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CHARACTERIZATION OF THE WOOD SPECIES *QUALEA ALBIFLORA* FOR STRUCTURAL PURPOSES

Tiago Capobianco Morando, André Luis Christoforo
Federal University of São Carlos
São Carlos, Brazil

Vinicius Borges De Moura Aquino
Federal University of Southern and Southeastern Pará
Santana Do Araguaia, Brazil

Francisco Antonio Rocco Lahr
University of São Paulo
São Carlos, Brazil

Greyce Bernardes De Mello Rezende, Raul Tadeu Lobato Ferreira
Federal University of Mato Grosso
Barra Do Garças, Brazil

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ABSTRACT

The present article aimed to characterize the wood specie *Qualea albiflora* (Mandioqueira), in order to enable its use for structural purposes. The tests to obtain the physical and mechanical characteristics were carried out according to the Brazilian standard ABNT NBR 7190, allowing the classification of the *Qualea albiflora* in the strength class C60, a wood species suitable for use in heavy constructions. After the characterization, it was verified with the aid of regression models (linear, logarithmic, exponential and geometric), that it is not possible to make use of the apparent density in the estimation of the other physical and mechanical characteristics, obtaining a bad adjustment in all the cases (R^2 < 50.00%) and the non-representativeness of the models adopted (P-Value> 0.05).

KEYWORDS: *Qualea albiflora*, regression models, physico-mechanical characterization, apparent density, timber structures.

INTRODUCTION

Wood is a material of recurrent use in the most diverse sectors of the economy, due to its wide availability, being a product found in abundance in nature, as well allowing its work with equipment of simple use (Pfeil and Pfeil 2003). Among the possibilities of use for civil construction, it can be seen from roofing, forms for reinforced concrete and composing structures responsible for high strengths, since in terms of resistance, it is comparable to the materials most commonly used in Brazilian civil construction, such as steel and reinforced concrete (Dias and Lahr 2004).

There is a great availability of wood species in Brazil, which can be used for a wide range of purposes, from the making of furniture to the structures of buildings and bridges. However, even the nation having a rich variety of species, few are actually used, leading to a predatory use of more usual species (Correa 1998, Sales 2004, Lahr et al. 2016).

In Brazil, to use timber structures, the data provided in Annex E of standard ABNT NBR 7190: 1997 are used, which relate to the physical and mechanical characteristics of some species of wood for balance moisture at 12%. However, there is a limited range of wood varieties and characteristics, thus making the characterization of more national species interesting (Christoforo et al. 2017).

In order to make proper use of wood as a structural material, its proper characterization is necessary, however, in order to obtain such values, it is necessary to follow the procedures described in Annex B of ABNT NBR 7190: 1997, which requires high cost of performing the tests, which hampers the correct use of the material (Dias and Lahr 2004).

A possible exit to characterize the wood is to make use of the apparent density, which is an easily obtainable experimental value, which consists on the ratio of apparent mass by its apparent volume and that allows the estimation of the other properties of the wood (Zenid 2009, Nahuz et al. 2013, Almeida et al. 2014, Machado et al. 2014, Christoforo et al. 2016, Christoforo et al. 2017).

Thus, to make proper use of wood as a structural material and contribute to the use of new wood species in civil construction, this research aims to characterize *Qualea albiflora* wood specie, determining its physical and mechanical properties and evaluate the possibility to estimate strength properties by apparent density.

MATERIALS AND METHODS

In all the tests, homogeneous lots were used, as required by the Brazilian standard (ABNT NBR 7190: 1997). Thus, for lumber, the batch volume cannot exceed 12 m^3, in which the specimens should be randomly removed, with the restriction of one per piece of wood. In order to carry out the tests, the wood specie *Qualea albiflora* was stored at a climate chamber with moisture content of approximately 12%, this being the value defined as the reference for equilibrium moisture by the Brazilian standard. All the tests described here were performed at the Wood and Timber Structures Laboratory (LaMEM) of the University of São Paulo (USP) at the São Carlos campus, according to the procedures described in Annex B of the Brazilian standard ABNT NBR 7190 (1997). The specimens used were obtained from a lot of wood from the north of the Brazilian state of Roraima (2°22'43''N; 60°55'46"W).

In this research, it was performed a full characterization, according the Brazilian Standard ABNT NBR 7190 (1997), determining the following physical and mechanical properties: apparent density ($\rho_{ap,12\%}$), total radial shrinkage (TRR), total tangential shrinkage (TTR), compressive strength parallel to the grain (f_{c0}), tensile strength parallel to fibers (f_{t0}), tensile strength normal to the grain (f_{t90}), shear strength parallel to the grain (f_{v0}), splitting strength (f_{s0}), conventional strength on static bending test (f_m), hardness parallel to the grain (f_{H0}), hardness normal to the grain (f_{H90}), toughness (W), modulus of longitudinal elasticity in compression parallel to the grain (E_{c0}), modulus of elasticity in tension parallel to the grain (E_{t0}) and conventional modulus of elasticity on static bending test (E_m). On Fig. 1, it is described the scheme of wood specimens.

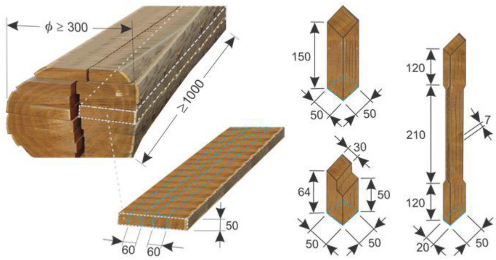

Fig. 1: Specimen scheme and dimensions of wood specimens (dimensions in mm).

It should be noted that 15 values for each one of its physical (3) and mechanical properties (9) were investigated, resulting in 180 experimental values obtained.

The machine used on the tests was an universal test machine EMIC®, with load cell of 500 kN, with stress rate of 10 MPa per minute.

The procedure described on Brazilian Standard ABNT NBR 7190 (1997) is similar to the procedure disposed on international standard ISO 13061 (2017), widely used internationally for wood characterization.

In order to allow classification of *Qualea albiflora* wood in one of the strength classes provided for in the Brazilian standard, it is used the Eq. 1, where f_{wk} is the characteristic strength and n is the number of specimens analyzed. To make use of Eq. 1, it is necessary to order the strength values in ascending order, to ignore the highest value, if the sample number is odd and not to adopt a characteristic value lower than f1 or 0.70 of the average strength.

$$f_{wk} = \left(2 \cdot \frac{x_1 + x_2 + \ldots + x_{\frac{n}{2}-1}}{\frac{n}{2} - 1} - x_{\frac{n}{2}} \right) \cdot 1{,}1 \quad (1)$$

The estimation of the physical and mechanical characteristics is done with the use of regression models, based on analysis of variance (ANOVA). From the data of the apparent density, obtained in the moisture content to 12% for the wood of the species *Qualea albiflora*, Eqs. 2 to 5 are used to verify the possibility of the estimation of the properties, being they correspondent to the linear regression models, exponential, logarithmic and geometric respectively.

$$Y = a + b \cdot \left(\rho_{ap,12\%}\right) \quad \text{(Lin – linear)} \quad (2)$$

$$Y = a \cdot e^{(b \cdot \rho_{ap,12\%})} \quad \text{(Exp – exponential)} \quad (3)$$

$$Y = a + b \cdot \ln(\rho_{ap,12\%}) \quad \text{(Log – logarithmic)} \quad (4)$$

$$Y = a \cdot \left(\rho_{ap,12\%}\right)^b \quad \text{(Geo – geometric)} \quad (5)$$

When using ANOVA, a significance level of 5% (α) was considered, and when the P-value is below that level, the estimate of the studied characteristic is accepted as a function of the apparent density, the opposite being done for when *P*-value is higher than the level of significance. That is, it is considered as the null hypothesis the non-representativeness of the set and, alternatively, the representativeness.

In order to determine the regression model that provides the best fit of the studied magnitude with respect to the apparent density, it is used the coefficient of variation (R^2) to find among the models considered significant by the ANOVA method, which best adjusts the values obtained.

RESULTS AND DISCUSSION

In Tab. 1, the physical and mechanical wood properties of the species *Qualea albiflora* are determined experimentally, knowing that they were obtained for a total of 15 specimens in a batch considered homogeneous, where are the mean values and CV is the coefficient of variation.

Tab. 1: Descriptive statistics of experimentally obtained values for wood species Qualea albiflora.

Properties	Mean value	Minimum	Maximum	CV (%)	f_{wk} (MPa)
$\rho_{ap,12\%}$ ($kg \cdot m^{-3}$)	850	790	910	3.9	----
TRR (%)	4.72	3.97	6.50	13.75	----
TTR (%)	9.34	7.34	11.09	12.10	----
f_{c0} (MPa)	70.93	54.00	93.00	14.64	60,5
f_{t0} (MPa)	91.00	41.00	140.00	32.49	63,7
f_{t90} (MPa)	2.85	1.40	5.70	50.61	1,99
f_{v0} (MPa)	17.13	12.00	22.00	15.73	15,03
f_{s0} (MPa)	0.57	0.40	1.00	29.09	0,4
f_M (MPa)	113.10	81.00	184.00	22.92	81
E_{c0} (MPa)	19143	14169	23297	12,78	----
E_{t0} (MPa)	18738	15375	21936	9,83	----
E_M (MPa)	18436	14717	25526	14,68	----
f_{H0} (MPa)	111,1	67	162	20,66	82,87
f_{H90} (MPa)	74,2	46	149	30,40	59,03
W (N.m)	118,4	85	166	19,86	----

When comparing the values obtained in Tab. 1 with those presented in Annex E of ABNT NBR 7190 (1997), it is noted that the values found are consistent with those already tabulated. In order to determine the apparent density property, it should be noted that this characteristic has an average of 0.85 $g \cdot cm^{-3}$, the same value found by Stolf and Lahr (2002), being also very close to the data provided by the Brazilian standard of 0.86 $g \cdot cm^{-3}$.

The Mandioqueira wood specie can be considered heavy ($\rho_{ap,12\%}$ = 0.85 $g \cdot cm^{-3}$) as it is pointed out by Zenid (2009), who classified Platonia insignis Mart wood species, with an apparent density close to *Qualea albiflora* ($\rho_{ap,12\%}$ = 0.82 $g \cdot cm^{-3}$) with such classification, and can be used for heavy civil construction, such as stakes, beams and columns.

The value determined for the compressive strength parallel to the fibers (f_{c0}), is in agreement with that determined by Nahuz et al. (2013), with a value of 56.5 MPa, allowing its classification with strength class C60, being this category, the same found by Christoforo et al. (2016), where compressive strength parallel to the grain of 59.0 MPa was determined.

The results obtained by Stolf and Lahr (2002) determined the values of toughness (W = 119 N·m) and static bending strength (f_M = 113.1 MPa), which are very close to those obtained experimentally in this research.

The Brazilian Standard ABNT NBR 7190 (1997) prescribes the maximum value for CV for the characterization to be considered adequate, i.e., the statistical significance of results is guaranteed with no further evaluation. The values are 18% for normal efforts and 28% for tangential efforts. The properties f_{t0}, f_{t90} presented a CV above the values higher than the values disposed on the Brazilian norm. It could be caused by the variability inherent to the tensile strength test (Pertuzzatti et al. 2018), for the parallel tensile strength test and the rupture form, which is fragile, for normal tensile strength test, considering the rupture plan on the wood specimen and the anatomic and internal structure of wood, demanding wood polyios is along the test. This literature demands more studies about this kind of rupture.

Tab. 2 presents the equation that best approximates the properties of wood specie *Qualea albiflora* by means of the apparent density. Where P-value allows evaluating the representativity (P-value < 0.05), or non-representativity (P-value > 0.05) of the regression models evaluated, R^2 is the determination coefficient, whose function is to show how well the adopted model can adjust the sample, and the parameters *a* and *b* are used to make the curve adjustment.

Tab. 2: Estimation of physical and mechanical properties of Qualea albiflora based on apparent density.

Properties	**Model**	**a**	**b**	**P-value**	**R^2 (%)**
TRR	Logarithmic	0.9703	-0.0760	0.2883	8.62
TTR	Logarithmic	12.490	-0.1780	0.0071	43.89
f_{c0}	Geometric	0.4594	0.1453	0.0394	28.72
f_{t0}	Geometric	0.6727	0.0531	0.0628	24.14
f_{t90}	Exponential	0.8796	-0.0110	0.1276	16.92
f_{v0}	Geometric	0.9434	-0.0360	0.5993	2.18
f_{s0}	Logarithmic	0.8263	-0.0450	0.1797	13.39
f_M	Geometric	0.6077	0.0718	0.1441	15.67
f_{H0}	Linear	0.8369	0.0001	0.7282	0.96
f_{H90}	Linear	0.8241	0.0004	0.3474	6.81
W	Logarithmic	0.4724	0.0799	0.0718	22.80
E_{c0}	Logarithmic	-0,564	0,1438	0,0251	32,98
E_{t0}	Logarithmic	0,5072	0,0351	0,7102	1,10
E_M	Logarithmic	-0,1890	0,1062	0,1023	19,19

For the wood specie *Qualea albiflora* it is not possible to use the apparent density as an estimator of the other wood properties, since, for most of the characteristics, the models evaluated are not representative (P-value > 0.05). The only exceptions found were for the compressive strength parallel to the fibers, tangential shrinkage and modulus of elasticity in the compression parallel to the fibers. However, they presented low coefficients of representativeness (R^2 < 50.00%), being not possible to use such models as an estimator.

A significant relationship was determined for the toughness of several wood species by Almeida et al. (2014), where a coefficient of determination of 87% for the geometric fit was reached.

It was studied by Logsdon et al. (2013) the dimensional stability of several species of wood and made the statistical treatment of the data by grouping the results, obtaining for most properties the best fit as the geometric, using the basic density as an estimator. However, for the characteristics of the radial and tangential contraction, the regression models did not return a satisfactory result (R^2 < 20% in both cases). While it was possible to estimate the dry apparent density and at 12% moisture content (R^2 > 95%).

The geometric fit for a set of species was again verified by Dias and Lahr (2004), where the properties ($f_{c0}, f_{t0}, f_{v0}, f_{s0}, f_{H0}, f_{H90}$ and W) were obtained on the basis of apparent density, finding satisfactory adjustments for all characteristics, with a minimum determination coefficient of 62%.

When analyzing the influence of the Cupiúba wood extraction region (Silva et al. 2018) used the apparent density to estimate the other properties, when analyzing only this specie, obtained satisfactory adjustments ($R^2 \geq$ 64.82%) with a predominance of linear adjustment.

CONCLUSIONS

In this research, the physical and mechanical characteristics of *Qualea albiflora* wood were determined experimentally, and values consistent with those of the literature were obtained, as well as Brazilian Standard ABNT NBR 7190. This wood specie was classified in the strength class C50 of the hardwoods, demonstrating the possibility to use this wood specie for structural purpose in civil construction. It was also found that it is not possible to estimate these properties by means of the density, since as shown in Tab. 2, most of the relationships are not significant (P-value > 0.05) and the expressions determined do not represent well the samples, because for all properties, the R^2 value was less than 50%, and the smaller the proximity to 100%, the lower the quality of the regression.

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Tiago Capobianco Morando, André Luis Christoforo
Federal University of São Carlos
Department of Civil Engineering
São Carlos
Brazil

Vinicius Borges De Moura Aquino*
Federal University of Southern and Southeastern Pará
Technology College
Santana Do Araguaia
Brazil
*Corresponding author: aquino.vini@hotmail.com

Francisco Antonio Rocco Lahr
University of São Paulo
Department of Structural Engineering
São Carlos
Brazil

Greyce Bernardes De Mello Rezende, Raul Tadeu Lobato Ferreira
Federal University of Mato Grosso
Earth and Exacts Sciences Institute
Barra Do Garças
Brazil