Physical and mechanical properties of *Eucalyptus saligna* wood for timber structures

Propriedades físicas e mecânicas da madeira de Eucalyptus saligna para estruturas de madeira

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Abstract

Due to its great availability in planted forests in Brazil**,** *Eucalyptus saligna* appears as a good species to be exploited, in order to assist in the consumption of wood for construction purposes. The aim of this research was to determine the physical and mechanical properties of *Eucalyptus saligna* wood species for its use in civil construction. The evaluation was based on 16 physical and mechanical properties obtained according to NBR 7190 (1997) standard. Two values of moisture content were considered: 30% (above the fiber saturation point) and 12% (equilibrium moisture content) according to NBR 7190 (1997). All obtained results obtained were statistically analyzed according to the t-test at the 5% level of significance. In addition, the characteristic strength properties were also determined, for batch classification in the strength classes recommended by the Brazilian standard. *Eucalyptus saligna* had an apparent density of 0.58 g/cm³ and a basic density of 0.73 g/cm³. The mechanical properties, presented f_{c0} and $f_{c0,k}$ equal to 46.80 and 32 MPa, respectively. The results indicated that *Eucalyptus saligna* wood can be used in the construction of timber structures as structural member

Keywords: Eucalypt. Strenght. Stiffness. Timber structures.

Resumo

A fim de auxiliar no consumo de madeira pela construção civil, o Eucalyptus saligna surge como uma boa oportunidade a ser explorada, devido à sua grande disponibilidade em florestas plantadas no Brasil. O objetivo dessa pesquisa foi determinar as principais propriedades físicas e mecânicas da madeira de Eucalyptus saligna para sua utilização na construção civil. Esta avaliação baseou-se em 16 propriedades físicas e mecânicas obtidas de acordo com a norma NBR 7190 (1997). Dois valores de teor de umidade foram considerados: 30% (acima do ponto de saturação das fibras) e 12% (teor de umidade de equilíbrio) de acordo com a NBR 7190 (1997). Todos os resultados obtidos foram analisados estatisticamente de acordo com o teste t ao nível de 5% de significância. Além disso, também foram determinadas as resistências características para classificação do lote nas classes de resistência recomendadas pela norma. O Eucalyptus saligna apresentou densidade aparente igual a 0,58 g/cm³ e densidade básica igual a 0,73 g/cm³. Em relação às propriedades mecânicas, apresentou f_{c0} *e* $f_{c0,k}$ *iguais a 46,80 e 32 MPa, respectivamente. De acordo com os resultados, foi possível concluir que o Eucalyptus saligna pode ser utilizado na construção de estruturas de madeira como elemento estrutural.*

***Palavras-chave**: Eucalipto. Resistência. Rigidez. Estruturas de madeira.*

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Introduction

Wood is a natural raw material obtained from natural or planted forests (MAZURANA *et al*., 2011; MATOS *et al*., 2012; TER STEEGE *et al*., 2016; TUISIMA-CORAL *et al*., 2017). In Brazil, *Eucalyptus* tree genus are utilized for a variety of applications, among them: pulp and paper, charcoal, essential oils, boards, firewood, construction, and furniture (GUIMARÃES JUNIOR *et al*., 2009, 2011; ALMEIDA; BRITO; PERRÉ, 2010; IWAKIRI *et al*., 2013; SOARES *et al*., 2015; MATTOS *et al*., 2014; NEIVA *et al*., 2015; BALLESTEROS *et al*., 2015).

For timber building structures, the knowledge of physical and mechanical properties of wood are very important, for its rational use (CALIL JUNIOR; LAHR; DIAS, 2003; CALIL JUNIOR; MOLINA, 2010; ANDRADE JUNIOR *et al*., 2014; LAHR *et al*., 2017a). The very purpose of wood characterization is to evaluate its possible use as a structural member (VIVIAN *et al*., 2010; CHEN; GUO, 2016, 2017; LAHR *et al*., 2017b). For this purpose, Brazilian Standard Code NBR 7190 (Associação Brasileira de Normas Técnicas (ABNT, 1997) presents all experimental procedures for the conduction of the testing of the specimens.

Another important characteristic of wood for timber structures is its moisture content (KOLMANN; CÔTÈ, 1968; HERZOG *et al*., 2000). In general, wood with higher moisture content presents lower mechanical properties (MATOS; MOLINA, 2016; ALMEIDA *et al*., 2016) and dimensional stability that is also influenced by moisture content (ALMEIDA *et al*., 2017).

Eucalyptus genus presents a fast growth that causes internal tension (growth stress) (BELTRAME *et al.*, 2015), and besides this, the dry process, must be carefully performed to minimize the occurrence of drying defects, for examples, bows, crooks, top cracks, cups and twists (ELEOTÉRIO *et al.*, 2014; REZENDE *et al.*, 2015). These defect types influence the physical and mechanical properties of wood (LIMA *et al.*, 2004).

Due to the scarce amount of reports available for this species, this research was aimed at determining the physical and mechanical properties of *Eucalyptus saligna* wood from different planted forests at two moistures content regimes (12 and 30%) for its use as structural timber.

Materials and methods

Eucalyptus saligna wood from a planted forest area in the State of São Paulo, Brazil was used for this research. 20-year old *Eucalyptus saligna* logs with an average 35 cm diameter were selected for the study. After the primary processing of the logs, the sawn timber boards were submitted to natural drying of the moisture contents adopted for this research: first above the fiber saturation point (30%) and at 12% moisture content as prescribed in NBR 7190 (1997).

Test specimens were prepared for physical and mechanical properties (Table 1) according to the Brazilian Standard, NBR 7190 (1997). For each property studied, moisture content was determined for 12 specimens according to NBR 7190 (1997) (except for the apparent density (ρ_{ap}) which is always determined at 12% m.c). For this purpose, 372 specimens were prepared. Toughness tests were carried out in *Charpy* machine according to D143 (AMERICAN…, 1999) and, another test specimen was carried out in AMSLER with load capacity equal to 25,000 kgf.

All the results from these sixteen physical-mechanical properties tests, with the exception of the apparent density (considered at 12% moisture content), were analyzed through t-test at a significance level of 5% (or P-value ≤ 0.05), investigating the moisture content influence.

The characteristic strengths were determined using Equation 1, according to NBR 7190 (1997). After determining the strength properties of 12 specimens, the results were placed in ascending order ($f_1 < f_2 < f_3 < f_n$) for the calculation of the characteristic strength of the wood (f_k), the value of the characteristic strength could not be less than f_1 and 70% of the average value of strength. Characteristic strength values were determined only to *Eucalyptus saligna* wood at 12% moisture content at 12%, according to NBR 7190 (1997).

$$f_k = \left(2 \cdot \frac{f_1 + f_2 + ... + f_{\left(\frac{n}{2}\right)-1}}{\left(\frac{n}{2} - 1\right)} - f_{\frac{n}{2}} \right) \cdot 1{,}1 \qquad \text{Eq. 1}$$

Results and discussions

Tables 2, 3, 4 and 5 present mean values (x), standard deviation (Sd), number of specimens (n) and P-values to physical and mechanical properties for each moisture content (MC), 12 and 30%, for *Eucalyptus saligna*.

Basic density decreased from 30 to 12% in about 1.69%. Through the t-test, the ρ_b not suffered the influence by the variation in moisture content (Table 2). *Eucalyptus saligna* wood studied in this research had an apparent density at 12% moisture content lower than the one determined by Müller (2014) for *Eucalyptus benthamii* wood (ρ_{ap} = 0.61 g/cm³). However, the basic density of *E. benthamii* (ρ_b = 0.52 g/cm³) was lower than the one in this study. The density values obtained in this study were close to those of other *Eucalyptus* wood species, such as: *Eucalyptus grandis* (ρ_{ap} = 0.57 g/cm³), and *E. dunnii* (ρ_{ap} = 0.77 g/cm³), *E. urophylla* (ρ_{ap} = 0.55 g/cm³) and *E. tereticornis* (BHAT *et al.*, 1987; EVANGELISTA *et al*., 2010).

The average density values obtained for *Eucalyptus saligna* wood species compare well with Brazilian native species, such as Cedro-amargo (*Cedrela odorata*), Cedro-doce (*Cedrella* sp.) and Cedrorana (*Cedrelinga catenaeformis*) (DIAS; LAHR, 2004).

The strength properties of *Eucalyptus saligna* indicated increases with the moisture content decrease (30 to 12%) such as 19.44% (9.1 MPa) compression parallel to grain, 0.2% (4.17 MPa) compression perpendicular to grain, 21.99% (21 MPa) tension parallel to grain, 24.39% (1 MPa) tension perpendicular to grain and 19.10% (17.5 MPa) in modulus of rupture in static bending. Thus, the t-test analysis showed f_{t0}, f_{t90} and f_{c0} suffered influence in their mean values when these properties were submitted to the moisture decrease (P-value ≤ 0.05), similar to the results obtained by Almeida *et al*. (2016). This situation was not similar in f_{c90}, because it did not present significant difference in their mean values with the decrease of moisture content (Table 3).

The modulus of elasticity of *Eucalyptus saligna* indicated increases with the moisture content decrease (30 to 12%) such as 14.31% (2,185 MPa) in compression parallel to grain, 4.15% (20 MPa) in compression perpendicular to grain, 14.39% (2,299 MPa) in tension parallel to grain and 7.56% (1,007 MPa) in E_M. The analysis of t-test identified the E_{c0} and E_{t0} had significant influence in their properties with moisture content decrease (P-value ≤ 0.05), whereas E_{c90} and E_M did not have any significant differences with regard to the decrease of moisture content (Table 4).

Finally, Table 4 revealed increases in the properties of shear parallel to the grain (20.74% or 3 MPa), cleavage parallel to the grain (26.14% or 0.23 MPa), perpendicular hardness (17.58% or 1.19 kN), parallel hardness (18.48% or 1.17 kN) and toughness (18.80% or 2.5 N·m) with reduced moisture content from 30% to 12% (KOLMANN; CÔTÈ, 1968). The t-test, indicated that all these five properties had significant effect with the reduced moisture content (P-value ≤ 0.05).

The batch of *Eucalyptus saligna* wood presented a compression strength parallel to grain characteristic value ($f_{c0,k}$) equal to 32 MPa (Table 6). Therefore, it was possible to classify this batch into class C30 of the dicotyledons according to the Brazilian Standard Code NBR 7190 (1997). The strength values of *Eucalyptus saligna* wood reported here was higher than that of *Eucalyptus benthamii* wood as determined by Müller *et al.* (2014).

Table 1 – **Physical and mechanical properties of *Eucalyptus saligna***

Properties	Symbol
Apparent density	ρ_{ap}
Basic density	ρ_p
Compression parallel to the grain	f_{c0}
Compression perpendicular to the grain	f_{c90}
Tension parallel to the grain	f_{t0}
Tension perpendicular to the grain	f_{t90}
Modulus of rupture in static bending	f_M
Modulus of elasticity in compression parallel to the grain	E_{c0}
Modulus of elasticity in compression perpendicular to the grain	E_{c90}
Modulus of elasticity in tension parallel to the grain	E_{t0}
Modulus of elasticity in static bending	E_M
Shear parallel to the grain	f_{v0}
Cleavage parallel to the grain	f_{s0}
Parallel hardness	f_{H0}
Perpendicular hardness	f_{H90}
Toughness	W

Table 2 – **Densities of *Eucalyptus saligna***

Properties	MC (%)	n	x	Sd	P-value
ρ_{ap} (g/cm³)	12	77	0.73	0.16	---
ρ_b (g/cm³)	30	73	0.59	0.16	0.6670
	12	77	0.58	0.12	

Table 3 – **Strength properties of *Eucalyptus saligna***

Properties	MC (%)	n	x	Sd	P-value
f_{c0} (MPa)	30	75	37.70	7.90	0.0000
	12	71	46.80	14.30	
f_{c90} (MPa)	30	74	4.60	2.10	0.5711
	12	75	4.80	2.20	
f_{t0} (MPa)	30	74	74.50	33.40	0.0014
	12	74	95.50	44.40	
f_{t90} (MPa)	30	77	3.10	1.20	0.0000
	12	77	4.10	1.70	
f_M (MPa)	30	73	74.10	14.10	0.0004
	12	74	91.60	38.20	

Table 4 – **Stiffness properties of *Eucalyptus saligna***

Properties	MC (%)	n	x	Sd	P-value
E_{c0} (MPa)	30	75	13,076	4,021	0.0023
	12	71	15,261	4,442	
E_{c90} (MPa)	30	74	458	212	0.5739
	12	75	478	217	
E_{t0} (MPa)	30	74	13,682	3,765	0.0018
	12	74	15,981	4,939	
E_M (MPa)	30	73	12,306	2,640	0.0666
	12	74	13,313	3,852	

Table 5 – **Mechanical properties of *Eucalyptus saligna***

Properties	MC (%)	n	x	Sd	P-value
f_{v0} (MPa)	30	73	11.00	2.10	0.0000
	12	73	14.00	3.90	
f_{s0} (MPa)	30	75	0.65	0.18	0.0000
	12	76	0.88	0.27	
f_{H90} (kN)	30	73	5,160	1,330	0.0047
	12	73	6,330	3,150	
f_{H0} (kN)	30	76	5,580	1,830	0.0095
	12	73	6,770	3,020	
W (N·m)	30	76	10.8	4.20	0.0018
	12	76	13.3	5.40	

The batch of *Eucalyptus saligna* wood presented a compression strength parallel to grain characteristic value ($f_{c0,k}$) equal to 32 MPa (Table 6). Therefore, it was possible to classify this batch into class C30 of the dicotyledons according to the Brazilian Standard Code NBR 7190 (1997). The strength values of *Eucalyptus saligna* wood reported here was higher than that of *Eucalyptus benthamii* wood as determined by Müller *et al.* (2014).

Lima *et al.* (2014) reported basic density, compression parallel to the grain and shear parallel to the grain of *Eucalyptus resinifera* wood, equal to 0.74 g/cm³, 55.87 and 16.16 MPa, respectively, all of which are higher than those determined for *Eucalyptus saligna* wood.

Table 6 – **Average (x) and characteristic strength (f_k) values of *Eucalyptus saligna***

Properties	x	f_k
f_{c0} (MPa)	46.80	32.00
f_{c90} (MPa)	4.80	3.40
f_{t0} (MPa)	95.50	66.00
f_{t90} (MPa)	4.10	3.00
f_M (MPa)	91.60	64.00
f_{s0} (MPa)	0.88	0.60
f_{v0} (MPa)	14.00	12.00

Almeida and Dias (2016) determined the apparent density and the compression parallel to grain of *Lyptus*® wood species (*Eucalyptus hybrid*) equal to 0.55 g/cm³ and 53.6 MPa, respectively. Even though the density was low when compared to *Eucalyptus saligna*, *Lyptus* presented a f_{c0} mean value higher than the batch of *Eucalyptus saligna*.

Conclusion

The present study concluded that:

(a) the batch of *Eucalyptus saligna* was classified under strength class C30 of the dicotyledons, after a large test campaign, and thus, it can be used safely as a structural member on timber structures;

(b) *Eucalyptus saligna* showed f_{c0} equal to 46.80 MPa and apparent density 0.58 g/cm³ at 12% m.c.; and

(c) at this reduced moisture content, 11 from 14 evaluated mechanical properties presented significant differences. Four strength properties showed an improvement in their mean values: f_{c0}, f_{t0}, f_{t90} and f_M. E_{c0} and E_{t0} showed an increasing trend in their average values with increasing m.c.

References

ALMEIDA, D. H. *et al.* Determinação da Rigidez de *Pinus elliottii* em Diferentes Teores de Umidade Por Meio de Ensaios Mecânicos Não Destrutivos. ***Scientia Forestalis,*** v. 44, n. 10, p. 303-309, 2016.

ALMEIDA, D. H.; DIAS, A. A. Comparison between test methods to determine wood embedment strength parallel to the grain. **Revista Árvore,** v. 40, n. 4, p. 741-748, 2016.

ALMEIDA, G.; BRITO, J. O.; PERRÉ, P. Alterations in Energy Properties of *Eucalyptus* Wood and Bark Subjected to Torrefaction: the potential of mass loss as a synthetic indicator. **Bioresource Technology,** v. 101, n. 24, p. 9778-9784, 2010.

ALMEIDA, T. H. *et al.* Density as Estimator of Dimensional Stability Quantities of Brazilian Tropical Woods. **BioResources**, v. 12, n. 3, p. 6579-6590, 2017.

AMERICAN SOCIETY FOR TESTING AND MATERIALS. **ASTM D143:** standard test methods for small clear specimens of timber. Philadelphia, 1999.

ANDRADE JUNIOR, J. R. *et al.* Avaliação das Estruturas de Cobertura em Madeira de Um Galpão de Estoques de Produtos Químicos. **Ambiente Construído**, Porto Alegre, v. 14, n. 3, p. 75-85, jul./set. 2014.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. **NBR 7190**: projeto de estruturas de madeira. Rio de Janeiro, 1997.

BALLESTEROS, J. E. M. *et al.* Evaluation of the Effect of Drying and Rewetting Cycles in Eucalyptus Pulps. **International Journal of Engineering and Technology,** v. 7, n. 5, p, 397-400, 2015.

BELTRAME, R. *et al.* Tensão de Crescimento e Sua Relação Com as Rachaduras de Topo em Toras de *Eucalyptus* spp. ***Scientia Forestalis,*** v. 43, n. 105, p. 63-74, 2015.

BHAT, K. M. *et al.* Wood Property Variation of 3-Year-Old Trees Among Four Eucalypt Species Grown in Kerala. **Journal of the Indian Academy of Wood Science,** v. 18, n. 2, p. 6-12, 1987.

CALIL JUNIOR, C.; LAHR, F. A. R.; DIAS, A. A. **Dimensionamento de Elementos Estruturais de Madeira**. Barueri: Manole, 2003.

CALIL JUNIOR, C.; MOLINA, J. C. **Coberturas em Estruturas de Madeira:** exemplos de cálculo. São Paulo: Pini, 2010.

CHEN, Y.; GUO, W. Mechanical Properties Evaluation of Two Wood Species of Ancient Timber Structure With Nondestructive Testing Methods. **BioResources,** v. 11, n. 3, p. 6600-6612, 2016.

CHEN, Y.; GUO, W. Nondestructive Evaluation and Reliability Analysis For Determining the Mechanical Properties of Old Wood of Ancient Timber Structure. **BioResources,** v. 12, n. 2, p. 2310-2325, 2017.

DIAS, F. M.; LAHR, F. A. R. Estimativa de Propriedades de Resistência e Rigidez da Madeira Através da Densidade Aparente. ***Scientia Forestalis,*** v. 65, p. 102-113, 2004.

ELEOTÉRIO, J. R. *et al.* Efeito da Espécie e da condição De Secagem na Formação de Defeitos na Madeira Serrada de Eucalipto. ***Scientia Forestalis,*** v. 42, n. 101, p. 41-47,2014.

EVANGELISTA, W. V. *et al.* Propriedades Físico-Mecânicas da Madeira de *Eucalyptus urophylla* S. T. Blake no Sentido Radial e Longitudinal. **Ciência da Madeira,** v. 1, n. 2, p. 1-19, 2010.

GUIMARÃES JUNIOR, J. B. *et al.* Painéis Compensados de Eucalipto: estudo de caso de espécies e procedências. **Cerne,** v. 15, n. 1, p. 10-18, 2009.

GUIMARÃES JUNIOR, J. B. *et al.* Painéis de Madeira Aglomerada de Resíduos da Laminação de Diferentes Procedências de *Eucalyptus grandis*, *Eucalyptus saligna* e *Eucalyptus cloeziana*. **Cerne,** v. 17, n. 4, p. 443-452, 2011.

HERZOG, T. *et al.* **Timber Construction Manual**. Berlin: Birkhäuser, 2000.

IWAKIRI, S. *et al.* Evaluation of the Use Potential of Nine Species of Genus *Eucalyptus* For Production of Veneers and Plywood Panels. **Cerne,** v. 19, n. 2, p. 263-269, 2013.

KOLLMANN, F.; CÔTÉ, W. A. **Principles of Wood Science and Technology**. Berlin: Springer-Verlag, 1968.

LAHR, F. A. R. *et al.* Physical-Mechanical Characterization of the *Eucalyptus urophylla* Wood. **Journal of the Brazilian Association of Agricultural Engineering,** v. 37, n. 5, p. 900-906, 2017b.

LAHR, F. A. R. *et al.* Shear and Longitudinal Modulus of Elasticity in Wood: relations based on static bending tests. **Acta Scientiarium Technology,** v. 39, n. 4, p. 433-437, 2017a.

LIMA, I. L. *et al*. Physical-Mechanical and Anatomical Characterization in 26-Year-Old *Eucalyptus resinifera* Wood. **Floresta e Ambiente,** v. 21, n. 1, p. 91-98, 2014.

LIMA, J. T. *et al.* Deformações Residuais Longitudinais Decorrentes de Tensões de Crescimento em Eucaliptos e Suas Associações Com Outras Propriedades. **Revista Árvore,** v. 28, n. 1, p. 107-116, 2004.

MATOS, G. S. B. *et al.* Desenvolvimento Inicial e Estado Nutricional de Clones de Eucalipto no Nordeste do Pará. **Acta Amazônica,** v. 42, n. 2, p. 491-500, 2012.

MATOS, G. S.; MOLINA, J. C. Resistência da Madeira ao Cisalhamento Paralelo às Fibras Segundo as Normas ABNT NBR 7190:1997 e ISO 13910:2005. **Revista Matéria,** v. 21, n. 4, p. 1069-1079, 2016.

MATTOS, B. D. *et al.* Biodeterioration of Wood From Two Fast-Growing Eucalypts Exposed to Field Test. **International Biodeterioration and Biodegradation,** v. 93, p. 210-215, 2014.

MAZURANA, M. *et al.* Balanço de Nutrientes em Povoamentos de *Eucalyptus saligna* Implantado Sobre Cambissolo Háplicono RS. **Revista Brasileira de Engenharia Agrícola e Ambiental,** v. 15, n. 9, p. 924-930, 2011.

MÜLLER, B. V. *et al.* Avaliação das Principais Propriedades Físicas e Mecânicas da Madeira de *Eucalyptus benthamii* Maiden et Cambage. **Floresta e Ambiente,** v. 21, n. 4, p. 535-542, 2014.

NEIVA, D. *et al.* Chemical Composition and Kraft Pulping Potential of 12 Eucalypt Species. **Industrial Crops and Products,** v. 66, p. 889-95, 2015.

REZENDE, R. N. *et al.* Efeito da Vaporização na Secagem de Tábuas de *Eucalyptus grandis.* **Cerne,** v. 21, n. 1, p. 37-43, 2015.

SOARES, V. S. *et al.* Análise das Propriedades da Madeira e do Carvão Vegetal de Híbridos de Eucalipto em Três Idades. **Cerne,** v. 21, n. 2, p. 191-197, 2015.

TER STEEGE, H. *et al.* The Discovery of the Amazonian Tree Flora With an Update Checklist of All Known Tree Taxa. **Scientific Reports,** v. 6, n. 29549, p. 1-15, 2016.

TUISIMA-CORAL, L. L. *et al.* Variation in Wood Physical Properties Within Stems of Guazuma Crinita, a Timber Tree Species in the Peruvian Amazon. **Maderas y Bosques,** v. 23, n. 1, p. 53-61, 2017.

VIVIAN, M. A. *et al.* Propriedades Físico-Mecânicas da Madeira de Canafístula aos 10 Anos de Idade. **Ciência Rural,** v. 40, n. 5, p. 1097-1102, 2010.

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