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Mechanical characterization of European species: *Picea-Alba mill* and Douglas-fir

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ABSTRACT: the behavior of timber notched beams undergoing mechanical (instantaneous and long term bearing loads...) and environmental (humidity, temperature...) loading are the principal aim of French CLIMBOIS JCJC ANR project. *Picea-Alba mill* and *Douglas-fir* are the two European local species tested in this study. The work presented here is the first part of the wider study; the objective of this part is mainly axed on the determination of mechanical characteristics of the specimens in two dimensions, usual solid wood beams tested in simple or double notched configuration in bending. The elastic moduli of tested beams have studied according to normative expressions given by the beam theory. Three normative relationships have been presented here according to the beam theory and regulatory requirements of Eurocode 5. The mechanical characteristics (modulus of elasticity) obtained here is an accordance with literature for the both species and shows that the two species have modulus of elasticity similar according to the experimental tests done here.

Keywords: *European species, Mechanical characterization, Experimental method, Bending test*

1 INTRODUCTION

The Massif Central's *Picea-Alba mill* (Sapin Blanc) covers 40% of the Auvergne forest and is the strategic resource for the first and the second transformation in wood's industry in France. Moreover, Douglas is one of the most used species in France and especially in the Limousin and Auvergne (Moutou Pitti et al. 2015). Utilization of these species in external conditions more or less protected constitute an important outlet (Toussaint et al. 2016). However, in presence of climatic variations (Humidity, temperature, wind,...), added to the long terms loads, the mechanical behaviour of these structures is found highly modified disturbing their implementation and shortening their life in service (Bastidas-

Arteaga et al. 2015). In this specific case, it appears necessary to study these species submitted to extrem loadings conditions.

One of the objectives of the ANR JCJC CLIMBOIS project (ANR 2013; Moutou Pitti et al. 2014) is to study the mechanical behaviour of cracked wood beams of *Picea-Alba mill* and *Douglas-fir* under the combined action of the climatic variation (moisture and temperature variations,...), long terms loads (creep, mechanosorptive effects,...) and the initial defects (cracks, knots, growth rings orientation,...). The tests presented here, are the preliminaries done on 12 beams of *Picea-Alba mill* and 13 beams of *Douglas-fir*. The real dimensions of these

beams have been obtained according to a finite element model coupled with experimental tests (Angelier et al. 2015; 2016; Diakhate et al. 2016; Moutou Pitti et al. 2016). According to the beam's theory their modulus of elasticity are calculated from their characteristics curves. These modulus are obtained via normative relationships from the theory of beams and regulatory requirements of Eurocode 5 (Manfoumbi 2012; De Bilbao 2010; Eurocode 2004; FCBA 2015). Three methods of the determination of these modulus of elasticity under flexural four point are presented. The equation for the determination of the global moduli of elasticity (with shear modulus), the equation for the determination of the global modulus (without shear modulus) and the equation of the determination of the local modulus of elasticity. The results of these calculations obtained here is in accordance with the literature.

In the first part of this work a description of material and methods are presented. Hence, the presentation of the protocol and the experimental device are described. Also, the types of specimens of beams of these both species are presented; the masses of all beams, their actual dimensions, and their moisture content are also posted. In the second part, some flexural four points tests are presented to determine the flexural modulus of elasticity of each beam tested. Then, the results from the typical curve obtained after the performed tests on the specimens of beams of the Picea-Alba mill and Douglas-fir and the discussion are presented.

2 MATERIALS AND METHOD

2.1 Description of materials and methods

The experimental campaign of CLIMBOIS project (ANR 2013) is divided in three levels. The level one with the flexural static tests and long terms on double notch beams and on simple notch beams specimens. The level two the flexural tests on specimens of small dimensions, and finally cracking tests on specimens MMCG (Mixed Mode Crack Growth) in single or combined mode.

In this work, the level one is presented, it concerns the flexural static tests on double notch beams. Figure 1 shows the model of specimen tested during the CLIMBOIS project, this model is one of all model which will be use during the project, for the tests in the variable climatic conditions and in the internal conditions, this figure shows also the position where the captors of position (LVDT sensors) and the forces sensors will be set. In our preliminary experimentation, the specimens tested is presented in figure 2 with all experimental devices use for this campaign.

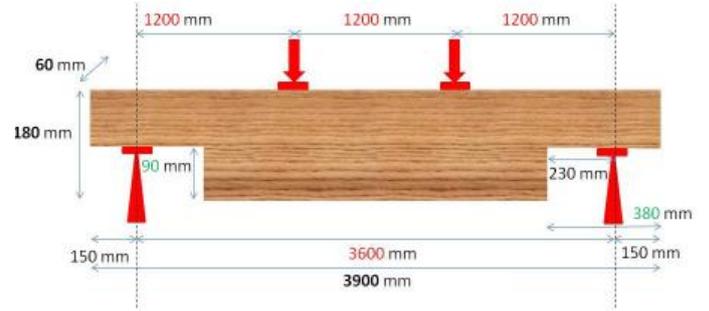


Figure 1. Geometrical characterization of selected notched beams tested in flexural point in CLIMBOIS project.

This part of mechanic tests is accompanied by physical measurements on the test body. These physical measures are driven by analog measurements on all the tests body. The objective of this campaign is to obtain additional information to reflect the observation conducted on the different tests beams. Table 1 shows different physics characterization of beams of Picea-Alba mill tested here.

Table 1. Characterization of beams of Sapin Blanc tested

	Length L (mm)	Width h (mm)	Thicness b (mm)	Humidity H (%)	Density
S1	3999	179	60.83	10.1	0.406
S2	4004	179	58.86	9.9	0.398
S3	4002	178	60.01	13.3	0.396
S4	3999	179	59.7	10.0	0.410
S5	3996	178	59.86	10.5	0.450
S6	4003	178	60.44	11.1	0.423
S7	4004	179	59.28	12.0	0.417
S8	4000	180	60.28	10.5	0.410
S9	4002	178	59.86	12.0	0.386
S10	4002	178	60.08	11.2	0.378
S11	4002	179	59.96	11.4	0.427
S12	4004	179	60.04	10.2	0.386
Average	4001.41	178.66	59.93	11.02	0.407
Standard deviation	1.94	0.55	0.35	0.81	0.02

This precedent table shows that there are not significant differences between moisture content (of all beams of Picea-Alba mill tested here 11.02 ± 0.82 % (average \pm standard deviation)).

The following table shows also the physic parameters of all beams of Douglas-Fir tested, the same finding can be done about the moisture content (11.11 ± 0.80 %) of beams studied here.

Table 2. Characterization physic of beams of Douglas test-

	Length L (mm)	Width h (mm)	Thickness b (mm)	Humidity H(%)	Density
D1	4032	178	59.66	10.3	0.405
D2	4027	178	59.38	10.0	0.391
D3	4054	174	59.12	12.8	0.517
D4	4049	176	58.5	10.8	0.428
D5	4054	174	59.31	11.2	0.466
D6	4056	175	59.01	11.5	0.447
D7	4057	174	58.9	11.8	0.471
D8	4032	174	58.59	10.5	0.431
D9	4056	176	59.37	12.4	0.486
D10	4050	174	58.93	11.7	0.497
D11	4053	178	58.99	10.7	0.415
D12	6107	174	59.34	9.6	0.419
D13	6105	178	59.64	9.6	0.393
Average	4364	17.62	59.13	11.11	0.445
Standard deviation	536	1.58	0.29	0.80	0,03

2.2 Experimental protocol

Experimental devices are illustrated in figure 2. The campaign of mechanical characterization of beams of Picea-Alba mill and Douglas fir concerned the determination of modulus of elasticity of these specimens in flexural four point (Figure 2).

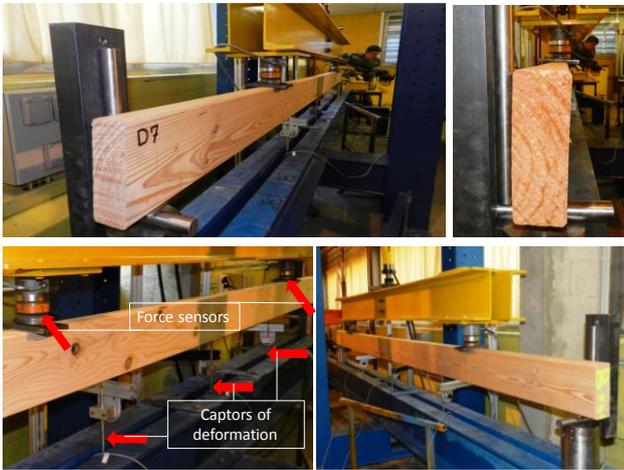


Figure 2. Experimental devices tests

The experimental device is composed of one electro-mechanical machine, a beam specimen of wood tested, a centralizer and a computer in order to record different data. The beams are loading and unloading in flexural four point till a maximal force equal at 5 kN (Figure 2). This force has taken from an elastic area to avoid the first crack of specimens and to rest in our objectives, knowing that the Douglas fir and Picea-Alba mill are respectively the maximum stresses of static break equal to 91 MPa and 80 MPa. On one test, the informations are send and

collected by two forces captors and three deformations captors.

3 RESULTS AND DISCUSSIONS

3.1 Results of experimental campaign

In this part the results of tests done on the beams of two species are presented. The curve of load path of each specimen is composed of one path of loading and one path of unloading (Figure 3).

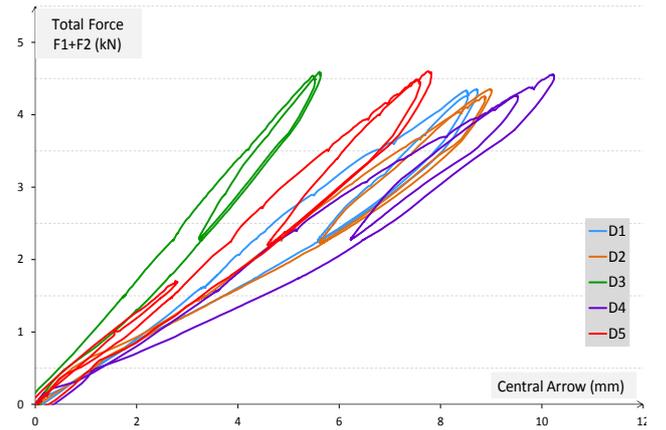


Figure 3. Curve of characterization of some beams of Douglas tested

The precedent figure shows the evolution of the curve of total Force applied on specimen versus the evolution of the central arrow of collected during the test. In the following figure the typical curve of evolution of total force versus the evolution of delta arrow of specimens tested is shown (figure 4).

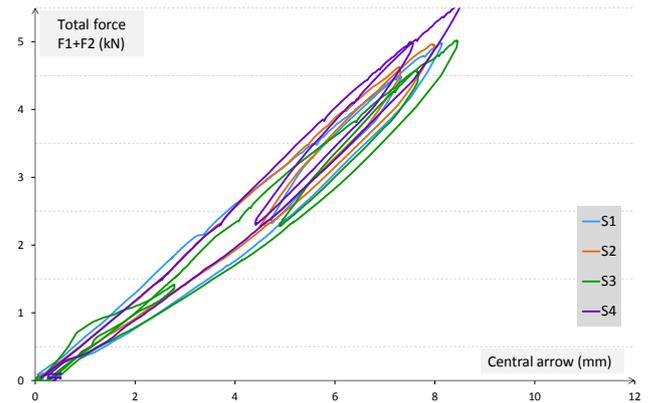


Figure 4. Evolution of total force applied vs delta arrow of some Picea Alba Mil' beams tested.

Delta arrow is given by the following equation:

$$\Delta u = u_2 - [(u_1 - u_3)/2] \quad (1)$$

Where, u_2 represent the central arrow, u_1 and u_3 represent respectively the arrow recorded (as u_3)

continuously by the LVDT sensors set at position 2, 1 and 3.

The figure 5 shows the evolution of total force applied on some beams of Picea-Alba mil versus the evolution of central arrow of these beams.

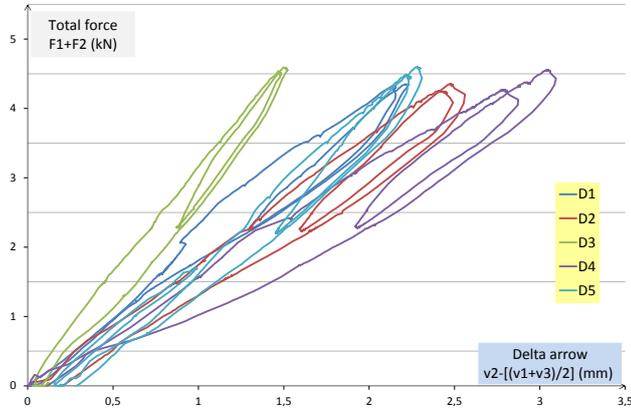


Figure 5. Typical curves of some beams of *Douglas fir* tested.

The following figure shows the evolution of total force applied versus the delta arrow record during the test of some beams of *Picea Alba Mil* tested.

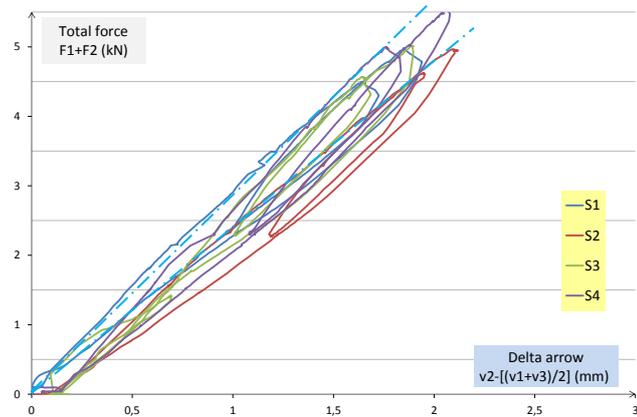


Figure 6. Evolution of total force applied vs delta arrow recorded.

About these typical precedent evolutions of curve we can see that for the two cases (evolution of total force with central arrow or with delta arrow) the curves have the same behavior. The load follow the same path for the same specimen in the two case.

Table 3 shows the values of different modulus of elasticity taken from the characteristic curves of beams of Douglas tested. These elasticity modulus are deduced from the equation (2) and (3), arising from the beam theory (Manfoumbi et al. 2012).

$$E_{0,g}(1) = \frac{\Delta F}{\Delta f} (L - a)(2L^2 + 2La - a^2) \quad (2)$$

Where, $\Delta F/\Delta f$ represent the slope of the curve of total force versus central arrow. L is the length between the two simple supports of the experimental devices (imparts Figure 1), a the distance between the two loads. $E_{0,g}(1)$ is the global elasticity modulus, this modulus does not take into account the effects of shear modulus. The figure 7 shows the specific dimensions of beams.

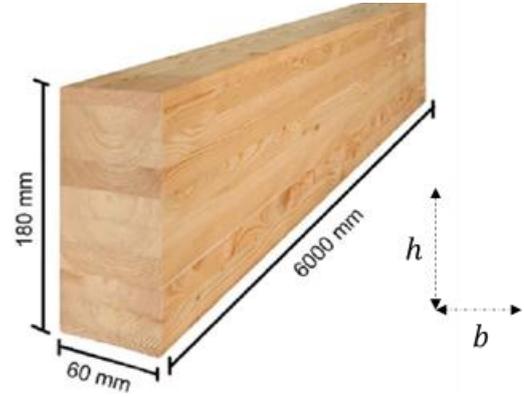


Figure 7. Dimension of specimen

Table 3. Values of elasticity's modulus of *Douglas'* beams calculated by equations (2), (3) and (4).

	$E_{0,g}(1)$ GPa	$E_{0,g}(2)$ GPa	$E_{0,l}$ GPa	$\Delta F/\Delta f$ (Nmm^{-1})	$\Delta F/\Delta u$ (Nmm^{-1})
D1	14.19	14.85	14.81	500	2000
D2	14.15	14.81	13.70	498.5	1850
D3	22.24	24.04	24.44	783.3	3300
D4	12.60	13.13	12.59	443.75	1700
D5	15.97	16.89	14.81	562.5	2000
D6	18.80	20.12	17.41	662.5	2350
D7	20.94	22.51	22.22	737.5	3000
D8	20.94	22.51	19.44	737.5	2625
D9	22.71	24.45	25.92	800	3500
D10	18.10	19.30	20.25	637.5	2735
D11	12.06	12.55	12.83	425	1733
D12	15.08	15.85	15.44	531.25	2085
D13	16.68	17.62	14.32	587.5	1933

The equation (3) gives the global modulus of elasticity ($E_{0,g}(2)$). This moduli of elasticity take into account the effects of shear modulus.

$$E_{0,g}(2) = \frac{3aL^2 - 4a^3}{2bh^3(2\frac{\Delta f}{\Delta F} - \frac{6a}{5Gb})} \quad (3)$$

As for the equation (2) the parameters a , L , and $\Delta F/\Delta f$ are the same, but h represent the height of beam tested and b is thickness as presented in figure 7. Table 4 shows the different values of modulus of elasticity take from the characteristic curves of Sapin Blanc beams tested.

The equation (4) gives the local modulus of elasticity ($E_{0,l}$). Its value is calculated between the two loads.

$$E_{0,l} = \frac{\Delta F}{\Delta u} \frac{a^3 \times 12}{bh^3 \times 8} \quad (4)$$

For this campaign of experimentation we have; $h = 180 \text{ mm}$, $b = 60 \text{ mm}$, $a = 1200 \text{ mm}$, $L = 3600 \text{ mm}$, and $G = 750 \text{ Nmm}^{-2}$ for Douglas Fir, $G = 560 \text{ Nmm}^{-2}$ for Picea Alba Mil.

Table 4. Values of elasticity's modulus of *Picea Alba Mil*' beams calculated by equations (2), (3) and (4).

	$E_{0,g}(1)$ GPa	$E_{0,g}(2)$ GPa	$E_{0,l}$ GPa	$\Delta F/\Delta f$ (Nmm^{-1})	$\Delta F/\Delta u$ (Nmm^{-1})
S1	17.74	19.17	21.85	625	2950
S2	18.45	20.12	21.78	650	2941
S3	16.97	18.31	19.62	597.75	2650
S4	18.59	20.12	19.66	655	2655
S5	17.04	18.31	19.44	600	2625
S6	22.29	24.67	20	785	2700
S7	19.30	21.01	18.88	680	2550
S8	16.61	17.84	17.40	585	2350
S9	15.08	16.12	14.31	531.25	1933
S10	15.08	16.12	15.67	531.25	2116.6
S11	14.90	15.94	15.67	525	2116
S12	15.33	16.40	16.29	540	2200

The comparison done between the modulus of elasticity calculated on each case for each beam of each type of the specimens studied here, shows that: For each species studied and for the three modulus calculated, the global modulus of elasticity ($E_{0,g}(2)$)

is the parameter which are the most value (in the two case), 18.36 ± 3.51 (average \pm standard deviation) for *Douglas Fir* and 18.67 ± 1.95 for *Picea Alba Mil*.

4 CONCLUSION

The experimental campaign of ANR CLIMBOIS project is vast, going from MMGC specimens for flexural tests on notched beams in structural sizes through specimens of different sizes. These tests are available in static tests and creep tests. The tests reported here are only those flexural type and the only results shown here are inherent to the characterization of two batches of materials constituting the base used materials. The focus is put on the complementary logic of these tests, their feasibility and their interest to supply the parameters of the theoretical and numerical models.

The physical and mechanical measurement done on two beams batches showed good homogeneity of the specimens in terms of density and humidity. The modulus of elasticity of each beam calculated according to three equations arising of beam theory of each species are close (table 3 and 4). This values are in accordance with those existing in literature. For this first experimental campaign an accent was put in the mechanical characteristic of these two species the second campaign is in progress. In the coming works, experimental creep tests will be performed in external conditions. Also, cubic specimens will be debited in tested wood in order to determine local elastic moduli following the dimensions of wood according a new identification technique (Nouali et al. 2014).

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