

# Static Bending Loading Diagram in Wood

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**Abstract** Three-point static bending test according to the code NBR 7190/1997 allows to determine two wood properties: modulus of elasticity and conventional value of Strength. According to this code, determination of the modulus of elasticity must be through loading cycle occurring between 10% and 50% of the rupture of an estimation sample. However, it is usual to perform these cycles using L/200 and L/1000 deflection parameters, where L is the value of the length. Given this, it becomes necessary to evaluate the loading diagrams in the bending tests to find out the existence of patterns on it. This work aimed to analyze the loading curves in the three-point static bending tests in eighteen free of defect samples, of square section and L/h equal to fourteen, made with *Simarouba amara Aubl.* wood at 12% moisture content. Analysis was focused on the force percentages applied (in relation to the rupture) for these samples present L/1000, L/200 and L/100 deflection values, and the elastic limit (LE) (in relation to the rupture) was determined. Results of the mean percentages were 4.11%, 22.51%, 44.63% and 78.51% for L/1000, L/200, L/100 and LE, respectively. According to results, it was possible to conclude that there is a pattern of samples behaviors subjected to three-points static bending, making possible to use deflection parameters in the loading cycles.

**Keywords** Loading cycle, Static bending, Wood

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## 1. Introduction

Wood is a renewable source material with important role in the furniture, paper and pulp, and construction industries [1-4]. In this last segment, wood can be used in frames, building components and structural elements such as pillars, trusses and beams [6, 7]. Beams are horizontal structural elements, subject to loads that generate stresses in the static bending (traction and compression). Thus, for better use of resources (wood, time and labor), it is necessary that the structural design is very well performed, which goes through the process of determining its physical and mechanical properties [8-10].

In Brazil, such determination must be made in accordance with the Brazilian Association of Technical Standards (ABNT) in its code ABNT NBR 7190: 1997 "Wood Structures Design". In Appendix B of this code, "Determination of Wood Properties for Structural Design", all procedures for carrying out tests are described. One of these tests is the static bending test for determination of the modulus of elasticity and the conventional strength value [11].

For modulus of elasticity determination, a loading cycle is performed, which must take place between 50% and 10% of the rupture force of a test sample used as an estimate and, after that, test at least 12 samples.

In the daily routine of mechanical properties of wood laboratories based on the Brazilian code, it is common to use a deflection parameter in the loading cycle to determine the modulus of elasticity (or stiffness) in bending. It is because this way it is possible to do the cycle without the test sample for estimation of rupture. This practice also speeds up the characterization of wood in general, as well as structural pieces presenting larger dimensions. Deflection parameters commonly used are L/200 and L/500, where L is the length.

In this respect, it is extremely important to know if these deflection parameters are compatible to the procedure described in the Brazilian code, and in addition, create a way for better use the code making the process of wood characterization faster.

This research aimed to verify the existence of a pattern between the deflection presented by the sample, due to the portion of exerted force on it (in relation to the rupture of the same sample) by the analysis of the loading diagrams of wood (for the modulus of elasticity determination), and them, determine a procedure to use the deflection as a parameter of loading cycle, showing more assertive values of applied percentage of force.

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## 2. Material and Methods

Based on the recommendations of Almeida [12], 18 samples with nominal dimensions 20 x 20 x 320 mm were made using wood with moisture content around 12% (equilibrium moisture), and the largest dimension of the sample in the parallel to the grain direction.

As the focus of the present research is the study of the test method, a homogeneous batch of wood was selected from a certified forest area. The tropical specie of wood Caixeta (*Simarouba amara Aubl.*) showed density at 12% moisture content around 0.40 g/cm<sup>3</sup> and according to the Brazilian code, it was belonging to the Strength Class C20 of the dicotyledons [12-14].

When referring to the static bending sample recommended by the Brazilian code, it has a length/height ratio of 21. However, the test specimens used in this research had this ratio equal to 14, due to the equipment used in the tests, EMIC Universal Testing Machine, not be able to perform tests in samples larger than 320 mm (Figure 1).



(a)



(b)

**Figure 1.** Static bending test: (a) EMIC Universal Testing Machine; (b) Sample of Caixeta wood

On the other hand, since all work was carried out by determining the stress exerted on the sample in relation to the rupture, and the strength of the sample is independent of the value of the length ( $L$ ) adopted in the test (being a characteristic of the sample), the results shown in this research can be adapted for more general studies.

Through the EMIC Universal Testing Machine software, the graphics force vs. deflection can be built, and it is possible to set the loading diagram of the static bending test for each sample, taking force applied and deflection values in the middle of the length. For carrying out the tests, the loading speed adopted was 5 mm of deflection per minute.

Parameters of loading diagram determined in this research were the percentages of applied force (related to rupture) for the sample presents deflection value equal to  $L/100$ ,  $L/200$  and  $L/1000$  (being  $L = 280$  mm), ie 2.80 mm, 1.40 mm and 0.28 mm, respectively, as well as the elastic limit (LE) of each sample.

Using the deflection parameters  $L/100$ ,  $L/200$  and  $L/1000$ , it was possible to know the force required for the samples present such deflection and thus relate them to their respective ruptures. For determination of the exact deflection at 10% and 50% of the rupture, regression models (linear, quadratic, exponential and geometric) were proposed to determine the denominator  $k$  of the  $L/k$  parameter as a function of the percentage of rupture (CR) that shows this deflection.

## 3. Results and Discussion

Figure 2 shows the loading diagrams for 18 samples of Caixeta wood in static bending test, as well as the deflection values for  $L/1000$ ,  $L/200$  and  $L/100$ .

From the analysis of the loading diagrams and using the deflection parameters  $L/100$ ,  $L/200$  and  $L/1000$ , it was possible to verify the necessary force to the samples present such deflections and, thus, to relate them with the respective rupture. Table 1 shows the mean values ( $x_m$ ), maximum (Max), minimum (Min) and coefficients of variation (CV) for % $L/100$ , % $L/200$  and % $L/1000$ , which represent percentages of applied force, in relation to the rupture, to the deflections reach the  $L/100$ ,  $L/200$  and  $L/1000$  values, respectively. %LE means the maximum percentage of force applied, in relation to the rupture, for the sample presents the linear aspect in the loading diagram.

According to Table 1, the average force percentages, in relation to the rupture, for the samples present  $L/100$ ,  $L/200$  and  $L/1000$  deflection were 44.63, 22.51 and 4.11%, respectively. It should be noted that the coefficients of variation of these results were less than 10% reaffirming their accuracy. The average elastic limit obtained was 78.51% of the rupture.

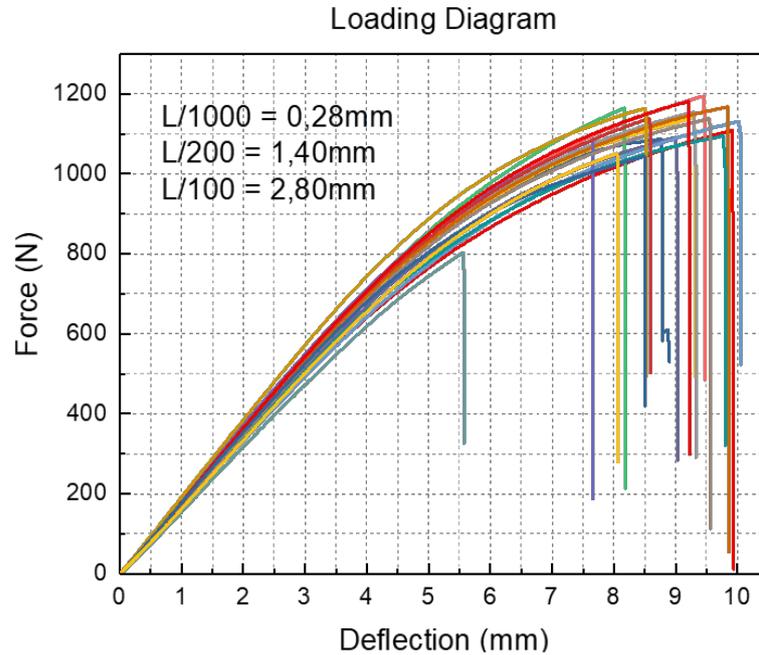


Figure 2. Loading curves in Static bending test for 18 samples of Caixeta

Table 1. Summary of results for percentages of force to reach all deflection values

Statistics	%L/100 (%)	%L/200 (%)	%L/1000 (%)	%LE (%)
$x_m$	44.63	22.51	4.11	78.51
CV (%)	7.40	7.66	9.51	8.49
Min	40.26	20.26	3.60	72.26
Max	54.78	27.45	4.90	97.43

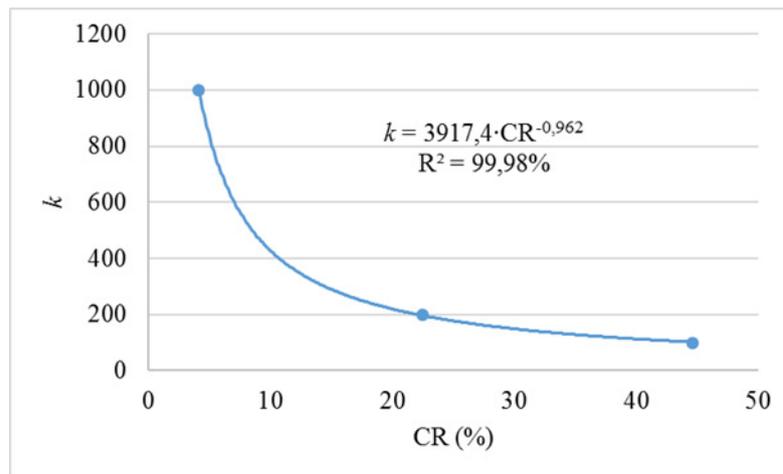


Figure 3. Static bending test: (a) EMIC Universal Testing Machine; (b) Caixeta sample

Geometric regression model was the one that presented the best coefficient of determination ( $R^2$ ) for estimating the  $k$  value of the parameter  $L/k$  (Figure 3), as a function of the percentage of the rupture force. The function  $k=3917.4 \cdot CR^{-0.962}$  presented a coefficient of determination equal to 99.98%, where CR denotes the percentage of the applied force in relation to the rupture.

This function described by the geometric regression model allows to determine the exact deflection when the samples are subjected to forces of 10% and 50% of the rupture. Using the diagram function of Figure 3, the deflection values found were equal to  $L/91$  and  $L/428$  to forces equal to 10% and 50% of the rupture, respectively.

## 4. Conclusions

According to the procedures adopted, as well as the results obtained using Caixeta wood, it was possible to perceive the existence of a pattern in the loading diagrams of the samples subjected to static bending, resulting in the existence of a force pattern (relation to the rupture), for deflection values presented by the samples tested. Therefore, the use of deflection parameters at the time of the loading cycles to determine the modulus of elasticity, instead of the use of an estimation test (force parameter), seems to guarantee the accuracy of the modulus of elasticity determination in bending. Authors suggest the expansion of the research in this sense, considering other species, as well as other cross sections (not square).

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