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Full Characterization of *Erisma uncinatum Warm* Wood Specie

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Abstract Wood is a material that for years has been used by man for a variety of purposes, particularly in rural and civil constructions. For the possibility of shortages of some wood species, the characterization of other little known species as alternatives is necessary. This research aimed to determine, with the aid of the Brazilian standard NBR 7190, physical and mechanical properties of *Cambará rosa* or *Cedrinho* wood (*Erisma uncinatum Warm*), and with the support of regression models (linear, exponential, geometric, logarithmic) based on analysis of variance (ANOVA), to estimate the values of strength and stiffness as a function of apparent density, for the density being a property of easy determination. Were obtained 12 determinations by physical and mechanical propertie, resulting in 204 experimental results. The mechanical properties of *Erisma uncinatum Warm* presented performance compatible with other species used in civil construction, but not being considered a high strength wood. By means of regression models to estimate the strength and stiffness values, it was found that no property can be estimated by the apparent density.

Keywords Characterization, *Erisma uncinatum Warm*, Regression model, Analysis of variance (ANOVA)

1. Introduction

The use of wood in construction is a practice carried out for many years by mankind from the need to stock up on food, overcoming obstacles to the construction of shelters [1]. Using wood in various purposes depends on the knowledge of its properties (physical, chemical, mechanical and anatomical) for more rational use of this material, which comes from natural sources, perfectly fulfills the requirements by the current environmental appeal of products and service furnish by mankind [2, 3].

The high demand allied with few wood species traded options has impacted on its prices, providing a new moment for the Brazilian timber industry, being necessary to define which new species could replace the traditionally used in construction [4-6]. Moreover, with the growing awareness of the population to use materials that cause the least harm to the environment, the wood from planted forests becomes a material with great potential [6].

Therefore, the wood *Erisma uncinatum Warm* (Figure 1) becomes a great option, especially to the north and a small part of the center-west region of Brazil, where the production of this wood specie is more pronounced [7].

Figure 1. Image of the *Erisma uncinatum Warm* Wood. Source: http://artemarcenaria.blogspot.com.br/2011/07/ficha-tecnica-cedrinho.html

By the density of the wood *Erisma uncinatum Warm* (0.650 g/cm³), it is also indicated for the glued laminated timber production and also provide adhesive compatibility [8]. It is worth mentioning that the use of a particular species of wood in construction, as well as any other material, the knowledge of its physical and mechanical properties is essential for the project, which allows a more economical and safe design.

The characterization of wood species is made by determining its mechanical and physical properties by standardized tests. In Brazil, the standard ABNT NBR 7190 [9] defines the parameters for its characterization. However,

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the drawback of many such tests is the need to use large and expensive equipment available in research centers [9].

On the other hand, a physical property of easy experimental determination is the apparent density, defined by the ratio between the mass and volume of the sample at 12% moisture. As the density is a basic physical property, its values allows the determination of an adequate estimation of the wood properties [2, 10]. The estimatimation of some properties of strength and stiffness by density via mathematical models (regression models) enables to the engineer a better pre-sizing of the structure.

In order to contribute to the use of new wood species in rural and construction, as well as in other applications, this study aimed to characterize the *Erisma uncinatum Warm* wood specie and evaluate the possibility of estimating the strength and stiffness properties investigated by the apparent density.

2. Material and Methods

The wood samples of the *Erisma uncinatum Warm* has been properly stored, with close to 12% moisture content, and this is the moisture balance established by the Brazilian standard [9].

All tests were carried out on the Laboratory of Wood and Wood Structures (*Laboratório de Madeira e de Estruturas de Madeira - LaMEM*), at the São Carlos Engineering School (EESC), University of São Paulo (USP).

The physical and mechanical properties (Table 1) were obtained according to the assumptions and calculation methods given by the Brazilian standard ABNT NBR 7190 [9] (Wooden Structures Project), provided on its Annex B. It should be noted that 12 values for each one of its physical (3) and mechanical properties (14) were investigated, resulting in a total of 204 experimental values obtained.

In addition to obtaining the physical and mechanical properties listed in Table 1, the wood *Erisma uncinatum Warm* has been properly classified in the timber strength classes [9], defined by determining its characteristic value of compressive strength parallel to the grain ($f_{c0,k}$).

To estimate the strength and the stiffness properties (Y), as a function of the apparent density (ρ_{12}) of the *Erisma uncinatum Warm* wood specie, regression models were used (Equations 1 to 4) based on analysis of variance (ANOVA), tested in a way to establish the best fit for estimated property.

$$Y = a + b \cdot \rho_{12} \qquad \text{[Lin - linear]} \tag{1}$$

$$Y = a \cdot e^{b \cdot \rho_{12}} \qquad \text{[Exp - exponential]} \tag{2}$$

$$Y = a + b \cdot Ln(\rho_{12}) \qquad \text{[Log - logarithmic]} \tag{3}$$

$$Y = a \cdot \rho_{12}{}^{b} \qquad \text{[Geo - geometric]} \tag{4}$$

By ANOVA regression models, considering the 5% level of significance (α), the formulated null hypothesis consisted by the non-representativeness of the tested models (H_0: $\beta = 0$), and the representativeness as an alternative hypothesis (H_1: $\beta \neq 0$). P-value greater than the significance level implies in the accepting H_0 (the model tested is not representative - ρ_{12} variations are unable to explain the variation in strength and stiffness property), refuting it otherwise (the model tested is representative).

Besides the use of ANOVA, which allows to accept or not the representativeness of the tested models, the coefficient of determination values (R^2) were obtained as a way to evaluate the variation capability in the apparent density to explain the estimated dependent variable, making it possible to determine, among the considered significant models (4 models for each of the 14 strength properties and estimated stiffness – resulting in 56 adjustments), the ones with the best fit.

Table 1. Mechanical and physical properties measured for the *Erisma uncinatum Warm* wood specie

Propertie	Notation
Apparent density	ρ_{12}
Total radial Shrinkage	RRT
Total tangencial Shrinkage	RTT
Compressive strength parallel to the grain	f_{c0}
Tensile strength parallel to the grain	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
Modulus of elasticity in parallel directions to the grain	E_{c0}
Modulus of elasticity in tension parallel to the grain	E_{t0}
Conventional modulus of elasticity on static bending test	E_m
Hardness parallel to the grain	f_{H0}
Hardness normal to the grain	f_{H90}
Toughness	W
Compressive strength in normal direction to the grain	f_{c90}

3. Results and Discussion

Tables 2 and 3 shows the mean values ($\overline{x}$), coefficient of variation (*Cv*), the lowest (*Min*) and the highest (*Max*) of the physical and mechanical properties of the *Erisma uncinatum Warm* wood, respectively.

Table 2. Physical properties results for the *Erisma uncinatum Warm* wood

Stat.	ρ_{12} (kg/m^3)	RRT (%)	RTT (%)
$\overline{x}$	680	5.83	10.55
Cv	0.05	0.12	0.09
Mín	620	4.72	8.85
Máx	740	7.02	12.19

Table 3. Mechanical properties results for the *Erisma uncinatum Warm* wood

Stat.	f_{c0} (MPa)	f_{t0} (MPa)	f_{t90} (MPa)	f_{v0} (MPa)
$\overline{x}$	34	45	4.9	14
Cv	0.15	0.30	0.15	0.16
Mín	27	31	4.2	11
Máx	43	67	6.4	18
Stat.	**f_{s0} (MPa)**	**f_m (MPa)**	**E_{c0} (MPa)**	**E_{t0} (MPa)**
$\overline{x}$	0.8	63	12967	12764
Cv	0.16	0.21	0.18	0.14
Mín	0.6	40	9732	10800
Máx	1.0	82	16960	15887
Stat.	**E_m (MPa)**	**f_{H0} (MPa)**	**f_{H90} (MPa)**	**W (N·m)**
$\overline{x}$	12376	51	67	33.39
Cv	0.07	0.09	0.12	0.19
Mín	10263	43	55	20.10
Máx	13587	60	79	41.20
Stat.	**f_{c90} (MPa)**		**E_{c90} (MPa)**	
$\overline{x}$	7.0		7095	
Cv	0.17		0.18	
Mín	5.0		4812	
Máx	9.0		9148	

The *Erisma uncinatum Warm* timber is classified as belonging to strength class C20, because it shows a characteristic value of compressive strength in the direction parallel to the grain (f_{c0}) equal to 34 MPa.

The obtained f_{c0} value for the *Erisma uncinatum Warm* wood is very close to the value obtained for *Paricá* wood (24 MPa) [2], *Toona ciliata* (27MPa) [11] and *Eucalyptus benthamii* Maiden et Cambage (37.34MPa) [12]. According to the study of Institute for Technological Research (*Instituto de Pesquisas Tecnológicas – IPT*) [7], such timbers can be used in the manufacture of doors, shutters, slats, gaskets, ceilings, scaffolding, formwork, furniture, among other utilities. However, because it's significantly lower f_{c0} value compared to the *Amescla-Aroeira* wood (59.03 MPa) [13], the *Erisma uncinatum Warm* wood is not recommended for use in medium to large structures.

The mean value obtained from the apparent density of 0.680 g/cm³ classifies *Erisma uncinatum Warm* wood as a heavy wood [14], with the same classification as *Minquartia guianensis*, *Lecythis poiteaui*, *Mezilaurus itauba*, *Manilkara huberi* and *Brosimum rubescens* [10]. However, *Erisma uncinatum Warm* wood is lighter, since the density of the other ranging from 0.835-0.904 g/cm³. It has higher density as compared to the wood densities of *Liquidambar sp.* [15], Pinus and Teca [2], *Cedrela fissilis*, *Hibrido clonal* and *Hovenia dulcis* [16], ranging between 0.478 and 0.577g/cm³. The softwoods, such as *Toona ciliata* [11], Paricá [6] and *Gallesia integrifólia* [16] presents density value range between 0.318 g/cm³ and 0.370 g/cm³.

The Brazilian standard ABNT NBR 7190 [9] determines maximum values for the coefficient of variation (*Cv*) for the characterization could be described as adequate, being 18% to the strength to normal efforts and 28% for tangential efforts. All properties met the values of the coefficients of variation required by the standard, but the tensile strength parallel to the fibers (f_{t0}), which exceeded the limit, showing a *Cv* equal to 0.30.

Tables 4 and 5 shows the best fits (by property) obtained using regression models for apparent density in the estimation of the values of strength and stiffness, respectively.

Table 4. Regression models for the strength values estimation of the *Erisma uncinatum Warm* by the apparent density

	Model	P-value	a	b	R^2 (%)
f_{c0}	Exp	0.7016	50.67	-0.57	1.53
f_{t0}	Lin	0.0985	-98.48	212.79	24.90
f_{t90}	Geo	0.4459	3.64	-0.73	5.92
f_{v0}	Log	0.5651	17.73	8.47	3.42
f_{s0}	Geo	0.5281	1.059	0.69	4.10
f_m	Geo	0.8598	69.01	0.27	0.33
f_{H0}	Log	0.6411	45.69	-14.17	2.26
f_{H90}	Exp	0.5538	108.70	-0.73	3.62
W	Log	0.4417	20.76	-32.25	6.03
f_{c90}	Exp	0.2730	2.0860	1.73	11.86

Table 5. Regression models for the stiffness values estimatimation of the *Erisma uncinatum Warm* by the apparent density

	Model	P-value	a	b	R^2 (%)
E_{c0}	Exp	0.51	28219.7	-1.17	4.38
E_{t0}	Log	0.20	6900.37	-14972.6	15.31
E_m	Exp	0.06	27346	-1.17	29.18
E_{c90}	Lin	0.14	-4997.41	17870.9	19.73

P-values above 5% from ANOVA regression models revealed the non-representativeness of the tested settings, showing that the apparent density not to be a good estimator of the strength and stiffness values for the *Erisma Warm uncinatum* timber.

The values of the coefficient of determination (R^2) near to 80% for the toughness estimated by apparent density obtained from Almeida *et al.* [2] were significantly higher compared to the values of the coefficient of determination in the estimation of the toughness (6.03%) obtained for *Erisma uncinatum Warm* wood. This result is justified by the use of various species of wood and different densities explored in Almeida *et al.* [2] research, which ended up favoring the quality of the obtained settings.

4. Conclusions

The results of this study allow us to conclude:

- From the obtained coefficient of variation values, the characterization of *Erisma uncinatum Warm* species can be considered in accordance with the required by the Brazilian standard [9].
- *Erisma uncinatum Warm* wood is classified into C20 strength class, because it presents a characteristic value of compressive strength ($f_{c0,k}$) equal to 34 MPa. Thus, it can be used in doors, shutters, strips, gaskets, liners, scaffolds , molds, furniture, and other utilities.
- The estimation of strength and stiffness values of the *Erisma uncinatum Warm* wood depending on the apparent density provided no significant adjustments by the regression models, showing unsuitable use of such estimation for this kind of wood.

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