EXPERIMENTAL ANALYSIS OF SLENDER TIMBER COLUMNS OF PINUS SPP

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Most practical timber columns are subject to combined action of axial and bending stresses. The resulting bending moments are caused either by transverse loading, applied end-moments, eccentric loading, creep or column imperfections. Deflection increments due to creep introduce a variable source of eccentricity to the axial load, because creep is highly dependent on the variable timber moisture content and on its initial value. Moreover, all columns have some imperfections, in practical terms.

The current Brazilian Code for Timber Structure Design, NBR7190-97 – Projeto de Estruturas de Madeira, [1], took over the former code based on the Allowable Stress concept. Pletz and Moura [5] explained that this radical change of safety philosophy was a huge advance which made possible to use the same design language of other structural materials (offering the same basis for comparison), and guarantee the benefits of the Limit State Design. On the other hand, as far as column design is considered, this Code intended to be very adherent to refined theoretical procedures, adopted some cumbersome expressions. When addressing the column design procedure, it takes into account the above mentioned aspects dividing columns into three groups, the short ones whose slenderness ratio is smaller than or equal to 40, the intermediate ones, whose slenderness ratio falls between the limits of 40 and 80 and the slender columns whose slenderness ratio is bigger than 80. The approach for the intermediate ones, involves the adoption of an approximation that assumes the columns have an initial sinusoidal shape, with a central eccentricity e_a and the axial load is applied with an eccentricity e_i. Applied end-moments and any other transverse loading that causes bending moments can be estimated by the eccentricity determined by the division of the bending moment by the axial load. In the case of slender columns, the Brazilian code additionally includes an eccentricity e_c, to consider the creep amplification effects on the other types of eccentricities. This procedure was criticized by Prof. Ernst Gheri [9], because of the following pitfalls: lack of simplicity, non-unified approach for the column problem and the presence of points of theoretical discontinuities in the design curve for columns around the slenderness ratios of 40 and 80. By the end of the revision process of the current NBR7190-97 Code [1], a new column design procedure was presented based on the Eurocode 5 formulation. In other words, the eccentricity approach was still adopted but in a simpler way. No attention was paid to the Eurocode limitations. The non-distinction between permanent and accidental loadings and the non-consideration of moisture effects on creep are some pitfalls. Not to mention the persistent criticism of the Eurocode approach from the technical community, the complexity of the calculation processes, and the lack of transparency.

Although experimental studies of timber columns can be found since early times of the structural engineering history, more is still to be done. Especially in Brazil, where native forests are losing fast their important role of the main resource of wood supply. Thus there is a need to adjust to new reality of available and easily renewable resources of wood Pinus and Eucalyptus. However, Pinus spp suffer from serious prejudice to structural application. Experimental analysis of slender columns of Pinus spp is an important step to be taken in order to demystify the wrong concepts among Brazilian engineers, about its mechanical properties.

This paper describes the results of experimental analysis of axially loaded slender columns made of visually and mechanically graded Pinus spp and Eucalyptus timber available in the Brazilian market. These results are part of an ongoing research project focusing axially and eccentrically loaded timber columns.

1 MATERIALS AND METHODS

In the testing program 144 pieces of sawn timber of size 50mm x 100 mm x 2600mm were employed. Each one was cut into two parts to produce three sets of columns. The first set consisted of columns of two different lengths, 580mm and 2020mm. The second one consisted of columns of 870 mm and 1730mm in length, while the third one of columns measuring 1150mm and 1450mm. Two types of columns were obtained; first one with a slenderness ratio of 40 and the second one 140, from the first set. Likewise, from the second set, columns of 60 and 120 slenderness ratios, and from the third set columns of 80 and 100 slenderness ratios. But more importantly, these sub-sets of columns have the same origin since they came from the same piece of timber.

First of all the moisture content of small clear specimens was determined, and a 14.40% average moisture content was observed. Then the moisture content of each column was determined through an electrical hygrometer. The results were corrected to 12 % moisture content.

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Compression tests were also conducted and revealed that its compressive strength class is C25 meaning that characteristic compressive strength is 25 MPa (NBR 7190). A visual inspection was undertaken in accordance with the NBR 7190:1997-Projeto de Estruturas de Madeira - Anexo G: Classificação visual de madeira serrada de coníferas, [1], which define types, sizes and positions of physical characteristics allowed into each structural grade. The size and position of knots as well as other potential strength reducing characteristics in each piece was compared with the size and position of these characteristics allowed in the various grading classes. The highest grades allow fewer and smaller defects in each piece of timber. The timber was classified as non-dense structural S3-ND (the lowest strength properties expected into this Grade).

2 DISCUSSION
The experimental data demonstrate clearly that the larger the slenderness ratios, the smaller the difference among the values of experimental ultimate axial loads. This can be attributed to the fact that in slender columns the bending stiffness is more significant than the compressive strength, contrarily to the short columns. Compared to the compressive strength, the bending stiffness depends less on the local aspects and more on the global ones. This is the main reason for the reduction of the number of interfering variables. As a consequence, the coefficients of variation are bigger for the short columns than for the slender ones. The results show a good agreement between Eurocode 5 and experimental data obtained in this study. The adjusted curve for the average ultimate axial loads keeps good similarity with the Eurocode curve. The curve of ultimate load values less the standard value of the ultimate load values fitted quite well to the Eurocode curve. In this study, The Eurocode curve was obtained with no safety factors, in order to compare to experimental data. The reduction in the load bearing capacity can be attributed to the slenderness effect. The $\lambda=140$ columns presented only 13,28% of the average load bearing capacity of the $\lambda=40$ columns. These numbers can be mainly related to the slenderness of the columns. It is important to mention that the variability of these relations decreases as the difference of slenderness ratio becomes bigger. All results are in good agreement with Eurocode 5 expressions for column design.

3 CONCLUSIONS
Timber column design procedures contained in the new Brazilian Timber Structure Design Code proposal–NBR7191-2012 adapted from Eurocode 5, seem to be in good agreement with the experimental results obtained in this study concerning, The testing of twin timber columns with different slenderness ratio proved to be a good strategy to quantify the effect of the slenderness ratio on the column performance. The results confirmed the outstanding role played by the slenderness ratio in the stability of timber columns.

The number of tested columns and wood species need to be increased significantly in order to obtain experimental data for the definition of characteristic and design values.

REFERENCES