Original Research Article

PHYSICAL AND MECHANICAL PROPERTIES OF SABIÁ WOOD SPECIE (*Mimosa caesalpiniaefolia* Bentham.)

Abstract

Wood is a natural material with technological properties that vary between species (genetic factors) and for the same species (edaphoclimatic factors). For structural use of wood in civil construction, physical and mechanical properties are of interest. The aim of this research was to determine the physical and mechanical properties of the Sabiá wood specie (*Mimosa caesalpiniaefolia* Bentham.) from *Caatinga*, and to evaluate the possibility of its use in civil construction. From a batch obtained from Juazeiro do Norte (CE), Brazil, with moisture content 12%, test specimens were fabricated to determine their physical and mechanical properties, according to ABNT NBR 7190:1997 Brazilian Standard Code. As physical properties, were determined: density at 12% moisture (ρ_{12}); radial (RRT), tangential (RTL) and longitudinal (RLT) shrinkages. Mechanical properties considered were: strength in compression parallel (f_{c0}) and perpendicular (f_{c90}) to the grain, tensile strength parallel (f_{t0}) and perpendicular (f_{t90}) to the grain, shear strength (f_{v0}) and cleavage (f_{s0}) parallel to the grain, modulus of elasticity (E_M) and rupture (f_M) in static bending, and modulus of elasticity in compression parallel (E_{c0}) and perpendicular (E_{c90}) to the grain. The characteristic strengths (f_k) were also determined for including the wood batch in the strength classes (ABNT NBR 7190:1997). The results obtained allow to classify the studied species as C40 / dicotyledons ($f_{c0,k}$ = 48 MPa) with density 1.04 g/cm³ and small values of shrinkage. These results enable the use of Sabiá wood specie for structural purposes in civil construction.

Keywords

Caatinga; Wood; Timber Structures; Civil Construction.

1. Introduction

Brazil has continental dimensions and, for this reason, presents in its territory different biomes (Amazon, Cerrado, Atlantic Forest, *Caatinga*, Pampa and Pantanal), each of them with special characteristics, mainly in relation to the flora [1]. It is estimated that, in the Brazilian Amazon region alone, there are approximately 12,000 tree species, most of them still without their known technological properties [2]. Research centers present studies on wood properties from native species of different biomes [3-6].

Brazilian native species Sabiá (*Mimosa caesalpiniaefolia* Bentham) comes from *Caatinga* (states of Ceará, Maranhão, Minas Gerais, Paraíba, Pernambuco, Piauí and Rio Grande do Norte). Their trees have height and diameter at breast height (DAP) of up to 10 m and 30 cm, respectively [7,8]. Sabiá wood shows a distinction between sapwood and heartwood (strong pink coloration). In addition, it is considered to be high density (ranging from 0.80 to 1.10 g/cm³) [9, 10].

For the use of wood as a raw material for the construction of structures, it is important to characterize its technological properties, mainly physical and mechanical [11,12]. The Brazilian Association of Technical Standards (ABNT) presents ABNT NBR 7190: 1997 "Timber Structures Design", reference document for such purpose [13].

In Annex B (Determination of wood properties for structural design) of ABNT NBR 7190:1997, the indications of the necessary tests and their respective methods for the characterization of the wood are presented for their use in structures [14-19].

Among the properties of interest, the strength in compression parallel to the grain (f_{c0}) is highlighted, since, it permits to determine the characteristic strength ($f_{c0,k}$), to frame a batch of wood in one of the resistance classes established by ABNT NBR 7190: 1997 [13] and direct its use as structural material [20-22].

The characterization of the batch of wood of a certain species is important before its use, since the wood is a natural material, it presents variabilities in its properties, which may be related by genetic questions [23-26] or even by edaphoclimatic characteristics [27-30].

The aim of this research is the determination of some physical and mechanical properties of the Sabiá wood specie (*Mimosa caesalpiniaefolia* Bentham) to verify the viability of its use as raw material for the construction of wood structures.

2. Materials and Methods

In order to carry out this research, was used batches of Sabiá wood specie from a certified area of Juazeiro do Norte, state of Ceará, Brazil (geographical coordinates: 07º12'47 "S, 39º18'55" W). The batches were obtained from legal reserve trees, which had their first processing still in the Northeast. The drying of air to the moisture content of the order of 12% (as recommended by ABNT NBR 7190:1997 [13]) occurred at Wood and Timber Structures Laboratory (LaMEM), of Structural Engineering Department (SET), School of Engineering of São Carlos (EESC), University of São Paulo (USP), in São Carlos, State of São Paulo, Brazil.

After stabilization of the moisture content (accompanied by portable electric meter), the specimens were prepared to estimate the physical and mechanical properties of Sabiá wood specie (Table 1). For each of the estimated properties, 12 specimens were performed according to the recommendations of ABNT NBR 7190:1997 [13].

Table 1 – Estimated physical and mechanical properties of Sabiá wood specie

Physical properties	Abbreviation
Apparent density with 12% moisture content	ρ_{12}
Total Radial Shrinkage	RRT
Total Tangential Shrinkage	RTT
Total longitudinal Shrinkage	RLT
Mechanical properties	Abbreviation
Strength in compression parallel to the grain	f_{c0}
Strength in compression perpendicular to the grain	f_{c90}
Modulus of elasticity in compression parallel to the grain	E_{c0}
Modulus of elasticity in compression perpendicular to the grain	E_{c90}
Tensile strength parallel to the grain	f_{t0}
Tensile strength perpendicular to the grain	f_{t90}
Shear strength parallel to the grain	f_{v0}
Cleavage strength parallel to the grain	f_{s0}
Modulus of rupture in static bending	f_M
Modulus of elasticity in static bending	E_M

The classification of the batches of wood of Sabiá wood specie in the strength classes recommended by the ABNT NBR 7190:1997 [13] was carried out using Equation 1, where f_k means the characteristic strength value, n the number of specimens. For the use of Equation 1, the strength values of each test specimens must be placed in ascending order ($f_1 < f_2 < f_3 \ldots < f_n$), discarding the largest value if the number of specimens is odd. The characteristic strength value cannot be less than the lowest strength value or 70% of the average value.Statistical analysis was performed at the Federal University of São Carlos (UFSCar), Brazil, using the software *Bioestat 5.3*.

$$f_k = \left(2 \cdot \frac{\left(f_1 + f_2 + f_3 ... + f_{\frac{n}{2}-1} \right)}{\frac{n}{2} - 1} - f_{\frac{n}{2}} \right) \cdot 1,1 \qquad \text{Equation (1)}$$

3 Results and discussions

Table 2 presents the mean values (x_m), the coefficients of variation (CV), the minimum (Min), maximum (Max) and characteristic values of strength for each studied property of Sabiá wood specie.

Table 2 – Estimated physical and mechanical properties of Sabiá wood specie

Properties	ρ_{12} (g/cm³)	RRT (%)	RTT (%)	RLT (%)	f_{c0} (MPa)
x_m	1.04	2.70	4.70	0.50	68.46
Min	0.94	1.38	3.26	0.50	61.55
Max	1.10	3.96	6.59	0.55	82.41
CV (%)	5.80	13.00	11.00	-	15.89
f_k	-	-	-	-	48
Properties	f_{c90} (MPa)	f_{t0} (MPa)	f_{t90} (MPa)	f_{v0} (MPa)	f_{s0} (MPa)
x_m	19.25	8.74	9.60	18.50	1.35
Min	13.47	5.94	6.99	9.20	0.66
Max	23.55	11.36	16.51	22.35	1.54
CV (%)	18.65	23.43	10.28	29.30	32.76
f_k	12	6.11	6.70	12	0.88
Properties	f_M (MPa)	E_M (MPa)	E_{c0} (MPa)	E_{c90} (MPa)	
x_m	56.35	14800	15400	820	
Min	43.35	12687	12165	575	
Max	74.19	17245	19208	985	
CV (%)	18.55	12.15	23.88	17.89	
f_k	39	-	-	-	

Sabiá wood specie presented density higher than that estimated for *Vatairea* sp., *Erisma uncinatum*, *Schizolobium amazonicum* and *Anadenanthera colubrina* [15,17-19]. The mean value of density determined for the Sabiá wood specie (ρ_{12} = 1.04 g/cm³) allows comparing it to other species, such as Champagne or Cumaru (*Dipterix odorata*), Cutiúba (*Goupia paraensis*), Ipê (*Tabebuia serratifolia*), Jatobá (*Hymenaea* sp.) and Tatajuba (*Bagassa guianensis*) [23].

Sabiá wood specie presented mean values of radial and tangential shrinkages lower than *Vatairea* sp., *Erisma uncinatum*, *Schizolobium amazonicum* and *Anadenanthera colubrina* [15,17-19]. In addition, their mean values of shrinkage are also lower than those determined by Dias and Lahr [23] for 40 Brazilian native species.

Analyzing the mean values of the physical properties presented by Sabiá wood specie, it is possible to recommend this wood specie for use as structural material and, for other purposes, within building construction, among them doors, windows and floors [12,20].

The average value of compressive strength parallel to the fibers (f_{c0}) presented by Sabiá wood specie was equal to 68.46 MPa, and its characteristic value ($f_{c0,k}$) equal to 48 MPa, which allows to include this batch in strength class C40 (dicotyledons), being able to be used for structural purposes. The result of $f_{c0,k}$ for Sabiá allows to compare it with others of the same strength class: Angelim-amargoso (*Vatairea fusca*), Angelim-araroba (*Vataireopsis araroba*) and Mandioqueira (*Qualea paraensis*) [23].

5. Conclusions

According to the results obtained for the studied properties of the Sabiá wood specie, it is possible to admit the possibility of its use in the civil construction as raw material for structures. The studied batch presented characteristic value in compression parallel to the grain equal to 48 MPa, which classified it as a C40 wood of dicotyledons. Regarding its physical properties, it had a mean density 1.04 g/cm³ and mean values of radial and tangential shrinkage lower than other Brazilian native species.

6. References

[1] Instituto Brasileiro de Geografia e Estatística (IBGE). Mapas de Biomas e de Vegetação. Available: <http://www.ibge.gov.br/home/presidencia/noticias/21052004biomashtml. shtm>. Portuguese (Accessed: 04 august 2017)

[2] Steege H, et al. The discovery of the Amazonian tree flora with an update checklist of all known tree taxa. Scientific Reports, Londres, v. 6, n. 29549, p. 1-15, 2016.

[3] Silva ES, et al. Colorimetria da madeira de oito espécies nativas do estado do Rio Grande do Sul, Brasil. Ciência da Madeira (Brazilian Journal of Wood Science), Pelotas, v. 6, n. 1, p. 31-37, 2015. Portuguese.

[4] Almeida DH, et al. Determination of density, shear and compression parallel to the grain strengths of Pariri (*Pouteria* sp.), Brazilian native wood specie. International Journal of Materials Engineering, Rosemead, v. 5, n. 5, p. 109-112, 2015.

[5] Cavalheiro RS, et al. Mechanical properties of Paricá wood using structural members and clear specimens. International Journal of Materials Engineering, Rosemead, v. 6, n. 2, p. 56-96, 2016.

[6] Almeida TH, Christoforo AL, Lahr FAR. Study of dimensional stability of Brazilian tropical wood species. 1. ed. Chisinau, República da Moldova: Lambert Academic Publishing, 2017. 113 p.

[7] Carvalho PER, et al. Sabiá *Mimosa caesalpiniifolia*: circular técnica 135. 1. ed. Colombo, PR: EMBRAPA, 2007. 10 p. Portuguese

[8] Gonçalves CA, Lelis RCC, Abreu HS. Caracterização físico-química da madeira de Sabiá (*Mimosa caesalpiniaefolia* Benth.). Revista Caatinga, Mossoró, v. 23, n. 1, p. 54-62, 2010. Portuguese.

[9] Paula JE. Madeiras que produzem álcool, coque e carvão. Atualidades do Conselho Nacional do Petróleo, Rio de Janeiro, v. 12, n. 72, p. 31-45, 1980. Portuguese.

[10] Ribaski J, et al. Sabiá (*Mimosa caesalpiniifolia*) Árvore de Múltiplo uso no Brasil. 1. ed. Colombo, PR: EMBRAPA, 2003. 4 p. Portuguese.

[11] Calil Junior C, Lahr FAR, Dias AA. Dimensionamento de elementos estruturais de madeira. 1. ed. Barueri, SP: Manole, 2003. 152 p. Portuguese.

[12] Calil Junior C, Molina JC. Coberturas em estruturas de madeira: exemplos de cálculo. 1. ed. São Paulo, SP: Pini, 2010. 207 p. Portuguese.

[13] Associação Brasileira de Normas Técnicas (ABNT). NBR 7190: Projeto de estruturas de madeira. Rio de Janeiro, 2007. 107 p. Portuguese.

[14] Logsdon NB, Finger Z, Borges CGA. Caracterização físico-mecânica da madeira de Perobamica, *Aspidosperma populifolium* A. DC. (Apocynaceae). Floresta**,** Curitiba, v. 38, n. 1, p. 11-21, 2008. Portuguese.

[15] Almeida DH, et al. Caracterização completa da madeira da espécie amazônica Paricá (*Schizolobium amazonicum* HERB) em peças de dimensões estruturais. Revista Árvore, Lavras, v. 37, n. 6, p. 1175-1181, 2013. Portuguese.

[16] Christoforo AL, et al. Characterization of tropical wood species for use in civil constructions. Journal of Civil Engineering Research, Rosemead, v. 3, n. 3, p. 98-103, 2013.

[17] Lahr FAR, et al. Full characterization of *Vatairea* sp wood specie. International Journal of Materials Engineering, Rosemead, v. 6, n. 3, p. 92-96, 2016.

[18] Lahr FAR, et al. Full characterization of *Erisma uncinatum Warm* wood specie. International Journal of Materials Engineering, Rosemead, v. 6, n. 5, p. 147-150, 2016.

[19] Christoforo AL, et al. Physico-mechanical characterization of the *Anadenanthera colubrina* Wood specie. Engenharia Agrícola, Jaboticabal, v. 37, n. 2, p. 376-384, 2017.

[20] Nahuz AR. Catálogo de madeiras brasileiras para a construção civil. 1. ed. São Paulo, SP: IPT, 2013. 103 p. Portuguese.

[21] Logsdon NB, Finger Z, Estevão JG. Descrição dendrológica e caracterização físico-mecânica da madeira de Amescla-aroeira, *Protium heptaphyllum* (Aubl.) March. (Burseraceae). Madeira: Arquitetura e Engenharia, São Carlos, v. 6, n. 17, p. 1-13, 2005. Portuguese.

[22] Logsdon NB, Finger Z, Penna ES. Caracterização físico-mecânica da madeira de Cedromarinheiro, *Guarea trichilioides* L. (Meliaceae). Scientia Forestalis, Piracicaba, v. 36, n. 77, p. 43-51, 2008. Portuguese.

[23] Dias FM, Lahr FAR. Estimativa de propriedades de resistência e rigidez da madeira através da densidade aparente. Scientia Forestalis, Piracicaba, n. 65, p. 102-113, 2004. Portuguese.

[24] Lobão MS, et al. Caracterização das propriedades físico-mecânicas da madeira de eucalipto com diferentes densidades. Revista Árvore, Lavras, v. 28, n. 6, p. 889-894, 2004. Portuguese.

[25] Oliveira JTS, Tomazello Filho M, Fiedler NC. Avaliação da retratibilidade da madeira de sete espécies de *Eucalyptus*. Revista Árvore, Lavras, v. 34, n. 5, p. 929-936, 2010. Portuguese.

[26] Almeida TH, et al. Density as estimator of dimensional stability quantities of Brazilian tropical woods. BioResources, Raleigh, v. 12, n. 3, p. 6579-6590, 2017.

[27] Cuecuecha OGV. et al. Densidad básica de la madera de los pinos y su relación con propiedades edáficas. Madera y Bosques, Xalapa, v. 21, n. 1, p. 129-138, 2015. Spanish.

[28] Huda ASMA, et al. Variation of the physical and mechanical properties of hybrid poplar clones. BioResources, Raleigh, v. 9, n. 1, p. 1456-1471, 2014.

[29] Lahr FAR, et al. Avaliação de propriedades físicas e mecânicas de madeiras de Jatobá (*Hymenaea stilbocarpa* Hayne) com diferentes teores de umidade e extraídas de regiões distintas. Revista Árvore, Lavras, v. 40, n. 1, p. 147-154, 2016. Portuguese

[30] Coral LLT, et al. Variation in wood physical properties within stems of *Guazuma crinita*, a timber tree species in the Peruvian Amazon. Madera y Bosques, Xalapa, v. 23, n. 1, p. 53-61, 2017. Portuguese.