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A08: Structure/properties relationships of time-dependent behavior of wood – from understanding mechanisms to determining predictive indicators

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Context and objectives

Observing the beams of an old floor that has been bent over time can lead us to wonder if the deformation is still occurring? Or if it has reached a limit state? If even sometimes if the floor will hold the loads? Even if many structures of our heritage show us that wood can resist in the long term, the evolution of its deformation remains an open question with important issues. Beyond civil engineering and wood construction requirements in serviceability, this question stands also for applications of engineering products based on solid wood, wood-based panels in the cultural heritage, or also wood for instruments making.

The expression of the delayed behavior is a determining factor in the longevity of wood for the majority of its structural uses. However, this evolution of the behavior of the wood material over time is expressed in very diverse ways, depending on the orientation of the mechanical loadings on the material, the surrounding hygro-thermal climate, the species diversity or the quality of the wood, etc. Even if many applications demonstrate the mechanical strength of the wood, it is still difficult to have a detailed predictive approach to delayed behavior, particularly because of the lack of description of the (micro)structure/properties relationships that can be observed in the different woods.

The objective of the thesis will be to strengthen our understanding of the origin of delayed wood behavior and to identify physico-mechanical parameters at different structural scales of wood, at different description times, and different conditions of temperature and humidity.

The study will be carried out on a large multi-criteria sampling and experimental campaigns in order to quantify the role of micro-structural parameters and to implement some rheological models that predict the observed behaviors.

The work will be focus on the following tasks :

Task 1: Identify the mechanisms and develop rheological models at micro-structural scales.

Task 2. Highlighting the rheological behavior of woods through various methods, including vibration, dynamics and statics.

Task 3. Conduct comparative statistical analyses to identify predictive indicators.

Material and methods

First, a literature review will be done to highlight relevant hypothesis at micro-structural scale. The experimental results on time-dependent behavior will be collected. A database tool can be provided containing all meta-data information of references and numerical data-sets. In this tool, we will collect for example specimen size, wood species, orientation, environmental conditions of temperature and relative humidity history, loading history, etc. This tool will be

helpful to perform comparative studies of literature experiments and optimize some long and sensitive experimental campaigns. For example, some authors provide some results as the relative deflection of creep experiments as others are providing the strain or the compliance. With this data-set analysis we will try to harmonize the experimental results in a common mechanical framework. Within this framework we should be able to outline some micro-mechanical contribution of material parameters such as density for example.

Secondly some rheological approach will be developed and tested on various experimental data from the database. Usually the rheological models are developed onto a small data amount from a few hygro-mechanical histories and/or specimens. Here the multiplicity of the data-sets will allow to discuss the robustness of the models developed.

Then some experimental campaigns will be done. To do so, a four-point bending device has been designed to test small specimens of 150 mm x 12 mm x 2 mm (Fig. 1).

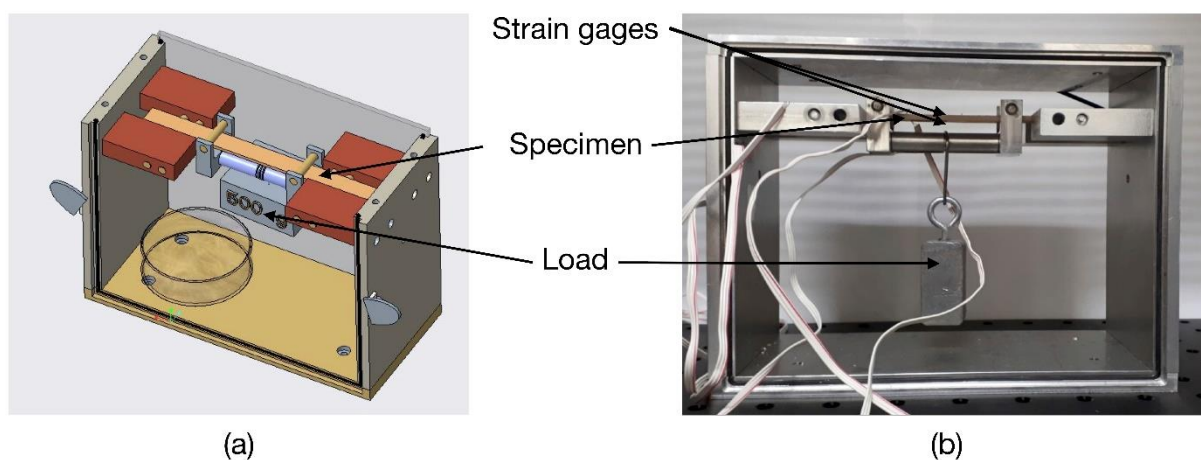


Fig. 1 : CAD model of the designed creep box (a) and aluminum-based first prototype (b)

Preliminary information on the specimens will be quantified by non-destructive methods. Under free-free vibration condition, the specific modulus and damping coefficient can be measured (Brémaud, 2011). Moreover, by X-ray diffraction, average microfibril angle (MFA) and grain angle can be measured (Montero et al., 2012). In addition various laboratory methods will be used to measure some mechanical properties and hygroscopic descriptors of the specimens. Then the creep test will be done. The four-point bending creep box will be placed in a climatic chamber with a temperature and relative humidity controlled environment. The moisture content of the specimen will be monitored. Strain gages would be placed to record information at the tension and compression side by adhesive. The creep test will be under a constant or changing environment with an elastic stress level.

A final step will be to try to find out some descriptors in order to predict the time-dependent behavior based on elementary information. We will try out to link for example the damping information to a particular time or strain level.

Results and discussion

The results of this PhD program will allow to handle some time-dependent data-set in a more constructive way to experiment rheological models. Then some models of creep would be constructed including the factor of temperature, moisture content, micro- and macro-structure of wood and so on. The main factor will be determined after the database tool constructed. The model can be separated into different parts including elastic part, which can be fully recovered;

plastic part, which cannot recover; hydro-expansion part, which is caused by absorption or desorption under unloading situation; visco-elastic part, which is time-dependent behavior; and mechano-sorptive part, which would present under loading at both absorption and desorption. (Hassani et al., 2015). Visco-elastic part, which is the main time-dependent part, can be represented by Kelvin body (Bodig and Jayne, 1982). The discussion of the repartition of the material response to coupled solicitation will be possible on various experimental data. In addition a specific focus will be done in the material parameters to discuss some rheological hypothesis of wood.

Conclusion

During this PhD, we will focus on the description of time depend behavior with a specific focus on the material origins of these phenomenons and on the rheological description adapted to these materials parameters. We also hope to find out some descriptors of the time-dependent behavior of the wood reachable by non-destructive measurements. With this approach we will improve our knowledge on this phenomenon and on the description of in-life use of wood materials.

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