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# Elastic constants of wood determined by ultrasound wave propagation

Raquel Gonçalves, Alex J. Trinca, Domingos G. P. Cerri, Bruno P. Pellis

**Laboratory of Nondestructive Testing**
FEAGRI – UNICAMP
Brazil

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# Objective

The purpose of this study was to evaluate the results of the three Young's modulus ($E_L$, $E_R$, $E_T$), the three shear modulus ($G_{LR}$, $G_{LT}$, $G_{RT}$) and the six Poisson ratios ($\nu_{LR}$, $\nu_{LT}$, $\nu_{RL}$, $\nu_{RT}$, $\nu_{TL}$, $\nu_{TR}$) using ultrasound with direct contact technology and three different geometries of test sample.


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# Introduction

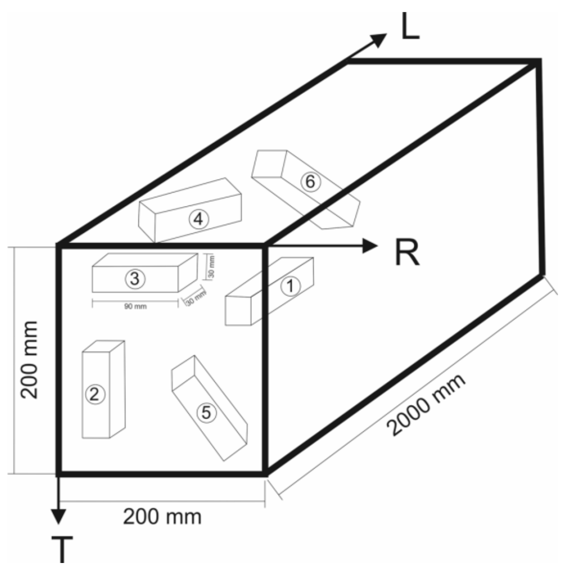
The Structural calculation software has become increasingly common and available for use by engineers and architects, but for use it is necessary the knowledge of properties along all major axes of wood.

# Material

The ultrasound tests were performed based on three different geometries: cubic prism, multifaceted disc and tetrahedron with 26 faces.

# Material

For the tests three species were used - *Eucalyptus saligna*, *Apulleia leiocarpa* and *Goupia glabra*.



# Material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# Material

For the multifaceted disks and tetrahedron. The face dimension of 20 mm was adopted because of the transducer diameter was 18 mm.

The transducers used to measure the longitudinal and transversal waves were 1000 kHz frequency.


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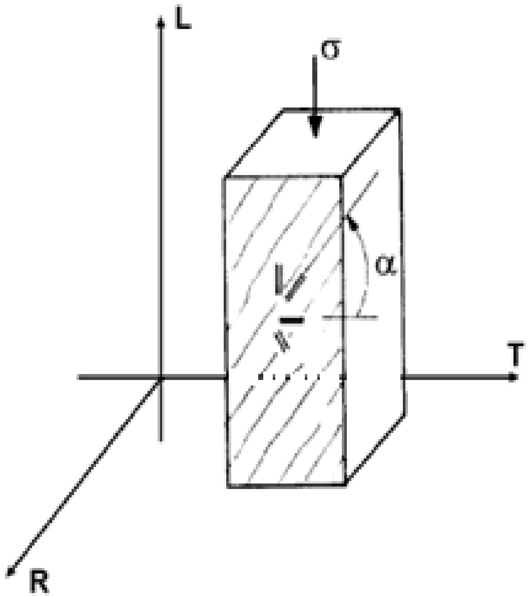
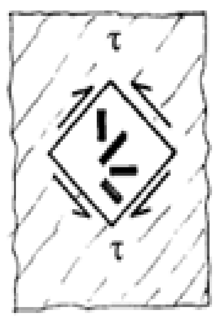
# Material

To the strain determination were used a total of 6 strain gages, 2 parallel to the charge and 4 perpendicular to the charge application. For the shear modulus (G) determination, the strain gages were positioned parallel to the charge application and in 45° with respect to the main orthotropic axis.

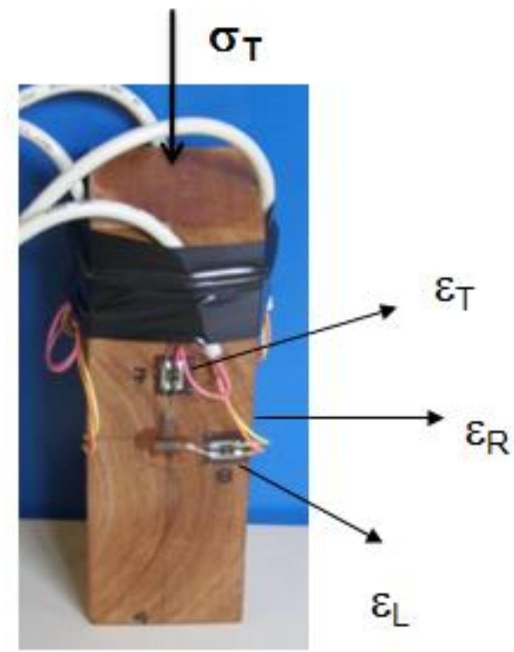
# Material




DETALHES

**CP tangencial**




$E_T = \sigma_T/\varepsilon_T$

# Material

The terms of the stiffness matrix [C] were obtained using the velocities and the densities of the samples applied to the Christoffell tensor. The elastic compliance matrix [S] was then obtained by the $[C]^{-1}$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# CONIDERATION

It is important to verify the order of the values, because this order is related with mechanical and acoustical properties. It is expected that $C_{11} > C_{22} > C_{33}$; $C_{44} < C_{55} < C_{66}$ and $C_{12} > C_{13} > C_{23}$.


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# TERMS OF STIFFNESS MATRIX( MPa)for *Apuleia leiocarpa*

| $C_{11}$ | $C_{22}$ | $C_{33}$ | $C_{44}$ | $C_{55}$ | $C_{66}$ | $C_{12}$ | $C_{13}$ | $C_{23}$ |
|---|---|---|---|---|---|---|---|---|
| **Prisms** | | | | | | | | |
| 23988 (3.54) | 3978 (0.64) | 2555 (2.39) | 549 (4.46) | 1427 (22.94) | 1850 (27.93) | 5499 (5.80) | 3773 (9.16) | 1340 (34.26) |
| **Multifaceted disks** | | | | | | | | |
| 22177 (2.44) | 4810 (7.68) | 3606 (5.98) | 763 (2.03) | 1384 (16.35) | 1576 (2.54) | 5524 (8.51) | 3221 (9.25) | 1959 (11.31) |
| **Polyhedral** | | | | | | | | |
| 23044 (3.80) | 4546 (4.18) | 3855 (3.72) | 799 (7.00) | 1617 (9.04) | 2317 (9.13) | 4931 (3.97) | 2684 (20.47) | 1237 (3.12) |


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# TERMS OF STIFFNESS MATRIX( MPa) for *Goupia glabra*

| $C_{11}$ | $C_{22}$ | $C_{33}$ | $C_{44}$ | $C_{55}$ | $C_{66}$ | $C_{12}$ | $C_{13}$ | $C_{23}$ |
|---|---|---|---|---|---|---|---|---|
| **Prisms** | | | | | | | | |
| 22551 (2.19) | 4200 (3.06) | 2279 (1.61) | 668 (4.39) | 1028 (22.02) | 2044 (1.51) | 5955 (2.24) | 1954 (12.39) | 936 (14.42) |
| **Multifaceted disks** | | | | | | | | |
| 21919 (7.47) | 4108 (3.37) | 2171 (7.69) | 651 (13.59) | 1213 (13.71) | 2189 (10.87) | 4932 (1.86) | 2248 (14.72) | 986 (15.04) |
| **Polyhedral** | | | | | | | | |
| 19589 (6.81) | 3787 (9.23) | 2077 (7.07) | 801 (4.94) | 1507 (6.16) | 1775 (3.11) | 4482 (13.61) | 1623 (13.95) | 734 (19.36) |


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# TERMS OF STIFFNESS MATRIX( MPa) for *Eucalyptus saligna*

| $C_{11}$ | $C_{22}$ | $C_{33}$ | $C_{44}$ | $C_{55}$ | $C_{66}$ | $C_{12}$ | $C_{13}$ | $C_{23}$ |
|---|---|---|---|---|---|---|---|---|
| | | | | **Prisms** | | | | |
| 28122 (2.05) | 8633 (2.94) | 3041 (2.64) | 851 (5.18) | 1235 (12.86) | 2486 (13.16) | 10931 (0.41) | 3111 (26.08) | 2171 (32.71) |
| | | | | **Multifaceted disks** | | | | |
| 27020 (5.78) | 7778 (4.35) | 2982 (7.03) | 784 (5.3) | 1186 (13.8) | 2332 (6.93) | 10031 (4.46) | 3258 (5.61) | 2351 (1.98) |
| | | | | **Polyhedral** | | | | |
| 27142 (5.89) | 5454 (6.57) | 2757 (5.9) | 690 (3.81) | 1087 (5.71) | 2144 (5.83) | 8191 (7.50) | 3480 (4.14) | 1730 (9.36) |


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# RESULTS

The statistical analysis considering the confidence interval, also indicate that the prism presented the better results followed by the disk and, in the end, the polyhedral. Though, it is important to remember that for this geometry the static and the ultrasound tests were made in the same sample, reducing the natural variability of the material


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# RESULTS

The results obtained in this research for Poisson’s ratio are similar, in order of magnitude, with that obtained by Preziosa *el al.* (1981), Bucur e Archer (1984), Preziosa (1982) and François (1995).




# RESULTS

The differences among velocities in the same directions obtained for the three geometries were below 10% for all species tested.

# RESULTS

The values that present more disagreement with the static tests are the $\upsilon_{RL}$ and $\upsilon_{LR}$ which present no statistical equivalence for none specie. On the other hand $\boldsymbol{\upsilon}_{\mathbf{TL}}$ and $\boldsymbol{\upsilon}_{\mathbf{RT}}$ show a good relation with static tests results for all species and samples geometries.


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# Conclusions

No specimen geometry is highlighted positive or negatively in terms of results. The prismatic samples presents results more related with static tests because both tests are made on the same sample.


# Conclusions

The polyhedral sample is easier to prepare and for obtain the complete stiffness matrix it is necessary only one sample while for the disk are necessary 3 samples and for the prisms 4 samples.


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- ajtrinca@mxb.com.br


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**THANK YOU FOR YOUR ATTENTION**