

Verification of Test Conditions to Determine the Compression Modulus of Elasticity of Wood

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Abstract The obtaining the modulus of elasticity in compression of the wood with the use of dial gauges, fixed on opposite faces of the specimens, may lead to deformation values and consequently to different elastic modulus as a function of the faces chosen for its attachment, being the timber an anisotropic material. This study aimed to evaluate the influence of two distinct positions for setting the dial gauges (A and B) in wood specimens tested in compression, using the assumptions of the test methods and calculation of the Brazilian standard ABNT NBR 7190: 1997. The woods evaluated in trials were the *Pinus elliottii* and *Corymbia citriodora*, being used seven specimens per species. A specimen was taken to the rupture, obtained the values of the maximum stress and strain (references) needed to obtain the elastic moduli of the six remaining specimens per species, certain non-destructively (two tests per piece). The results of analysis of variance revealed the equivalence between modules elasticity in compression parallel to the grain for both wood species investigated, resulting not significantly arrangement of dial gaugesto determine the properties of stiffness. However, the anisotropy of wood, these results cannot be extrapolated to other woods of the same or different species, justifying the setting of dial gauges in two different positions, allowing for judging whether or not the equivalence between the modulus of elasticity.

Keywords Wood, Compression Parallel to the Grain, Stiffness

1. Introduction

The wood itself as one of the oldest building materials, being used mainly because of its availability in nature, ease of handling, manufacturing and excellent relationship weight/strength[1-3].

The timber was presented as a cellular material, produced by a mechanism of continuous growth of plants. There are several species of trees throughout the world, but with all common features such as a cellular structure with an arrangement in the form of concentric rings, which ensures orthotropic mechanical properties of wood, directly related to its orientation relative to the main axis[4].

Chemical and mechanical properties can differ for the same species of wood according to the location of their extraction. Other parameters such as climate and soil conditions can affect the growth of the tree, directly influencing their properties. Moreover, factors such as the presence of us, opening cracks during drying and inclination of the fibers cause the strength of the woods have great

variations[5-7].

According to[1], the mechanical properties of wood are dependent on the density, the percentage of juvenile wood, the width of the rings, the angle of the microfibrils, the amount of extractives, moisture content, the intensity of insect attack, the type and location and number of nodes, among other factors, making it difficult to obtain need all their elastic parameters to be used in structural projects[8, 9].

In order to enable the rational use of wood in structures mechanical tests are performed to obtain the equivalent properties, obtained from experiments and calculation procedures of standardized normative documents, such as the standard ABNT 7190[10], widely used by engineers, architects and designers for material characterization due to mechanical stresses and also for proper and safe design of structural elements.

Among the mechanical properties of materials used in the design of a structure highlights the modulus of elasticity (MOE), enabling the setting to provide displaced and deformations in structural components subjected to the action of the imposed loads (limit state).

Be of great interest for the knowledge of the modulus of elasticity in compression wood, allowing the design of structural elements subject to compressive stresses, several studies have been conducted[11-19], in order to verify

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Published online at <http://journal.sapub.org/ijaf>

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experimentally and numerically the influence of composition anatomical tissue timber (anisotropy) in physical, chemical and mechanical properties, as well as to characterize wood species not yet known.

This study aimed to investigate the influence of positioning of dial gauges (positions A and B) to determine the modulus of elasticity of wood in compression parallel to the grain, enabling determine possible differences between then.

2. Materials and Methods

The wood species used in this study were the *Corymbia citriodora* (Strength class C40) and *Pinus elliottii* (Strength class C30), made seven specimens per type of timber to perform in compression test[10], extracted from different parts of a batch considered homogeneous, with moisture content near 12%, as established by the Brazilian standard[10].

The specimens were manufactured with square cross section of 5.0cm and 15cm of length[10], and are free of defects. The dimensions of the sides of the specimens were performed with a caliper accurate to 0.1 mm.

The dial gauges were fixed in two different positions, A and B, as illustrated in Figure 1, two bending tests were performed in the same specimen per wood species. Of each species, one of seven specimens was taken to rupture, allowing discover tensions (σ) and strain (ϵ) for the 10% and 50% of the maximum stresses and strains, used to determine the modulus of elasticity (Equation 1) in the other specimens, as required by the Brazilian standard[10].

$$E_{c,0} = \frac{\sigma_{50\%} - \sigma_{10\%}}{\epsilon_{50\%} - \epsilon_{10\%}} \quad (1)$$



Figure 1. Specimen timber with *Corymbia citriodora* setting the dial indicators: Positions A and B

To check the statistical equivalence between the modulus of elasticity for the two species of wood was used analysis of variance (ANOVA), performed as an aid software Minitab® version 14.

3. Results

Tables 1 and 2 present the descriptive statistics related to the modulus of elasticity (MOE-A, -B MOE) in compression parallel to the grain of *Corymbia citriodora* and *Pinus elliottii* wood respectively, obtained with the use of dial gauges positioned on the faces A and B (Figure 1), X_m is the arithmetic mean, SD the standard deviation and CV the variation coefficient of specimens.

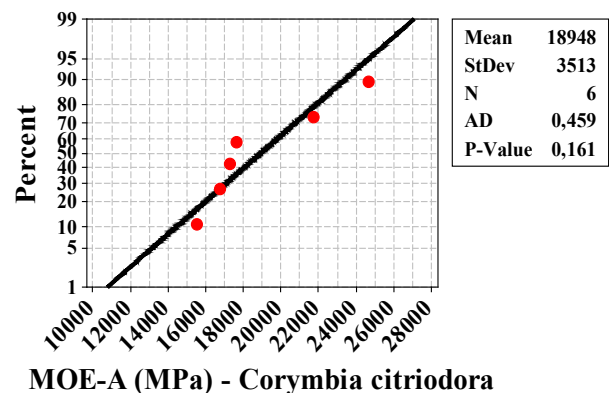
Table 1. Modulus of elasticity of *Corymbia citriodora* wood

Specimen	MOE-A (MPa)	MOE-B (MPa)
1	15545	17458
2	21736	11960
3	16764	16641
4	24706	19352
5	17310	18189
6	17629	15470
X_m	18948	16512
DP	3512,9	2592,1
CV (%)	19	16

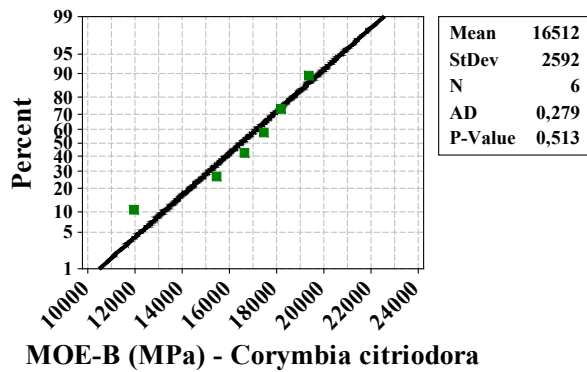
Table 2. Modulus of elasticity of *Pinus elliottii* wood

Specimen	MOE-A (MPa)	MOE-B (MPa)
1	8697	7913
2	10062	10409
3	12963	10985
4	9119	11038
5	13634	14636
6	10343	8683
X_m	10803	10611
DP	2035,3	2347,8
CV (%)	20	22

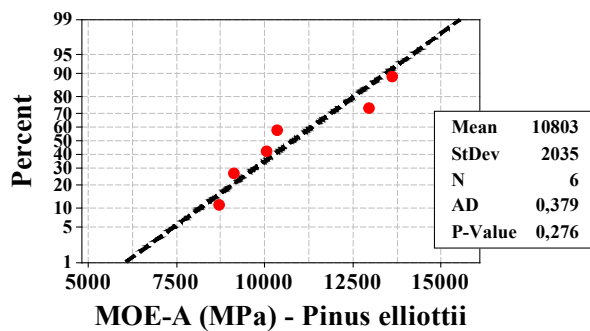
Figure 2 shows the normality graphs of the modulus of elasticity of *Corymbia citriodora* and *Pinus elliottii* wood respectively.



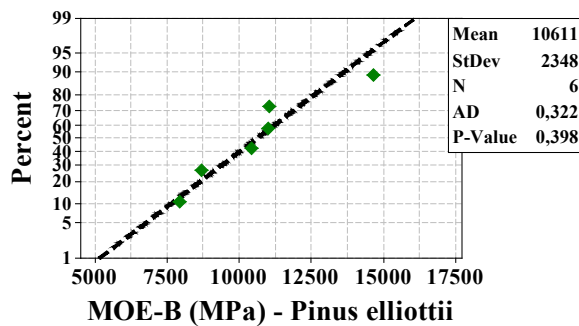
(a)



(b)



(c)



(d)

Figure 2. Graphs of normality for the modulus of elasticity of the woods investigated

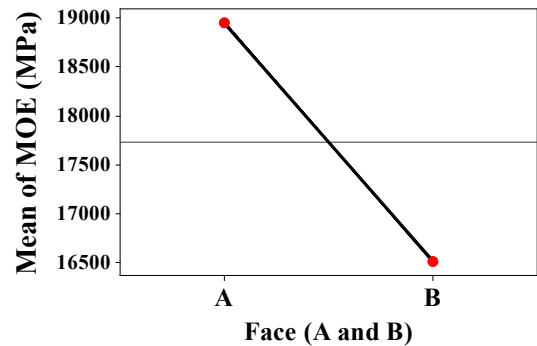
The P-values of normality tests of Anderson-Darling (Figure 2) on the modulus of elasticity for the *Corymbia citriodora* (0.161) and *Pinus elliottii* (0.513) woods were both higher than 0.05, proving to be normal the data distribution[21].

Table 3 shows the results of the ANOVA factor, position of the dial gauge to obtain the modulus of elasticity (MOE-A; EOM B).

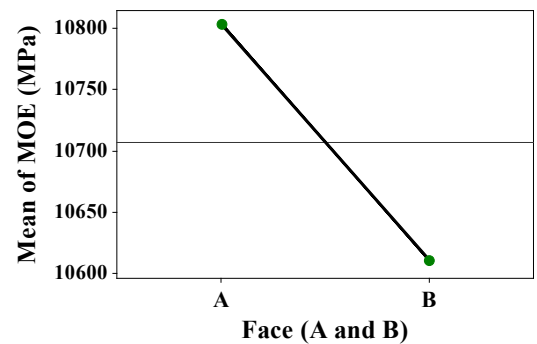
Table 3. P-values from the ANOVA on the MOE of the wood investigated

	P-value	R ² (Adj.)
<i>Corymbia citriodora</i>	0,202	7,32%
<i>Pinus elliottii</i>	0,882	0,00%

Figure 3 shows the main effect plots of the MOE for the wood species evaluated.



(a)



(b)

Figure 3. Main effects plot of the MOE for the *Corymbia citriodora* (a) and *Pinus elliottii* (b) wood species

P-values obtained by ANOVA of MOE for both wood species were greater than 0.05[21], notes the equivalence between the values, there was no significant the position of the dial gaugesto determine the stiffness properties of wood evaluated.

To validate the results of the ANOVA, it is necessary to ensure normality, independence and homogeneity of the residuals for the MOE of both wood species. Figures 4 and 5 shows the results concerning the normality of the residuals for the rigidity of both wood species, and independence and uniformity shown in Figures 6 and 7.

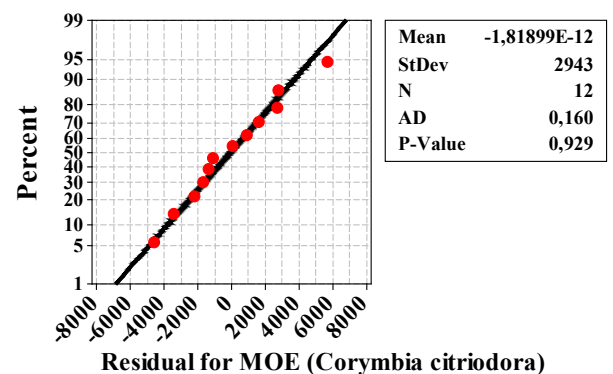


Figure 4. Normality plot of residuals of ANOVA on MOE for the *Corymbia citriodora* species

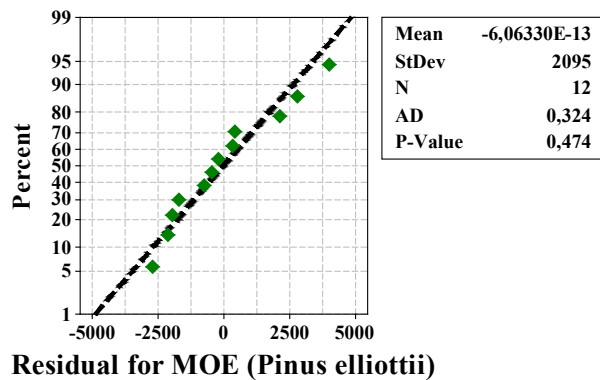


Figure 5. Normality plot of residuals of ANOVA on MOE for the *Pinus elliottii* wood species

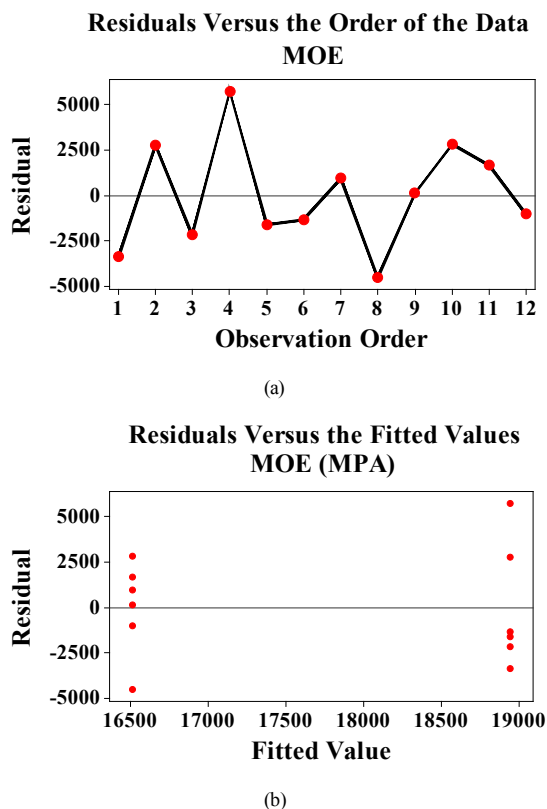


Figure 6. Independence (a) homogeneous and (b) residuals of ANOVA on the MOE of wood *Corymbia citriodora* wood species

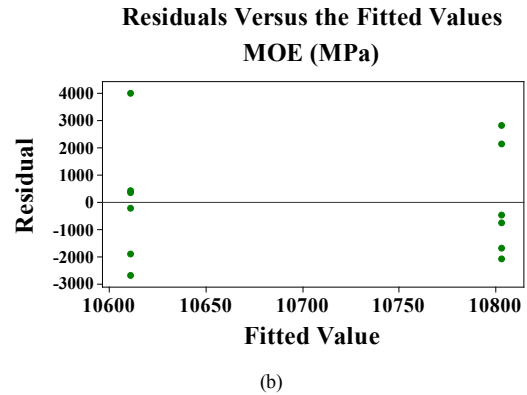
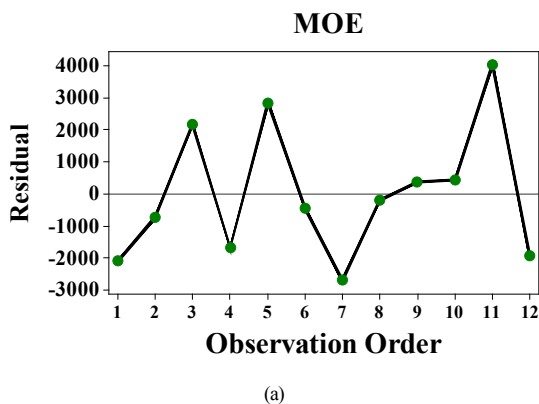


Figure 7. Independence (a) homogeneous and (b) residuals of ANOVA on the MOE of *Pinus elliottii* wood species

The results shown by the graphs of Figures 2-7 validate the ANOVA model, proving they are the equivalent the compression modulus of elasticity of the wood investigated.

4. Conclusions

By the results of the analysis of variance was verified statistical equivalence between the modulus of elasticity of both wood species, revealing, for the specimens tested, not significant position of dial gauges in the calculation of the modulus of elasticity. As the wood an anisotropic material (orthotropic), the results obtained in this study cannot be extrapolated to the same wood species or different species, implying the use of dial gauges in two different positions in the specimen, enabling assess equivalence or not of the elastic moduli obtained.

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