

# Influence of the Wood Specimen Position on Calculus of the Bending Modulus of Elasticity

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**Abstract** For the anisotropy presented by wood, the established positions of the specimens in the bending test can significantly alter the properties of strength and stiffness. This study aimed to evaluate, with the aid of the Brazilian standard ABNT NBR 7190:1997, the influence of the wood specimens position to determine the bending modulus of elasticity. The wood species used in the trials (three point static bending) were *Corymbia citriodora* and *Pinus elliottii*, and used six specimens per species. Each piece gave rise to four experiments, performed with a non-destructive form, differentiated only by the position of the specimen in the bending test (sides: A - lowest; B; C; D - higher value), providing four values of elastic modulus per specimens. The experiments were considered non-destructive for the largest displacement value in trials does not exceed the measure  $L/200$  ( $L$ -usable length of the specimen), ensuring physical and geometric linearity for the woods tested, as established by the Brazilian standard. The results of analyses of variance showed statistical equivalency between the modulus of elasticity of both wood species, resulting in independence of the specimen position to determine the bending stiffness. However, by the orthotropic behaviour of wood, the results obtained cannot be extrapolated to other woods of the same or different species, thereby justifying the change of the specimen position in the bending test, allowing evaluate the equivalence or not between the modulus of elasticity.

**Keywords** Bending, Stiffness, Wood Anisotropy

## 1. Introduction

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

The timber presented as a cellular material, produced by a continuous mechanism 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 node, opening cracks during drying and fiber

inclinations promote great variations in physical and mechanical properties [5-7].

According to [1], the mechanical properties of wood are dependent on the density, 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 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 ABNT NBR 7190 [10] standard, 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 bending modulus of elasticity, allowing the design of wooden

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structural elements subject to bending stresses, several studies have been conducted[11-18], in order to verify 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.

However, in bending tests, the positioning of the specimens can influence the results of elastic moduli, justified by the anisotropy of wood[19].

This study aimed to investigate the influence of using four different positions of wood specimens in bending tests to obtain the bending modulus of elasticity, enabling determine possible differences between the stiffness values obtained.

## 2. Material and Methods

The wood species used in this study were *Corymbia citriodora* (Strength Class C 40) and *Pinus elliottii* (Strength Class C30), being manufactured six specimens per type of timber for holding bending 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 115cm of length[10], and are free of defects. The dimensions of the sides of the specimens were performed with a calliper accurate to 0.1 mm.

The three points static bending test (Figure 1) was the structural model used to determine the modulus of elasticity, conducted non-destructively by the high values of displacements in the trials are limited to  $L/200$  measured[10],  $L$  being the distance between supports in the bending test. This ratio ensures physical and geometric linearity of the wood specimen tested.



Figure 1. *Corymbia citriodora* timber specimen in the bending test

Each specimen was tested four times in bending, giving four values of modulus of elasticity (MOE) per specimen and per type of wood species used, only differentiated by the positions of the elements in the experiments (sides: A - lowest; B; C; D - higher value). The modulus of elasticity of the wood pieces were obtained with the use of Equation 1,  $F$  being the value of the load responsible for the displacement  $\delta = L/200$ ,  $L$  the effective length of the specimen and  $b$  and  $h$  measures concerning the width and height of the cross

section respectively.

$$MOE = \frac{F \cdot L^3}{4 \cdot \delta \cdot b \cdot h^3} \quad (1)$$

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

## 3. Results

Tables 1 and 2 present the descriptive statistics concerning the bending modulus of elasticity (MOE-A; EOM B; EOM C; -D MOE) of *Corymbia citriodora* and *Pinus elliottii* wood species respectively, obtained from four different positions of the specimens in trials,  $X_m$  being the arithmetic mean, SD standard deviation and CV the coefficient of variation of the samples.

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

Specimen	MOE-A (MPa)	MOE-B (MPa)
1	15504	15593
2	13623	12255
3	14283	15634
4	16689	16825
5	18704	18504
6	16681	16226
<b>Xm</b>	15914	15840
<b>SD</b>	1847	2058
<b>VC (%)</b>	12	13
Specimen	MOE-C (MPa)	MOE-D (MPa)
1	15058	15370
2	13165	12293
3	12931	12075
4	17053	16962
5	18554	18905
6	16772	16817
<b>Xm</b>	15589	15404
<b>SD</b>	2261	2737
<b>VC (%)</b>	15	18

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

Specimen	MOE-A (MPa)	MOE-B (MPa)
1	13938	13672
2	12077	12283
3	14439	15805
4	13028	14394
5	13824	13870
6	13251	14508
<b>Xm</b>	13426	14089
<b>SD</b>	831	1157
<b>VC (%)</b>	6	8
Specimen	MOE-C (MPa)	MOE-D (MPa)
1	13850	13547
2	11940	12186
3	14530	15669
4	13073	14349
5	13687	13824
6	13565	14598
<b>Xm</b>	13440,8	14028,8
<b>SD</b>	873,8	1165,1
<b>VC (%)</b>	6,5	8,3

Figures 2 and 3 illustrate respectively the normality plots of modulus of elasticity for the *Corymbia citriodora* and *Pinus elliottii* wood species.

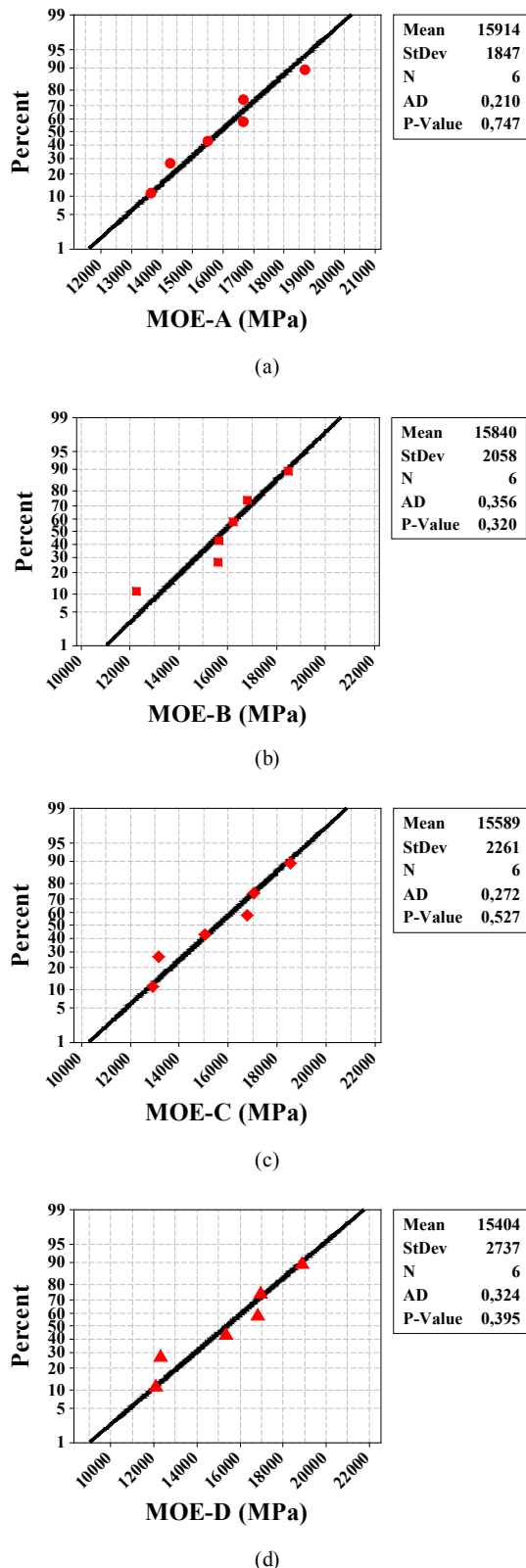


Figure 2. Normality plot for the bending modulus of elasticity of *Corymbia citriodora* wood species

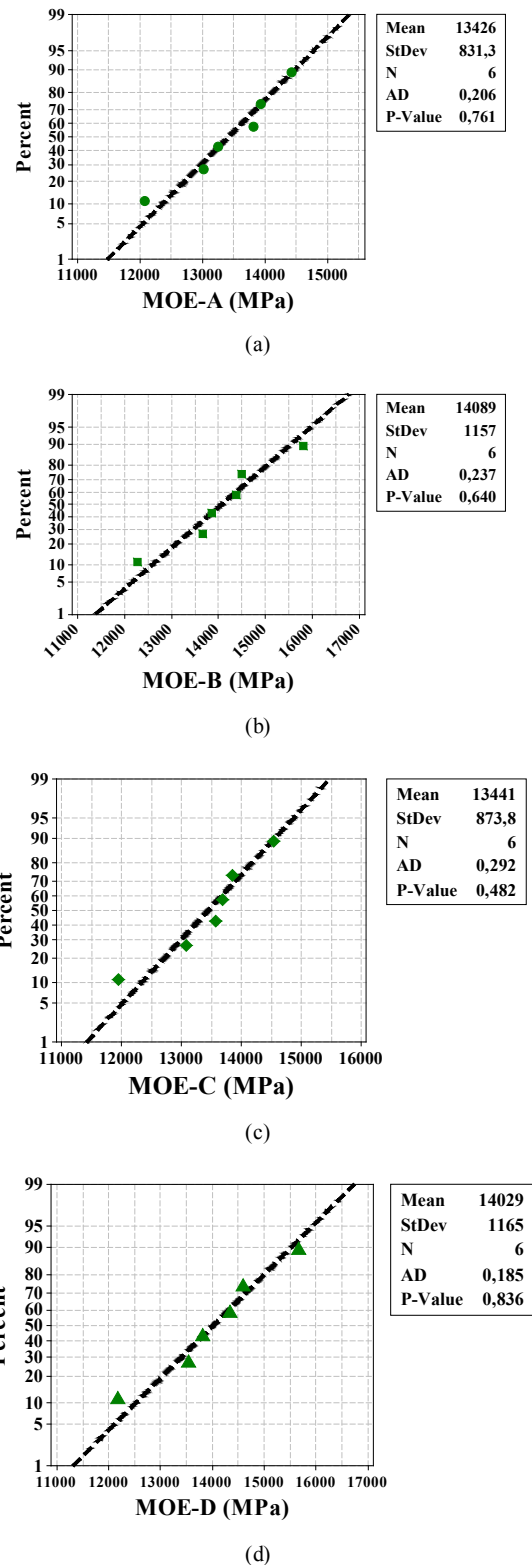


Figure 3. Normality plot for the bending modulus of elasticity of *Pinus elliottii* wood species

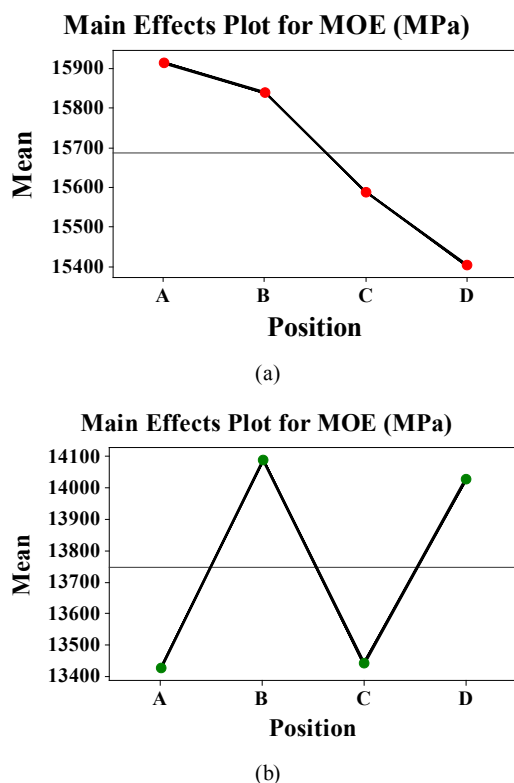
The P-values of Anderson-Darling's normality tests (Figure 2) of the modulus of elasticity for the *Corymbia citriodora* and *Pinus elliottii* woods were both greater than 0.05, proving to be normal distribution of data[20].

Table 3 shows the results of the ANOVA of the position factor for the specimen to determine the modulus of elasticity (MOE-A; EOM B; EOM C; MOE-D).

**Table 3.** P-values from the ANOVA for the MOE

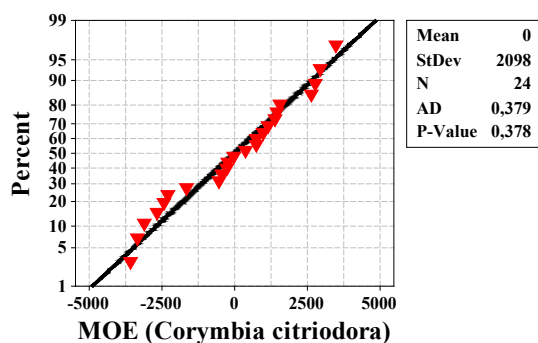
	P-value	R2(Adj.)
<i>Corymbia citriodora</i>	0,978	0,00%
<i>Pinus elliottii</i>	0,531	0,00%

Figure 4 shows the main effect plots for the MOE.

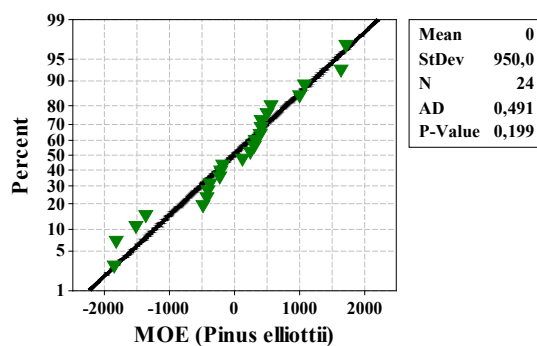


**Figure 4.** Main effects plot for the MOE of *Corymbia citriodora* (a) and *Pinus elliottii* (b) wood species

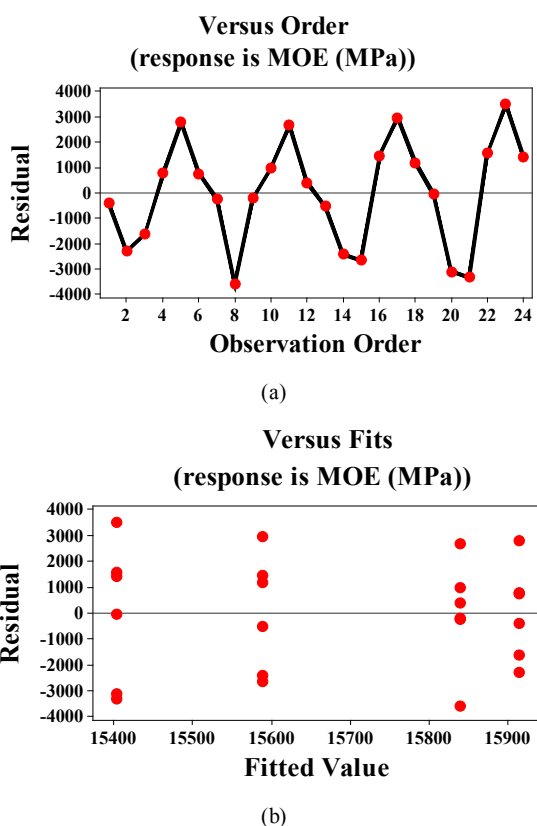
P-values obtained from ANOVA for the MOE of the two wood species being greater than 0.05[20], notes the equivalence between the values, indicating that the specimen position is not significant to determine the properties of stiffness evaluated.



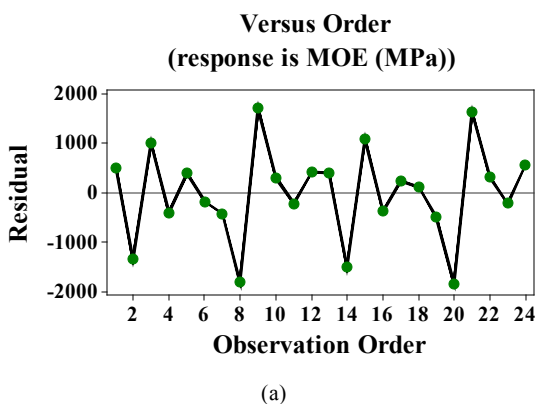
**Figure 5.** Residuals plot of ANOVA on MOE of *Corymbia citriodora* wood species

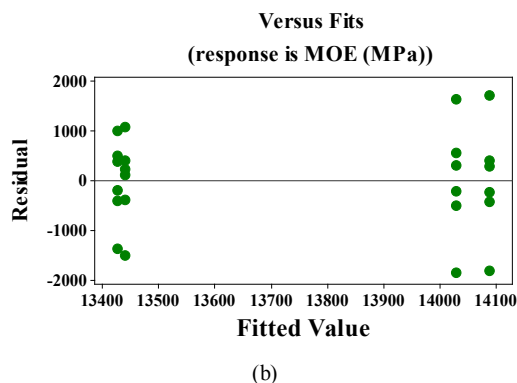


**Figure 6.** Residuals plot of ANOVA on MOE of *Pinus elliottii* wood species



**Figure 7.** Independence (a) and homogeneity (b) residuals of ANOVA on the MOE of *Corymbia citriodora* wood species





**Figure 8.** Independence (a) and homogeneity (b) residuals of ANOVA on the MOE of *Pinus elliotii* wood species

To validate the results of the ANOVA, it is necessary to ensure normality, independence and homogeneity of the residuals for the MOE. Figures 5 and 6 shows the results of the normality tests of the residuals from ANOVA, and the independence and homogeneity present in Figures 7 and 8.

The results obtained from the graphs of Figures 2-8 validate the ANOVA model, proving to be the equivalent the bending modulus of elasticity of the wood species investigated.

## 4. Conclusions

The results of the analysis of variance revealed statistical equivalence between the modulus of elasticity of the wood species, showing, for the specimens tested, not be significant the position of the specimen to determine the bending modulus of elasticity. As the wood an anisotropic material, the results obtained in this study cannot be extrapolated to the same or different wood species, implying the use of four different positions of the specimen in bending tests, enabling judge the equivalence or otherwise of elastic moduli obtained.

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