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TECHNOLOGICAL CHARACTERIZATION AND CORRELATION BETWEEN MECHANICAL AND PHYSICAL PROPERTIES OF THE WOOD OF THUJA (TECTRACANALIS ARTICULATA) OF THE KHEMISSAT REGION IN MOROCCO

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ABSTRACT

The aim of this study is the physico-mechanical characterization of a Moroccan wood: Thuja (Tectracanalis Articulata). The physical tests (density, radial shrinkage, tangential and volume) and mechanical (longitudinal modulus EL, breaking stress in compression and shear strength) were performed on specimens while respecting each corresponding test standards. The physical nature of the wood presents a high dimensional stability, with an average dry density of 0.68 and a basic density of 0.63. The mechanical properties are rather low, with a resistance to axial compression of 35 MPa, a static bending strength of 82, 22 MPa, and a static modulus of elasticity of about 7437MPa .In this paper we have demonstrated a good correlation between the wood density and the mechanical characteristics of the wood through an experimental study conducted on 30 specimens per test.

Keywords: physico- mechanical, physical tests, longitudinal modulus, flexural breaking stress in compression, shear strength.

INTRODUCTION

The behavior law, of minimal complexity, able to account for certain specificities of the mechanical behavior of the wood material, implies taking into consideration the strong anisotropy of this material. This has led many researchers to develop varied, complex and often expensive experimental means to identify the many elastic constants (at least 9) necessary to account for the three-dimensional elastic behavior [1], of the wood considered, the experiments being to be renewed for the various species.

Wood is an inspiration material for use in various fields, but the lack of understanding its behavior in the face of external mechanical stresses and its dimensional stability inhibits any industrial development. In this context, we sought to determine the physical characteristics, namely the anhydrous density d_0, the basal density d_b and the retract ability as well as the mechanical characteristics of this species: Longitudinal elastic modulus, static flexure failure stress and axial compression stress using standardized specimens of abundant resinous species in Morocco also In this paper we try to verify the existence of a law that connects the basic mechanical characteristics of wood namely the module of young longitudinal and the compressive stress to the density of thuja: Thuja of Morocco. "Tectracanalis Articulata" is an endemic species of the southern western Mediterranean, especially in the countries of North Africa where the extent of its extent decreases from west to east: Morocco comes in first place with more than 243348 ha [2], this kind is very widespread especially in the hot and dry parts of the kingdom and it is more known among craftsmen by its magnifying burr which is an outgrowth that is in the end which can reach up to 300 kg with beautiful color and smell.

MATERIAL AND METHODS

The test specimens used are made from the randomly selected logs of trees. These trees have no defects or rot. The shaping of the specimens was carried out using diametric plates 20 mm thick Figure-1, While respecting the various dimensions of the specificities of each test.

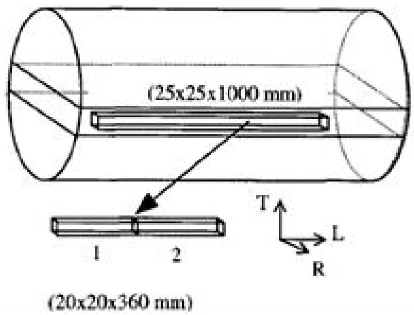

Figure-1. The cutting of radial bar for the test pieces preparation.

Wood is a heterogeneous material whose properties vary according to the species, the water content (influence on volume, density), the part of the tree considered (perfect wood, juvenile, mature, etc.) and the direction of the effort to which it is subjected. For this reason, the characterization of the essence requires the determination of these physical parameters first and subsequently those mechanical.

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Physical characteristics

The physical properties of wood vary from one species to another, depending on the nature and growing environment of the tree. A good knowledge of its characteristics is imperative to determine its use. The determination of the physical properties, in particular the densities and the shrinkage, is carried out on 20 mm edge cuboid specimens cut according to the three preferred directions of the wood (radial, tangential and longitudinal), while respecting the French standard NF B 51-006.

The moisture content: It is the quantity of water contained in the wood in question, expressed as a percentage (%) of its weight in the anhydrous state. The most accurate and frequently used method is the weighing of the specimens, before and after passing through the ventilated oven to maintain the temperature at (103 ± 2) ° C until the mass is stabilized. For this purpose, we used a precision electronic scale of 0.001 g and a digital caliper with a sensitivity of 10^{-2} mm. This test is carried out according to standard NF B51 004.

Retractability: Retractability is the physical property of wood used to evaluate dimensional stability and, therefore, the behavior of wood in drying. The test is carried out according to the French standard.

Anisotropy (A): This value is expressed as the ratio of tangential shrinkage to radial shrinkage. It gives an indication of the importance of the deformations which may appear during drying below the saturation point of the fibers.

The density (Dh): The amount of woody material contained in a given volume of wood for giving moisture content. It is a very fluctuating quantity, for which it is expressed at a given moisture content H%.

The infra-density (Db): It is also called the basal density of the wood, is the ratio of the anhydrous mass to the volume of the sample in the state of saturation according to the French standard NF B 51-005, this parameter is important to consider because it represents for each sample the ratio of two constant values in contrast to the density, which varies according to the moisture content.

$$d_H = \frac{m_H}{V_H} \quad (1)$$

$$d_0 = \frac{m_0}{V_0} \quad (2)$$

$$d_b = \frac{m_0}{Vs} \quad (3)$$

$$R_R(\%) = \frac{L_R^S - L_R^0}{L_R^0} * 100 \quad (4)$$

$$R_T(\%) = \frac{L_T^S - L_T^0}{L_T^0} * 100 \quad (5)$$

$$R_V(\%) = \frac{V_H - V_0}{V_0} * 100 \quad (6)$$

With:

m_H: Mass of the specimen in the moisture state H;
m_0: Mass of the specimen in the anhydrous state;
V_H: Volume of the test specimen in the humidity state H;
V_0: Volume of the test piece in the anhydrous state;
L_R^S : Width of the test piece in the radial direction the saturated state;
L_R^0 : Width of the test piece in the radial direction the anhydrous state;
L_T^S : Width of the specimen in the tangential direction the saturated state;
L_T^0 : Width of the specimen in the tangential direction the anhydrous state.

The moisture content of the specimens was determined by the double weighing method NFB51 004, namely:

$$H(\%) = \left(\frac{m_H - m_0}{m_0}\right) * 100 \quad (7)$$

With:

H: Wood moisture;
m_H: Wet mass;
m_0: Anhydrous mass;

Mechanical properties

The wood presents a variety of mechanical parameters which must be considered when discussing the quantitative description of the mechanical behavior of this material. Therefore, several mechanical tests have been carried.

Bending test 4 points: The longitudinal modulus of elasticity is a technologically essential property for structural uses where wooden parts are frequently subjected to static bending according to their greatest direction, that is to say parallel to the fibers. It is an indicator of the rigidity of wood.

The purpose of this test is to determine the longitudinal elastic modulus E_L and the static bending stress σ_{fs}. To do this, we tested solid wood specimens of dimensions 20x20x360 mm cut in the three preferred directions of the wood (radial, tangential and longitudinal) (Figure-2), while respecting the standard NB51-008.

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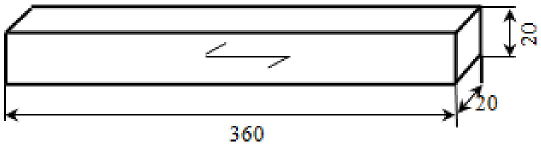

Figure-2. Bending specimen test.

The specimen was placed in the device of the four-point flexion shown schematically in Figure-3.

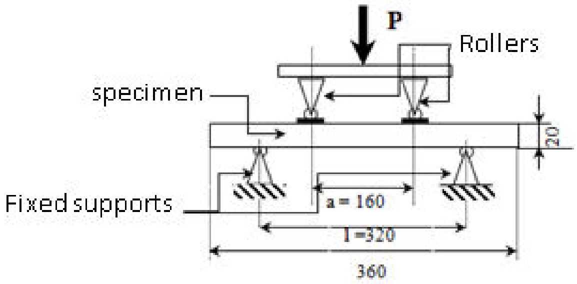

Figure-3. Bending specimen the device of the four-point flexion.

The test piece is placed on two free rotating cylinders mounted on fixed supports. The force is applied to the sample via two cylinders of the same free rotating diameter, mounted on movable supports, separated from the length (Figure-3). The force is applied in increments to the sample. As shown in Figure-4 for each load level, the boom is measured using two micrometers.

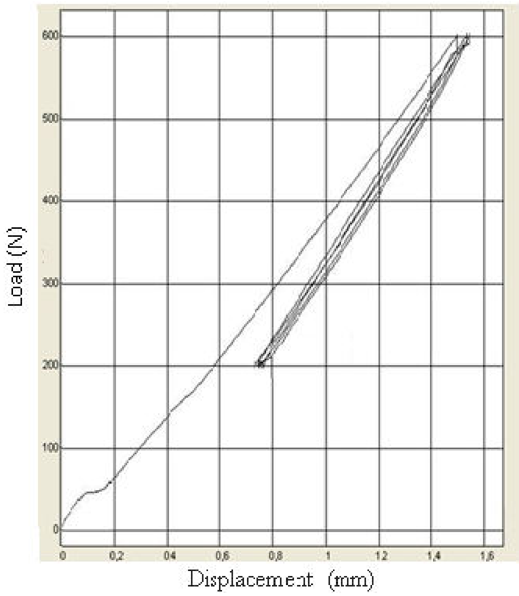

Figure-4. The curve load-displacement of the bending tests 4 points for the determination of the boom.

(a)

(b)

Figure-5. Scheme of the four-point bending device (a) before failure and (b) after failure.

The EL module, expressed in MPa, was calculated from the following equation:

$$E_L = \frac{3P(l-a)m^2}{8bfh^3} \qquad (8)$$

The rupture stresses (σfs), expressed in MPa, and was determined as follows:

$$\sigma_{fs} = \frac{3P_{max}(l-a)}{2bh^2} \qquad (9)$$

With:

P : Total bending load (N);

P_{max} : Maximum load applied to bending failure (N);

l : Distance between the axes of the cylindrical supports (mm);

a : Distance measured between the axes of the loading heads (mm);

m : Distance measured between the axes of the cylinders of the measuring instrument holder (mm)

b : Measured width of the specimen (mm),

h : Measured height of the test piece (mm),

f : Deflection in the middle of the specimen (mm).

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Axial compression

This test consists in determining the compression stress (σa) of the wood under an axial compression force applied progressively with a speed and exerted parallel to the wire of the wood in order to obtain the rupture of a test piece of dimensions 20 × 20 × 60 mm by crushing (NF B 51 -007) as shown in figure-6.

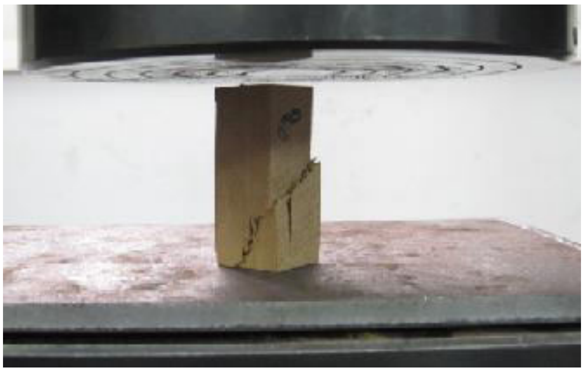

Figure-6. Compression test.

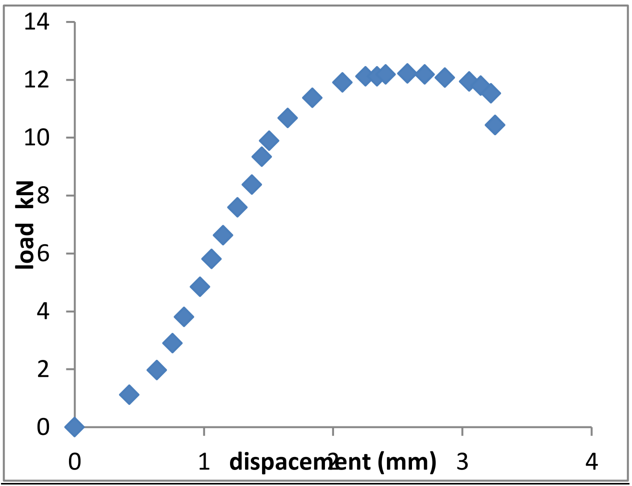

Figure-7. The load-displacement curve of a standardized Thuja wood specimen subjected to a compression test.

If the wood has a fragile character during a tensile test, the ruin is however in compression is clearly ductile. Indeed, on the curve there is a substantially linear zone that can be qualified as elastic limited by the compressive elastic limit stress, followed by a plastic deformation zone limited by the tensile stress. Where it is expressed in MPa and calculated as follows.

$$\sigma_a = \frac{P_{max}}{ab} \quad (10)$$

With:
a and b: Dimensions of cross-section of specimen (mm);
P_{max}: Maximum load (N);

RESULTS

Table-1 presents the mean values and the standard deviations of the physical and mechanical properties of the Thuja wood.

Table-1. Physical and mechanical characteristics of wood Thuja.

	Average	Standard deviation
d_H g/cm^2	0.68	0.03
d_0 g/cm^2	0.63	0.02
d_b g/cm^2	0.60	0.02
$R_v(\%)$	4.98	0.46
$R_T(\%)$	2.90	0.45
$R_R(\%)$	1.83	0.06
A	0.64	0.11
E_L (MPa)	7437	148.1
$\sigma_a(MPa)$	35	0.38
$\sigma_{fs}(MPa)$	82.22	25.93
$R_{Lc}(MPa)$	30	2.41

The results obtained allow us to classify the Thuja as a heavy wood, with high dimensional stability and low rigidity.

DISCUSSIONS

Dimensional stability

Retractability conditions the deformation of the parts during drying; it can also be responsible for the problems encountered on the wood elements used, problems resulting from deformations due to losses or recoveries of wood moisture due to hygroscopic variations [3-4].

One cannot then speak of dimensional stability without mentioning a very important parameter: the coefficient of Anisotropy A (ratio of two tangential and radial withdrawals). Indeed, it is a direct consequence of the heterogeneity of the material in question.

Figure-8 shows the evolution of the anisotropy coefficient of the transverse recesses as a function of the density measured at 12% of water content on a set of 836 species. These data are derived from the CIRAD Wood Physical and Mechanical Properties Database [5]. We can see in this figure that the Thuja Tetraclinis Articulata, with a transverse shrinkage anisotropy coefficient of 0.68, has a low transverse anisotropy, compared to the majority of the other species.

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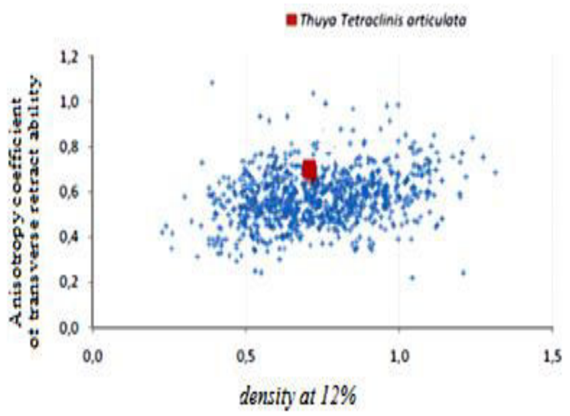

Figure-8. Anisotropy coefficient of transverse retract ability / density at 12% of 836 species (database).

Comparison of the Young's modulus of thuja with other species:

Thuja is the second most abundant resinous species in Morocco, it supports heat and has other very important chemical characteristics, but it has a low rigidity. E_L = 7437MPa <10 000 MPa. It would then be interesting to compare it with other Mediterranean species. In Table-2 we report our results as well as those determined by other authors on the same species or similar species (Table-2) presented below.

Table-2. Comparison of Young's modulus of thuja wood with other species (a) our work, (b) work [6], (c) work [7].

Wood	Longitudinal Young Modulus MPa
Pin d'Alep	11450
Chêne vert (c)	13445
Erable	10000
Epicéa	13000
Frêne	10000
Thuja (a)	7436
Thuja (b)	6086

From the Table-2, the results obtained are close to those of the literature [4]. It is a heavy wood with low rigidity. Then it can be said that it is the weakest among all the species found in the Mediterranean basin. However, this wood has strong qualities: its longevity which exceeds 400 years, resistance to diseases, its beauty its dimensional stability allows it to be excellent wood for cabinetmaking.

Correlation between mechanical properties and density h of the wood

The density strongly influences the mechanical characteristics of the wood, but the dispersion discovered suggests that other parameters may occur such as the number of rings and the angle of the fiber, among others. We chose to work on the density h relation and two mechanical characteristics, namely the Young longitudinal modulus and the axial compression stress.

Correlation between Young modulus and density h

The elastic properties of wood are sensitive to the variations of the physical state of materials considered [8] To determine this correlation, we performed the 4-point bending test mentioned earlier the four-point bending test on a number of 30 test pieces.

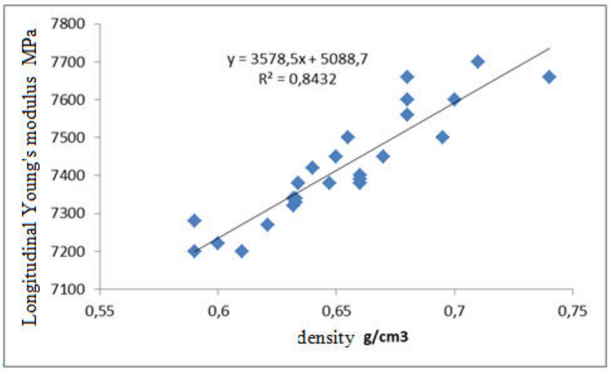

Figure-9. Representation of the Longitudinal Young's modulus MPa as a function of the density of the wood.

The compression stress correlation and density

In most of its uses, wood is called to work in axial compression. It is for this reason that it is very judicious to seek the relationship between the density and the critical stress by compression

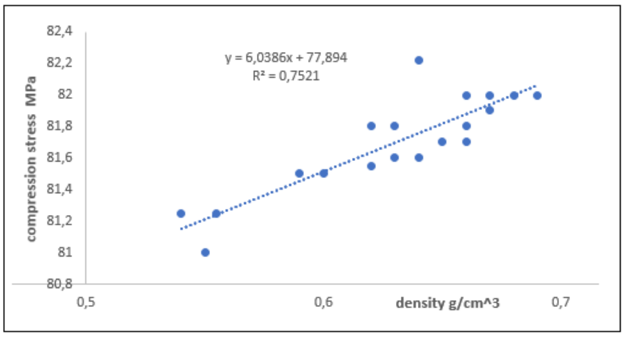

Figure-10. Representation of the compression stress MPa as a function of the density of the wood.

The results obtained confirm that there is a linearity relation between the most important mechanical characteristics and the density of softwood as already announced by Guitard *et al* [9]. Who propose a linear model to predict the Young's modulus from the density?

CONCLUSIONS

This study made it possible to improve the knowledge concerning the stiffness of Tetraclinis Articulata wood from measurements of the modulus of elasticity (Young's modulus) which is widely used in the technological field of wood. This module characterizes the overall behavior of wood. We have also determined the basic physical and mechanical characteristics such as anhydrous density d_0, basal density d_b, retractability, static flexure rupture stress, axial compression stress. The physical characteristics obtained in this study allow the classification of Thuja wood as hardwood to mid hard, heavy to medium heavy and nervous. For the mechanical characteristics, we notice that this wood has an average rigidity.

We can conclude by using a statistical treatment that the density as a highly explanatory physical parameter of the total variability of the elastic characteristics inters and intra species.

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