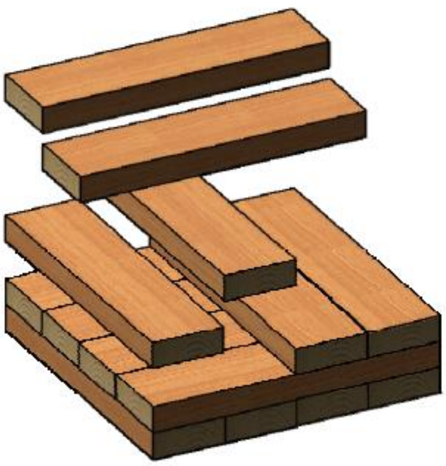
MLCC panels consist of several stacked layers composed of wood-oriented lamelas typically with 90-degree angulation and glued to their wider faces with adhesive for use in structural elements. Sometimes, in addition to gluing, nails or wooden pegs can be used to join the layers (GAGNON et al., 2013; MOHAMMAD et al., 2012; NAVARATNAM et al., 2020; RAHMAN et al., 2020; WANG; GONG, CHUI, 2015).

Figure 1- Cross section of a 5-layer MLCC panel. Source: Yeh, Kretschmann and Wang (2013).



MLCC panels are usually manufactured with a number of odd layers, with the thickness of the blades ranging from 16 mm to 51 mm and the width ranging from 60 mm to 240 mm. (GAGNON et al., 2013; MOHAMMAD et al., 2012; YEH; KRETSCHMANN; WANG, 2013). Figure 2 illustrates the assembly configuration of the MLCC panel (MOHAMMAD et al., 2012).

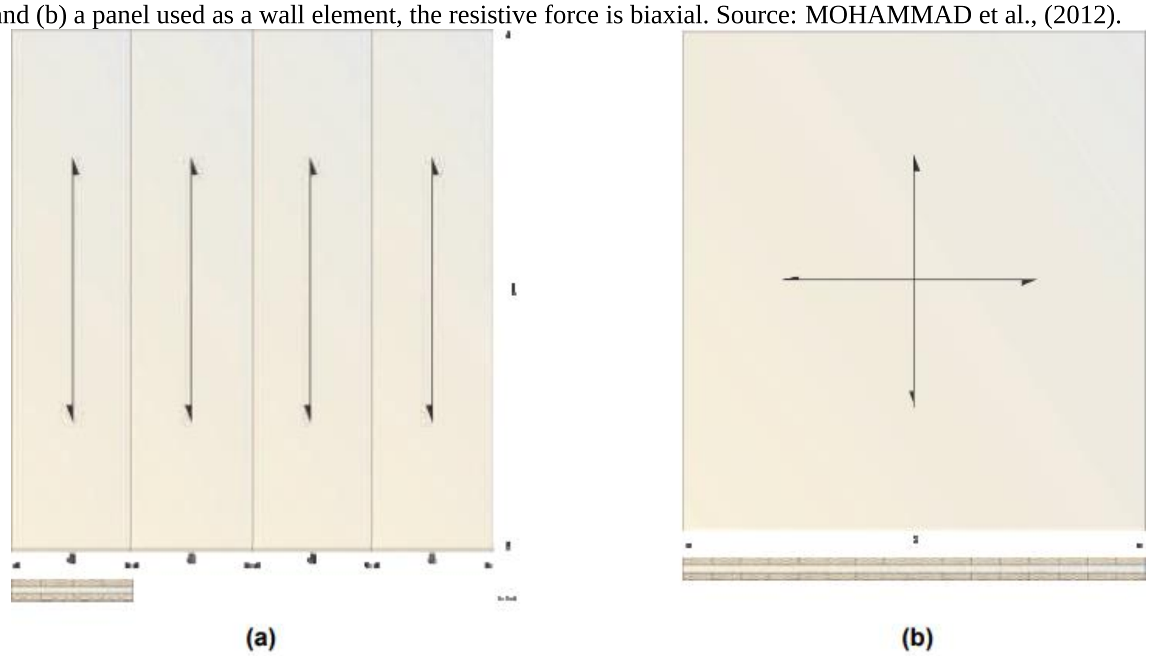
Figure 2 - Mlcc panel mounting configuration. Source: MOHAMMAD et al. (2012).



When used as a floor element, the panels have a unidirectional characteristic because despite the orthogonalityof the water that composes it, the anatomical elements of these pieces are oriented in the direction perpendicular to the force that acts on it (Figure 3a).

When used as a wall element thel amelas positioned in the vertical direction, usually those that make up the outside of the panel, are subjected to the compression effort parallel to the fibers, while the blades positioned in the horizontal direction are being subjected to the effort the compression perpendicular to the fibers, in this layout the panel has bidirectional characteristic (Figure 3b) (GAGNON et al., 2013; MOHAMMAD et al., 2012; NAVARATNAM et al., 2020; RAHMAN et al., 2020).

Figure 3 - Action of the resistive forces of the MLCC panel, in which (a) is a panel used as a floor element, the resistive force is uniaxial and (b) a panel used as a wall element, the resistive force is biaxial. Source: MOHAMMAD et al., (2012).



4 MAIN ADVANTAGES OF CROSS-GLUED LAMELADA WOOD

The cross-lamination process improves dimensional stability to the product, increasing its strength and stiffness properties in both directions, giving these panels a bidirectional action capability and allowing the achievement of a product with homogeneous properties (DI BELLA; JU et al, 2019; MITROVIC, 2020; GAGNON et al., 2013; MOHAMMAD et al., 2012).

In addition to the characteristics appropriately cited, mlcc has the advantages of high prefabrication rate, convenient transportation, fast installation and low damage to the environment of the place where it is being inserted (DI BELLA; MITROVIC, 2020; LI et al., 2019).

MLCC panels also play an important role in the economy when wood pieces from various sustainable sources are used for their production. The new standard of the Brazilian Association of Technical Standards, ABNT, NBR 7190 of 2022 does not allow the use of wood from demolition, even if it meant a correct destination for the parts. Another relevant factor is the low primary energy consumption that require wood-based constructions. In this way, the construction system also adapts to the principles of sustainability, ensuring the use of a renewable resource (DI BELLA; MITROVIC, 2020).

Because wood is a combustible material, one of the biggest challenges of civil construction is fire safety. However in MLCC panels carbonization occurs slowly and controlledly allowing the panels to maintain good structural behavior for a long time, presenting great potential for fire resistance. An additional extension of the resistance time is possible by increasing the thickness of the panel, as well as using non-combustible seabed solutions (DI BELLA; MITROVIC, 2020).

Thus, the excellent characteristics presented by the MLCC have motivated the search for the classification of several wood species, aimed at using them in the manufacture of this element (GONG et al., 2019).

5 MANUFACTURING PROCESS

The mlcc panel manufacturing process can be described in nine steps (Figure 4): sawn wood selection, wood grouping, lumber planing, reduction of parts for the desired bonding dimensions, adhesive application, MLCC panel configuration, mounting for pressing, machining, marking, packaging and product shipping. Each step can include several substeps (GAGNON et al., 2013; MOHAMMAD et al., 2012; YEH; KRETSCHMANN; WANG, 2013).

The steps can be divided into two phases. The first phase consists in the preparation and treatment of the raw material. In this step the gills that will make up the panel submitted to the drying process in chambers at a relative humidity of 12 ± 2%, later begins the visual or mechanical classification (VILELA, 2020).

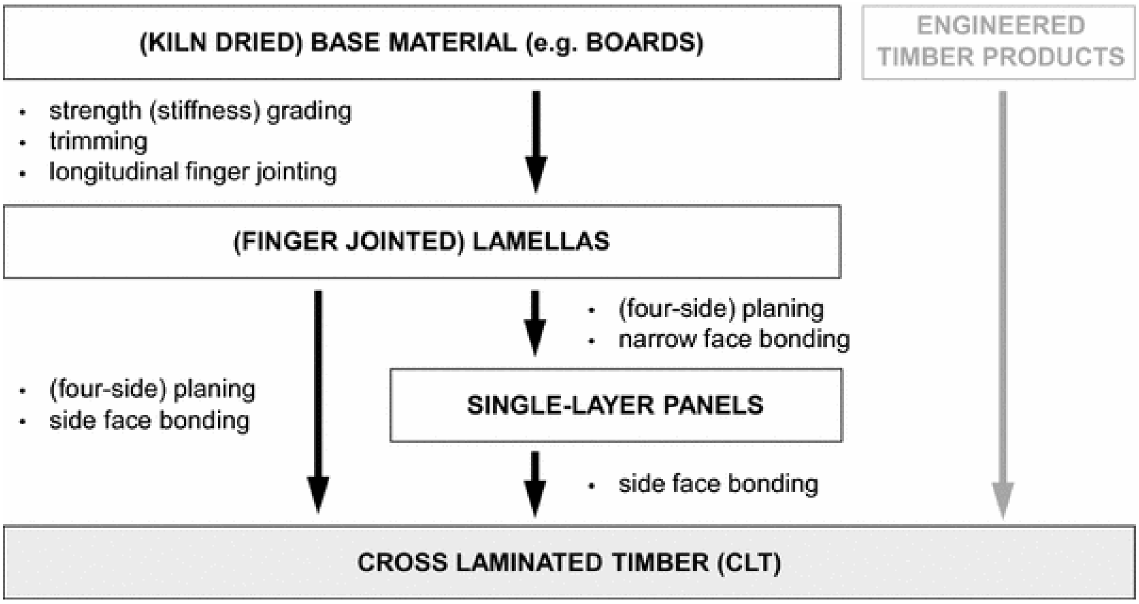
To avoid the use of woods with different mechanical and physical properties, classification patterns require that the same wood species or combinations of species that hold similarity in their properties be used within the same layer of the MLCC panel, while allowing adjacent layers of MLCC to be made of different species or combinations of species (YEH; KRETSCHMANN; WANG, 2013).

However, the saddlesthat have low mechanical resistance or undesirable anatomical characteristic are removed in the classification stage ensuring the homogeneity of the physical and mechanical properties of the parts used (VILELA, 2020).

After the treatment and preparation phase of theamelas, the assembly phase of the panels begins. For this purpose, adhesive is applied for use in structural elements on one of the widest faces of the lamelas layer. Then another layer of lamelas is positioned transversely. This repeats alternately until the desired number of layers to make up the panel is reached. (GAGNON et al., 2013; YEH; KRETSCHMANN; WANG, 2013; VELELA, 2020).

After the assembly of the layers, they are subjected to the pressing process to ensure greater support between the adhesive and the adherent. After curing the adhesive, the MLCC receives the final finish depending on the design

Figure 4 - Processo of manufacture of the MLCC panel - Overview. Source: BRANDNER et al. (2016).



The key to a successful MLCC manufacturing process depends on the control of parameters that can affect the quality and performance of the product, one of these parameters consists in the correct choice of adhesive, and polyurethane, melamine, isocyadate and phenolic base are commonly used (GAGNON et al., 2013; YEH; KRETSCHMANN; WANG, 2013).

6 MLCC IN CONSTRUCTION

Because it is an industrialized product , mlcc allows high precision in the manufacturing process. The panels are prefabricated and transported to the construction site where they are connected by means of fastening systems such as screws and nails developed especially for these types of elements, such as those presented by the company Rothoblass (https://www.rothoblaas.pt). Thus, the process is characterized by rapid completion at the construction site, greater safety, less demand for workers on site, and less waste (GAGNON et al., 2013).

MLCC panels are typically used as load-carrying plate elements in structural systems such as walls, floors, and roofs. When used as floor and/or roof elements, the main mechanical characteristics of the panel that should be taken into account are: bending resistance, shear strength, compressive strength perpendicular to the fibers. In the case of being used as wall components, they must present satisfactory mechanical resistance to bending, shear and parallel compression efforts (GAGNON et al., 2013; MOHAMMAD et al., 2012; NAVARATNAM et al., 2020).

7 MLCC APPLICATIONS

This item dealswith the presentation of images of some works that have the MLCC panel in its structure. Figure 5 illustrates a single-family home in Rykkinn, Norway.

Figure 5 - Single-family house in Rykkinn, Norway. Source: GAGNON et al. (2013).

Figure 6 shows asingle-family c-wings in Klagenfurt, Austria.

Figure 6 - Csingle-family wings in Klagenfurt, Austria. Source: GAGNON et al. (2013).

Figure 7 shows a country house in Québec, Canada.

Figure 7 - Country house in Québec, Canada. Source: GAGNON et al. (2013).

In the work of Gagnon et al. (2013) it is possible to visualize other constructions that used the characteristics of this element to employ it in its structure.

8 FINAL CONSIDERATIONS

Engineered wood products have aroused interest in wood constructions due to the excellent physical and mechanical properties they providein terms of structural safety.

Among the engineered products of wood, mlcc as a structural element has had a lot of diffusion. Because it is an industrialized product, manufacturing allows the removal of undesirable defects that wood naturally presents.

The lamelar configuration allows the achievement of a solid rectangular structural element, presenting high strength, rigidity and dimensional stability, suitable to be used as structural components of floors and walls, being a potential competitor to steel and concrete. In the applicationof thelgumas constructions that use these materials there are records of many cases in which the MLCC exceeded the physical and mechanical properties presented by them.

In Brazil, the constructions in MLCC are in the initial stage of development and with immense difficulties to grow even though it is believed to have a considerable market potential in the country. Companies that have mlcc in their production line generally use timber of coniferous species in the same way as countries of the European continent and North America, in which the most frequent use of manufacture of these panels is made with coniferous species. In 2022, after the last version of 1997, Norma Brasilieita de de de estruturas de madeira was revised and published by ABNT, whose current standardization includes normative instructions that enable projects in Lamelada Colada Cruzada (MLCC) wood known in the English language as Cross Laminated Timber (CLT).

REFERENCES

BRANDNER, R.; FLATSCHER, G.; RINGHOFER, A.; SCHICKHOFER, G.; THIEL, A. Cross laminated timber (CLT): overview and development. **European Journal of Wood and Wood Products**, v. 74, p. 331-351, 2016.

CHERRY, R.; MANALO, A.; KARUNASENA, W.; STRINGER, G. Out-of-grade sawn pine: A state-of-the-art review on challenges and new opportunities in cross laminated timber (CLT). **Construction and Building Materials**, v. 211, p. 858-868, 2019.

DAVIDS, W. G.; WILLEY, N.; ANIDO, R. L.; SHALER, S.; GARDNER, D.; EDGAR, R.; TAJVIDI, M. Structural performance of hybrid SPFs-LSL cross-laminated timber panels. **Construction and Building Materials**, v. 149, p. 156-163, 2017.

DI BELLA, A.; MITROVIC, M. Acoustic characteristics of cross-laminated timber systems. **Sustainability**, v. 12, 5612, 2020.

GAGNON, S.; BILEK, E. M.; PODESTO, L.; CRESPELL, P. Introduction to cross-laminated timber. **In:** CLT Handbook: cross-laminated timber. Chapter 1. Co-published by U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Binational Softwood Lumber Council (BSLC), 572p., 2013.

GONG, Y.; LIU, F.; TIAN, Z.; WU, G.; REN, H.; GUAN, C. Evaluation of Mechanical properties of cross-laminated timber with different lay-ups using Japanese larch. **Journal of Renewable Materials**, v. 7, n. 10, p. 941-956, 2019.

JU, Z.; HE, Q.; ZHANG, H.; ZHAN, T.; HONG, L.; LIN, Y.; LU, X. Calculation of sound insulation for hybrid CLT fabricated with lumber and LVL and comparison with experimental data. **MATEC Web of Conferences**, v. 275, 2019.

LI, H.; WANG, B. J.; WEI, P.; WANG, L. Cross-laminated timber (CLT) in China: A state-of-the-Art. **Journal of Bioresources and Bioproducts**, v. 4, n. 1, p. 22-30, 2019.

MOHAMMAD, M.; GAGNON, S., DOUGLAS, B. K.; PODESTO, L. Introduction to cross-laminated timber. **Wood Design Focus**, v. 22, p. 3-12, 2012.

NAVARATNAM, S.; NGO, T.; CHRISTOPHER, P.; LINFORTH, S. The use of digital image correlation for identifying failure characteristics of cross-laminated timber under transverse loading. **Measurement**, v. 154, p. 2020.

PANGAVHANE, S. A.; MAGARPATIL, H. R. Dynamic performance of tall mass-timber buildings. **Journal of Engineering Sciences**, v. 11, p. 242- 253, 2020.

RAHMAN, M. T.; ASHRAF, M.; GHABRAIE, K.; SUBHANI, M. Evaluating timoshenko method for analyzing CLT under out-of-plane loading. **Buildings**, v. 10, 184, 2020.

ROSS, L. A.; GAGNON, S.; KEITH, E. Structural design of cross-laminated timber elements. In: **CLT Handbook**: cross-laminated timber. Chapter 3. Co-published by U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Binational Softwood Lumber Council (BSLC), 572p., 2013.

VILELA, R. **Desempenho estrutural de placas de cross laminated timber submetidas à flexão**. 2020. 249f. Dissertação (Mestrado em Engenharia Civil), Universidade Estadual de Campinas, Campinas, SP, 2020.

WANG, Z.; FU, H.; GONG, M.; LUO, J.; DONG, W.; WANG, T.; CHUI, Y. H. Planar shear and bending properties of hybrid CLT fabricated with lumber and LVL. **Construction and Building Materials**, v. 151, p.172-177, 2017.

WANG, Z.; GONG, M.; CHUI, Y. H. Mechanical properties of laminated strand lumber and hybrid crosslaminated timber. **Construction and Building Materials**, v. 101, p. 622-627, 2015.

WEI, P.; WANG, B. J.; LI, Z.; JU, R. Development of cross-laminated timber (CLT) products from stress graded Canadian hem-fir. **Wood Research**, v. 65, n. 2, p. 335-346, 2020.

YEH, B.; KRETSCHMANN, D.; WANG, B. Cross-laminated timber manufacturing. In: **CLT Handbook**: cross-laminated timber. Chapter 2. Co-published by U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Binational Softwood Lumber Council (BSLC), 572p., 2013.

ZMIJEWKI, T.; WOJTOWICZ-JANKOWSKA, D. Timber - Material of the future - Examples of small wooden architectural structures. **IOP Conference. Series: Materials Science and Engineering**, v. 245, 2017.