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HYGRIC BUFFERING CAPACITY OF TWO BIO-BASED MATERIALS

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Abstract

This paper deals with the hygric properties of a new bio-based material called “rape straw lime concrete” in comparison with a “hemp lime concrete” which is considered as the reference material. The tests are conducted on the moisture buffer capacity which is estimated from the moisture buffer value (MBV) determined under equilibrium condition. The results showed that the materials have very interesting hygric properties and exhibit an excellent moisture buffer capacity. However, the addition of a plaster layer to the materials, reduces significantly the moisture buffer potential.

Introduction

In the last few decades, clean and durable materials take an important place in the researches in order to reduce the building sector pollutants, which acting on the environment. Among the materials, the vegetable particles used as aggregates for the concrete in building material can contribute effectively to reduce greenhouse gas emissions thanks to its ability to capture carbon dioxide during its life cycle [1]. The hemp or straw concretes is used to cover the walls of masonry, or to fill the timber-framed structures in new and old buildings and, it can be used to isolate the roofs or floors. The previous studies focused on physical and hygrothermal characteristics have shown that these materials have a low conductivities (it about 0.1 W/(m.K)) [2, 3], and high moisture buffering capacity which leads damping the high variations of relative humidity and hence maintain

indoor hygrothermal comfort [4, 5]. In addition, the both hemp and straw concretes have a high water vapor permeability which is approximately 2.5×10^{-11} kg/(Pa.m.s) [6, 3]. At whole building scale, these materials, allow moderate the daily indoor relative humidity variations, thanks its high moisture buffer capacity (2.02 g/(m².%RH)) [7].

This paper presents a new bio-based material called "rape straw lime concrete" by combining the rape straw with a lime-based binder. The choice of other resources such as rape straws as aggregates is related to its large availability in France and in the world.

The tests have been conducted on the moisture buffer values inspired by the Nordtest project [8], which represent the ability of material to dampen the indoor relative humidity variations thanks to their moisture sorption capacity. The effect of adding layer plaster to the material on the moisture buffer capacity has been investigated.

Materials and method

Manufacturing

The hemp and straw concretes are comprised of water, lime-based binder and plant particles such as hemp shivs for hemp concrete (HLC) case and rape straw for rape straw concrete (SLC). The binder used contains around 75 % of rich lime (Ca(OH)₂), 15 % of hydraulic lime and 10 % of puzzolon binders.

The method fabrication of these concretes consists in mixing the aggregates, the water and binder. The

fresh concrete then was manually filled in the mold and then damped. The proportion of each component by mass percentage is presented in Table 1.

Table 1: Proportion of lime binder, hemp/straw and water by mass for concretes.

Material	Granular	Lime	Water
HLC	16	36	48
SLC	14	36	50

Moisture buffering capacity

The hygroscopic materials like bio-based concrete can contribute to moderate the indoor relative humidity variations and improve comfort for occupants thanks to its moisture adsorption/desorption [9, 8]. Farther more, it is important to have moderate relative humidity in indoor building to inhibit the growth of mold and increase the life of building structure [10].

As to know, the properties of materials performed under steady state and equilibrium conditions of relative humidity and temperature which are not more realistic to study the hygric behavior of materials under dynamic conditions. To assess the moisture buffer capacity of hygroscopic materials inside building, the Nordtest project [8] proposed an experimental approach which leads to evaluate the Moisture Buffer Value (MBV). There is notice that the MBV is not an intrinsic property of the material because the value takes into account the mass transfer resistances at the boundary. The aim of this part is to determine the MBV values of studied materials and to experimentally investigate the impact of add plaster layer to specimen on the moisture buffer capacity.

MBV experimental protocol

The practical MBV indicates the amount of water vapor uptake or release by material per open surface area, during a certain period of time when it is subjected to variations in relative humidity of the surrounding air. Experimentally, the sample is subjected to cyclic step-changes in relative humidity between 75 % RH during 8 h and 33 % RH during 16 h respectively at a constant temperature of 23°C (Fig. 1).

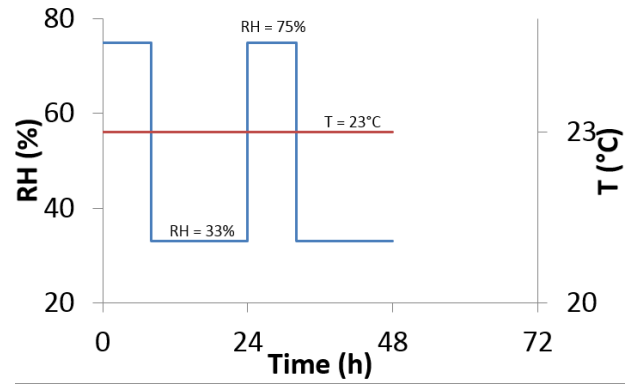


Fig. 1: Temperature and relative humidity variation : Nordtest protocol

The MBV value is calculated at steady-state by the following equation:

$$MBV = \frac{\Delta m}{A \cdot (RH_{high} - RH_{low})} \quad 1$$

Where Δm is the moisture uptake/release during the period, $RH_{high/low}$ the high/low relative humidity level and A is the exposed surface.

The MBV value is determined in steady state, which is supposed to reach, when between three consecutive cycles, the change in mass Δm [g] is less than 5 % between the last three cycles (Δm is the average between the weight gain during the moisture uptake and the weight loss during drying). In addition, the difference between the weight gain and weight loss within each cycle should be less than 5 % of Δm .

For this to be done a climate chamber (CL2 Biacimatic Type -25) was used (see Fig. 2) which can control the temperature and the relative humidity in the range of -20-90 °C with an accuracy of ± 0.3 °C and 10-98 %RH, with an accuracy of ± 2 %RH respectively. The temperature is kept being constant at 23°C in the climate chamber.

Based upon previous study, the thickness of samples (with the area of 100 cm²) using in the tests is 7 cm which higher than the moisture penetration. For each material, three samples were prepared. The back and edges of samples were sealed with aluminum tape as shown in Fig. 2. These were then placed in the climatic chamber. The gravimetrical determination of the moisture absorption/desorption as function of time was made inside the climate chamber using a balance with 0-750 g and 0.001 g resolution. The specimens were weighed every 30 mn.



Fig. 2: Specimens for MBV measurement.

Result and discussion

Moisture buffering capacity

The mass of moisture uptake and release for the SLC sample at steady state, is showed in Fig. 3. The MBV obtained of hemp concrete is equal to $2.02 \text{ g}/(\text{m}^2 \cdot \% \text{RH})$, which is very close that values in the range of 1.75 to $2.15 \text{ g}/(\text{m}^2 \cdot \% \text{RH})$ given by [6, 8, 22]. These results lead the validation of experimentation protocol done in this work. The MBV value of the SLC is equal to $2.59 \text{ g}/(\text{m}^2 \cdot \% \text{RH})$ which is higher and better moisture buffering capacity than that of HLC.

Rode [8] propose classification of material building construction according to its MBV value. He defines five ranges for practical moisture buffer values classes varied from negligible to excellent, has been used. Both hemp and straw concretes bio-based materials exhibit an "excellent" moisture buffer performance, according to this classification.

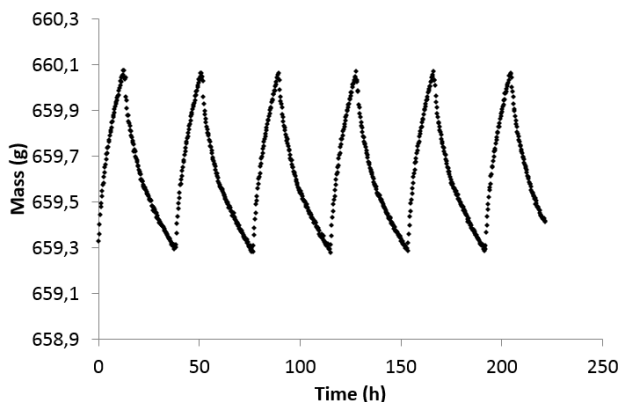


Fig. 3: Moisture uptake and release for the SLC sample at steady state.

Effect of add plaster layer

In practice, these raw walls mainly coated with a plaster that will give them a better seal to reduce the high permeable to air and to correct the surface imperfections. This section focuses of the effect of the add 2 cm of plaster layer to the samples, on the MBV values.

As can be seen in

Figure 4, the plaster layer added to the materials lead to reduces strongly the moisture buffer. For the both materials, the MBV is reduces for 56% which according to the Nordtest classification, the moisture buffering capacity passed from excellent to good and moderate for hemp concrete case. This result confirms that the dynamic exchange of moisture occurs mainly in the first layer of material. This last has been confirmed and evaluated by simulation, for both materials, in previous studies, which its value not exceed 3 cm [11].

This leads to the conclusion that the choice of the nature of plaster layer of wall and its thickness might be based on the moisture buffer value and the penetration depth to keep a suitable capacity to moderate the variation of relative humidity within building.

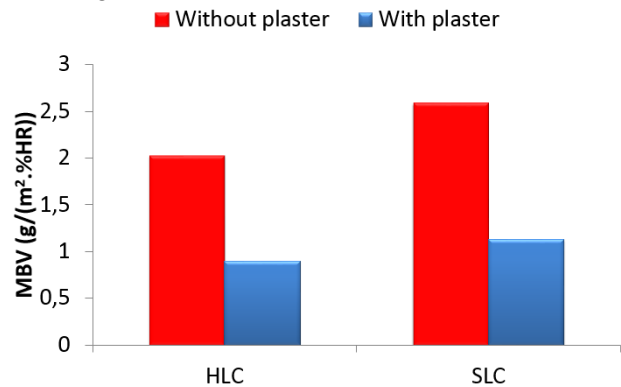


Figure 4: MBV value of SLC and HLC with and without plaster layer

Conclusions

This article focuses on the characterization of the moisture buffer capacity based on Nordtest protocol of two materials: the first one is a new bio-based material called "lime straw concrete" and the second one is lime hemp concrete. The effect of add a plaster layer to the material on moisture buffer value has been investigated.

The both materials have a high absorption capacity and diffusion of water vapor.

The hygric characterization under dynamic conditions has been done according to the Nordtest protocol. It is shown that the MBV values for HLC and SLC concretes are respectively 2.02 and 2.59 g/(m².% RH). Both materials exhibit an "excellent" moisture buffer capacity. The adding of 2 cm plaster layer to the material leads to significant reduction of MBV. However, the choice of the nature of plaster layer of wall and its thickness might be based on the moisture buffer value and the penetration depth to keep a suitable capacity to moderate the variation of relative humidity within building.

KEYWORDS

Straw lime concrete, Hemp lime concrete, plaster, Hygric properties, Moisture buffer capacity

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References

- [1] M. Boutin, C. Flamin, S. Quinton et G. G, «Analyse du cycle de vie-Compounds thermoplastique chargés fibres de chanvre et mur en béton de chanvre banché sur ossature bois,» Rapport d'étude, INRA, Lille, 2005.
- [2] F. Collet and S. Pretot, "Thermal conductivity of hemp concretes: Variation with formulation, density and water content," *Constr. Build. Mater.*, vol. 65, pp. 612-619, 2014.
- [3] A. Evrard and A. De Herde, "Hygrothermal performance of lime hemp wall assemblies," *J. Build. Phys.*, vol. 34, pp. 15-25, 2010.
- [4] A. Tran Le, C. Malouf, T. Mai, E. Wurtz and F. Collet, "Transient hygrothermal behaviour of a hemp concrete building envelope," *Energy Build.*, vol. 42, pp. 1797-1806, 2010.
- [5] Rahim, M; Douzane, O; Tran Le, A.D; Promis, G; Laidoudi, B; Crigny, A; Dupre, B; Langlet, T, "Characterization of flax lime and hemp lime concretes: Hygric properties and moisture buffer capacity," *Energy Build.*, vol. 88, pp. 91-99, 2015.
- [6] F. Collet, M. Bart, L. Serres and J. Miriel, "Porous structure and water vapour sorption of hemp-based materials," *Constr. Build. Mater.*, vol. 22, pp. 1271-1280, 2008.
- [7] E. Latif, M. Lawrence, A. Shea et P. Walker, «Moisture buffer potential of experimental wall assemblies incorporating formulated hemp-lime,» *Building and Environment*, vol. 93, pp. 199-209, 2015.
- [8] C. Rode, R. Peuhkuri, H. Lone, B. Time, A. Gustavsen, T. Ojanen, J. Ahonen et K. Svennberg, « Moisture buffering of building materials,» *Nordic Innovation Centre Report : BYG-DTU R-126. ISSN*, p. 1601–2917, 2005.
- [9] A. Shea, M. Lawrence and P. Walker, "Hygrothermal performance of an experimental hemp-lime building," *Constr. Build. Mater.*, vol. 36, pp. 270-275, 2012.
- [10] J. Lstiburek, «Moisture, building enclosures, and mold,» *HPAC Heating, Piping, Air Conditioning Engineering*, vol. 74, pp. 77-80, 2002.
- [11] M. Rahim, A. TranLe, O. Douzane, G. Promis et T. Langlet, «Numerical investigation of the effect of non-isotherme sorption,» *Journal of Building Engineering*, vol. 7, p. 263–272, 2016.

