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STRENGTH AND MOE OF POPLAR WOOD (*POPULUS ALBA* L.) ACROSS THE GRAIN: EXPERIMENTAL DATA

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Abstract

The paper is centred on the mechanical characteristics of poplar wood (*Populus alba* L.), particularly on selected short term loading tests (strength and modulus of elasticity) across the grain. The reason for such work arises from the necessity to deepen the knowledge of the mechanical behaviours of this species to apply it to a better conservation of painted panels. Tension and compression tests perpendicular to the grain, at three different wooden moisture content values, are described. The results show no evident differences at various moisture content values and for different loading tests.

1. Introduction

During the Renaissance period (XIII-XV sec.) many artists, such as Giotto, Leonardo da Vinci, Botticelli, Raffaello and Caravaggio (just to cite a few examples), painted their masterpieces on wooden supports. In the Tuscany area most of these supports were made of poplar wood (*Populus alba* L.) because of its availability, its technological characteristics and easy processing [6]. By the time elapsing many problems in conservation of the artworks have developed. Painted panels are really complex objects because of the heterogeneity of the used materials, such as wood, gypsum, animal glues, colours and varnish [6]. Each one contributes to the conservation (or deterioration) of the objects according to its physical or mechanical behaviour. Actually the painted panels, that today we admire in museums or churches, show damages both to the painted layers, such as craquelure or bucklings, and to the wooden supports, such as cupping and cracks [1,2] and the anatomical direction are specially important because the perpendicular to grain ones contribute very much to the phenomena. These damages are due to the climatic conditions cyclic variations and the contemporary presence of mechanical restraints on the painting panels themselves, particularly the crossbeams and the frame, if it is present. When the climatic conditions vary, particularly the relative humidity of the air (RH), also the moisture content (MC) of the painting panels changes, trying to reach the new equilibrium value. The wooden support is usually restrained, as already explained, and it is not able to deform. The inner forces, due to the restraining, produce loss of dimension or cracks. In order to deepen the basis of the mechanism that is responsible of these damages on the wooden supports of the painted panels, a wide research has carried out at DISTAF, and a part of it is described in this paper. The main aim of the whole work is the physical and mechanical characterization of new poplar wood, measuring the density, the restraining/swelling coefficient, the diffusion coefficient, the strength and MOE values, the visco-elastic deformation, the compression set shrinkage across the grain to apply such knowledge to a better conservation of painting panels. This paper is centred on the description of the utilized methods and the obtained results of short term loading tests according to three different equilibrium moisture content.

2. Materials and methods

The tested specimens are obtained by new poplar wood (*Populus alba* L.). They are clean, with straight grain, or as much as possible, and cut as cubes (30x30x30 mm) in order to represent a small “unit” of a painted panel. Specimens are cut according to three different directions: perfectly radial (identified by the abbreviation 0 in the following graphs), perfectly tangential (identified by the abbreviation 90 in the following graphs) and 45, that is the intermediate direction between the others (identified by the abbreviation 45 in the following graphs). After cutting, the specimens are put in three different boxes in order to be equilibrated at three different moisture contents. In each box a unique climate is realized: dry climate (30% RH and 30°C), normal climate (65% RH and 20°C) and

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humid climate (85% RH and 30°C). Each one represents a particular state: the humid and dry climates are the extreme values in order to magnify the phenomena, while the normal climate represents the standard one. When the specimens get equilibrated each set reaches the following equilibrium moisture content (EMC): dry specimens 6%, normal specimens 12% and humid specimens 15%.

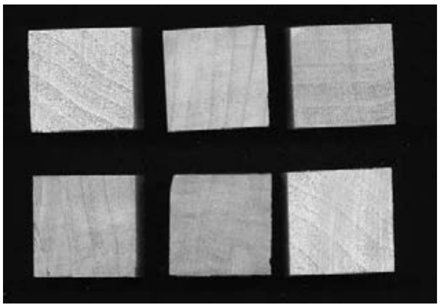
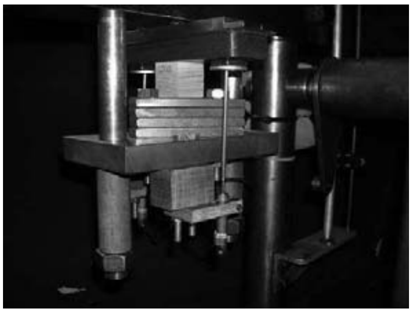
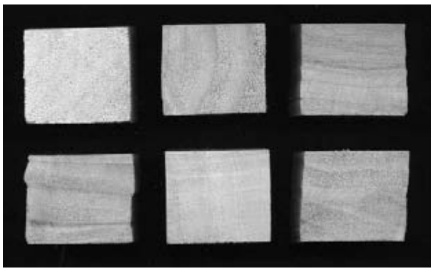


Fig. 1: specimens to be tested.

Tests in tension and compression have been carried out. The specimens have been set between two plates, and a force is applied to realize the compression tests. The compression across the grain do not cause a definite fracture of the material, because as it is well-known wooden cells deform without breaking. Therefore it is necessary to determine a clear strength limit and value, even if it is a calculated instead of a measured one. It has been derived according to the European standard UNI EN 408.

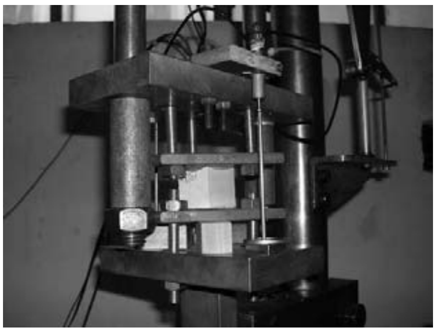


(a)

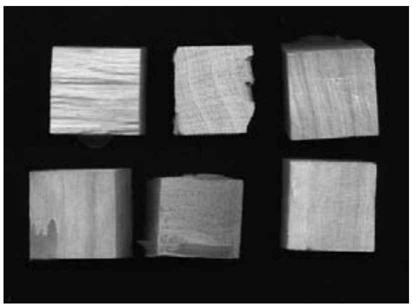


(b)

Fig. 2: compression tests (a), specimens tested in compression (b).The specimens have been glued, using an epoxy resin, on two plates to realize the tension test. The tension tests has been carried out till the fracture of the specimens, so the strength value is measured.



(a)



(b)

Fig. 3: tension tests (a), specimens tested in tension (b)

Both in the tension and compression tests the deformation is measured trough two displacement transducers, one on each side in order to obtain a medium value that could represent the deformative behaviour of the specimen.

3. Results

3.1. Compression tests perpendicular to the grain

The calculated strength values are grouped in an homogeneous way (see fig. 3). They are between 2,50 and 5,50 MPa, 3,96 MPa on the average. No influence of the anatomical directions is evident. Analysing the strength values according to the EMC, we observe that as the moisture content increases, the strength decreases.

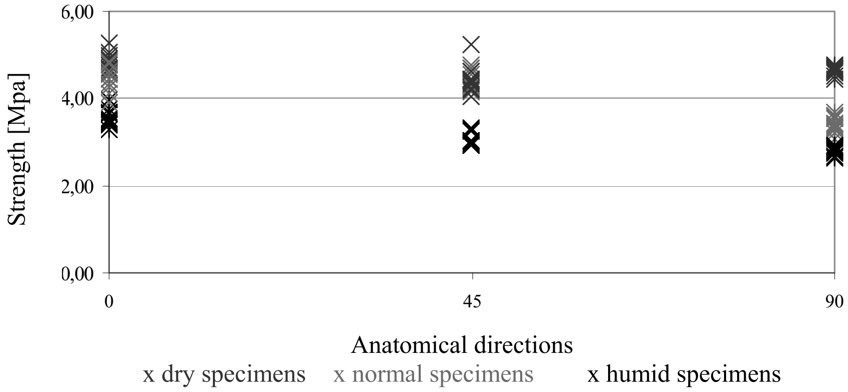


Fig. 3: Strength vs loading direction

The modulus of elasticity (MOE) is the measure of the material stiffness: the bigger the value is, the stiffer the material is (see fig. 4). The calculated values are between 150 and 750 MPa, on the average 328 MPa. As it is evident by the graph (fig. 4), the MOE values are related to the moisture content of the specimens: as the MC increases, the stiffness decreases. Moreover it is greater in radial direction (> 400 MPa for dry specimens) and smaller in T direction (<300 MPa). A further comment is requested for the radial tests. Indeed the MOE values show a greater variability, probably due to influence of the rays. In the radial tests, the rays are parallel to the loading direction, and it leads to a biological non-homogeneity of the specimens, that affects the MOE values. The presence of rays is not significant for the other tests that give more homogeneous results.

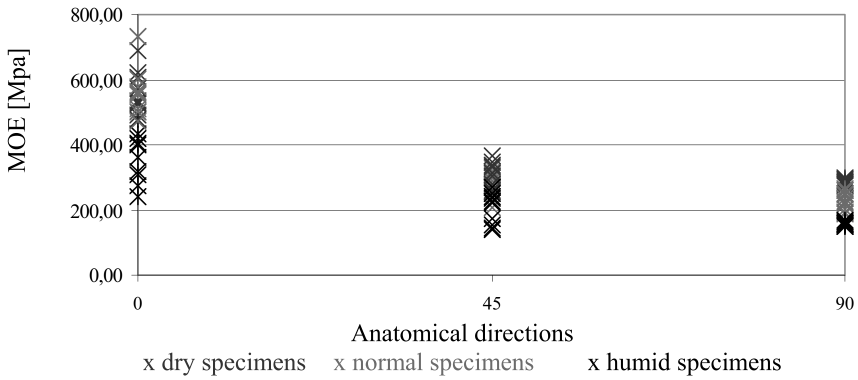


Fig. 4: MOE vs loading direction

3.2. Tension tests perpendicular to the grain

The strength values are measured (see fig. 5), and they are between 2,00 and 6,20 MPa, 3,30 MPa on the average.

As shown for the compression tests (see § 3.1), the biological variability of the specimens is evident for the radial direction. Once again it depends on the direction of the rays compared to the loading direction. Another aspect needs to be discussed: the normal specimens show greater values than the dry and humid ones. Actually the largest values are expected for the drier specimens. This behaviour has been pointed out by many authors [3,4,5], and it could be due to a chemical or physical deterioration of the wood as a consequence of low moisture content (EMC ≤ 6%).

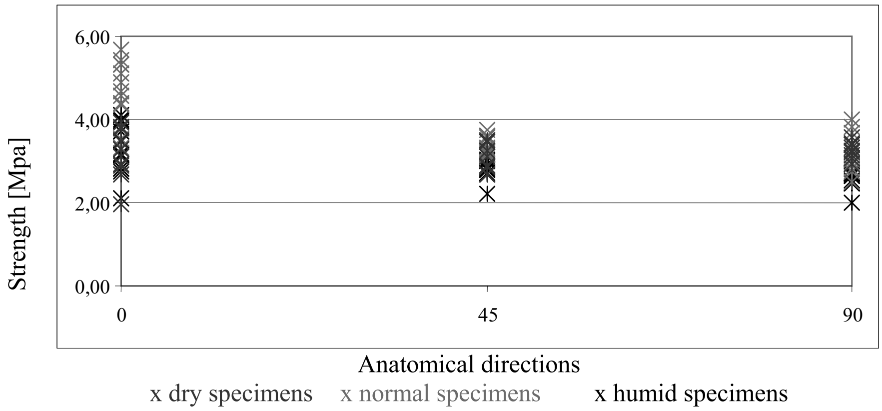


Fig. 5: Tensile strength vs loading direction

The MOE values (fig. 6) are between 150 and 550 MPa, on the average 288 MPa. The values are related to the EMC, exactly as for the compression tests (see § 3.1), as the moisture content increases the stiffness decreases. It is greater in radial direction (> 300 MPa) than in tangential one (< 300 MPa), and the variability along the radial direction is still present.

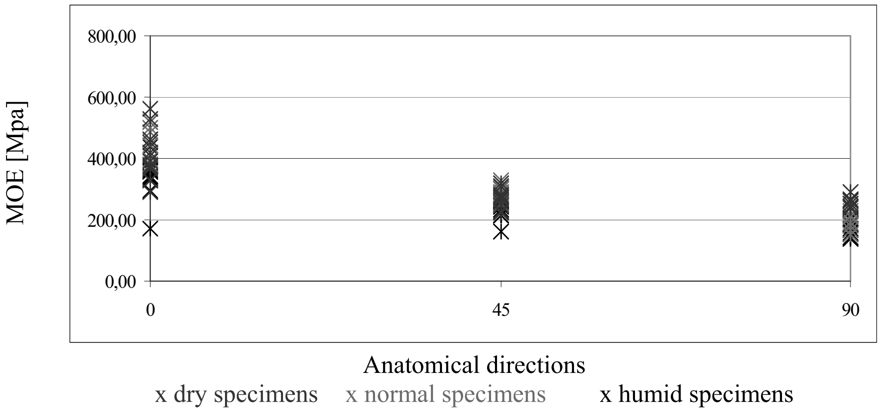


Fig. 6: MOE vs loading direction

4. Conclusions

The tests have shown no evident differences when comparing all the results. The moisture content does not influence significantly the strength and the modulus of elasticity. The same can be said for the anatomical directions. From this homogeneity arises the choice to calculate average values, both for strength and MOE, including the different EMC and loading directions (see Table 1).

Table 1: strength and MOE average values.

	Compression values	Tension values
MOE	328 MPa	288 MPa
σ	3,96 MPa	3,30 MPa

A comment, that could be a future investigation of the wood behaviour, is requested for the strength value of normal specimens in tension tests, that is greater than the others.

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