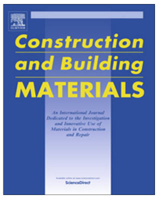
ARTICLE IN PRESS

Construction and Building Materials xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat



Study of a hempcrete wall exposed to outdoor climate: Effects of the coating

A. Piot [a,b,*], T. Béjat [a,b], A. Jay [a,b], L. Bessette [c], E. Wurtz [a,b], L. Barnes-Davin [c]

[a] *Univ. Grenoble Alpes, INES, F-73375 Le Bourget du Lac, France*
[b] *CEA, LITEN, Department of Solar Technologies, F-73375 Le Bourget du Lac, France*
[c] *Vicat, 4, rue Aristide Bergès - les trois vallons, F-38081 l'Isle d'Abeau cedex, France*

HIGHLIGHTS

- Cement based hemp concrete walls exposed for one year to indoor controlled and outdoor climate.
- 2 different exterior coatings were compared.
- Modelling was used to determine material properties and for extrapolation of results.
- Results show that the wall is sensitive to the fact that the exterior coating absorbs rain or not.
- Results show that drying can last several month.
- Results show that model with properties determined in steady-state presents some limitations.

ARTICLE INFO

Article history:
Received 5 July 2016
Received in revised form 21 December 2016
Accepted 22 December 2016
Available online xxxx

Keywords:
Hemp concrete
Hygrothermal behaviour
Outdoor climate exposure
Natural Prompt cement

ABSTRACT

Hemp concrete is becoming a popular building construction material, as it has a low environmental impact and helps reducing the heat conductivity of walls. The generally used binder is lime, but in this study a prompt natural cement binder was used. The objective of this study was to analyse the behaviour of a hempcrete wall in realistic conditions. 2 test walls made of prefabricated hemp concrete blocks were built. Those walls were exposed to the outdoor climate on the one side, and to a controlled indoor climate on the other side. 2 different exterior coatings were applied. The experiment lasted one year. In addition, numerical simulations were carried out. The model was used to determine the material properties and to help understand the behaviour measured.

The results show that an important humidification of the wall can occur if the coating is not well chosen. The exterior coating must be very permeable to water vapour, but it seems to be important to prevent the absorption of rain as well, otherwise, the humidity inside the wall can lead to degradations such as mould growth or increased thermal conductivity. Both numerical simulation and measurements show that applying a vapour permeable coating on the blocks does not slow down the drying process, the hempcrete itself being the limiting factor.

1. Introduction

Since the increase in the energy costs and the awareness of the impact of human activities on the climate, there has been done a huge effort of both research and policies to reduce the energy consumption of the building sector. Further work is still necessary, as the European union has recently committed itself to a reduction in the greenhouse gases emission of 40% by 2030 in comparison with 1990 [13].

This has led to an increase in the insulation level of building envelopes in order to reduce energy consumptions for heating and cooling buildings. Therefore, it has become more and more important to take into account the environmental impact of the construction materials in the design of eco-friendly buildings, as they take an increasing proportion of the total impacts in the life cycle analyses, as shown in Blengini and Carlo [6]. In this regard, the so-called bio-based materials have much interests (renewable resource, eventually locally grown, CO_2 sink…). However, risks are also associated with bio-based products, such as the sensitivity to

---

* Corresponding author at: CEA, LITEN, Department of Solar Technologies, F-73375 Le Bourget du Lac, France.

E-mail address: arnaud.jay@cea.fr (A. Piot).

http://dx.doi.org/10.1016/j.conbuildmat.2016.12.143
0950-0618/

Please cite this article in press as: A. Piot et al., Study of a hempcrete wall exposed to outdoor climate: Effects of the coating, Constr. Build. Mater. (2017), http://dx.doi.org/10.1016/j.conbuildmat.2016.12.143

mould or insects. Such risks have to be taken into account when one studies this kind of materials.

Ip and Miller [16] show that hemp is an important greenhouse gas sink potential. The review carried out by Ingrao et al. [15] shows that many reasons can explain why the hemp based products are more and more popular: the cultivation of hemp has a good yield, and needs only few fertilization and herbicide. As a vegetal material, it has a high level of CO_2 sequestration during its growing phase, therefore being very efficient in term of reducing climate change indicators, and uses only a few non-renewable resource.

The hemp concrete or hempcrete is a mixture of hemp shives and of a binder, cement or lime for example. Hempcrete benefits from the porous structure of the shives, giving a lightweight product with a low thermal conductivity, a good acoustical insulation, and making it a hygrothermal responsive material.

Numerous studies on the matrix and material properties can be found in the literature, either experimental characterisation or numerical studies [7,8,11,20,21]. The objectives are mainly to characterize the physical properties of the material and quantify the impact of hempcrete characteristics (density, relative humidity...) on the thermal properties (thermal conductivity, -capacity and -diffusivity). Walker and Pavia [26] focus on the effect of binder on the hygrothermal properties of hempcrete. The moisture buffer value (MBV) of hempcrete is also investigated, together with the impact of coating or wall rendering on this MBV [18]. Collet and Pretot [12] conducted experimental studies in controlled climate (temperature and relative humidity) test chambers, showing that applying coating did reduce the vapour diffusion through the wall.

Only few authors report the behaviour of a hempcrete wall exposed to real outdoor conditions. Shea et al. [25] describes a small test-building made of hempcrete and shows its ability to strongly buffer the moisture level inside the room. Latif et al. [19] studied 2 walls, one with and one without vapour barrier, made of wood-hemp insulation exposed to real climate. No significant difference was found between walls' experimentally determined U-values.

In this paper we present the study of 2 hempcrete walls exposed during one year to outdoor climate on one side and to controlled climate on the other side. The binder used to make the hempcrete is a natural Prompt cement. PROMPT is a natural hydraulic binder manufactured from a single raw material without additives. It results from firing an argillaceous limestone of regular composition extracted from homogeneous rock strata, between 800 °C and 1200 °C in a vertical kiln, followed by very fine grinding. The walls are coated on both side, the exterior coating differs between the 2 walls. The measurements are analysed to see how the walls respond to different solicitations (indoor humidification, outdoor humidity, rain loads) with the help of numerical modelling. The article outlines the importance of the choice of coatings on the long term performance of the hempcrete.

The first part of the paper will present the experimental set-up, then the numerical model used is introduced. This model is compared to the measurements to determine the material properties, in particular of the coatings. The following paragraphs of the paper present the analysis of the role of the interior coating, and in the end the role of the exterior coating.

2. Experimental set-up

2.1. Test walls

Two test walls were built on the outdoor exposure site of CEA at INES (Le Bourget du Lac, France, 45°38′ N, 5°52 E). They are composed of precast hempcrete blocks (31 cm × 60 cm, thickness of 30 cm), and were assembled on site by the end of June 2012.

The blocks used here are prefabricated and the binder used is a natural Prompt cement which has the property to be fired at lower temperatures than ordinary Portland Cement. They are assembled through a dry mortarless construction (with tongue and groove keys [1]). The hemp-concrete blocks are self-bearing but not structural, therefore a concrete post and beam structure was used (size of the post $15 * 15\ cm^2$). The composition of the concrete is described in Bessette and Sommain [4].The dry density is of $350\ kg/m^3$.

On the interior side, both walls are covered with traditional, commercially available lime-based render. The exterior coating differs between the 2 constructions. On one wall, the coating applied is an industrial, pre-mixed, lime- and cement-based, and containing additives; on the second one, a hand-mixed (prepared on site) lime- and cement-based coating is used. Both coatings have a similar colour (which is unfortunately not well depicted by Fig. 1), in order to have a comparable behaviour towards solar radiation. The experiment has shown that the industrial coating did not absorb rain, as opposite to the hand-mixed coating. This is shown in paragraph 5.

The walls have a square shape (3.3 m side). Fig. 1 gives some pictures of the walls and a cross section.

Those walls were installed on "PASSYS" test cells, which allow one face of the wall to be exposed to indoor climate (indoor temperature varied between 15 °C and −28 °C while humidity emission varied between 170 g/h and 200 g/h), the other to real outdoor climate. The PASSYS test cells outer dimensions are 8.44 m long, 3.61 m wide and 3.8 m high. The cells are made of a metallic frame with 5 walls strongly insulated ($U = 0.09\ W/m^2\ K$), also water- and vapour proof. The 6th face is reserved for a wall of maximum $3.6 * 3.3\ m^2$ to be tested. The studied wall is exposed to outdoor conditions on one side and to controlled indoor conditions on the other side. Each cell is placed on a raised support which allows free air circulation under the floor.

The tested walls are oriented towards South. The indoor air volume of the test room is of $30\ m^3$. Indoor temperature is controlled by a small blowing air-conditioning unit (either cooling or heating). Moisture can be generated by an ultra-sonic generator. The flow-rate of moisture is measured by weighing continuously. Different indoor conditions were imposed: free-floating temperature, heating, cooling, with or without moisture generation (see Table 1). No mechanical ventilation is used.

2.2. Monitoring system

The set-up enables to collect temperature, relative humidity, heat flux data inside the wall and the test room.

Sensirion SHT75 sensors are used to record relative humidity and temperature for the air and in the material. Accuracy of those sensors is 1.8%-RH and 0.5 °C.

In order to follow the transfer inside the wall, they are set at different depths (see Fig. 2):

- at the surface of interior plaster,
- at the interface between interior plaster and hempcrete blocks,
- in the middle of the hempcrete blocks,
- and at the interface between hempcrete blocks and external plaster.

The sensors were placed inside the blocks through a hole drilled from the top of each block, the wire going down perpendicular to the main heat- and moisture fluxes, in order not to disturb the latter. This set-up is installed at 3 heights in the wall, close to the concrete post (on the left-hand side of the wall depicted in Fig. 2 and in

Please cite this article in press as: A. Piot et al., Study of a hempcrete wall exposed to outdoor climate: Effects of the coating, Constr. Build. Mater. (2017), http://dx.doi.org/10.1016/j.conbuildmat.2016.12.143