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► **To cite this version:**

Maximin Varnier, Nicolas Sauvat, Cédric Montero, Frédéric Dubois, Joseph Gril. Long-term mechanical behavior of hardwood species in outdoor conditions. 11th International Conference on Mechanics of Time-Dependent Materials (MTDM 2018), Sep 2018, Milan, Italy. hal-01939197

HAL Id: hal-01939197

<https://hal.science/hal-01939197>

Submitted on 29 Nov 2018

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Long-term mechanical behavior of hardwood species in outdoor conditions

VARNIER Maximin¹, SAUVAT Nicolas^{1*}, MONTERO Cédric², DUBOIS Frédéric¹, GRIL Joseph³

¹ GEMH, Univ. Limoges, EA 3178, F-19300 Egletons

² LMGC, Univ. Montpellier, CNRS, F-34090 Montpellier

³Institut Pascal, CNRS, Univ. Clermont-Auvergne, F-63000 Clermont-Ferrand

*nicolas.sauvat@unilim.fr

Keywords : Creep, French hardwood, Mechanosorption, Viscoelasticity

Introduction

Timber structures in outdoor conditions are simultaneously subjected to mechanical loading and thermo-hydric variations. Moreover, effect of time induces creep. Thus, wood can be considered as a viscoelastic material depending on moisture content, with shrinkage-swelling effects. In addition, when subjected to humidity variation, deformation may persist during drying phase, as a hygro-lock effect [1], [2]. Eurocode 5 [9] takes into account creep phenomena for softwood through a k_{def} coefficient, as a ratio between instantaneous deformation and delayed deformation according to three service classes. We propose to investigate if molecular composition and microstructure of hardwoods, different from softwoods, induce differences in mechanical behavior. For this purpose, creep tests are carried out on oak, beech and poplar in three different environments. These data will be used to match a finite element rheological model considering the physical phenomena involved.

Objectives and Methodology

Long-term deformation U_{LT} is often the dimensioning criterium of a bending beam (Serviceability Limit State). However, only the instantaneous response U_{inst} , i.e., at the moment of mechanical loading Q of the structural element is known. The delayed behavior of a softwood is described in Eurocode 5 through k_{def} coefficient, according to following equation:

$$U_{LT} = U_{inst} * (1 + k_{def}) \quad (1)$$

The three service classes retained in the standard, represent indoor, intermediate and outdoor environmental conditions, with three k_{def} values for softwood: 0.6; 0.8 and 2, respectively. k_{def} combines several physical phenomena in a convenient way. But the hygroscopic, inhomogeneous, orthotropic nature of its biopolymer composition makes the study of wood mechanical behavior very complex. Mechanical properties also depend on temperature as well as moisture content [1, 3]. A wooden beam subjected to a deformation coupled with water variation expresses shrinkage or swelling, viscoelasticity and mechanosorption. This last phenomenon is still poorly understood; it could be assigned to chemical reactions between bound water and cell-wall polymers [1], and comparable to the behavior of shape memory materials, activated by moisture content [4]. The model presented is based on thermodynamics principles, with a generalized Kelvin Voigt model [5], [6]. The different phenomena can be separated in the model proposed by Dubois and Husson [7, 8], and extended to 3D .

The experimental device for this project consists in a simple and robust 4-point bending apparatus. It has been designed for outdoors service class 3 at Egletons (alt 600 m, mid-mountain climate) and Montpellier (alt 27 m, Mediterranean climate) and unheated indoors service class 1-2 in Egletons.

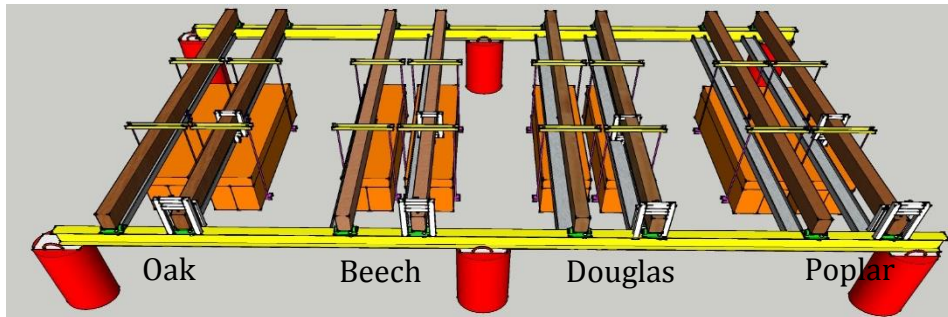


Fig 1: Creep device of service class 1

Beech and poplar were not used in service class 3. Beams are 3 m long, 150 mm high and 75 mm width. After a visual classification according to standard NF B 52-001, beams are individually charged by concrete weights. Their mass is determined according to a deflection ratio.

Results and analysis

Height variations are measured at different points, but in this paper only midspan deflection is presented. Evolution of k_{def} for both Egletons environments is shown in Fig 2

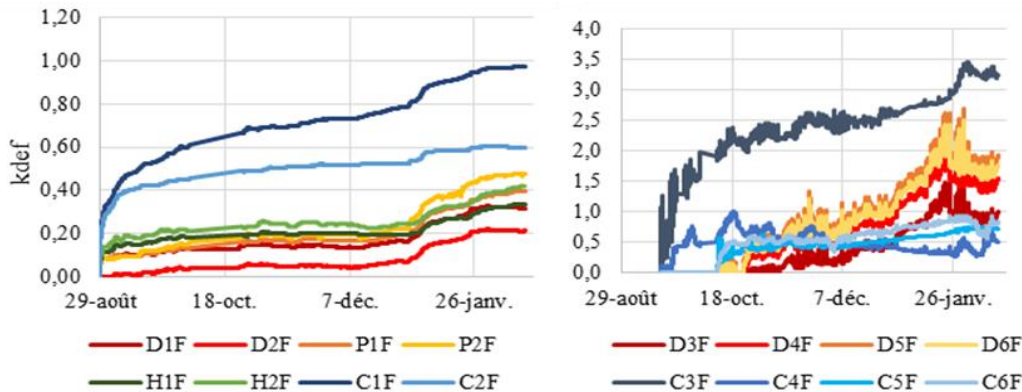


Fig 2 : Evolution of k_{def} for service class 1 (left) and 3 (right) in Egletons. Dxx: Douglas; Cxx: Oak, Hxx : Beech, Pxx : Poplar

Tests began in August and September 2017. Oak appears to have a strong moisture response, unlike other hardwoods and Douglas. Eventually, these results will match modeled results to identify mechanical properties of hardwood species.

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