ICMB23

2nd International Conference on Moisture in Buildings (ICMB23), online, 3-4 July 2023

Lime-hemp as wall insulation: long-term monitoring system to investigate the hygrothermal performance

Timo De Mets*[a], Antoine Tilmans[a], Elke Knapen[b]

a. Energy and Renovation Division, Buildwise, Belgium
b. Faculty of Architecture and Arts, Hasselt University, Belgium

Abstract

Lime-hemp has attracted attention as insulation material due to its promising ecological and hygrothermal properties. However, proper design and execution are crucial, as long-lasting moisture accumulation could lead to material degradation. This paper presents a case study that investigated the hygrothermal performance of lime-hemp as external wall insulation in a renovation project. To enable long-term monitoring with minimal disruption to building occupants, a low-cost and flexible monitoring system was developed and installed. The results emphasize the importance of the external render in protecting the insulation from moisture damage. Without adequate rain protection, moisture accumulation can occur. The findings provide valuable insights for designers and builders considering the use of lime-hemp.

Peer-review under the responsibility of the organizing committee of the ICMB23.

Keywords: Lime-hemp; long-term monitoring; hygrothermal behaviour; bio-based insulation

1. Introduction

In an effort to reduce energy consumption and make buildings more energy-efficient, it is important to also consider the environmental impact of the materials used. One solution is the use of bio-based materials such as lime-hemp that is considered to have a low environmental footprint. Moreover, lime-hemp has a relatively low thermal conductivity (0.06 - 0.16 W/(m.K), depending on density and material composition), good moisture buffering capacity, and high thermal inertia, making it a suitable choice for thermal insulation. However, adequate constructional detailing and accurate execution on-site are crucial, as severe long-lasting moisture accumulation could cause the hemp shives to degrade and support mould growth.

To evaluate the hygrothermal behaviour of lime-hemp in a specific wall composition, sometimes numerical simulations are used [1]. However, these tools have limitations such as reliance on accurate material properties that may not be available, oversimplification of certain phenomena, and inherent uncertainty that can be difficult to quantify. Long-term on-site measurement provides a useful alternative, as it allows for investigation of the hygrothermal behaviour of buildings under real-world conditions, including the impact of indoor and outdoor environments and material execution. However, traditional monitoring methods often use expensive equipment that requires access to the building's power supply, can be disruptive for occupants, and may be challenging to access and analyse data in real-time. To address these limitations, a new monitoring system has been developed that is both low-cost and flexible, making it an ideal solution for long-term building monitoring.

This extended abstract details the features and capabilities of this monitoring system and presents the results of a case study with lime-hemp as external wall insulation where this monitoring system has been installed.

2. Monitoring system

A monitoring system is designed to evaluate the temperature and relative humidity at various depths within walls. The system comprises of a microcontroller unit (MCU) that is connected to a series of sensors, specifically the Honeywell HIH 8121 digital sensor with a declared accuracy of ± 0.5°C and ± 2.0% RH. To install the sensors, usually a small hole is drilled into the wall and the sensors are placed within. For the current prototype, these sensors are placed in a PVC tube filled with PU-foam to allow an easy insertion through the drill hole and accurately guarantee the sensor location, but this may be optimized in the future. The MCU, fixed to the wall, reads the sensor data and remotely transmits it to a server. The current monitoring system sends data every 30 minutes using the Sigfox network for data transmission, a LPWAN (low-power wide-area network) with more than 97% of the Belgian territory covered. With 6 AA batteries, the device has an autonomy of about 1 year and 2 months. This monitoring system offers several benefits including its cost-effectiveness, low power consumption, independence from the building's power supply and network, and minimal disruption to the building occupants.

* Corresponding author. +32 2 655 77 11, timo.de.mets@buildwise.be

 DOI: 10.14293/ICMB230036

The effectiveness of our monitoring system was tested in 9 buildings, with 25 examined walls and 103 temperature/relative humidity sensors. The system performed effectively in the majority of cases, with only one exception in an urban building where poor network signal led to significant data loss. To address this issue, options such as the use of repeaters to enhance network coverage or implementation of an alternative network system could be considered.

3. Case study

The results presented in this study are based on the monitoring of a typical single-family house located in Wavre, Belgium. Two walls were selected for the study, both having the same composition of 30 cm masonry bricks insulated with prefabricated lime-hemp blocks, but different orientation (either facing north or west). The insulation is applied during 2018 on both the exterior wall (20 cm, with an external lime render) and interior wall (6 cm). The study specifically focuses on investigating the relative humidity within the external wall insulation, at 4 - 8 cm from the external render. (Figure 1, left)

The measurements reveal that for the north-oriented wall, the relative humidity in the external wall insulation follows the pattern of the outdoor conditions. In contrast, the relative humidity in the west-oriented wall is generally higher, particularly at the beginning of the measurements and during the period of April to July 2020 (Figure 1, right). This initial high relative humidity is likely due to the fact that the external render was applied in the summer of 2019, resulting in the lime-hemp being exposed to rain for several months. This effect is expected to be more pronounced on the west-oriented walls, as they are more exposed to wind-driven rain. Notably, during the months of February and March 2020, a high amount of rain was observed on the west-oriented wall. Following this rainy period, the relative humidity in the external wall insulation for this orientation increased, while the relative humidity for the north-oriented wall, which received less rain, decreased.

These findings suggest that the chosen external lime render may not effectively protect against rain. This is further highlighted by the sensor placement in the north wall, 4 cm further outside. The conclusion is consistent with previous studies [2, 3], which have found that certain external renders can lead to moisture accumulation in lime-hemp insulation.

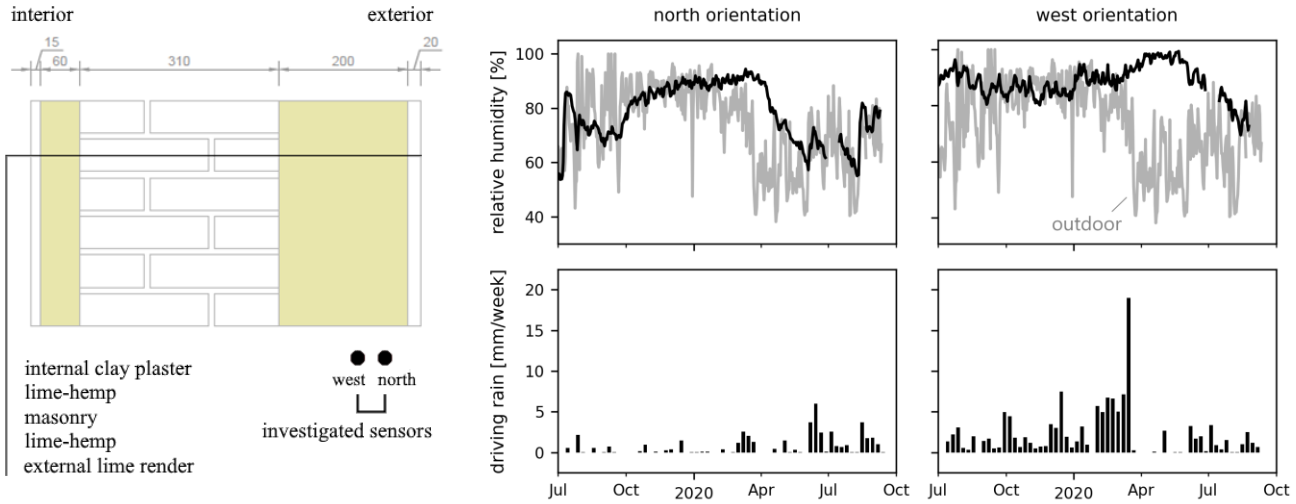

Figure 1. Wall composition, sensor locations (left). Relative humidity in the insulation and outdoor environment, and driving rain for both wall orientations (right). The relative humidity is averaged on a daily basis for visual clarity, and the driving rain is calculated based on nearby rain and wind measurements.

4. Conclusion

The paper presents a low-cost and flexible monitoring system for evaluating the hygrothermal behavior of buildings. The results from a case study using the system to monitor a single-family house with lime-hemp as external wall insulation are presented. The study found that the choice of external render is crucial in determining the hygrothermal behavior of lime-hemp wall insulation. The external lime render used in the west-oriented wall provided inadequate rain protection, leading to a higher relative humidity compared to the north-oriented wall with less rain exposure.

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