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Study of Density and Normal Flexion to Fibers of Four Species of Amazon Wood for Use in Civil Construction

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Abstract

The Amazon is characterized by being a region with great potential for wood producing forests of the most varied species. Wood has always been and continues to be an important material used in civil construction, whether as structural, closing, furniture and other purposes, however, the national production of wood has always been characterized by the indiscriminate deforestation of the most important *species. In recent years, due to the appeal for the use of materials that harm the environment as little as possible, wood has become a material with great potential to be used in different sectors of the economy. Lately, research in order to elucidate the properties of wood is increasing, however, there is still much to be discovered, especially in relation to the new species that are being reforested in Brazil. Wood is traditionally one of the main materials used in all stages of civil construction, due to the diversity of species with different properties and uses. This work aims to evaluate Amazonian woods such as Cedrorana (Cedrelinga cateniformis), Piquiarana (Caryocar glabrum and C.villosum), Red Tauari (Cariniana micranta) and Macacauba (Platymiscium ulei) used in civil construction. The physical and mechanical properties regarding density and resistance to normal flexion of fibers were evaluated. As density is one of the most important properties regarding the indication of uses for wood, and being one of the properties that provides more information about its characteristics, with the results obtained it was observed that the flexural strength has a correlation with density.*

Keywords: Amazon, wood, density, flexion, civil construction.

1. INTRODUCTION

Wood is one of the main raw materials used in Brazil and in the world, as it is a sustainable material it has its use highlighted in several areas of the economy. In its use, wood has several environmental and economic benefits, such as non-aggression to the environment because it is a material that comes from a renewable source of energy and acts to reduce the greenhouse effect due to the consumption of toxic gases during the process of photosynthesis (Ferro et al., 2013)

It is a material of biological origin and therefore does not have linear, identical anatomical characteristics. Wood has a high rate of variability, which is strongly influenced by factors related to anatomy and even the positioning of the cut on removal (Calil Junior et al., 2003); (Rocco Lahr, 1983); (Trugilho et al., 1996).

Like concrete and steel, the use of wood, whether in civil construction or in other areas, has its advantages and disadvantages. Among the main advantages according to Furiati (1981), there is the ability to effectively resist compression efforts and traction, it is a light material when compared to concrete and has high mechanical resistance, offers excellent workability and presents good natural conditions with regard to thermal and acoustic comfort.

In Brazil, wood is used for several purposes, ranging from residential and commercial buildings, churches, bridges, in addition to being used in the furniture industry and also in buildings in aggressive environments, such as in the chemical industries, buildings on the edge -marine, tanneries, etc. (Gesualdo, 2016).

The use of wood as a building material is still much lower than reinforced concrete, despite that Brazil has shown a great forest potential to meet the current demand. According to the Brazilian Tree Industry (IBÁ), Brazil is currently a world reference in the planted tree sector, due to its strong performance in terms of sustainability and innovation.

According to Pereira and Lentini (2010), the exploitation and commercialization of wood is one of the main economic activities in the Amazon region, along with mining and livestock. For Lentini (2008), in the Amazon forestry sector, sawn wood represents a 4.5% share of world trade in forest products and utensils.

Based on data from IMAZON - Fatos Florestais (2005), the largest portion of timber production in the Amazon is traded in Brazil, about 64% of production is consumed by Brazilians. Among the main consumers is the state of São Paulo, which corresponds to a consumption of 15% at national level, distributed among the sectors of the furniture industry and civil construction.

In Brazil, the use of wood in civil construction is quite diversified, being used in temporary structures such as shoring and rafters for reinforced concrete structures, scaffolding and forms; it is also used definitively, as for example in roof structures, piles for foundations, posts, sleepers and crosspieces. In addition, wood is intended for the use of finishing tools and fences in buildings, such as: frames, panels and partitions, ceilings, floors and furniture (Mello, 2007).

According to Zenid (2009), wood in civil construction is, in practice, classified as external and internal heavy; light external and internal structural; decorative internal light, of general utility, in frames and for domestic floors. The heavy external wood includes the parts used for bridges, poles, submerged piles, railway sleepers, frameworks, etc. Internal heavy wood, on the other hand, includes sawn wood pieces used in frameworks for roofing structures, rafters, boards and planks.

Still according to Zenid (2009), the class of light external construction and internal structural light wood comprises the sawn pieces in the form of planks and props that are used for shoring, forms for concrete and scaffolding, and also the slats and rafters that are used as auxiliary parts in roofing structures. In addition to these classes, we also have sawn and processed wood used in ceilings, wainscoting and panels that are classified as decorative internal light, these woods have colors and designs that contribute to the classification in decorative.

This work aims to evaluate the properties of density and resistance to normal flexion of the fibers of four species of Amazonian wood, Cedrorana (Cedrelinga cateniformis), Piquiarana (Caryocar glabrum and C.villosum), Red Tauari (Cariniana micranta) and Macacauba (Platymiscium ulei) used in civil construction.

2. THEORETICAL REVIEW

Recognizing the physical properties of wood are fundamental to defining the purposes for which it will be used, in addition to attributing to the project other aspects, such as aesthetics and economy, in accordance with its properties, which can be grouped and classified into more appropriate uses, such as for example in roofing structures, application in indoor and outdoor building environments (Zenid, 2009).

The moisture content is defined as the amount of water existing in a material in relation to its mass, where in wood several of its properties will be changed. By definition, the moisture content of wood is defined as the relationship between the weight of the water contained in its interior and its weight in the fully dry condition, defined as a percentage (Kollman, 1959); (Moreschi, 2010).

Although it is not considered classified as a specific quality of the wood, it refers to a parameter that affects the performance of the material, as it influences considerably mainly the mechanical properties of the wood. The correct use of wood depends on the moisture content control.

Changes in the moisture and density of the trees' wood are the main causes of failures due to drying, such as stinking and warping that occur in the wood stocked in the sawmills. We can observe these defects in frames and floorboards, pieces that are produced before the wood enters hygroscopic balance with the environment. Regulating the moisture content of wood is essential for its correct use, as it has a direct relationship with its properties, workability and susceptibility to fungi (Silva, 2012); (Barros, 2016).

Wood is classified as a semi-porous material, it removes water from the environment when it is moist, in the same way that it loses moisture when it is even dry. It has a hygroscopic characteristic that is one of the most relevant qualities in the study of wood performance, as it interferes with mechanical and physical properties, preservation and drying, durability, finishes and derived products (Melo, 2002).

According to Moreschi (2010) the specific mass of wood from a recently felled tree is due to the water confined in the cellular and intercellular spaces of the wood, the water soaked in the cell walls and the water that belongs to the chemical composition of the wood.

The wood is considered dry when the moisture content is in balance with the relative humidity of the environment where the wood will be used. Live or recently felled trees have a high moisture content. The sawn timber trade in Manaus for structural purposes has many wooden materials that end up drying in the sawmill deposit. This situation results in cracked and warped parts after receiving inspection (Zenid, 2009).

Density is the property defined as the relationship between the weight of dry wood and its volume, resulting from the actions between the anatomical, morphological and chemical characteristics of the wood. Being a quality benchmark for certain uses of wood, being directly related to other relevant characteristics such as humidity and resistance. In addition to being a notable indicator of the quality of a woody substance integrated in a sample of wood, in anatomical terms it is related to the ratio between the volume of cell walls and the volume of flames, which is influenced by its average dimensions, the quantity of extracts and other components non-fibrous (Melo, 2002); (Barrichelo, 1979).

The density varies from one species to another and depends on several factors, such as soil, climate, forestry, type of treatment, in addition to the number of inorganic and organic substances that make up the wood. It is considered one of the most important properties of wood, because as the oil density decreases, it reduces the mechanical resistance and its natural durability, however in the opposite direction they increase the workability and permeability and preservative solutions. It is an efficient reliable property for wood quality analysis, as it presents good correspondence with other properties, but does not objectively indicate and conclude the values of mechanical properties, existence of defects, fiber dimensions and calorific value (Mello, 2007); (Panshin & De Zeeuw, 1980).

According to Rezende and Escobedo (1988), the density of wood can be expressed using three considerations: (1) Apparent density (ρap), expressed by the relationship between mass and volume, defined under the same humidity conditions (U), and variable dependent on the value of U; (2) Density at 0%, determined as the ratio between mass and volume obtained for fully dry wood U = 0, where mass and volume are determined after drying process in oven 103 ± 2 ° C, and (3) Basic density (ρb), established as the relationship between dry mass, zero humidity, and volume saturated in water.

2.1 Mechanical properties

The mechanical properties of wood determine the measure of its resistance to external forces, being divided into elasticity and resistance properties. The resistance of wood to such forces depends on the magnitude of the forces and the way in which the loading is applied. Justifying the importance of defining the mechanical properties of wood, due to the economic and safety needs of the various sets of structural elements. (Tsoumis, 1991); (Calil, 2003).

The mechanical properties of wood are influenced by several reasons, such as moisture content, age of the tree, moisture content, chemical constituents, temperature, specific mass, presence of faults and others. These are properties that are directly related to their density, the densest woods are usually the resistant ones, although there are variations in the properties in woods with the same density (Kollmann & Côté Jr 1968), (Melo, 2002).

For the definition of the resistance properties of the wood, mechanical tests are carried out, however due to the high cost to perform the tests with structural parts, they are performed with specimens and the results of these tests are used to find the structural calculation tensions (Melo, 2002).

Tension is defined as the relationship between force per unit area, in wood there are three types of tensions: compressive tensin, tensile, flexural and shear tension. The modification in the dimension of the piece by the application of efforts of external efforts is called deformation, and the correlation between effort and deformation is equivalent to the so-called elastic regime; however, this relationship loses proportionality, within the so-called plastic regime (Cartagena, 1982).

The mechanical properties of wood are influenced by several factors, such as age of the tree, grain angle, moisture content, temperature, chemical constituents, state of deterioration, specific mass, anatomical constitution, flaws in the wood, presence of knots and others (Kollmann & Côté Jr 1968).

The strength properties of wood are directly related to its density, so that the densest woods are usually the most resistant, although there are variations of these properties in woods with the same density (Melo, 2002).

2.2 Normal flexural strength to fibers

In order to understand the flexion test, it is necessary to mold a piece in which the fibers are arranged parallel to their length. The experiment consists of applying a load in the middle of the specimen that is supported on two extreme supports, causing tension and deformation in the shape of a circular arc. The deformation caused causes a shortening of the fibers on the concave side, where they will be compressed, while the convex side will undergo elongation with fiber traction. In the line where the voltage inversion is found, it is known as the neutral line.

When the wood is required for the simple bending test, a load P is applied in the middle of a specimen that rests on two supports, causing tensions within it and deformation until rupture. The static bending test includes three types of tensions: tensile, compression and shear, as shown in figure 01, the greatest influence is the compression and tensile tensions. The rupture in pieces of wood subjected to bending occurs through the propagation of cracks in both the traction and compression areas, with a reduction in the compressed area and an increase in the traction area, eventually ending with the traction rupture (Kollmann & Côté, 1968); (Bodig & Jayne, 1993); (Calil, Lahr & Dias 2003).

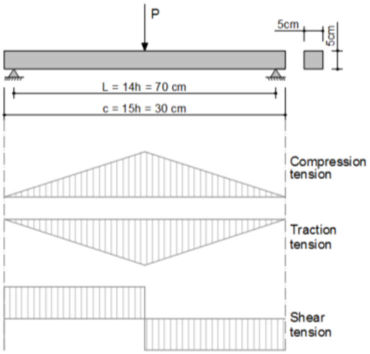


Figure 1 - Flexion tension.

3. MATERIALS AND METHODS

For the object of the study, samples of regional wood from four (04) distinct species were used, acquired at *Alicerce Madeiras*, selected in logs with a length of 4 m and a section of 20 x 10 cm, randomly selected, with dimensions necessary to make all the samples needed for the tests, as shown in figures 2 and 3. After their acquisition, the samples were transported to the IFAM laboratory and stored so that variations in their characteristics and physical properties were avoided.

Figure 2 - Samples of the species studied.

Figure 3 - Samples of the species under study after modeling at the IFAM joinery.

The experiment studied tree species from the Amazon Region sold in Manaus in the State of Amazonas. The species with their respective common and scientific names are shown in table 1.

Evaluate Amazonian woods such as Cedrorana (Cedrelinga cateniformis), Piquiarana (Caryocar glabrum and C.villosum), Red Tauari (Cariniana micranta) and Macacauba (Platymiscium ulei) used in civil construction.

Table 1: Scientific and common name of species

Scientific Name	Common Name
Cedrelinga cateniformis	Cedrorana
Caryocar glabrum e C.villosum	Piquiarana
Cariniana micranta	Tauari-vermelho
Platymiscium ulei	Macacauba

3.1 Humidity

In the IFAM dosing laboratory, the initial mass (mi) of the specimen was determined on a 10 kg scale with an accuracy of 0.01 g; then the specimen was taken to the drying chamber, with a maximum temperature of 103 ° C ± 2 ° C, as shown below in figures 4 and 5. During drying, every 6 hours, the mass of the specimen was measured until it occurred a variation less than or equal to 0.5% in relation to the last measurement. This last reading was the dry mass (ms).

Figure 4 - Specimen being exposed to an oven to remove moisture

Figure 5 - Specimen after 24 h in the Greenhouse

3.2 Basic Density

The density determination was carried out in accordance with ABNT NBR 11,941 / 2003. The basic density is the ratio of the dry mass to the saturated volume; thus, in the laboratory, specimens with dimensions of (5 x 7 x 20) cm were immersed in a tank with water for a period of 48 hours until the saturated volume was calculated by the final dimensions of the specimen submerged in water. Then, the samples were taken to the oven at a temperature of ± 103 ° C, until they reached constant weight, to obtain the dry weight (Figures 6 and 7).

Figure 6 - Mass Collection of the Macacaúba specimen.

Figure 7 - Mass collection from the Piquiarana specimen.

3.3 Normal flexural strength test for fibers

The flexural strength test was carried out on defect-free specimens, determined in a dry state in an oven, with approximately 12% humidity, according to the humidity test described above, keeping the samples in a controlled environment until the tests were carried out. The equipment used to perform the mechanical tests was a universal electromechanical testing machine UMC 60 tons with the aid of the pavitest global-UMC software, belonging to the Laboratory of Construction Materials and Material Resistance, of the Federal Institute of Education, Science and Technology of the Amazonas - IFAM.

The flexion tests were performed on specimens with dimensions of (3.0x9.0x 75.0) cm, made from sawn planks of logs 4 meters long, 20 centimeters wide and 10 centimeters in length thickness, defect-free parts, figures 8 and 9.

The press was loaded with an increasing monotonic load at a rate of 10 MPa /min, until the fibers in the specimens rupture. The maximum resistance was given immediately by the software that integrates the press, being able to compare the average resistance of the specimens during the test.

Figure 8 - Specimens molded in the joinery for the flexion test.

Figure 9 - Specimens after the flexion test.

4. RESULTS AND DISCUSSIONS

The maximum, minimum, average, standard deviation and coefficient of variation obtained for the basic density of the four wood species studied are shown in table 1. Of the four species studied, the one with the highest average basic density was the macacaúba (990.33 kg / cm3), followed by piquiarana with (926.90 kg / cm3), tauari with (628.25 kg / cm^3) and cedrorana with (548.81 kg / cm3).

Table 2 - Values of basic densities, minimum, maximum, average, standard deviation and coefficient of variation for the samples of cedrorana, macacaúba, piquiarana and tauari.

BASIC DENSITY (Kg/cm³)				
SAMPLES	CEDRORANA	MACACAÚBA	PIQUIARANA	TAURI
CP1	555,56	992,59	933,33	637,04
CP2	540,74	992,59	925,93	614,81
CP3	548,15	985,19	918,52	629,63
CP4	550,80	990,95	926,90	631,52
Minimum	**540,74**	**985,19**	**918,52**	**614,81**
Maximium	**555,56**	**992,59**	**933,33**	**637,04**
Average	**548,81**	**990,33**	**926,90**	**628,25**
Standard deviation	**6,16**	**3,51**	**6,07**	**9,50**
Coefficient of variation (%)	**1,12**	**0,35**	**0,65**	**1,50**

According to Melo et al (1990), tropical woods can be classified as density into light, medium and heavy, where values for light woods ≤ 0.51 g / c^3, for species of medium density woods between 0.51 g / cm^3 and 0.72 g / cm^3, while for heavy wood the density is ≥ 0.72 g / cm^3.

Density is one of the most relevant properties with reference to the designation of uses for wood. It presents itself as one of the properties that provides the most clarification regarding the characteristics of the wood, being directly associated with its resistance.

Although the method of determining the basic density can have a great influence on the results, comparisons with the values reported by the literature demonstrate the consistency of the results obtained in the present study. The variations in the research results may be related to the ages of the species studied, hereditary trends, material collection procedure and also environmental factors.

According to the classification of general uses for civil construction, lumber pieces of macacaúba and piquiarana can be used mainly for structural purposes such as roofs, sea stakes, bridges, immersed works, heavy structures and observation towers (IPT, 2012). Cedrorana and tauari despite having several uses in construction, such as frames and floors, its medium density is quite attractive for the wood segment, as this type of wood presents better performance when we use products and equipment for finishing.

With the results presented in table 1, the Amazonian species studied were within two ranges of 500 kg / cm^3 to 800 kg / cm^3, where Cedrorana and Tauari fit, the same range as Angelim-araroba and Angelim-pedra and still Cedro Amargo and Cedro Doce. The second range, which ranges from 801 kg / m^3 to 1200 kg / m^3, fits Macacaúba and Piquiarana, the same range as Angelim-ferro and Catiúbae, still Miquiqueira and Branquilho (Pfeil and Pfeil, 2003).

4.1 Normal flexural strength test for fibers:

For the four tested samples of each type of wood, the parameters of bending tension are presented in minimum, maximum, average values, standard deviation and variation coefficient presented in table 2. The lowest mean values of resistance, standard deviation are observed and variation coefficient were for the cedrorana species, with 53.78 MPa, 1.72 and 3.20, respectively.

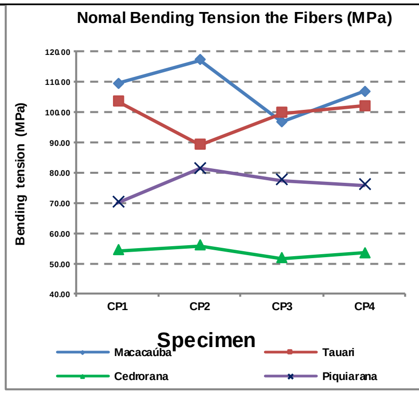
Although the cedrorana species had the lowest density values, it is statistically the best species in relation to the variation of results in the normal flexural strength test for fibers. In parts applied in civil construction and essentially subjected to bending and within the load limit, they guarantee greater reliability of the projects, allowing a better period of useful life of the structures.

Table 3 - Normal Flexion Tension Values for fibers, minimum, maximum, average, standard deviation and variation coefficient for cedrorana, macacaúba, piquiarana and tauari samples.

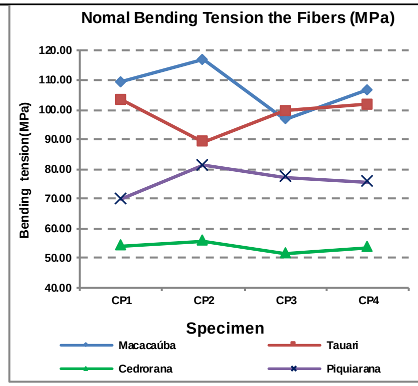
NORMAL FLEXURAL TENSION OF THE FIBERS (MPa)				
SAMPLES	**CEDRORANA**	**MACACAÚBA**	**PIQUIARANA**	**TAURI**
CP1	54,25	109,41	69,98	103,47
CP2	55,65	116,95	81,34	89,05
CP3	51,50	96,65	77,27	99,61
CP4	53,70	111,30	78,43	92,41
Minimum	**51,50**	**96,65**	**69,98**	**89,05**
Maximium	**54,25**	**116,95**	**81,34**	**103,47**
Average	**53,78**	**108,58**	**76,76**	**96,14**
Standard deviation	**1,72**	**8,57**	**4,83**	**6,58**
Coefficient of variation (%)	**3,20**	**7,89**	**6,29**	**6,84**

The cedrorana and piquiarana species presented the lowest results, as shown in graph 1, but with resistance values of the ranges for the dicots. While the compression stresses for the four species are shown in graph 2, with stress values for the macacaúba and tauari species of 108, 58 MPa and 96, 14 MPa relatively, but with the highest values of standard deviation and variation coefficient. They are species that, when subjected to structural elements of civil construction, need greater safety coefficients in order to maintain the stability of the structures.

According to Walter Pfeil and MichèlePfeil (2003) the presence of defects and reverse fibers reduces and substantially alters the resistance to normal flexion to the fibers. Consequently, sawn timber pieces of structural dimensions, the normal bending stresses to the fibers can be smaller and more variable than pieces tested without defects.



Graph 1: Normal flexural tension of the fibers



Graph2: Normal flexural tension of the fibers

5. FINAL CONSIDERATIONS

The Amazon is characterized by being a region with great potential for wood producing forests of the most varied species. Greater knowledge of the physical and mechanical properties of wood is essential to rationalize the use of this raw material.

Density is one of the most relevant properties with reference to the designation of uses for wood. It presents itself as one of the properties that provides the most clarification regarding the characteristics of the wood, being directly associated with its resistance.

The lowest mean values of resistance, standard deviation and coefficient of variation were for the cedrorana species, with 53.78 MPa, 1.72MPa and 3.20MPa, respectively. Although the cedrorana species had the lowest density values, it statistically showed the best result in relation to the variation of results in the compression resistance test parallel to the fibers.

In sawn wood pieces of structural dimensions, the normal flexural stresses to the fibers can be lower and more variable than pieces tested without defects.

BIBLIOGRAPHIC REFERENCES

1. Associação Brasileira de Normas Técnicas. Madeira–Determinação de densidade básica. NBR 11.941, Rio de Janeiro, 2003.
2. Barrichelo, L.E.G. & Foelkel, C.E.B. Estudos para produção de celulose sulfato de seis espécies de eucalipto. IPEF, Piracicaba, (12):77-95, jun. 1976.
3. Barros, S. V. Dos S. Avaliação da qualidade da madeira de árvores da Amazônia por método não destrutivo de propagação de onda: tomógrafo de impulso e stress wave timer. Tese (Doutorado) - INPA, Manaus, 2016.
4. Bodig, J., Jayne, Ba. Mechanics of Wood and Wood Composites. Krieger Publ. Comp. Malabar. 712p. 1993.
5. Calil. C. J.; Dias, A. A.; Lahr, F. A. R. Dimensionamento de Elementos Estruturais de Madeira. 1. ed. Barueri, SP: Manole, 2003.
6. Junta Del Acordo De Cartagena. Manual de diseño para maderas Del grupo andino. Lima, PADT-REFORT, 1984.
7. Ferro F. S.; Icimoto F. H.; Almeida D. H.; Christoforo A. L.; Rocco Lahr F. A. (2013). Verification of test conditions to determine the compression modulus of elasticity of wood. International Journal of Agriculture and Forestry, California, v.3, n. 2, p. 66-70.
8. Furiati, M. Classificação estrutural de peças de madeira. 1981. Dissertação (Mestrado)–Departamento de Estruturas, Escola de Engenharia de São Carlos, Universidade de São Paulo, São Carlos, 1981.
9. Gesualdo, F. A. R. Estruturas De Madeira.Disponível em: <http://www.feciv.ufu.br/sites/feciv.ufu.br/files/Anexos/Bookpage/Notas_de_Aula_Madeiras.pdf> 2003. Acessado em janeiro de 2016.
10. Indústria Brasileira De Árvores. Relatório Anual IBÁ 2017. Disponível em: <http://iba.org/pt/biblioteca-iba/publicacoes>. Acessado: 23/11/2020.
11. IPT-Instituto De Pesquisas Tecnológicas. Catálogo de madeiras brasileiras para a construção civil. Coordenação Augusto Rabelo Nahuz. São Paulo: IPT - Instituto de Pesquisas Tecnológicas do Estado São Paulo, 2013.
12. Kollmann, F. F. P. Tecnologia de La Madera y sus aplicaciones. Madrid. Tomo I. Instituto Forestal de Investigaciones y Experiencias y Servicio de laMadera. 647 p. 1959.
13. Kollmann, F. F. P.; Côté Junior, W. A. Principles of wood science and technology. Berlin: Springer, v. 2, 1968. 674 p.
14. LENTINI, M. - Como funciona a indústria madeireira. Belém, 2008. Disponível em:<http://empresasefinancas.hsw.uol.com.br/industria-da-madeira1.htm>.Acesso em: 12 dezembro, 2020.
15. MELLO R.L. PROJETAR EM MADEIRA: UMA NOVA ABORDAGEM. 2007. Dissertação (Mestrado) – Faculdade de Arquitetura e Urbanismo de Brasília, Universidade de Brasília, Brasília, 2007.
16. Melo, J.E.; Coradin, V.T.R.; Mendes, J.C. 1990. Classes de densidade de madeira para a Amazônia brasileira. In: Anais do Congresso Florestal Brasileiro 6: 695-699. São Paulo, SP, Brasil.
17. MELO J.E. Madeira: características e aplicações. Brasília: LPF/IBAMA, 2002 (Apostila do programa Brasil Joga Limpo).

18. MORESCHI, J. C. Propriedades da madeira. Ministério da educação e do desporto. Setor de ciências agrárias da Universidade Federal do Paraná. Curitiba: Departamento de engenharia e tecnologia florestal, 2010.
19. PANSHIN, A. J. & DE ZEEUW, C. Textbook of technology. 4th ed. New York: McGraw Hill; 1980.
20. PEREIRA, D.; SANTOS, D.; VEDOVETO, M.; GUIMARÃES, J.; VERÍSSIMO, A. – Fatos florestais da Amazônia 2010 – Belém, PA: Imazon, 2010.Disponível em: <http://www.florestal.gov.br/publicacoes/tecnico-cientifico/relatoriotecnico-florestas-nativas-de-producao-brasileiras>Acesso em: 05 de dezembro, 2020.
21. PFEIL, W.; PFEIL, M. Estruturas de madeira. LTC, Rio de Janeiro, 2003.
22. REZENDE, M. A.; ESCOBEDO, J. F. Retratibilidade volumétrica e densidade aparente da madeira em função da umidade. IPEF, n.39, p.33-40, ago. 1988.
23. Rocco Lahr, F. A. (1983). Sobre a determinação de propriedades de elasticidade da madeira. São Carlos. 216p. Tese (Doutorado) - Escola de Engenharia de São Carlos da Universidade de São Paulo.
24. SILVA, Fernando. Métodos não destrutivos como ferramenta para apoio aos planos de manejo florestal sustentado na Amazônia. Dissertação (Mestrado) - INPA, Manaus, 2012.
25. SOBRAL, L. et. al. Acertando o alvo 2: consumo de madeira amazônica e certificação florestal no Estado de São Paulo. Belém: Imazon, 2002. 72p.
26. Trugilho, P. F.; Lima, J. T.; Mendes, L. M. (1996). Influência da idade nas características físico-químicas e anatômicas da madeira de Eucalyptus saligna. Revista Cerne. Lavras. v. 2, n.1, p.94-111.
27. TSOUMIS, G. Science and technology of wood. Nova York: Chapman & Hall, 1991. 494p.
28. ZENID G.J. Madeira: Uso sustentável na construção civil. 2. Ed. São Paulo: Instituto de Pesquisas Tecnológicas: SVMA, 2009.