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Adaptation of Eurocode 5 standard to French hardwoods - Proposal of new hygroscopic equilibrium charts

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Introduction

As a hygroscopic material, wood behavior is dependent on its surrounding climatic conditions. To describe moisture content evolutions in timber structure elements is essential to predict phenomena related to drying process, mechanical behavior, cracks, and also risk of fungal attacks. Several studies have been carried out to highlight the influence of humidity and temperature on equilibrium moisture content of wood [1]–[4]. Other studies have been focused on the influence of temperature on hygroscopic equilibrium [5], [6]. But, these results were mostly obtained on softwoods, and especially for drying applications. Thus, only one equilibrium hygroscopic chart is proposed in National Annexes of Eurocode5. In this work, the specificity of species, either softwood or hardwood, is considered to adapt equilibrium charts to more realistic conditions including outdoor conditions. An analysis of sorption hysteresis is presented leading to the distinction between hardwoods and softwoods. Temperature influence is developed for every sorption property. New specific and more accurate interactive charts are finally proposed in this paper.

Objectives and Methodology

Hygroscopic equilibrium as a function of relative humidity for a given temperature is represented by sorption isotherms. In the literature, several explanations for determining the equilibrium water content for given temperature and humidity can be found either phenomenological [3,7] or based on thermodynamics [4]. Many isotherms of sorption are proposed for wood species, as for other hygroscopic materials. Wood is a hygroscopic material characterized by a small hysteresis compared to other biological species [8] or clays. The fiber saturation point, estimated from the volume shrinkage, can vary from 22% to 34% [9]. In this study, we propose to simplify the different isotherms of wood species from the bibliography to propose only two specific curves for hardwoods and softwoods respectively. Thus, different species are only distinguished by the saturation moisture content value. Many tests of sorption isotherms at several temperatures have shown the influence of temperature on moisture content. A hygroscopic equilibrium chart is proposed in Eurocode5, only for softwood, to define moisture content according to relative humidity and temperature. Thus, Perré [6] and Merakeb [10] proposed a first correction of equilibrium moisture w_s at 100%RH. However, this approach does not consider the physical properties of the material, and is only an identification based on test at several temperatures. We propose to explain this phenomenon by presenting the thermodynamic exchanges whose temperature represents a catalyst according to the Le Chatelier's principle (Fig 1).

$$w_s(T) = \left(w_s^0 + \frac{C_{anh}}{C_w} \right) \cdot \exp\left(-\frac{C_w}{L} \cdot T \right) - \frac{C_{anh}}{C_w} \quad [3]$$

w_s^0 represents the saturation moisture content at temperature $T=0^\circ\text{C}$. The heat capacities of anhydrous wood C_{anh} and water C_w , as well as the latent heat of the water vaporization L are non-dependent temperature properties are supposed constant in the moisture content and thermal

ambient ranges. Our analytical model is compared with data from the EC5 and the linearized function proposed by Perré in Fig.1, present a very good correlation.

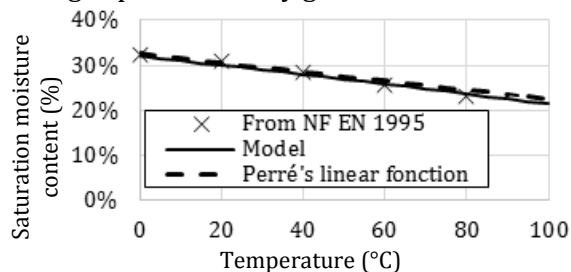


Fig 1: Comparison of thermodynamic approach, and normative values

This approach justifies the influence of temperature on the saturation moisture content as a function of the thermodynamic properties characterizing each species.

Results and analysis

Let us consider the example shown in Fig.2. The left graph (2.a) is the normative response used in Eurocode 5 [11]. The second right graph (2-b) is a proposed adaptation for oak. At the point 65%/20°C, moisture content is 12.5% in 2-a) and 14.5% in 2-b). According to different conditions, the gap between the normative chart and the specific propositions can reach 5%. Initial moisture content distribution, not presented in this paper, could be taken into account in the proposed method.

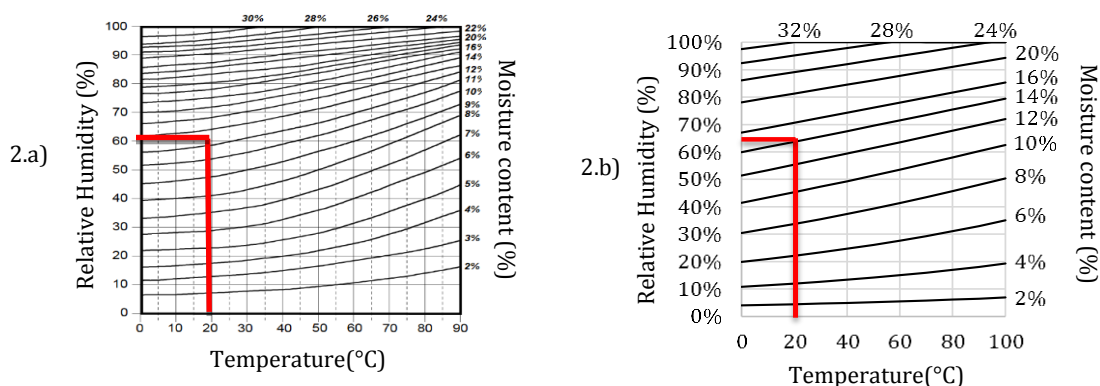


Fig 2 : Equilibrium moisture content charts: a) Normative chart from EC5 b) proposition for oak

References

- [1] J. F. Siau, *Transport Processes in Wood*, vol. 2. Berlin, Heidelberg: Springer Berlin Heidelberg, 1984.
- [2] I. Langmuir, « The adsorption of gases on plane surfaces of glass, mica and platinum », *J. Am. Chem. Soc.*, vol. 40, p. 1361-1403, 1918.
- [3] R. W. Dent, « A sorption theory for gas mixtures », *Polym. Eng. Sci.*, vol. 20, n° 4, p. 286-289, mars 1980.
- [4] S. Merakeb, « Couplage hygromécanique dans le processus de diffusion dans le bois », 2006.
- [5] R. Keylwerth, « Bundesforschungsanstalt für Forst und Hozwirtschaft, Reinbek Institut für Holzphysik und mechanische Holztechnologie », 1964.
- [6] P. Perré et B. K. May, « A Numerical Drying Model That Accounts for the Coupling Between Transfers and Solid Mechanics. Case of Highly Deformable Products », *Dry. Technol.*, vol. 19, n° 8, p. 1629-1643, août 2001.
- [7] A. J. Stamm, *Wood and cellulose science*. Ronald Press Co., 1964.
- [8] J. F. Rijdsdijk, *Physical and Related Properties of 145 Timbers*. Dordrecht: Springer Netherlands, 1994.
- [9] J. Gérard et al., « Tropix ». CIRAD, 2011.
- [10] S. Merakeb, F. Dubois, et C. Petit, « Modeling of the sorption hysteresis for wood », *Wood Sci. Technol.*, vol. 43, n° 7-8, p. 575-589, nov. 2009.
- [11] AFNOR, « NF EN 1995-1-1/NA », 2010. .