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6 authors, including:

Diego Henrique de Almeida
University of São Paulo

Tiago Hendrigo de Almeida
University of São Paulo

Julio Cesar Molina
University of Sao Paulo State (UNESP), Brazil

Fabiane Ferro
University of São Paulo

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Embedment Strength of *Pinus* sp. Wood to Metal Pins

Diego Henrique de Almeida[1, a], Tiago Hendrigo de Almeida[2, b], Julio Cesar Molina[2, c], Fabiane Salles Ferro[1, d], André Luis Christoforo[3, e] and Francisco Antonio Rocco Lahr [1, f]

[1]Wood and Timber Structures Laboratory (LaMEM), Department of Structures Engineering (SET), São Carlos Engineering School (EESC), São Paulo University (USP), Brazil

[2]Industrial Wood Engineering, Experimental Campus of Itapeva, Estadual Paulista University (UNESP), Brazil

[3]Department of Mechanical Engineering (DEMEC), São João del Rei Federal University (UFSJ), Brazil

[a]almeidadh@usp.br, [b]tiago.hendrigo@gmail.com, [c]molina@itapeva.unesp.br, [d]fsferro@usp.br [d]alchristoforo@yahoo.com.br, [e]frocco@sc.usp.br

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Abstract. To know the physical and mechanical properties of wood to be employed as structural elements in is an important factor for its use in a rational way. The connections between members of timber structures are also relevant topic once local stress concentrations can occur and safety must be seriously taken in account. Brazilian Code ABNT NBR 7190: 1997 "Design of Timber Structures" provides guidelines for connections calculation based on two alternative limit states: wood strength to embedment or bending of the bolt. The purpose of this paper is estimate the strength to embedment of *Pinus* sp. to bolts in three directions with respect to the grain: parallel, perpendicular and inclined at 45º. Specimens obeying requirements of Brazilian Code related to bolts diameter (10mm) were prepared and tested. The embedment strength in parallel direction to the fiber was the highest and the failure modes were more frequent crushing and cleavage.

Introduction

Connections in timber structures are points with higher stress concentrations of stresses and designers must consider carefully all parameters involved to provide compatible safety to structural set. To joint timber wooden structural elements is needed once several limits are usually imposed to lumber dimension and because of new structural shapes often challenge engineers of the segment.

Various types of connections between structural elements are available. Among them, the most usual are the so-called pins (exemplified by the nails and bolts), since they can be used in various connection configurations besides being of easy acquisition and application.

Brazilian Code ABNT NBR 7190: 1997 [1] provides the parameters for connections sizing made of metal pins. Referred Code takes in account two important limit states in these cases: wood strength to embedment or bending of the bolt [2, 3, 4].

Wood strength to bolt embedment is defined as a crushing in holes walls of wood elements, caused by stress concentration [4]. Some factors influence this strength, such grain inclination related to force in joined bars, wood specie (coniferous or dicotyledons), pre-drilling, among others [5, 6].

Brazilian Code ABNT NBR 7190: 1997 [1] furnishes bases to determine wood strength to embedment (f_e). As required by this Code, f_e is estimated by means of the ratio between force (F_e), that causes a residual specific deformation of 2‰ (Fig. 1), and area (A) of bolt embedment. A is obtained by multiplying specimen thickness (t) by bolt diameter (d), as exposed in Eq. 1.

$$f_e = \frac{F_e}{A} = \frac{F_e}{t \cdot d}. \quad (1)$$

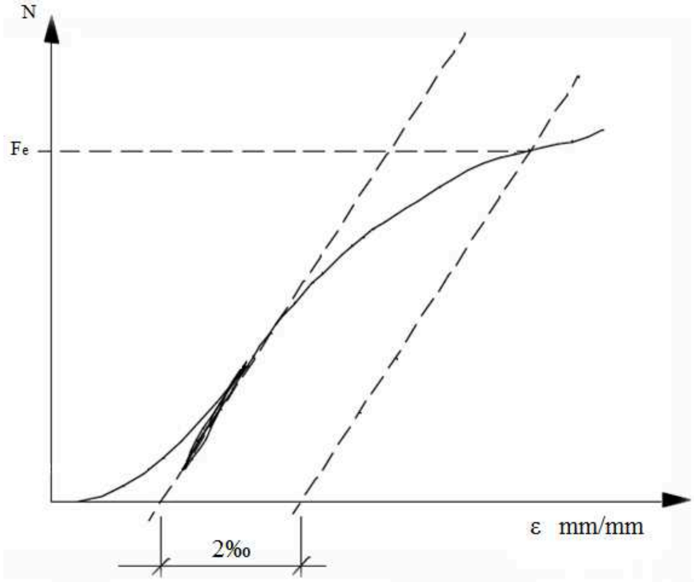

Fig. 1. Embedment strength vs.specific deformation diagram. Adapted [1].

The aim of this work is to evaluate wood strength to bolt embedment. *Pinus* sp. was chosen as reference wood specie and three different directions related to the grain were considered parallel, perpendicular and 45 degrees.

Materials and Methods

Tests were carried out in Wood and Timber Structures Laboratory (LaMEM), Structural Engineering Department (SET), São Carlos Engineering School (EESC), São Paulo University (USP).

For the tests, *Pinus* sp. specimens were made with moisture content around 12%. Six specimens for each in three different directions related to the grain: parallel, perpendicular and 45° (Fig. 2). Metal bolts with 10mm diameter were used. Tests obeyed requirements of Brazilian Methods, as exposed in Annex B, ABNT NBR 7190: 1997 [1]. An universal testing machine electronic Dartec, load capacity 100 kN, was employed to test realization.

(a) (b) (c)

Fig. 2. *Pinus* sp.specimens: (a) parallel, (b) 45º and (c) normal to the grains.

Results and Discussions

Table 1 shows average values (X_m), standard deviations (S_d) and coefficients of variance (CV) wood strength to embedment, *Pinus* sp. specie, in the mentioned directions. Number of specimens, for each situation, is denoted by x.

Table. 1. Average values of wood strength to embedment, *Pinus* sp. [MPa].

Embedment strength	f_{e0}	f_{e45}	f_{e90}
x	12	12	12
X_m	22	13	7
S_d	4,50	3,30	2,60
CV [%]	23	28	43

Result analysis shows higher values of strength in the direction parallel to grain, and lower in the parallel to the grain. Other researches, approaching this theme, have conclude in the same way [7, 8, 9, 10], but they didn't worked with *Pinus* sp. Analog observations can be exposed related to different wood mechanical properties, such strength in compression and tension parallel to grain [6].

Regarding to failure modes of the specimens, cleavage in grain direction and excessive deformation caused by crushing in contact area between bolt and wood (Fig. 3) predominated. These failure modes were also observed in surveys conducted by other authors using woods *Pinus* [4, 6, 7, 9, 11, 12].

(a) (b)

Fig. 3. Failure modes: (a) crushing in hole wall of wood piece; (b) cleavage in grain direction.

Conclusions

The study of wood strength to embedment is important for the design of timber structures whose members are joined by bolts or nails.

The direction parallel to grain led the greater wood strength to embedment of bolts, and perpendicular to the grain the smaller, considering *Pinus* sp.

Failure modes: cleavage in grain direction and excessive deformation caused by crushing in contact area between bolt and wood predominated, considering *Pinus* sp.

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