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A numerical case study of a wall composed of pre-cast rapeseed concrete blocks

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Abstract

In recent years, there has been increasing interest in using biosourced materials in construction due to their low environmental impact and favorable hygrothermal properties. This study aims to evaluate the hygrothermal performance of a wall constructed with rapeseed concrete under actual weather conditions. To this end, a case study is conducted using the WUFI software, with various coatings and according to the climate conditions on Ile de France. The results of the thermohygric characterization of non-load-bearing insulating bio-based concrete blocks were used as input data for simulations conducted using the WUFI tool. The results show that the wall has good hygrothermal behavior when an external mineral coating with an Sd value of 25 is added. The recommended thickness for good thermal insulation and temperature phase shift is 30 cm.

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Keywords: WUFI; Rapeseed concrete; Hygrothermal performances; Wall

1. Introduction

Building materials play an important role in energy consumption, especially during the manufacturing process, which is one of the most important sources of greenhouse gas emissions and grey energy. Therefore, it is becoming essential to find strategies to reduce this grey energy and to design construction materials with low environmental impact. One of the most relevant solutions is bio-based materials, which are derived from local and abundant resources such as fibers and plant aggregates. These alternative materials seem to be a promising approach for building materials. Therefore, this study evaluates the hygrothermal performance of walls constructed from a bio-sourced construction material derived from rapeseed straw under various meteorological conditions (particularly in the Haut-de-France region) and with different types of coatings.

2. Methodology

The coating materials used in this study were extracted from the database of WUFI software. An attempt has been made to select materials with low gray energy. The wall was made of rapeseed concrete that had previously been manufactured in the Laboratory Innovative Technologies [1]. The physical, thermal and hygric properties of rapeseed concrete were measured in the laboratory. The density of rapeseed concrete is 380kg/m^3 , thermal conductivity is $0.093\text{ W}\cdot\text{m}^{-1}\cdot\text{k}^{-1}$, water vapor permeability has a value of 4.7, and porosity is 80%. The climate chosen for this study is represented by the meteorology of the town of Trappes in the Ile-de-France region, which is characterized by cool summers and mild winters. The indoor conditions used in the simulation were generated based on EN 15026 (DIN EN 15026, 2007). In this study, the various hygrothermal criteria in relation to building materials were discussed. One of the most important criteria is the total moisture content of the rapeseed concrete, which can lead to problems such as condensation, drying rate, and mold. The article also discusses phase shift and damping, which are related to the dynamic response of the medium, and their calculation methods. The simulation studies were carried out over 5 years to achieve stabilization of thermohygroscopic exchanges in the wall. Table 1 shows the different configurations studied.

Table 1. Simulated wall configurations

(Interior)	layer1	layer 2	layer 3	layer 4
Case 1	Plaster 20 mm	Wall 200 mm	Mineral coating 30 mm	
Case 2	Plaster 20 mm	Wall 400 mm	Mineral coating 30 mm	
Case 3	Plaster 20 mm	Wall 400 mm	Lime coating 30 mm	
Case 4	Plaster 20 mm	Cellulose fiber insulation 100 mm	Wall 200 mm	Mineral coating 30 mm
Case 5	Plaster 20 mm	Wall 300 mm	Mineral coating 30 mm	

3. Results

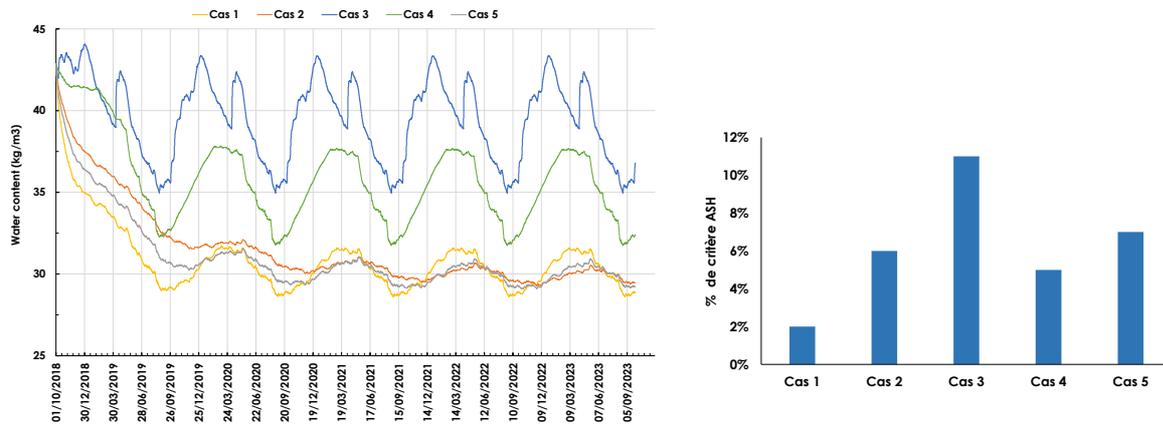


Figure 1. (a) Total water content of the wall with different coatings (b) Ash criteria of the wall with different coatings

Figure 1. (a). shows the evolution of the total water content in the wall with the different coating cases presented in Table 1. This water content decreased with time for cases 1, 2 and 5, and therefore the wall thickness had no influence. It can also be seen that the addition of internal insulation (case 4) increased the total water content in the wall. As explained by Ibrahim and Nocentini [1,2] the addition of internal insulation decreased the temperature in the wall, which enhanced the relative humidity within the supporting materials and thus increased their water content. Case 3 appeared to be the least favorable case, without added insulation and with an external lime plaster. This is because this type of render has a low resistance to water vapor diffusion. All walls showed partial drying over the five-year period. For both types of walls, the best rate corresponded to thin support walls: case 1 (20 cm) and case 5 (30 cm). The ASHREA-160 criterion was determined here at the interface of the external plaster of each wall over the selected period of five years. Figure 1(b) shows the percentage of time this criterion is not met. A value of less than 10% is considered not to present a risk. All cases comply with the ASHREA-160 criterion, except for case 3 due to the high permeability of its lime-based exterior render. Table 2 presents the values of the thermal phase shift and the damping factor of the complete walls with the different cases of cladding on the load-bearing insulating blocks and non-load-bearing insulating blocks. It can be noticed that the thickness played an important role on the phase shift, as well as the type of external cladding: case 1=Wall200, case 2=Wall400, case 5=Wall300 and case 3=Wall400+lime plaster; the added insulation also impacts this phase shift: case 4. The thermal diffusivity and thickness of the material particularly affected the time lag and damping factor of a wall. The lower the thermal diffusivity of its layers and the greater the thickness, the greater the time lag and damping. Cases 2 and 5 give the best phase shift, with a minimum of 12 hours.

Table 2. Rate of drying, thermal lag, and decrement factor of different configuration

	Case 1	Case 2	Case 3	Case 4	Case 5
Rate of drying	67%	31%	14%	24%	32%
Time lag (h)	7	17	5	11	12
Damping factor	0,151	0,141	0,139	0,132	0,132

4. Conclusion

In this study, a numerical simulation carried out with the WUFI software illustrated the hygrothermal behavior of walls made of biosourced concrete in different configurations. For the wall made with rapeseed concrete blocks, an external mineral coating was sufficient to ensure good hygrothermal comfort, and a thickness of 300 mm allowed to ensure a thermal resistance in accordance with the regulatory requirements. However, the study showed that the addition of insulation increased the water content in the wall.

References

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