

# Properties of *Eucalyptus umbra* Wood for Timber Structures

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**Abstract** This study involved the study of physical and mechanical properties of *Eucalyptus umbra* wood for its use in timber structures. Two physical and fourteen mechanical properties tests were performed according to Brazilian code ABNT NBR 7190:1997. Two moisture contents were considered: above the Fiber Saturation Point (30%) and standardized point 12%. Decreasing the moisture content, this study presented an increase in eight mechanical properties. Oppositely, five mechanical properties presented decreasing of values, and one single variable persisted stable. But statistical perspective supported by the t-test, only three mechanical properties ( $f_{t90}$ ,  $f_{H0}$  and  $W$ ) increased significantly. According to results obtained in this study, it is possible to use *Eucalyptus umbra* wood as raw material for structures.

**Keywords** Mechanical properties, Physical properties, Timber structures, Wood

## 1. Introduction

Wood is used as raw material in several sectors of economy, such as cellulose and paper production [1] and oriented strand board panels (OSB) [2]. For each purpose, their properties should be estimated, due to the variability found among different species [3] and, within the species itself, due to anatomical factors [4], edaphoclimatic [5] and moisture content [6].

For wood use as structural element in construction of bridges [7], trusses [8] among others [9], physical and mechanical properties are the most important [10-12].

In Brazil, the code ABNT NBR 7190:1997 [13] governs design of timber structural elements considering physical and mechanical properties determined by the procedures in its annex B.

Among species that can be used in civil construction, the most important are those belonging to genus *Eucalyptus* and *Corymbia* [14, 15]. Because of their rapid growth, eucalypt species have emerged among the major alternatives for lumber production in Brazil for the coming years [16].

*Eucalyptus umbra* is a species from Australia, with little diametric, Specific gravity, chemical constituents and

anatomical characteristics variabilities [17]. In addition, *Eucalyptus umbra* is resistant to attack by bio-deterioration agents [18].

This study aims to investigate the possibility of *Eucalyptus umbra* wood use in timber structures, through its physical and mechanical properties, estimated in two different moisture contents (12% and 30%) according to Brazilian code [13].

## 2. Materials and Methods

*Eucalyptus umbra* wood samples had origin in five logs collected in a planted forest at Rio Claro, São Paulo state, Brazil. These trees presented diameters from 0.17 to 0.26 m and 28 years old.

According to experimental procedures recommended by Brazilian code [13], the following physical and mechanical properties were estimated for *Eucalyptus umbra* wood:

- Specific gravity ( $\rho_b$ );
- Density ( $\rho_{ap}$ );
- Compression parallel to grain strength ( $f_{c0}$ );
- Compression perpendicular to grain strength ( $f_{c90}$ );
- Tension parallel to grain strength ( $f_{t0}$ );
- Tension perpendicular to grain strength ( $f_{t90}$ );
- Shear parallel to grain strength ( $f_{v0}$ );
- Cleavage parallel to grain strength ( $f_{s0}$ );
- Modulus of rupture in static bending ( $f_M$ );

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- Modulus of elasticity in compression parallel to grain ( $E_{c0}$ );
- Modulus of elasticity in compression perpendicular to grain ( $E_{c90}$ );
- Modulus of elasticity in tension parallel to grain ( $E_{t0}$ );
- Modulus of elasticity in static bending ( $E_M$ );
- Hardness parallel to grain ( $f_{H0}$ );
- Hardness perpendicular to grain ( $f_{H90}$ );
- Toughness (W).

Two moisture content conditions were verified for wood samples: above saturation fiber point (30% moisture content), and standardized point for structures [13] (12% moisture content). For each property and density 6 specimens were made.

Considering that results for two moisture contents are independent and normal distributed, t-test was performed to verify differences among groups averages. Statistical hypotheses of t-test are established by two conditions, where averages do not differ ( $H_0: \mu_1 = \mu_2$ ) and the opposite ( $H_1: \mu_1 \neq \mu_2$ ). In this study, data variances were considered different and unknown. Decision was focused on P-value and t-test significance level (5%).  $H_0$  hypothesis was rejected when P-value was lower than 5%. Statistical analyzes were carried out using R version 3.4.2 software.

### 3. Results and Discussions

Table 1 shows, for all physical and mechanical properties of *Eucalyptus umbra* wood, and both moisture content (Mc), the average values ( $x_m$ ), standard deviations (Sd) and t-test performed P-values.

Decreasing moisture content of *Eucalyptus umbra* wood, from 30% to 12%,  $\rho_{ap}$  decreased 0.13 g/cm<sup>3</sup>, or 13% of its initial value. T-test analysis for  $\rho_{ap}$  was rejected the null hypothesis of averages equivalence, i.e., density presented significant difference when moisture content decreased from 30% to 12% (P-value < 0.05).

Along moisture content decrease condition,  $f_{c0}$  presented decrease of 6% (2.7 MPa) and  $f_{c90}$  40% (2.1 MPa), as well as  $f_{t90}$  presented increase of 60% (1.8 MPa) and  $f_M$  increase of 7% (5.7 MPa).  $f_{t0}$  did not present any variation. Through t-test, only  $f_{t90}$  presented significant P-value, i.e., Tension parallel to grain strength presented significant difference when moisture content changed (P-value < 0.05).

For decreasing condition for moisture content,  $E_{c0}$  increased 6% (853.1 MPa) and  $E_M$  increased 3% (394.3 MPa).  $E_{c90}$  and  $E_{t0}$  decreased around 41% (211.1 MPa) and 7% (1277.3 MPa), respectively. T-test applied for modulus of elasticity indicated that all properties did not present significant P-value, i.e., modulus of elasticity did not present significant difference when moisture content changed (P-value > 0.05).

$f_{s0}$  decreased 20% (0.17 MPa).  $f_{v0}$ ,  $f_{H90}$ ,  $f_{H0}$  and W increased 16% (2.5 MPa), 64% (1343 N), 28% (324 N) and 16.89% (2.5 Nm), respectively. T-test for  $f_{s0}$ ,  $f_{v0}$ ,  $f_{H90}$ ,  $f_{H0}$  and

W resulted significant difference with moisture content decrease (P-value < 0.05).

Gonçalves et al. (2009) [19] studied mechanical properties of a hybrid *Eucalyptus urophylla* x *Eucalyptus grandis* species, finding average values of  $f_M$ ,  $E_M$ ,  $f_{c0}$  and  $\rho_{ap}$  (12% moisture content) equal to 103.2 MPa, 12.474 MPa, 67.38 MPa and 0.56 g/cm<sup>3</sup>, respectively. *Eucalyptus umbra* wood presented higher density and lower  $f_{c0}$  and  $f_M$  values compared to hybrid *Eucalyptus urophylla* x *Eucalyptus grandis*.

**Table 1.** Physical and mechanical properties of *Eucalyptus umbra* wood at 12% and 30% moisture contents

Properties	Mc (%)	$x_m$	Sd	P-value
$\rho_{ap}$ (g/cm <sup>3</sup> )	30	1.02	0.03	0.0042
	12	0.89	0.08	
$\rho_b$ (g/cm <sup>3</sup> )	12	0.70	0.05	-
$f_{c0}$ (MPa)	30	45.4	9.0	0.4951
	12	42.7	4.1	
$f_{c90}$ (MPa)	30	5.2	1.8	0.0588
	12	3.1	1.6	
$f_{t0}$ (MPa)	30	90.4	26.9	1.0000
	12	90.4	57.0	
$f_{t90}$ (MPa)	30	1.2	1.4	0.0398
	12	3.0	0.5	
$f_M$ (MPa)	30	78.4	15.1	0.6370
	12	84.1	24.8	
$E_{c0}$ (MPa)	30	13,723.7	3620.5	0.6259
	12	14,576.8	2465.6	
$E_{c90}$ (MPa)	30	519.3	179.7	0.0564
	12	308.2	157.9	
$E_{t0}$ (MPa)	30	17,089.7	4086.5	0.6528
	12	15,812.4	5562.4	
$E_M$ (MPa)	30	13,916.5	3499.8	0.8328
	12	14,310.8	3074.5	
$f_{v0}$ (MPa)	30	13.10	2.40	0.1665
	12	15.60	3.40	
$f_{s0}$ (MPa)	30	0.86	0.14	0.0428
	12	0.69	0.11	
$f_{H90}$ (N)	30	749	1.31	0.0672
	12	2,092	1.41	
$f_{H0}$ (N)	30	851	0.91	0.0315
	12	1,175	2.71	
W (Nm)	30	12.30	4.60	0.0012
	12	14.80	5.40	

Lima *et al.* (2011) [17] evaluated for 25 years-old *Eucalyptus umbra* trees from a forest area at Piracicaba city, in Sao Paulo State,  $\rho_{ap}$  0.621 g/cm<sup>3</sup> (12% moisture content). Comparing literature values to the obtained in this study, their values were about 10% lower than the obtained here (0.69 g/cm<sup>3</sup>).

Torres *et al.* (2016) [20] determined  $\rho_b$ ,  $\rho_{ap}$ ,  $f_{c0}$  and  $E_{c0}$  for *Eucalyptus camaldulensis* wood, resulting 0.47 g/cm<sup>3</sup>, 0.581 g/cm<sup>3</sup>, 25.31 MPa and 12,379 MPa, respectively. These results are lower than the ones determined for *Eucalyptus umbra* wood.

## 4. Conclusions

Through decrease of moisture content and emphasized condition of this study for *Eucalyptus umbra* wood, was verified the increasing of eight mechanical property values. In other hand five mechanical properties of this eucalypt species decreased their values. Furthermore, tension parallel to grain strength remained constant.

Statistically, among 14 mechanical properties of *Eucalyptus umbra* wood, only three properties ( $f_{90}$ ,  $f_{H0}$  and  $W$ ) increased values significantly with moisture content change.

According to presented results for *Eucalyptus umbra* wood, it is possible to conclude the feasibility of its use as raw material for design of timber structures.

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