

Mechanical behaviour of Eucalyptus wood modified by heat

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Summary Eucalyptus wood (Blue gum) shows very high mechanical performances, presents very few knots and gives strong glued joints, reasons that justify its interest for structural uses, carpentry and furniture components or even building construction. The inconveniences of this species are its slow and difficult drying process and its low dimensional stability – with very high swelling and shrinkage coefficients.

The drying process has been studied at INETI and the problem revealed to be solved with appropriate drying schedules and the stresses released by a steam treatment. Heat treatment of Eucalyptus wood has been identified as one of the most promising techniques to increase its dimensional stability. Studies in this area still proceed.

This paper presents some test results that show the influence of heat treatment in the strength properties of this wood, namely the bending modulus of elasticity and tensile strength perpendicular to grain, in addition to the explanation of dimensional stability evaluation and some results of dimensional stability treatments.

Introduction

Everybody who works with biological materials knows the difficulty in the characterisation of physical and mechanical properties due to the great variability and dispersion of data resulting from the tests. One solution is to make a great number of tests and treat the data statistically. Sometimes this is not possible or takes a long time. Another solution would be to use some type of non-destructive test. When studying the strength change resulting from some kind of wood modification, it is very difficult to detect very slight differences, since the results of tests can be influenced by wood variability itself. This happens when using different samples on destructive tests (one set for control and another for modified wood). With a non-destructive test we can reuse the same sample in a repetition after some modification. One very important non-destructive test is the evaluation of modulus of elasticity and this is the reason we used MOE to detect the strength behaviour of wood before and after heat treatment.

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Heat treatment

Heating wood modifies the cell wall components in all mass of the wood sample. This chemical modification is accompanied by an increase of dimensional stability, at the expenses of some chemical degradation of wood. Higher levels of stability and liquid water repellence are obtained, but at same time some strength properties became altered, namely hardness and abrasion resistance that are reduced. Wood colour becomes darker in all mass, which can be useful for some species. According to Shiraishi et al. (1993) an exposure of three hours at 180 °C and atmospheric pressure gave a ASE value about 25%.

A French enterprise has launched in the market a new product based in high temperature treatment. The treatment is based on establishment of chemist bridges between macromolecules under the effect of heat in controlled atmosphere and pressure. They tell about water repellence, dimensional stability, resistance to insects and fungi, compatibility to end finishing products and weak thermal conductivity, but nothing about mechanical behaviour.

Anti-swelling efficiency

The ASE index (anti-swelling efficiency) is the most known method of evaluation of the dimensional stabilisation processes, but there are some differences in applying this method, namely the dry and wet conditioning of the samples. The most severe but the fastest is comparing the dimensions of the samples between oven dried and saturated in water at room temperature. For some authors the swelling is evaluated from air dried at 12% moisture content to a wet condition after stabilisation at 80% relative humidity and 25 °C. These conditions are less severe than the immersion in water and oven dry, but represents more closely the real conditions in the interior of houses.

$$S = \frac{D_w - D_d}{D_d} \times 100$$

where, S is the Swelling; D_w , Wet dimension, after immersion in water; D_d , Dry dimension, after oven dry.

$$ASE (\%) = \frac{S_{nt} - S_t}{S_{nt}} \times 100$$

where, ASE is the Anti-swelling efficiency; S_{nt} , Swelling of non-treated sample; S_t , Swelling of treated sample.

If the swelling of treated sample equals the non-treated the ASE index is 0%. If the swelling of treated sample is zero the ASE index is 100%.

The ASE admits for calculation, stabilised conditions, but sometimes (for some species or treatments) the delay to get equilibrium is very long. Then there is the risk of having different results depending on the time. By other hand the ASE don't give information about the rate of swelling that is an important parameter. The ASE values must be complemented with other information namely the graphics of swelling.

Strength properties

Strength evaluation on wood and wood derivatives is a problem when using destructive testing, because we have to extrapolate the results of some samples to the actual pieces. Taking into account the data dispersion expected with these types

of materials there is always a risk to take the values of test samples to wood components in structural applications. Besides this, the wood has local defects, knots, grain deviation, different densities from the core to the sapwood, etc., that increases the variability. Another inconvenience of destructive tests is that we can not repeat the tests or even use the same sample to evaluate other properties. One of the best solutions is to use the modulus of elasticity to characterise the strength behaviour of the wood, since the experience says that there is a close correlation between this characteristic and other strength properties as bending strength, transverse tensile strength and compression.

This principle is industrially used in stress grading machinery when they correlate the bending deformation to some defined load values. For small clear specimens this modulus of elasticity evaluation would be useful to complete the knowledge of the wood and allows using the same sample for other tests or repeating the same test in different circumstances.

Material and testing procedure

Eucalyptus wood used in these tests was the *Eucalyptus globulus* Labill. from a Portuguese origin, presenting an average reference density of $850 \text{ kg} \cdot \text{m}^{-3}$. All the samples were taken from the same board. The total shrinkage values in tangential direction were 14%.

The procedures to evaluate the Modulus of Elasticity (E) or the Apparent Modulus of Elasticity (MOE), has slight changes from standard to standard, namely the application of load in one or two points, the span, dimension of the samples and units. We used a 20×20 mm section sample and a span of 325 mm. The maximum load applied corresponded to 40% of the expected bending load rupture. The formula for calculation was:

$$\text{MOE} = \frac{L^3 \cdot (F_2 - F_1)}{4 \cdot B \cdot H^3 \cdot (D_2 - D_1)}$$

where MOE is the apparent modulus of elasticity (N); (MPa); L, span (mm); $F_2 - F_1$, difference load between point 2 and point 1 (N); B, width of the sample (mm); H, height of the sample (mm); $D_2 - D_1$, difference of bending deflection, 2 - 1 (mm).

Results of tests and discussion

In Table 1 are presented the results of tests with different common products used for wood surface protection, in order to have a measure of the efficiency of the heat treatment comparing with those products (products that don't form a rigid layer at the surface).

Table 1. Anti Swelling Efficiency for different treatments

Treatment	ASE (%)
Parafine	10
Wax	14
Glucose	12
PEG 1000	42
Heat 180 °C	24

From the analysis of Fig. 1 it becomes evident the straightness of the deformation curves, which proves that they are perfectly in the elastic zone. The heat modified samples revealed the higher relation load/deformation for modified wood presenting in consequence the apparent modulus of elasticity shown in Table 2. Since special attention has been paid to grain direction, Table 3 shows the results of samples tested in flat-grained and in edge-grained, which revealed a very slight increase in flat-grained for both normal and modified wood.

Other verifications were that treated wood presented a strong burned smell and the cutting properties were affected. The sawdust was similar to powder but the surfaces were good. The biggest difference was found in the colour. Eucalyptus is a very white wood but after treatment it became dark brown. The samples were tested a second time some days after the first set of tests and the results were exactly equal, which validates the method as a non-destructive and reliable procedure.

A little bit surprisingly the difference in density was inferior to 0.5%. The biggest difference was found in transverse tensile strength, which presented an average of 2618, MPa for the control samples and an average of 1892 MPa for wood modified by heat.

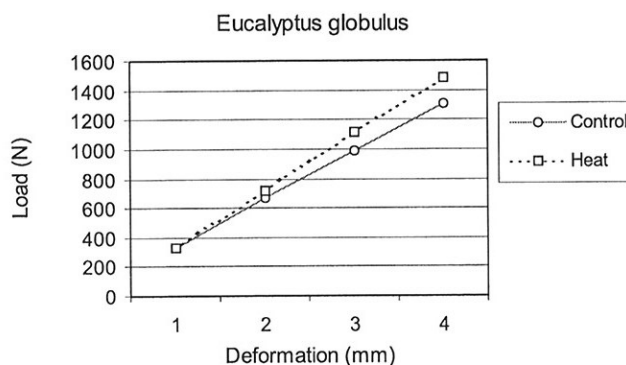


Fig. 1. Comparison of the bending deformation of control samples, and heat-treated samples (three points load, span 30 mm, section of the samples 20 × 20 mm)

Table 2. Apparent modulus of elasticity, treated and normal wood

	MOE (MPa)	Standard deviation (MPa)
Control samples	15 974	1 115
Heat treated samples	27 646	717

Table 3. Apparent modulus of elasticity according to grain direction

	Annual ring directions	MOE (MPa)
Normal wood	Flat-grained	16 157
	Edge-grained	15 791
Treated wood	Flat-grained	28 193
	Edge-grained	27 099

Conclusions

Taking into account the results of these tests, it can be said that strength properties were slightly affected. The apparent modulus of elasticity was a little bit higher on treated than on normal wood, despite a reduction of 26% in transverse tensile strength. Another conclusion was that we didn't find hardly any difference between bending strength in samples tested in flat-grain, comparing to the same samples tested in edge-grain.

If heat treatment of this species is a solution to moisture vulnerability, consequently to the high values of shrinkage and swelling, so the strength properties will not be a barrier to the use of this species in structural applications.

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