Moisture transfer in bio-based materials:
Application to wood floors on a hempcrete screed

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ABSTRACT Hempcrete is known for its advantages in the field of construction, but the lack of standards on this material leads to a lack of guarantees on site. Nowadays, professionals use a sensible approach to evaluate the drying of hempcrete. The goal of this research is to propose a relevant method to assess the water content by in-situ measurements with usual devices. A wood moisture meter was calibrated for hempcrete in order to monitor the drying of a hempcrete screed and enhance the existing database on the hydric transfer mechanisms in hempcrete.

Keywords hempcrete, water content, calibration, drying

I. INTRODUCTION

Nowadays, the field of construction has a role to play in the ecological transition, with the use of bio-based materials for example. Hempcrete is one of them, but its application is limited today, because few regulations exist [Construire en Chanvre, 2012]. It leads to a lack of guarantees on site: taking responsibility is difficult for the actors. This research focuses on the use of hempcrete as a screed under a wooden floor. To be able to lay the parquet, the craftsman must ensure that the hempcrete is dry enough to not damage the parquet due to moisture transfer (deformation, swelling…). Nowadays, it is often the sensory approach of professionals, with the visual aspect of hempcrete, which makes it possible to guarantee that the hempcrete has achieved an adequate threshold of drying. To address this issue, the following aspects are investigated:

- How to measure the water content on site? No specific device calibrated to measure the water content in hempcrete exists. Wood devices will be used. [S. Glass, 2009] [J. Fester, 2019]
- How evolves the water content of hempcrete during its drying? Indeed, hempcrete is a mix between three elements: hemp shives, binder and water. Due to its high porosity [S. Amziane, 2013], it reacts to its environment, and in particular to the relative humidity of the air [F. Collet, 2007]. Absorption and desorption curves describe this phenomenon [F. Bennai, 2017].

II. EXPERIMENTAL PROTOCOL

TABLE 1. Formulation of the hempcrete samples

Shives IsoCanna® (kg)	20
Formulated lime Tradeco® (kg)	50
Water (kg)	60
Water/Binder (-)	1,2
Binder/shives (-)	2,5

Hempcrete (table 1) is projected by workers, into two formworks (1 m x 1 m x 0.1 m), with a plastic sheet in the bottom, divided in 100 cubic cells shaping 100 samples of 0.1 m x 0.1 m x 0.1 m (Figure 2).

FIGURE 2. Board with hempcrete samples

Moisture meter Hydrometer HTR 300 (company Gann) for wood applications is used to measure the moisture content in hempcrete, depending on dry mass. The moisture content is computed from the measure of the conductance between the end of two electrodes (45 mm or 60 mm depth) inserted in the material. To calibrate the device for hempcrete, a calibration curve, which gives the moisture meter value (metered MC) as a function of the gravimetric mass loss (gravimetric MC), was built up. The experimental protocol followed was:

Take 12 samples from one of the formworks; Dry the samples in an oven at 40°C for 1 week; Prepare polypropylene containers with different relative humidities in using saturated salt solutions (Table 2) at ambient temperature (around 18°C); Place 3 samples in each humid environment, on plastic supports so that the samples are not in contact with water; Close the lid; After 1 month, the moisture equilibrium is almost achieved (stabilization of the mass): measure the humidity of each samples with the moisture meter in 4 positions: at 45 mm and 60 mm depth on the upper and lower sides (mean value of these 4 measures is used); Weigh the mass of wet (m_{wet}) and dried (m_{dry}) sample (40°C for one week), and calculate the gravimetric water content (ω) with equation 1.

$$\omega_{(\%)} = \frac{m_{wet} - m_{dry}}{m_{dry}} \times 100 \quad (1)$$

TABLE 2. **Saturated salt solution and environments at 18 °C**

Environment	Relative humidity	Type of salt / environment	Quantity of salt	Salt/water ratio (-)
1	36%	Ambient	-	-
2	49%	Potassium carbonate (K_2CO_3)	5.5kg (3.2l solution)	1.7
3	78%	Sodium chloride (NaCl)	2.2kg (4l solution)	0.55
4	99%	Water only	-	-

Meanwhile, the drying of the two hempcrete formworks, which were placed into 2 different environments: 10 °C temperature and 55 % air humidity (T10-H55) or 15 °C temperature and 50 % air humidity (T15-H50), were monitored. Each week, the water content of 15 samples on each board was measured with the moisture meter at 2 two different depths (45 and 60mm).

III. RESULTS AND DISCUSSIONS

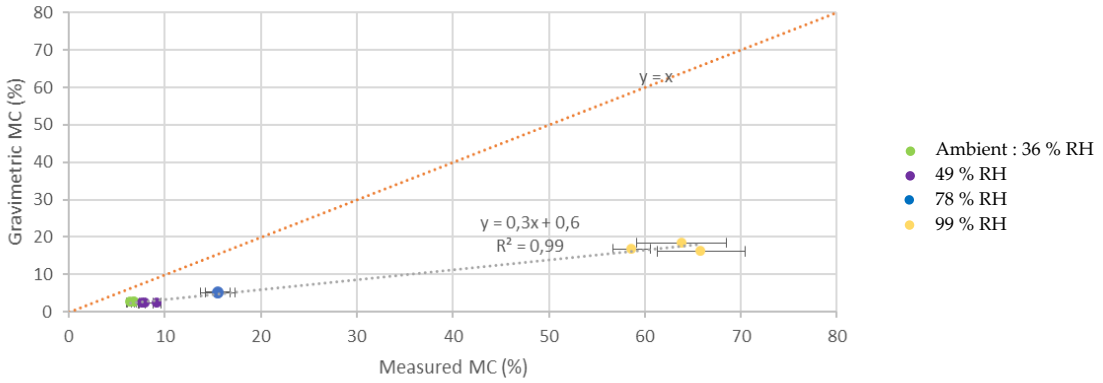

FIGURE 1. **Calibration curve**

$$MC_{grav} = 0,3\ MC_{meter} + 0,6 \quad (2)$$

From the calibration graph (figure 1) a linear trend line (equation 2) is obtained. Figure 3 depicts the evolution of the gravimetric moisture content of the 2 hempcrete boards derived from the moisture meter values using calibration equation 2. In regard of the standard deviations, only general tendencies are highlighted. The drying is not stabilized after more than 2 months. Hempcrete in environment T10-H55 seems to have a more uniform hydric state than the one in environment T15-H50, which indicates a gradient between the upper face and the heart of sample. Existing recommendations [Construire en Chanvre, 2018] preconizes a drying of 1 cm / week (without specific environmental conditions defined) for an hempcrete screed, before laying a floor on it. Water content of wood has to be under 18% (class 2) to avoid rotting of the wood which is achieve after 65 days in this study (following the recommendation, 10 weeks or 70 days are needed for these samples). Nevertheless, a higher humidity content can be acceptable for only avoid the swelling of wood floor throughout its laying.

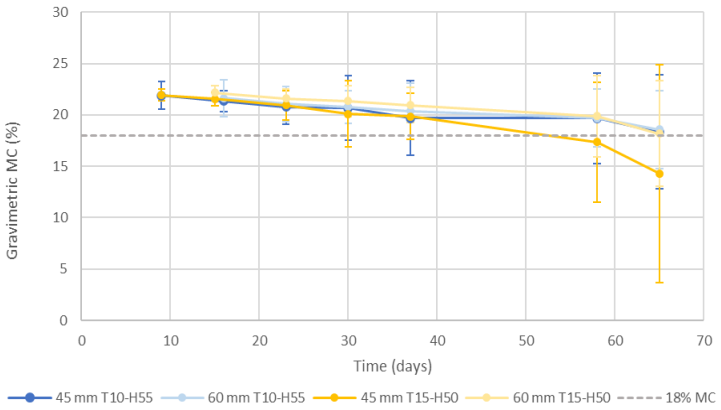

FIGURE 2. **Drying follow-up, calibrated with calibration formula (2)**

VI. CONCLUSION

This research validates an experimental calibration protocol to conduct in-situ measurement of the water content on hempcrete structures with a usual wood moisture meter. This protocol was applied to monitor the evolution of the drying of a hempcrete screed in an ambient environment. Future words could be performed by refining the moisture meter calibration curve, a following hempcrete drying longer, by tests under "summer" conditions with a higher temperature and lower air humidity and by investigation the hydric transfer between wood and hempcrete.

REFERENCES

S. Amziane, & L. Arnaud. (2013). Les bétons de granulats d'origine végétale, application au béton de chanvre, Paris: Lavoisier.

Construire en Chanvre; Q. Pichon, & J.-M. Naumovic. (2018). Guide des bonnes pratiques, Béton et mortier de chanvre (Tome 3) : Préconisations techniques, optimisations et performances.

Construire en Chanvre. (2012). Règles professionnelles d'exécution d'ouvrages en béton et mortiers de chanvre, Isolation de sol, SEBTP, Paris.

F. Bennai, N. Issaadi, K. Abahri, et al. (2017). Experimental characterization of thermal and hygric properties of hemp concrete with consideration of the material age evolution. *Heat Mass Transfer (2018)* 54:1189–1197. https://doi.org/10.1007/s00231-017-2221-2

F. Collet, M. Bart, L. Serres, & J. Miriel. (2007). Porous structure and vapour sorption of hemp-based materials, *Construction and Building Materials 22 (2008)* 1271–1280, doi:10.1016/j.conbuildmat.2007.01.018

J. Fester, H. Kjeldsen, Peter F. Østergaard, & J. Nielsen. (2019). A new set-up for the calibration of wood moisture meters, *19th International Congress of Metrology 18002 (2019).* https://doi.org/10.1051/metrology/201918002

S. V. Glass, & C. G. Carll. (2009). Moisture meter calibration for untreated and ACQ-treated southern yellow pine plywood, *Research Note FPL-RN-0312.*