ISSN : 0974 - 7486 Volume 12 Issue 1

Materials Science

An Indian Journal

Full Paper

MSAIJ, 12(1), 2015 [017-021]

Mechanical behaviours of wood before and after heat-treatment. Part 2: Properties in flexion of beech and of poplar

Moulay Ismail Sabouk[1,4], Patrice Berthod[1,2,4]*, Mathieu Pétrissans[1,3,4]

[1]Faculty of Science and Techniques, (FRANCE)

[2]Laboratoire de Chimie du Solide Minéral (LCSM, UMR 7555), Team "Thermodynamic and Corrosion", (FRANCE)

[3]Laboratoire d'Etudes et de la Recherche sur le Matériau Bois (LERMAB, EA 4370), (FRANCE)

[4]University Henri Poincaré, B.P. 70239, 54506 Vandoeuvre-lès-Nancy, (FRANCE)

E-mail : patrice.berthod@lcsm.uhp-nancy.fr

ABSTRACT

Heat-treatments may be applied to wood to reinforce its resistance against biologic attacks. However this may modify the mechanical properties of this material and such consequences must be better known. In this work the two following wood species are concerned: beech and poplar. In the first part this was the compression properties which were analysed versus heat-treatment. In this second part the work is extended to flexion properties: elasticity modulus and rupture modulus. Bending tests were performed on four samples for each wood species and each state (raw or heat-treated). It appeared here that, contrarily to what was previously observed for compression, applying the considered heat-treatment led rather to a decrease in the mechanical properties revealed by bending tests.

KEYWORDS

Woods;
Heat treatment;
Mechanical behaviour;
Flexion.

INTRODUCTION

Wood is sensitive to biologic aggressions. To improve its resistance a heat-treatment is often applied[1-3]. This effectively enhances the biologic resistance[3] but it also induces changes in other properties: decrease in density and in hygroscopic character[4,5], colour changes and improvement in dimensional stability[2]. Heat-treatment may have some consequences on the mechanical resistance of wood. It was earlier found that the heat treatment may cause a decrease in Young's modulus and rupture modulus[6-9]. But the opposite results can be also found, as observed for beech and poplar[10] during compression tests at ambient temperature.

After having studied, in the first part of this work, the effect of a heat-treatment on the physical and compression properties of beech and poplar, it was here envisaged to investigate the effect of heat-treatment on flexure properties of the same wood species, by performing bending tests.

EXPERIMENTAL DETAILS

Preparation of the wood samples and determination of their densities and the humidity degrees

As for the compression samples tested in the first part of the study[10] the samples for bend test were ma-

Figure 1 : The bending test apparatus with a raw wood sample ready to be tested

chined in planks bought by Prodeo S.A. (Avenches, Switzerland). Preliminary sawed to obtain smaller boards (33 cm × 20 cm × 3 cm) some of them were heat-treated in an electrical furnace (heating up to 230°C, dwell and cooling down to laboratory temperature) under a nitrogen flow coming from a bottle. The other boards were not heat-treated (raw wood) to allow comparisons.

The raw boards as well as the heat-treated ones were sawed and thereafter they were planed in order to obtain the samples. Sixteen samples were thus available for the bending tests:

- Eight samples of beech: four raw samples and four heat-treated samples
- Eight samples of poplar: four raw samples and four heat-treated samples

The dimensions of all of them were: 200 mm × 50 mm × 25 mm.

The methods of determination of the volume mass and the humidity level of the beech and poplar samples in the two states (raw and heat-treated) were already described in the first part of this work[10].

The bending tests

The testing machine which was used for the bending tests was the one previously used for the compression tests[10]: an electro-mechanical MTS ALLIANCE RT/100 testing machine (capacity: 100kN) driven by the TESTWORKS 4 software of MTS. It was equipped with an apparatus allowing three points-flexion test. This one is illustrated with a positioned wood sample in Figure 1.

During the tests the applied force was continuously measured with the 100kN-cell present between the horizontal mobile part and the upper part of the bending test apparatus. The shifting of the upper support (a metallic cylinder) was considered to value the deformation of the sample. It was continuously measured by considering the position of the horizontal mobile part.

The space between the two lower supports was 165 mm. The rate of the movement of the upper contact point was 25 mm / min for all test and the tests were continued until rupture.

RESULTS AND DISCUSSION

The bending tests were performed on all the prepared samples (illustration in Figure 2 in the case of a heat-treated sample), for a time long enough to reach rupture. The compressive strain was recorded in the same time as the increasing force applied. The progressive deformation of the samples in flexion is illustrated in Figure 3 (on one of the heat-treated samples) and some of the obtained {central upper support movement → applied force} are presented in Figure 4 as illustrative examples.

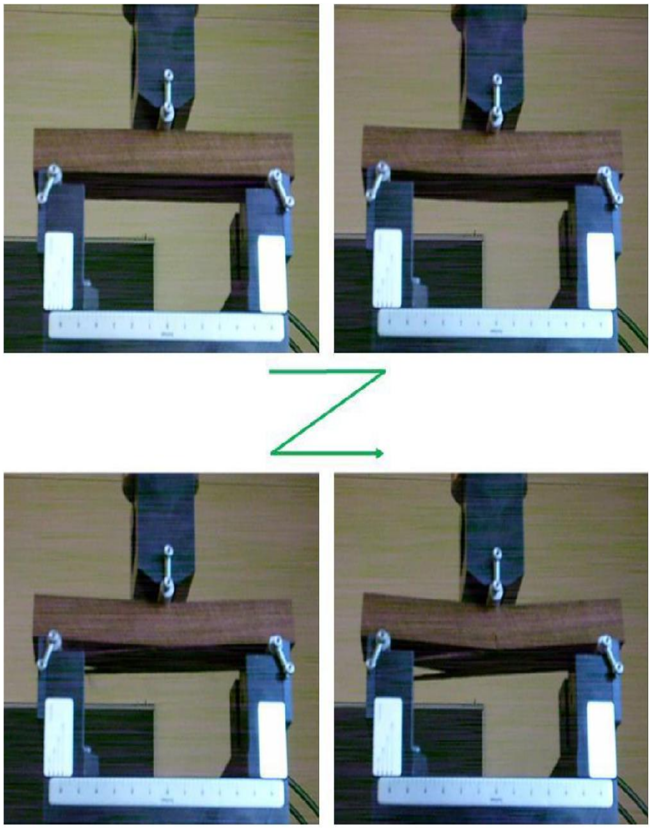

Figure 2 : Successive views of the bending test of one of the wood samples; (here: heat-treated wood)

The results of elasticity modulus and rupture modulus (rupture strength) which were determined on the curves are listed in TABLE 1 for raw and heat-treated beech and in TABLE 2 for raw and heat-treated poplar.

The elasticity modulus was calculated according to equation (Eq. 1) while the rupture modulus was calculated according to equation (Eq. 2).

$$Elasticity\ modulus = \frac{F_e \times {L_{ls}}^3}{4 \times b \times h^3 \times z} \quad (1)$$

$$Rupture\ modulus = \frac{3 \times F_r \times L_{ls}}{2 \times b \times h^2} \quad (2)$$

where; F_e is the value of the applied force when the end of the elastic deformation is reach; F_r is the value of the applied force when the end of the rupture is reach; z is the shifting of the upper support (from its initial position at the test beginning) when the elasticity limit is reached; b is the width of the sample; h is the thickness of the sample; L_{ls} is the space between the two lower supports.

General commentaries

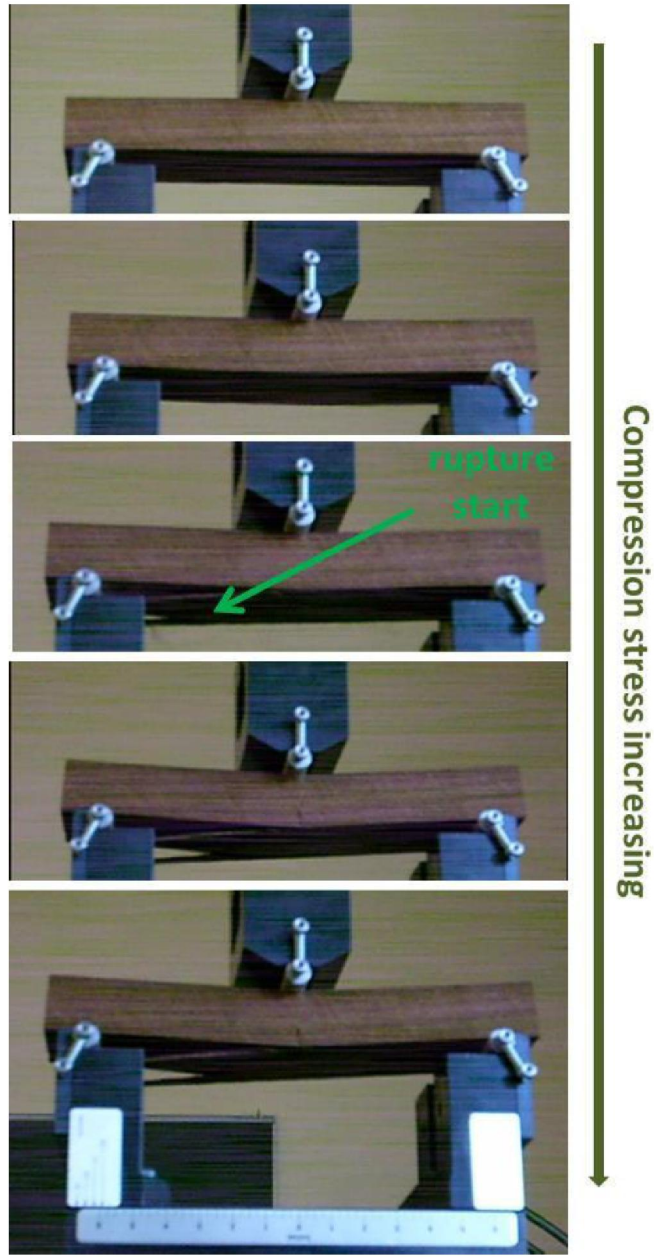

Figure 3 : Progressive deformation of a sample during bending test

By looking at TABLE 1 and TABLE 2 one can see that the elasticity modulus of beech was increased by the heat-treatment while it was more the inverse effect for poplar. Concerning the rupture modulus a significant decrease due to the heat-treatment can be noticed. The latter result is in good agreement with what was observed by Shi et al[7] and by Mburu et al[8].

Thus as previously seen for the compression properties for the same wood species[10], the applied heat treatment modifies the mechanical behavior of

TABLE 1: Flexure properties and physical properties of the beech samples in the two conditions; (raw and heat-treated)

BEECH	Mechanical properties		Physical properties	
	elasticity modulus (GPa)	Rupture modulus (MPa)	Density (kg / m^3)	Humidity (%)
Raw	4.23±0.7	126±16	437	7.3±0.9
Heat-treated	5.88±0.17	106±6	371±17	2.6±0.2

TABLE 2: Flexure properties and physical properties of the poplar samples in the two conditions; (raw and heat-treated)

POPLAR	Mechanical properties		Physical properties	
	elasticity modulus (GPa)	Rupture modulus (MPa)	Density (kg / m^3)	Humidity (%)
Raw	2.29±0.14	8 ±4	437	7.3±0.9
Heat-treated	1.93±0.19	58±6	371±17	2.6±0.2

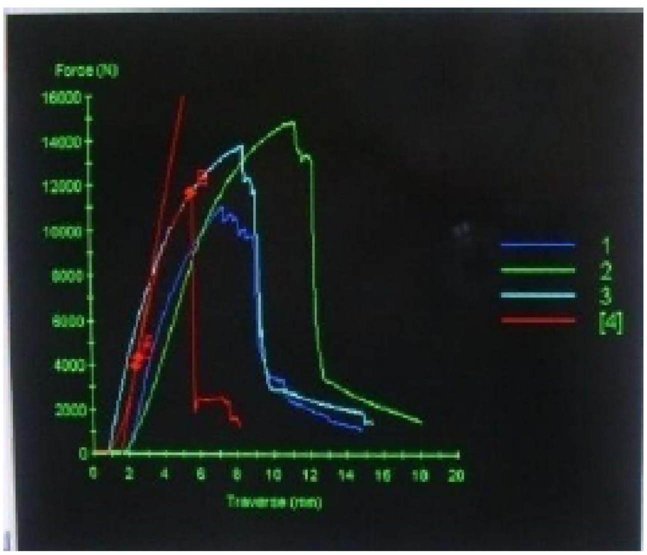

Figure 4 : Some of the bending test curves obtained

beech and poplar when bending-solicited. However this was here not in the same direction since heat-treatment tended more increasing/improving the rigidity and the rupture strength in compression. This shows that the behavior of wood may be rather complex and the heat-treatment (with its consequences on both density and humidity, values reminded in the last columns of TABLE 1 and TABLE 2) has an influence which depends on the solicitation mode.

CONCLUSION

As seen in the first part which dealt with the compression properties[10], and in this second part concerning flexion deformation, the heat treatment which can be applied to wood to strengthen it against biologic aggressions may have significant consequences on the

Figure 5 : Some of the raw and heat-treated beech and poplar samples after bending test

mechanical behavior of this material. The effects are not all clear and the work on these two wood species – beech and poplar – and this type of heat-treatment may be thereafter enriched with, for example, tensile tests and Brinell indentation to extend the study to tensile properties and hardness. The heat-treatment parameters may be also changed to investigate the influence of temperature and duration.

REFERENCES

[1] J.A.Santos; Wood Science and Technology, **34**, 39 **(2000)**.

[2] S.Mouras, P.Girard, P.Rousset, P.Permadi, D.Dirol, G.Labat; Annals of Forest Sciences, **59**, 317 **(2002)**.

[3] D.P.Kamdem, A.Pizzi, A.Jermannaud; Holz as Rohund Werstoff, **60**, 1 **(2002)**.

[4] B.F.Tjeerdsma, M.Boonstra, H.Militz; Internaational Research Group on Wood Preservation, Document no IRG/WP 98-40124.

[5] T.Nakano, J.Miyazaki; Holzforschung, **57(3)**, 289 **(2003)**.

[6] O.Unsal, N.Ayrilmis; Journal of Wood Sciences, **51**, 405 **(2005)**.

[7] J.Shi, D.Kocaefe, J.Zhang; Holz als Roh und Werkstoff, **65**, 255 **(2007)**.

[8] F.Mburu, S.Dumarçay, J.F.Bocquet, M.Pétrissans, P.Girardin; Polymer Degradation and Stability, **93**, 401 **(2007)**.

[9] S.Korkut; Building and Environment, **43**, 422 **(2008)**.

[10] M.I.Sabouk, M.Pétrissans, P.Berthod; Materials Science: An Indian Journal, submitted.