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Hygrothermal performance of the building envelope with low environmental impact: case of a hemp concrete envelope

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Abstract This document is a case study of hemp-based materials integrated into the building envelope for African and North American's applications. The objective is to evaluate the energy performance of hemp concrete for construction in Montreal, Canada, where heating predominates and in Dori, Burkina Faso, where air conditioning predominates. The effect of thermal and hygrothermal comfort of hemp concrete, glass wool, cement block and compressed earth brick walls were simulated to quantify the benefits on overheating during the hottest months for the city of Dori and the risk of mould growth in the walls of the building in winter for the city of Montreal.

1. Introduction

Globally, the building sector alone accounts for more than 32% of final energy consumption and contributes to one third of GHG emission [1]. In order to improve the energy performance of buildings, which are responsible for nearly 50% of GHG emissions, designers and researchers need to improve the building envelope even before thinking about improving mechanical systems[2]. Indeed, the key factor in determining the energy efficiency of a building is the design and manufacturing quality of its envelope. With this in mind, current studies on building envelope components are focusing on new renewable, biobased and at the same time energy efficient materials. Hemp concrete is one of the biobased materials studied for its integration in the envelope of current buildings and in countries where the demand for heating or cooling is paramount. Indeed, Burkina Faso has a tropical climate, with very high temperatures throughout the year, especially in the city of Dori, located in northern Burkina Faso. These temperatures can reach 45 °C at certain times of the day. The majority of the average monthly temperature yearly is above 24 °C. The buildings are in cooling mode all the time, hence the interest of this study. The introduction of new environmentally friendly, energy demand-saving and cost-saving materials in Burkinabe construction will not only reduce energy demand in buildings but also allow people who cannot afford air conditioning to have buildings with more pleasant indoor temperatures. With this in mind, we are studying the possibility of integrating hemp concrete into the building envelope of the city of Dori.

2. Methodology

In this study, the simulations performed on the building envelopes are based on ANSI/ASHRAE 160 and DIN4108 standards by determining the inputs of the different properties of the wall elements and the outputs that concern the indoor temperature at 21.9°C for the city of Montreal and 24 °C for the city of Dori. The indoor humidity is set to 50% for all simulations and the limit in the walls to 80% according to ANSI/ASHRAE 160. The simulation is performed out for three successive years (01/01/2014 to 01/01/2017) for the city of Dori and the city of Montreal to have more stable and satisfactory results. Hemp properties from the studies performed in Lyon, France, by Samri [3] and in Toronto, Canada, by Dhakal [4] were used for the hemp concrete walls. The WUFI Pro 6.2 software, used to perform the simulation, is a one-dimensional hygrothermal building envelope simulation software. In this study, coupled heat-moisture transfer calculations of different walls were performed. The hygrothermal properties of the hemp concrete were manually entered into the database of the WUFI Pro 6.2 software, the data of the other materials were taken directly from the WUFI Pro 6.2 software. For the city of Dori (Burkina Fasso), three different wall assemblies were evaluated: i) cement block wall, ii) compressed earth brick wall and iii) hemp concrete wall. For the city of Montreal (Quebec, Canada), a glass wool wall, two hemp concrete walls, respectively formulated in Lyon (France) and in Toronto (Canada), were evaluated as well. Figure 1 and 2 shows the simulation steps for each wall for the cities of Dori and Montreal and wall systems.

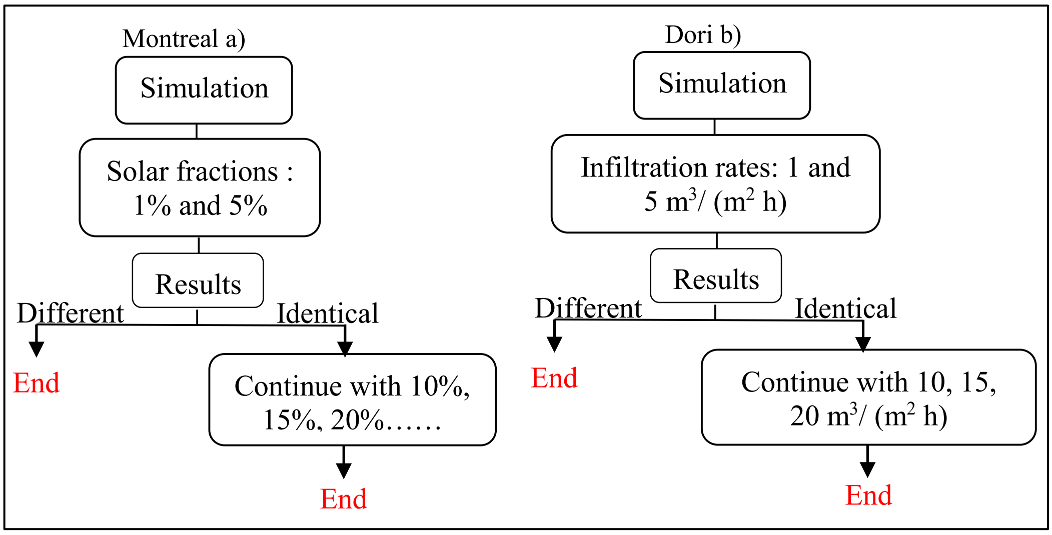

Figure 1. Simulation steps for the city

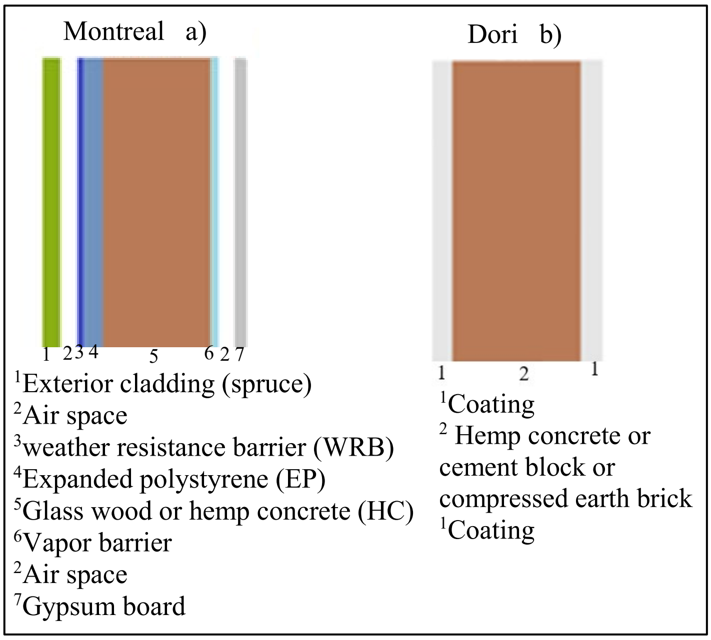

Figure 2. Wall assemblies for simulation.

3. Results

For the three different walls, the simulated temperatures, in the city of Dori, and humidity, in the city of Montreal, are respectively shown in Figures 3 and 4, more results are presented in another study [5]. The maximum internal temperatures of hemp concrete walls are 24.69°C, while those of mud brick and cement block walls respectively are 27.09 °C and 29.22°C for exterior temperatures varying between 15°C and 36 °C for some months (Figure 3).

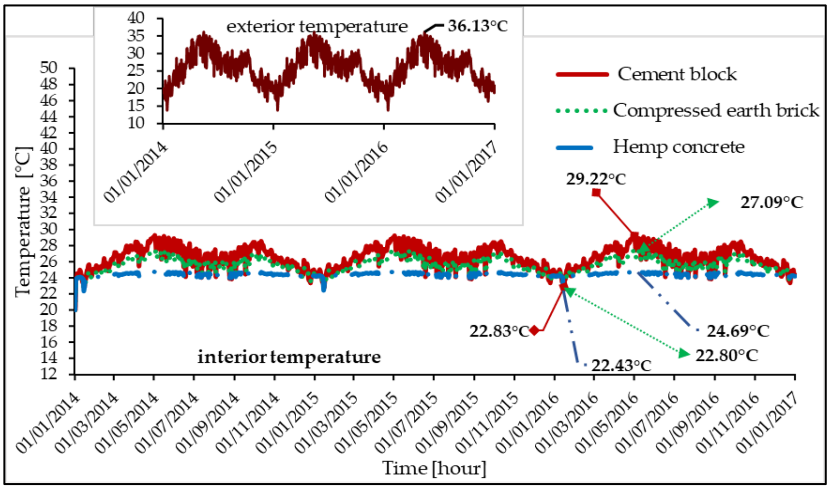

Figure 3. Exterior air temperature and interior temperature of the surface of different materials simulated for the city of Dori.

When the relative humidity exceeds 80% for a long period of time in the wall, water condensation occurs, followed by the formation of mold and mechanical damage to the building structure. The moisture content of the outer surface of the expanded polystyrene in contact with the glass wool is 100% (EP_GW) for more than two months (Figure 4), which can cause the appearance of mold. The glass wool wall has a large condensation area for an air infiltration rate of $1m^3/m^2h$. The moisture content of the exterior surface of the expanded polystyrene in contact with the hemp concrete is between 79% and 85% RH (EP_HC). The hemp concrete wall may present a risk of moisture condensation on its exterior interface for an air infiltration of $1m^3/m^2h$. For the interior environment, the interior humidity of the concrete is between 51% and 58%. These values are in agreement with the conditions stated by Samri [3] and ASHRAE 160. According to Samri [3], the interior humidity of a house is between 35% and 65% while the humidity of the interior surface of the glass wool is below 30% for more than four months per year (red curve).

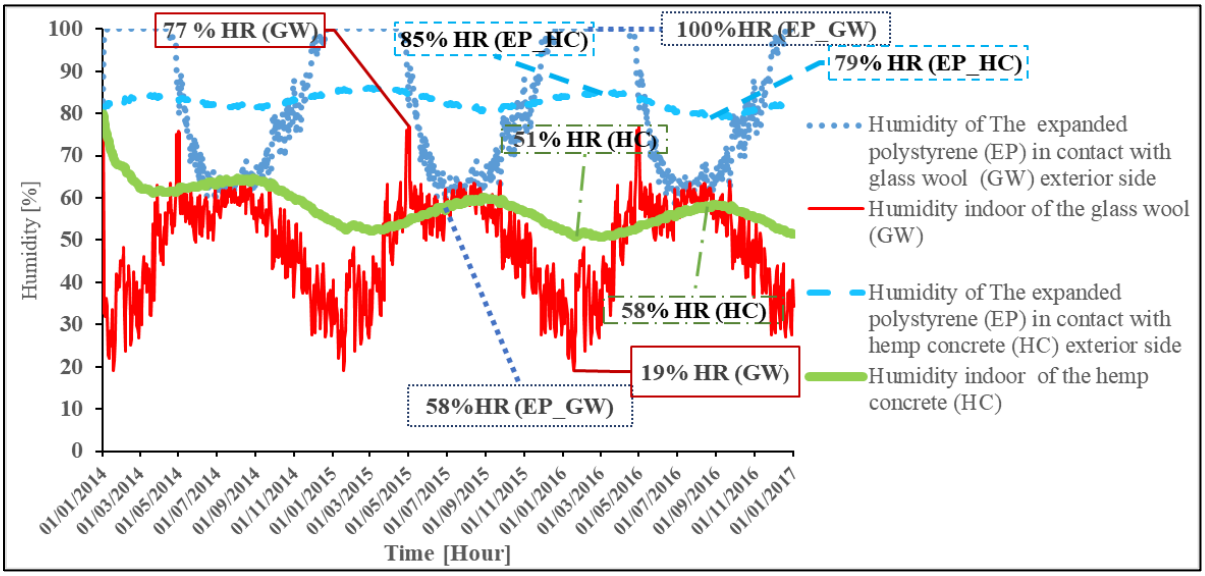

Figure 4. Humidity of the exterior surface of expanded polystyrene (EP) and interior surface of the glass wool (GW) and hemp concrete (HC) for the city of Montreal.

4. Conclusion

This paper presents some results of a case study on hemp concrete and cement block and compressed earth brick walls. Numerical simulation of the hemp concrete wall structure indicates that this material is very porous, heterogeneous, and anisotropic influencing its hygrothermal properties. However, it is a material that can store heat and moisture and can release it when needed. This latter has been found in the literature except in case of water penetration due to driving rain as the simulation results showed [5]. The results of the study of D. Bayol confirm those obtained in this study concerning the regulation of the indoor temperature [6]. They show that hemp concrete can be used in the construction of typical walls in warm countries, regardless of the fractions of solar radiation arriving on the outer surface of the walls. The introduction of hemp concrete in building construction in Burkina Faso could contribute to the reduction of energy consumption in buildings due to air conditioning and could be added to the local building materials. These results provide a first insight to show the possibility of integrating biobased materials in addition to earthen materials in construction in tropical countries instead of cement materials.

References

[1] Thibault, H.-L. and E.H. El Andaloussi, L'efficacité énergétique dans le bâtiment en Méditerranée. Futuribles, 2011. 376: p. 47-59.
[2] Commission de Coopération Environnementale, Le bâtiment écologique en Amérique du Nord : Débouchés et Défis. 2013: p. 80.
[3] Samri, D., Analyse physique et caractérisation hygrothermique des matériaux de construction: approche expérimentale et modélisation numérique. Ecole Nationale des Travaux Publics de l'Etat, 2008: p. 284.
[4] Dhakal, U., et al., Hygrothermal performance of hempcrete for Ontario (Canada) buildings. Journal of cleaner production, 2017. 142: p. 3655-3664. Normalement on devrait voir les noms de tous les auteurs
[5] Kabore, A., Modélisation hygrothermique de l'enveloppe du bâtiment avec le matériau de chanvre. 2020, École de technologie supérieure. p. 250.
[6] Bayol, D., Eco-construction -Bioclimatique - le beton de chanvre vous permet un bonus pour construire plus. 2016.