IMPACTS OF CLIMATIC CHANGES AND CREEP LOADINGS ON THE CRACKED DOUGLAS (*PSEUDOTSUGA MENZIESII*) TIMBER BEAM IN OUTDOOR CONDITIONS

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ABSTRACT

The Douglas is one of the most used species in France, especially in the Auvergne-Rhone Alpes Regions. This species found in unprotected outdoor environment is a major resource for the wood industry. However, variations in moisture content (*MC*), relative humidity (*HR*) and temperature (*T*) coupled with creep, can weaken its mechanical resistance. The main objective of this work is to study the mechanical behaviour of cracked wood beams under climate changes (*T, HR* and *MC*), the long-term loadings and the defects of wood (cracks, knots, orientation of annual rings etc). In this study, the evolutions of the crack length and the crack opening are presented. The results show the influence of climatic changes on the sustainability of timber structures of Douglas beams.
Keywords: climatic changes, crack propagations, douglas.

1 INTRODUCTION

The forest is an undisputed potential for the global ecosystem and is a real economic asset for the Auvergne-Rhône Alpe Regions in particular, and for France in general; this is a crucial issue for the planet. In the Massif Central, two species attract professionals, the White Fir (*Abies Alba* Mill) And the Douglas (*Pseudotsuga menziesii*). White Fir covers approximately 20% of the vast Auvergne region and is an indispensable resource in the field of timber structures. Douglas fir is one of the most widely used species in France, particularly in Limousin (11%) and Auvergne (14%). However, in the presence of moisture and temperature variations in addition to long-term loads, the mechanical behaviour of these structures is greatly modified, which can complicate or limit their use and their service life [1, 2].

Today, variations in climatic conditions combined with the initial defects in wood play a very important role in the lifetime of wooden structures [1]. One of the objectives of this study is to set up an experimental characterization of the propagation of crack submitted at different climatic changes. This will allow to predict the behaviour of wooden structures under the effect of climatic variations, taking into account the initial defects of the wood knots, cracks, rings, etc.), climatic parameters (*HR, T* and *MC*) and creep.

This work consists of three parts. In the first part of this study, the experimental devices and the methods used are presented; the second part discusses the results obtained during the test; and the third part explains the conclusion and the perspectives for the next campaign.

2 MATERIALS AND METHODS

In this work, the test campaign is carried out on the wooden beams of *Pseudotsuga Menziesii* (Fig. 1a). In advance, the beams are tested by bending four points to a maximum force lower than the elastic limit [3]. This experimental phase is aimed at obtaining the mechanical

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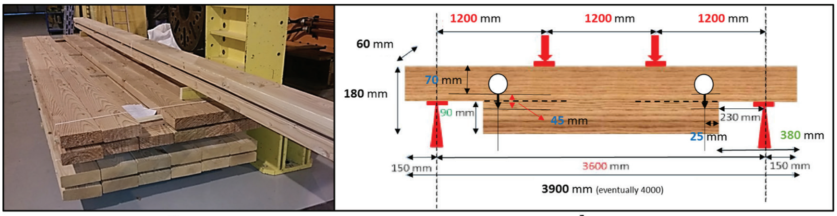

a b

Figure 1: (a) Beams of *Pseudotsuga Menziesii* and *Abies Alba Mil.* (b) Geometrical configuration of beam tested during the creep test.

Figure 2: (a) comparator; (b) Outdoor creep test; (c) Upper supports (cross-beam); (d) lower supports (beam-beam); e) LVDT sensors.

characteristics (modulus of elasticity) of the beams, which will help to classify them from the most rigid to the least rigid [3]. Then, a criterion of priority selection of the beams to be loaded is made. Although the objective is to cover as many climatic periods as possible, in order to avoid having too long a load period, the duration of the project is limited. The beams chosen for the outdoor tests are then sized and prepared (Fig. 1b).

This method consists of placing the comparators at the notches of each beam (Fig. 2a) to follow the progression of crack opening and a graduated line with 1 cm increment to follow the length propagation of the crack (Fig. 1b). After the preparation of the beam, the second step of the loading protocol consists in setting up the experimental system (Fig. 2).

Then, in accordance with the measuring equipment previously presented, a daily follow-up of the evolution of the degradation parameters (opening of the crack, length of the crack tip) of the beams is carried out. The results shown here are of two beams of Pseudotsuga Menziesii loaded in external climatic conditions.

3 RESULTS

The results presented in this work concern two beams of *Pseudotsuga Menziesii* (*PM*) called D9 and D6. These beams have been loaded during the period from June 2016 to January 2017 (Fig. 3). Fig. 3 shows the evolution of the climatic parameters (*T, HR* and *MC*) during the testing period. We can observe a correlation between the *HR* of the environment and the MC of the telltale beam. This correlation is explained by the fact that, an increase of *T* results in a decrease of *HR* and *MC*, and a decrease of *T* results in an increase of *HR* and *MC*. According to these observations, all along this work, *T* as the adjustment variable has been considered

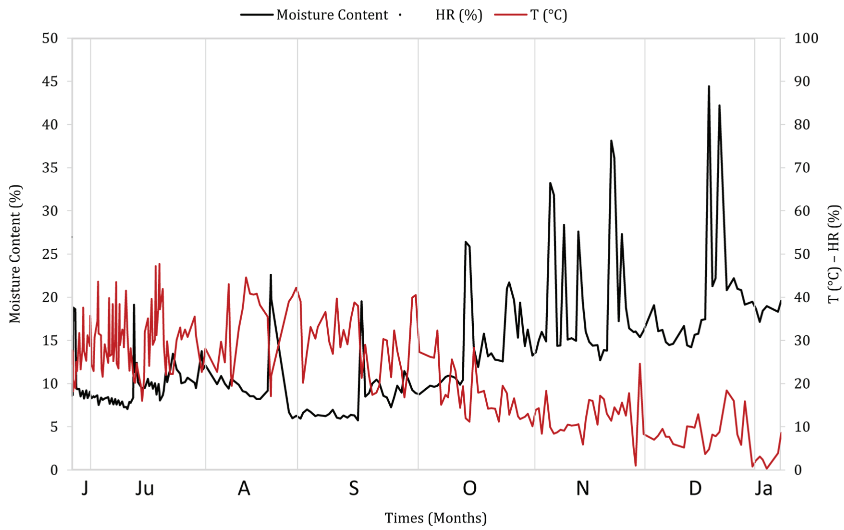

Figure 3: Evolution of the climatic parameters (*T*, *HR* and *MC*) during the period of test (From June 2016 to January 2017).

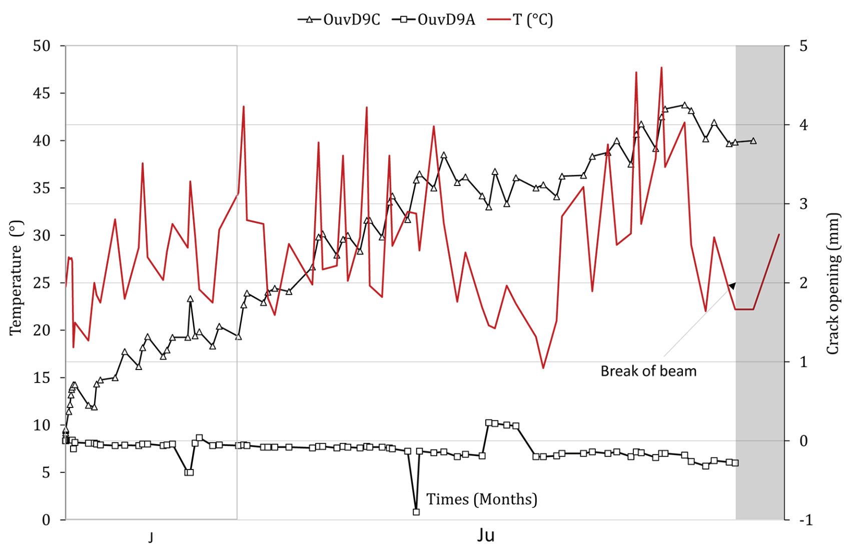

Figure 4: Propagation of crack opening of beam D9 until its break.

for the rest of the climatic parameters (*HR* and *MC*) that have been taken into account here. The impact of its variation on *PM* beams will also be taken into account to understand the impact of the other parameters (*HR* and *T*).

3.1 Effects of the variation of temperature on the crack opening

Figs 4 and 5 show the respective relationships between crack openings of D9 and D6 in the time with temperature. There is for each curve (Figs 4 and 5) an impact of *T* on the

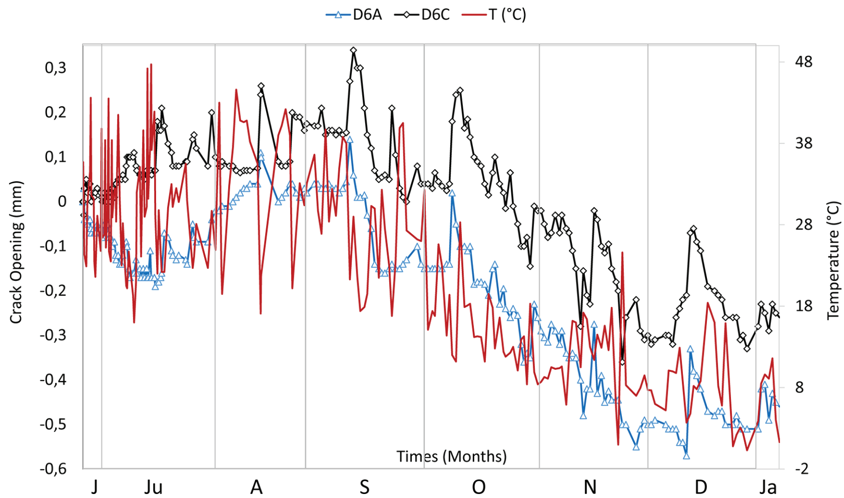

Figure 5: Propagation of crack opening of beam D6.

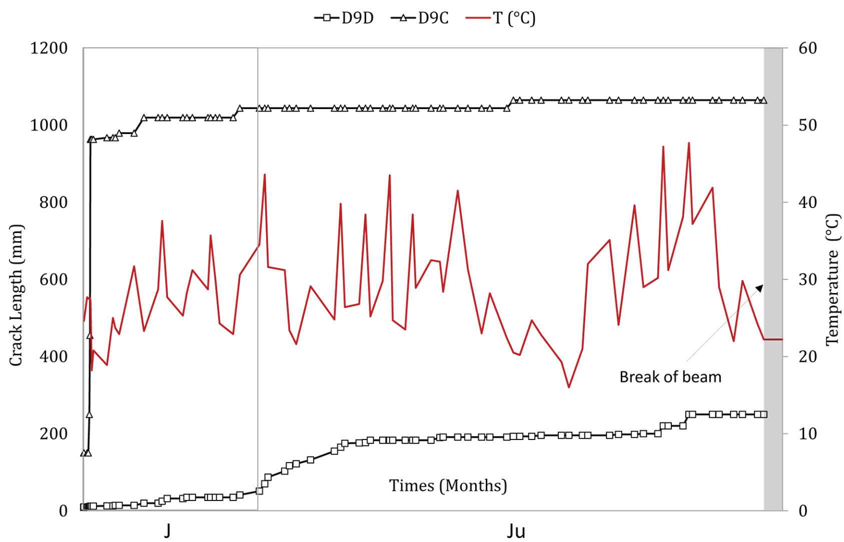

Figure 6: Propagation of crack lengths of beam D9 until its break.

propagation of crack opening. Indeed, according to these curves when *T* decreases (*HR* and *MC* increase) the crack opening increases and when *T* increases (*HR* and *MC* decrease) the crack opening decreases. This phenomenon can be explained by the hygroscopic nature of the wood material that takes on humidity when *T* decreases (*HR* and *MC* increase) and losses humidity when *T* increases (*HR* and *MC* decrease).

3.2 Effects of the variation of temperature on the crack length

Fig. 6 shows the relationship, in the times, between the evolutions of crack length appeared during the setting up of experimental devices with *T* (HR and *MC*). For the period from June

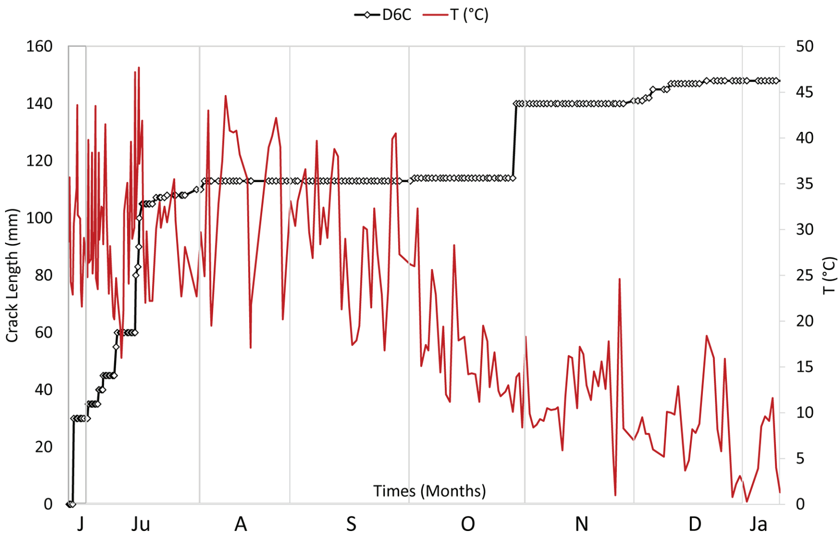

Figure 7: Propagation of crack length of beam D6.

(J) to August (A), there is a great propagation of crack length (Fig. 7). In most cases, the crack length increases with increase of *T* (The decrease of *HR* and *MC*). According to these curves (Figs 6 and 7) there is a definite impact of *T* (*HR* and *MC*) in the evolution of crack length and therefore in the lifetime of the structures.

4 CONCLUSION

The purpose of this work was to study the effects of climatic changes (*T, HR* and *MC*) on the propagation of the crack and the lifetimes of timber structures of *Pseudotsuga Menziesii*. The previous observations made on the results obtained, show that there is considerable impact of climatic parameters (*T, HR* and *MC*) on the lifetime of the beams of the *PM* studied. According to these observations, there is an acceleration in the degradation of wood in the driest period (high temperature, low relative humidity and low moisture content of wood). This work is concerned with the experimental characterization of the propagation of crack versus climatic parameters. For the next campaign, particular attention will be given to take into account the influence of climatic variations and creep coupled with wood defects. The main objective of these experimental campaigns is to propose a numerical viscoelastic model on finite element software, taking into account the different parameters previously mentioned.

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