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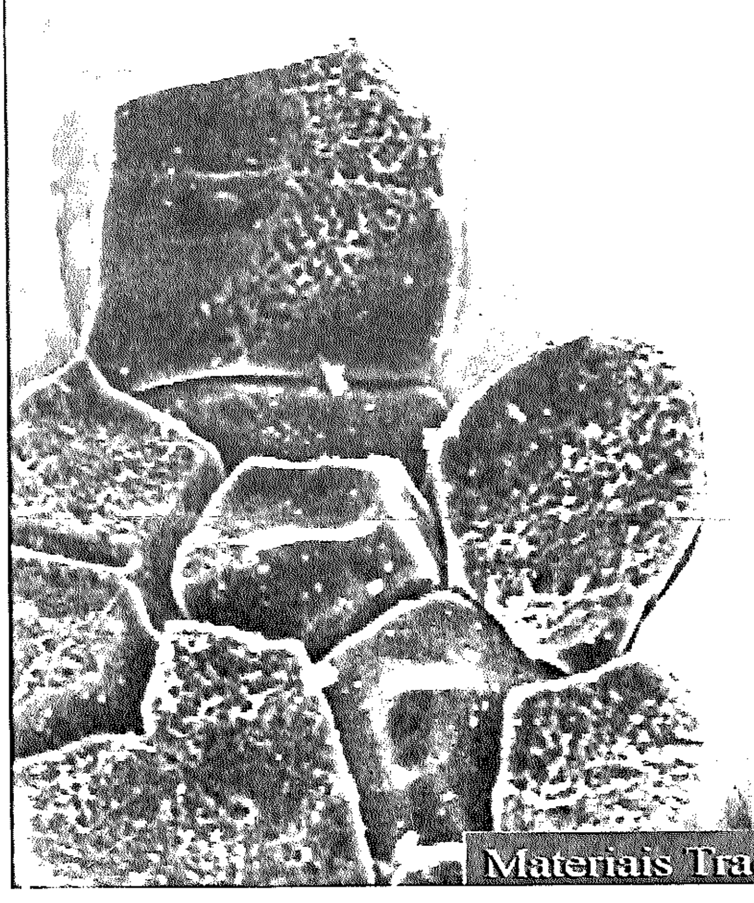

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TESTING METHOD FOR COMPRESSION PERPENDICULAR TO GRAIN IN WOOD

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Abstract: This work presents an experimental study with the aim to define test procedures and conventional strength for the characterization of wood in compression perpendicular to grain, employing unusual test. Several points were discussed: specimen geometry, speed of test, direction of loading referred to the growth rings and moisture conditions. Based on the experimental data, a new test specimen and a test procedure are proposed to be employed in wood characterization in compression perpendicular to grain. This method was included in the new Brazilian Code in Timber Structures (NBR 7190-97 - Projeto de estruturas de madeira, of the Associação Brasileira de Normas Técnicas).

Keywords: wood, compression perpendicular, mechanical properties.

Introduction

The anatomical constitution of wood provokes its performance behavior when subjected to compression perpendicular to grain. Stress-strain behavior is approximately lineal for low stress; large strain is observed at the failure. Some different stress levels, characterized by certain phenomena, have been proposed to estimate wood strength under compression perpendicular to grain. This work presents an experimental study with the aim to define test procedures and conventional strength for wood under compression perpendicular to grain.

Literature Review

The behavior of the wood under compression perpendicular to grain is very different than for other solicitations. In compression perpendicular, large strain without the occurrence of failure can be observed. According to Hellmeistter [10] (1973), "after the elasticity limit the wood admits great plastic deformation and easily they begin to be squashed".

2-190

Generally, the most critical orientation for the compression perpendicular is in the direction tangential to the growth rings. Bolza & Kloot [4] (1963) present data to mechanical properties of Australian timbers, where this fact can be verified.

The Associação Brasileira de Normas Técnicas [2] (ABNT) didn't present in "NBR-6230/1980 - Ensaios físicos e mecânicas de madeiras" the method of testing for compression perpendicular to grain.

The preliminary text proposed by the Laboratório de Madeiras e de Estruturas de Madeiras [12] (LaMEM, 1987), São Carlos School of Engineering, São Paulo University, "Madeira - Determinação de suas caracterísitcas", presents method of test for compression perpendicular to grain. Figure 1 shows the specimen and the arrangement of the test, which presents a partial compression of load surface through the rigidity steel plate. The strength is estimated as the stress level corresponding to 1 % strain.

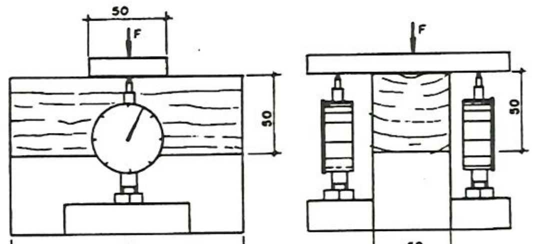

Figure 1. Specimen and test arrangement (LaMEM)

D143-83 - Standard Methods of testing small clear specimens of timber of the American Society for Testing Materials [1] (ASTM, 1993) presents specimen and disposition of testing similar to the shown in the figure 1. It specifies speed of testing (0,3 mm/minute) and loading application in direction tangential to the growth rings. The values obtained in this test are stress at 2,5 mm strain and stress at elasticity limit. The testing proposed by

Comission Panamericana de Normas Técnicas [5] (COPANT, 1972), COPANT-466, is identical to ASTM.

These testing methods with partial compression of loading surface are used since a long time, probably starting from the wood sleepers. However, several authors have criticized them. Bodig & Jayne [3] (1982) point out that the results obtained through the rehearsal of ASTM should not be used to determine the actual properties of the wood in compression perpendicular to the grain. Wolcott [14] et al. (1989) affirm that the testing method of ASTM doesn't measure pure compression. Fusco & Almeida [9] (1989) affirm that the stress determined from the testing method proposed by LaMEM [12] that cannot represent the strength in compression perpendicular to the grain.

ISO 3132, of the International Organization for Standardization (1975), uses specimen with cross section with 20 mm and length, measured in the direction of the grain, between 30 and 60 mm. If the growth rings of specimen have more than 4 mm thickness, the cross-section can be increased so that it specimen has 5 rings. The conventional strength is considered as the stress level where the tangent module of elasticity to reduce for 2/3 of the module of elasticity in the linear range (see figure 2).

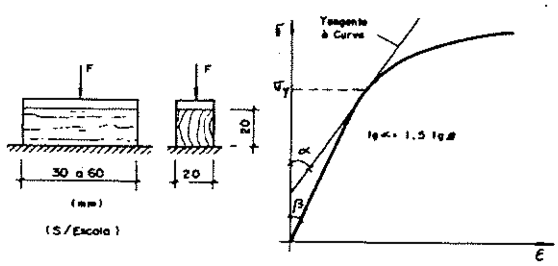

Figure 2. Specimen and strength (ISO-3132[11])

Madsen et al [13], 1982, use size specimen 38 x 90 mm in the transverse directions, and 145 mm in the longitudinal direction. Pointing out that the material presents a ductile behavior, and that it is difficult to define a limit state in the case of compression perpendicular to grain, they define the yield stress σy as the stress at a 0.2% offset strains (figure 3).

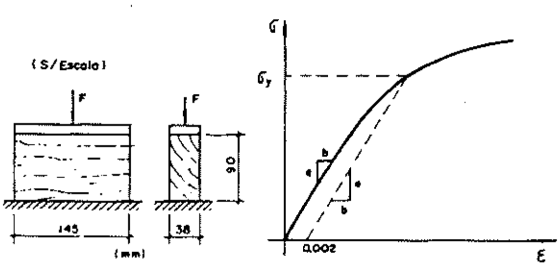

Figure 3. Specimen and strength (Madsen et al[13])

Feldborg[7] (1991) suggests determination of the conventional resistance of the wood similar to the presented in the figure 3, being admitted, however, stress at 1% offset strain.

Fusco[8] (1993) presented a proposal of normalization of the wood strength. He indicated that the strength to compression perpendicular to grain should be determined in a test of uniform compression, with total duration of 3 to 8 minutes, in specimen with cross section with 50 mm and length of 100 mm.

The existence of two antagonistic ways for the testing methods in compression to the grain was verified. The methods of testing of ASTM, COPANT, and the proposed by LaMEM specify that the test should be accomplished with partial compression of the specimen. The methods of the ISO and of another mentioned authors specify total compression.

Materials and Methods

Preliminary tests were conducted for six species with the objective of defining the strength of the wood in compression perpendicular, initial tests were made for six species. Later, complementary tests were made for three species. The height of specimen (100 a 120 mm) must be bigger than the dimensions of the cross section (50 mm), considering the conclusions of Dias [6] (1994).

Six wood species were chosen to obtain a wide variation in the specific gravity. The tests were made in two moisture content levels: air dry (12% to 15%) and wet. So, the qualitative influence of these factors (moisture content and specific gravity) in compression perpendicular to grain can be observed. The table 1 shows wood species and the specific gravity (at 12% of moisture content) of the specimen (mean values).

Table 1. Specie x specific gravity

Specie	ρ_{12} (kN/m^3)
Peroba rosa *(Aspidosperma polyneuron)*	7.0
Goiabão *(Planchonella pachycarpa)*	9.1
Maçaranduba *(Manilkara spp)*	9.9
Guapuruvu *(Schizolobium paraibum)*	4.7
Ipê *(Tabebuia spp)*	9.3
Cupiúba *(Goupia glabra)*	8.4

The six specimens of the same specie (three for each one of the moisture condition) were tested in identical condition of load application (speed of testing and direction referred to the growth rings). The strains were measured in the central portion (50 mm) of the specimen (see figure 4).

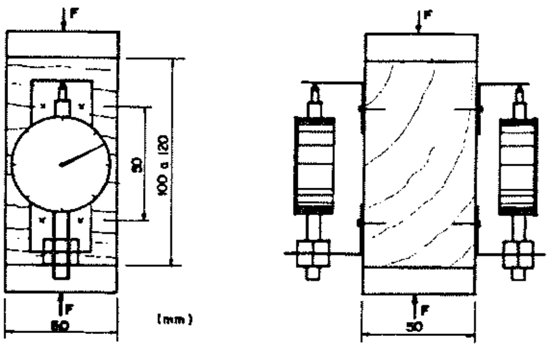

Figure 4 - Specimen and obtainment of strains

The curve stress x strain obtained for each test doesn't present the failure stage of the specimen, because of the method employed to measure the strain and the possibility of occurrence of brittle failure causing damages to the deflectometers. The following values are obtained of these curves.

- stress at 1% strain ($\sigma_{1\%}$)
- stress at 0.2% offset strain ($\sigma_{r.0.2\%}$)
- strain at $\sigma_{r.0.2\%}$ stress
- stress at 1% offset strain ($\sigma_{r.1\%}$)
- strain at $\sigma_{r.1\%}$ stress
- module of elasticity E (in the straight portion)

The figure 5 presents the way of obtaining these parameters.

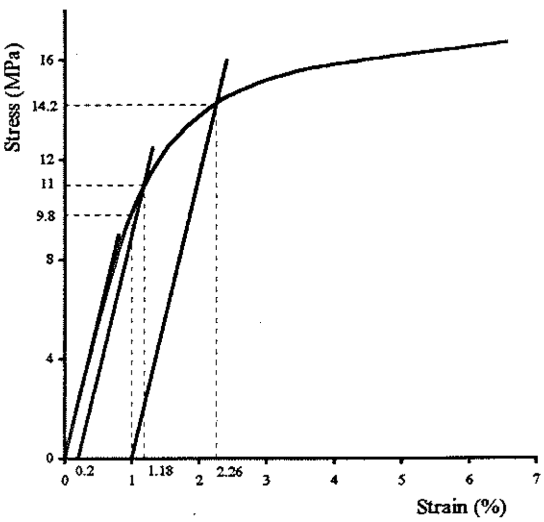

Figure 5. Definition of parameters

The employed method to measure the deformations didn't allow the elaboration of the curves stress x strain at the failure of the specimen. In the complementary tests, the curves were obtained inclusively at the failure stage through of the use of machine of testing (DARTEC) with digital system control for load application and displacement acquisition. It possible to analyze the behaviour in the failure stage.

Six specimen of the species Eucalipto citriodora (*Eucalyptus citriodora*) and Castanheira (*Bertholletia excelsa*), and four of the species Maçaranduba (*Manilkara sp*), all in the air-dry condition of moisture content, were tested. The strain was measured in the total height of the specimen, admitting them as being the same to the displacement of machine ram. The following values were obtained from the curves stress x strain of these tests:

- stress at 0.2% offset strain ($\sigma_{r.0.2\%}$)
- strain at $\sigma_{r.0.2\%}$ stress
- stress at failure ($\sigma_{failure}$)
- strain at $\sigma_{failure}$
- module of elasticity E (in the straight portion)

Results

The tables 2 and 3 present summary of results of initial tests in the air-dry and wet moisture condition, respectively.

Table 2. Means values and coefficients of variation (air-dry)

Specie	$\sigma_{1\%}$	$\sigma_{r.0.2\%}$		$\sigma_{r.1\%}$		E
	σ(MPa)	σ(MPa)	ε(%)	σ(MPa)	ε(%)	(MPA)
Peroba Rosa	9.77 (5.6%)	11.10 (0.9%)	1.22 (9.5%)	14.27 (0.4%)	2.31 (6.1%)	1124 (10.8%)
Goiabão	9.05 (6.0%)	8.52 (9.7%)	0.88 (10.6%)	11.26 (3.1%)	1.90 (4.6%)	1300 (10.4%)
Maça-randuba	15.73 (2.9%)	15.60 (1.7%)	0.97 (6.0%)	19.83 (1.8%)	1.98 (3.3%)	2025 (7.0%)
Guapu-ruvu	4.00 (2.5%)	4.57 (2.5%)	1.23 (6.1%)	6.17 (2.5%)	2.41 (6.0%)	451 (5.1%)
Ipê	14.27 (4.8%)	13.97 (2.1%)	0.95 (7.1%)	17.57 (1.2%)	1.96 (4.2%)	1857 (8.9%)
Cupiúba	10.58 (1.7%)	9.40 (2.8%)	0.78 (7.1%)	12.92 (2.0%)	1.80 (3.9%)	1623 (6.5%)

Table 3. Means values and coefficient of variation (wet)

Specie	$\sigma_{1\%}$	$\sigma_{r.0.2\%}$		$\sigma_{r.1\%}$		E
	σ(MPa)	σ(MPa)	ε(%)	σ(MPa)	ε(%)	(MPA)
Peroba Rosa	6.00 (5.8%)	6.42 (4.6%)	1.11 (0.9%)	8.33 (3.9%)	2.17 (0.5%)	713 (6.0%)
Goiabão	6.37 (4.5%)	5.97 (1.0%)	0.91 (7.6%)	8.13 (1.9%)	1.96 (3.7%)	850 (10.1%)
Maça-randuba	11.02 (2.5%)	10.00(2.0%)	0.84 (4.3%)	13.98 (1.3%)	1.89 (2.6%)	1579 (6.2%)
Guapu-ruvu	2.78 (7.3%)	2.60 (5.1%)	0.91 (4.0%)	3.97 (8.9%)	2.06 (0.6%)	372 (9.2%)
Ipê	10.50 (1.9%)	10.25 (4.3%)	0.95 (4.6%)	13.32 (4.0%)	1.96 (1.9%)	1225 (2.0%)
Cupiúba	8.23 (0.7%)	7.80 (0.0%)	0.84 (1.2%)	9.33 (1.6%)	1.76 (0.6%)	1225 (2.0%)

The figure 6 presents, as example, the stress x strain curves for the six specimens of Peroba Rosa in the two moisture conditions.

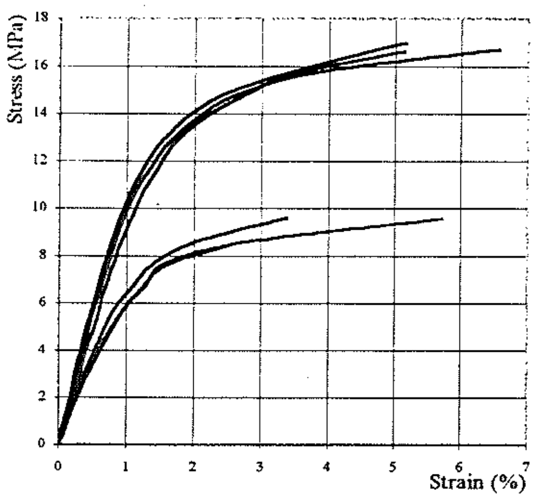

Figure 6 - Stress x Strain

The table 4 shows the results of the complementary tests:

Table 4 - Mean values and coefficients of variation

Espécie	$\sigma_{r.0.2\%}$		$\sigma_{failure}$		E
	σ(MPa)	ε(%)	σ(MPa)	ε(%)	(MPa)
Eucalipto citriodora	11.37 (2.8%)	1.41 (5.8%)	19.69 (7.6%)	10.85 (17.5%)	949 (6.4%)
Casta-nheira	7.80 (2.2%)	1.42 (2.2%)	15.00 (10.1%)	20.02 (35.4%)	642 (1.0%)
Maça-randuba	15.06 (3.9%)	1.41 (2.7%)	28.47 (24.9%)	15.06 (3.9%)	1290 (1.1%)

Conclusions

The stress x strain curves obtained in the initial tests present the same shape to the several species and the moisture conditions. The specimen presented large strain at the failure, and it was not possible to admit uniform stress distribution on the cross section anymore. The tests don't give reliable results at failure stages.

This could also be observed in the complementary tests: the stress and strain at the failure present much variability than the stress and strain at $\sigma_{r.0.2\%}$.

Other aspect to point out is the failure shape referred on the growth rings disposition on the specimen. Sometimes, for not so high strains, brittle failure can occur if the growth rings are oblique.

So, the strength of wood in compression perpendicular to grain should be established by the behavior relationship to deformations. We suggest the conventional strength as the stress at 0.2 % offset strain, which is recommended for ductile materials. For bigger stresses an exaggerated increase in strains for constant increments of stress can be observed.

References

[1] American Society for Testing Materials. *Annual book of ASTM standard.* Philadelphia, ASTM, v. 4.09: Wood, 1993.
[2] Associação Brasileira de Normas Técnicas. *Ensaios físicos e mecânicos de madeiras - NBR6230.* Rio de Janeiro, ABNT, 1980
[3] Bodig, G.J.; Jayne, B.A. *Mechanics of wood and wood composites.* New York, Van Nostrand Reinhold, 1982.
[4] Bolza, E.; Kloot, N.H. *The mechanical properties of 174 Australian timbers.* Melbourne, CSIRO, 1963.
[5] Comission Panamericana de Normas Técnicas. *Maderas - Método de determinação de la compression perpendicular al grano.* Buenos Aires, COPANT, 1972.
[6] Dias, A.A. *Estudo da solicitação de compressão normal às fibras da madeira.* São Carlos, 1994, 144p. Tese (Doutorado) Escola de Engenharia de São Carlos, Universidade de São Paulo.
[7] Feldborg, T. Determination of some mechanical properties of timber in structural sizes. In: INTERNATIONAL TIMBER ENGINEERING CONFERENCE, LONDON, 2-5 setembro, 1991. Anais... London, v.2, p.2189-2199, 1991.
[8] Fusco, P. B. Uma proposta de normalização das resistências da madeira estrutural. In: 1 EREMEM, São Paulo, 4-5 novembro, 1993. Anais... São Paulo, EPUSP-IBRAMEM, p.213-233, 1993.
[9] Fusco, P.B.; Almeida, P.A.O. Fundamentos para o estabelecimento de um método de ensaio de compressão normal das madeiras. In: III EBRAMEM, São Carlos, 26-28 julho, 1969. Anais... São Carlos, EESC-USP, v.4, p.19-26, 1993.
[10] Hellmeister, J.C. *Sobre a determinação das características físicas da madeira.* São Carlos, 1973. 161p. Tese (Doutorado) - EESC-USP.
[11] International Organization for Standardization. ISO-3132 - Wood - Testing in compression perpendicular to grain. Switzerland, ISO, 1975.
[12] Laboratório de Madeiras e de Estruturas de Madeira. *Madeira - Determinação de suas características.* São Carlos, LaMEM, 1987.
[13] Madsen, B.; Hooley, R.F.; Hall, C.P. A design method for bearing stresses in wood. *Canadian Journal of Civil Engineering,* v.9, p.338-349, 1982.
[14] Wollcott, M.P.; Kasal, B.; Kamke, F.A.; Dillard, D. Testing small wood specimens in transverse compression. *Wood and Fiber Science,* v. 21, p.320-329, 1989.