

PHYSICAL-MECHANICAL CHARACTERIZATION OF *Eucalyptus urophylla* WOODDoi: <http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v37n5p900-906/2017>**FRANCISCO A. R. LAHR^{1*}, MARTA C. DE J. A. NOGUEIRA², VICTOR A. DE ARAUJO³,
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ABSTRACT: *Eucalyptus urophylla* consists in a wood-producing species, which offers a natural multiple raw material of good quality for applications in rural and civil constructions. However, *Eucalyptus urophylla* still has a small utilization as building parts and elements, resulting from the possible ignorance and low diffusion of its structural possibilities. Thereby, the present research aims to measure the main thirteen mechanical properties of *Eucalyptus urophylla* wood for two different moisture contents, 12% and 30% (green wood). Furthermore, in these two conditions of moisture content evaluation, volumetric mass densities were also evaluated. At the end of this evaluation, which included 2688 determinations, all the obtained results were statistically treated with t-test at a 5% of significance level in order to evaluate the influence of moisture content in the evaluated properties. Twelve mechanical properties were significantly affected by moisture content, and the behavior pattern consisted in increasing the values of the properties with the reduction of the moisture content.

KEYWORDS: Timor White Gum, strength modulus, cracking, shear stress, hardness, density.

INTRODUCTION

The increasing consumption of wood products raises the use of wood from native forests. Therefore, the implantation of planted forests constitutes a viable alternative for reducing the pressure exerted on native forests (Paiva et al., 2013). *Eucalyptus* wood has a greater applicability (Wallis, 1970), since each day *Eucalyptus* wood has been consolidating as an important raw material for different industrial applications (Plaster et al., 2012).

It is native to the Myrtaceae family (Sein & Mitlöhner, 2011; Lorenzi et al., 2003); the Timor White Gum is a species of *Eucalyptus* (Wiersema & León, 2016) whose scientific name is *Eucalyptus urophylla* S.T. Blake (Corbasson, 1986; Boland et al., 2006). This species is also found in Indonesia (Vieira & Bucsan, 1980; Scanavaca Jr & Garcia, 2003a; Martins-Corder et al., 1996), Ivory Coast (Wencelius, 1983, Corbasson, 1986), Cameroon, Gabon, Guyana, Madagascar (Corbasson, 1986), Congo (Corbasson, 1986; Gouma 1998), Vietnam (Sein & Mitlöhner, 2011), Malaysia, Papua New Guinea (Soerianegara & Lemmens, 1993), among others. In addition, *Eucalyptus urophylla* is present in Brazil (FAO, 1981; Gonçalves & Passos, 2000; Oliveira et al., 2005; Andrade et al., 2010; Guimarães JR. et al., 2012) from its introduction during the 1970s, through seeds harvested in several islands belonging to Indonesia (Rocha et al., 2006).

Perennial, *Eucalyptus urophylla* can reach heights of 45 to 55 m, however, in unfavorable environments this tree develops as a twisted bush (Sein & Mitlöhner, 2011). Of great size and fast growth, this species constitutes in a perennial tree with straight and cylindrical trunk, covered by a thick bark endowed with fine longitudinal cracks of gray-dark color (Lorenzi et al., 2003). Due to the supply of dark forests, this species offers great utility as protection for livestock breeding in hot and humid climates (FAO, 1981).

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The wood of the *Eucalyptus urophylla* has a texture between moderately thick to thick. The color of its core is reddish brown or dark reddish brown, while its sapwood is white, cream or light pink (Soerianegara & Lemmens, 1993). This species is a moderately quality wood-producing tree, although its slender architecture makes it possible to direct it to landscaping (Lorenzi et al., 2003).

Eucalyptus urophylla is used for the production of plywood (Almeida et al., 2004; Guimarães JR et al., 2012), agglomerates (Mendes et al., 2014), cement-wood panels (Mendes et al., 2011), LVL (Guimarães JR et al., 2015), OSB (Mendes et al., 2009), floors (Padilha et al., 2006), lumber (Scanavaca Jr & Garcia, 2003b; Gonçalves et al., 2009), furniture (Plaster et al., 2012), cellulose pulp and kraft paper (Lorenzi et al., 2003; Queiroz et al., 2004; Santos & Sansígolo, 2007; Liu & Zhou, 2011), charcoal and biomass (Santiago & Andrade, 2005; Rezende et al., 2010; Assis et al., 2012; Reis et al., 2012; Gadelha et al., 2015; Wiersema & León, 2016), among others.

Due to the potential of *Eucalyptus urophylla* wood for the construction, Valle et al. (2013) have shown that this species presents easy treatment and penetration of chemicals preservation.

Despite the great potentiality, *Eucalyptus urophylla* wood still has low levels of use in civil construction (Christoforo et al., 2014), which is also justified by the lack of knowledge of its physical and mechanical properties, especially in the absence of characteristics such as age or region source. Due to the problem raised, this research aimed to present the main physical and mechanical properties of the *Eucalyptus urophylla* species as well as to investigate the effect of the moisture content (12%, 30% - saturated) in the properties evaluated, reinforcing the wide possibility of use timber as structural elements.

MATERIAL AND METHODS

Eucalyptus urophylla wood logs from eight Brazilian cities (Table 1) were duly housed in the Wood and Wood Structures Laboratory (LaMEM), in São Carlos Engineering School (EESC), at São Paulo University (USP). It should be emphasized that the tests also occurred in the dependence of the LaMEM, and that the determination of the physical and mechanical properties for the wood in the two moisture contents (12%, 30%) followed the Brazilian standard ABNT NBR 7190 (ABNT, 1997).

TABLE 1. Information of *Eucalyptus urophylla* wood specie.

Number of Logs	Number of Beams	Age	Diameter (m)	Region
1	2	39	0.300	Rio Claro
2	2	39	0.299	Rio Claro
3	2	39	0.330	Rio Claro
4	6	8	0.250	Mogi-Guaçu
5	9	8	0.230	Mogi-Guaçu
6	8	41	0.350	Camaquã
7	2	8	0.220	Avaré
8	3	8	0.235	Avaré
9	2	8	0.200	Avaré
10	2	8	0.225	Avaré
11	2	8	0.230	Avaré
12	2	8	0.220	Avaré
13	2	8	0.220	Avaré
14	2	8	0.200	Avaré
15	2	8	0.225	Avaré
16	2	8	0.220	Avaré
17	4	12	0.228	Itirapina
18	4	12	0.235	Itirapina
19	5	12	0.225	Itirapina
20	9	42	0.350	Bebedouro
21	6	22	0.277	Restinga
22	5	14	0.241	Lençóis Paulista
23	5	14	0.239	Lençóis Paulista
24	4	14	0.249	Lençóis Paulista
25	2	14	0.230	Lençóis Paulista
26	3	14	0.247	Lençóis Paulista

The physical properties evaluated consisted of the basic and apparent densities. Strength values were obtained in the normal and parallel compression, parallel and normal traction, in the static bending test, shear and spinning, and the stiffness values were calculated in the normal and parallel compressions, parallel traction and static bending, being also determined the hardness in the parallel and normal directions. It is noteworthy that 2654 determinations (number of values obtained from physical and mechanical properties) were obtained involving wood in both moisture content (12%, 30%). The number of determinations (n) of each property and for each moisture content is explained in Tables 2 to 5.

After the physical-mechanical tests (15 properties), the results were evaluated by means of the t test analysis at a level of significance of 5% (P-value <0.05), with the objective of investigating the influence of the moisture contents in the physical and mechanical properties of the woods. By the formulation of the hypotheses, P-value higher than the level of significance implies accepting the null hypothesis (the means of the two groups are equivalent), and rejecting it otherwise (means of the two groups are not equivalent).

RESULTS AND DISCUSSION

Table 2 shows the number of determinations (n), mean values (MD), standard deviations (sd) and the P-value (Probability P) of the test t concerning wood densities for the two moisture contents.

TABLE 2. Results for *Eucalyptus urophylla* wood densities.

Properties	TU (%)	n	MD	sd	P-value
Apparent density (g/cm ³)	12	95	0,74	0,16	----
Volumetric mass density (g/cm ³)	30	87	0,56	0,11	0,5409
	12	95	0,57	0,11	

MC: moisture content; n: number of determinations; MD: mean of density; sd: standard deviation.

From the t test (Table 2), the volumetric mass density was not significantly affected by the moisture content variation. Table 3 shows the results of the descriptive statistics and the t test for the strength values of the wood evaluated at the two moisture contents.

TABLE 3. Results obtained for strength modulus of *Eucalyptus urophylla*.

Properties	MC (%)	n	MS	sd	P-value
Parallel Compression (MPa)	30	86	35.7	8.0	0.0000
	12	93	46.0	13.8	
Normal Compression (MPa)	30	84	4.3	2.6	0.0000
	12	91	6.5	2.8	
Parallel Traction (MPa)	30	84	78.5	26.9	0.2244
	12	91	84.2	34.7	
Normal Traction (MPa)	30	81	3.1	1.1	0.0000
	12	91	4.2	1.3	
Static Bending (MPa)	30	84	70.7	18.1	0.0000
	12	92	87.7	28.6	

MC: moisture content; n: number of determinations; MS: mean of strength values; sd: standard deviation.

By reducing the moisture content from 30 to 12%, all the strength values evaluated indicated increases in their properties, evidenced by the increases of 22.39% (10.3 MPa) in the parallel compression, 33.85% (2.2 MPa) in normal compression, 6.77% (5.7 MPa) in parallel traction, 26.19% (1.1 MPa) in normal traction and 19.38% (17 MPa) in static bending (Table 3). The analysis of the t test indicated that the properties of parallel and normal compression, normal traction and static bending were significantly influenced by the reduction in the moisture content of

the wood (P-value <0.05), as discussed in the research developed by Logsdon & Clil JR (2002), it was not observed in the parallel traction, that did not undergo significant variations influenced by the difference of the moisture content (P-value > 0.05).

Table 4 shows the results of the descriptive statistics and the t test for the values of the elasticity modulus for the wood evaluated in the two moisture contents.

TABLE 4. Results for elasticity modulus of *Eucalyptus urophylla*.

Properties	MC (%)	n	Me	sd	P-value
Parallel Compression (MPa)	30	85	11969.3	4003.2	0.0207
	12	92	13391.7	4100.6	
Normal Compression (MPa)	30	84	539.9	98.35	0.0014
	12	91	640.7	275.8	
Parallel Traction (MPa)	30	84	13649.3	3973.9	0.0070
	12	91	15382.2	4416.6	
Static Bending (MPa)	30	84	11395.9	3045.5	0.0000
	12	92	13416.7	3018.1	

MC: moisture content; n: number of determinations; Me: mean of the elasticity modulus; sd: standard deviation.

Similarly, the evaluated elasticity modulus also indicated increases in all its properties, such as: 10.62% (1422.4 MPa) in parallel compression, 11.27% (1732.9 MPa) in the parallel traction, 15.73% (100.8 MPa) in normal compression and 15.06% (2020.8 MPa) in static bending (Table 4). The analysis of the t test indicated that in the four properties (parallel and normal compressions, parallel traction and static bending), the values of the elasticity modulus had a significant influence (P-value <0.05) on their means when the moisture content was reduced from 30 to 12% (Logsdon & Clil JR, 2002).

Table 5 shows the results of the descriptive statistics and the t test for the values of shear strength, crack strength and hardness in the normal and parallel directions for the wood evaluated in the two moisture contents.

TABLE 5. Values of the shear strength, cracking and hardness in normal and parallel direction.

Properties	MC (%)	n	M _P	sd	P-value
Shearing (MPa)	30	85	10.6	1.5	0.0000
	12	93	13.9	3.1	
Cracking (MPa)	30	83	0.64	0.17	0.0000
	12	92	0.87	0.33	
Normal Hardness (N)	30	87	5.25	1.40	0.0000
	12	93	6.43	1.97	
Parallel Hardness (N)	30	84	4.93	1.62	0.0051
	12	93	5.73	2.12	

MC: moisture content; n: number of determinations; M_P: mean properties; sd: standard deviation.

In addition to the strength properties evaluated, the normal and parallel hardness and the shear and cracking increased with the reduction of the moisture content in the order of 18.35% (1.18 kN), 13.96% (0.8 kN), 23.74% (3.3 MPa) and 26.44% (0.23 MPa), respectively (Table 5). The t test indicated that the four properties were influenced in their means by the reduction in the moisture content of the wood (Table 5).

CONCLUSIONS

Based on the results, with the reduction of the moisture content of 30% to the value (12%) pre-established by the Brazilian standard ABNT NBR 7190 (ABNT, 1997), it can be concluded that:

- The volumetric mass density was not affected significantly by the variation of the moisture content;
- The following mechanical properties of *Eucalyptus urophylla* presented significant increases: shear strength in parallel and normal compressions, normal traction and static bending; elasticity modulus in parallel and normal compressions, parallel traction, static bending; shearing; cracking and hardness in the parallel and normal directions to the fibers;

Considering the increments obtained for twelve mechanical properties evaluated, it was verified that the wood of the *Eucalyptus urophylla* presented higher strength and stiffness values for the moisture content of 12%, which may stimulate a greater use of this species in structural elements and components under such conditions.

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