Etude de Moyens Innovants d'Amélioration des Performances Energétiques dans le Bâtiment : Expérimentation et Modélisation

Doctorant·e
TAOUIRTE Yousra

Direction de thèse
LOUAHLIA Hasna (Directeur·trice de thèse)
EL ALAMI MUSTAPHA (Co-directeur·trice de thèse)

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Rapporteurs de la thèse
CHOUKAIRY KHADIJA Université Sultan Moulay Slimane
SAADANI RACHID Université Moulay Ismail

Membres du jurys
BENHAMOU BRAHIM, , Université CADI AYYAD
CHOUKAIRY KHADIJA, , Université Sultan Moulay Slimane
EL ALAMI MUSTAPHA, , Université Hassan II de Casablanca
GOUNNI AYOUB, , Université Hassan II de Casablanca
GUALOUS Hamid, , UCN - Université de Caen Normandie
KRIRAA MOUNIR, , Université CADI AYYAD
LOUAHLIA Hasna, , UCN - Université de Caen Normandie
SAADANI RACHID, , Université Moulay Ismail

Abstract

The transition to sustainable, energy-efficient construction is a key issue in the fight against climate change and the reduction of the building sector's carbon footprint. To meet these challenges, the use of bio-sourced materials represents a promising alternative, thanks to their low environmental impact and natural thermal and hygrometric regulation properties. However, these materials still have limitations in terms of energy performance and hygrothermal stability, requiring optimization for their large-scale integration into modern construction. One of the most innovative approaches in this field involves coupling these materials with phase-change materials (PCMs), capable of improving their thermal inertia and stabilizing humidity variations. In this study, two types of bio-sourced materials were selected and analyzed: lightened earth, used as insulation, and wattle and daub, a load-bearing material. Experimental characterization was carried out to assess their thermal and hygrometric properties, revealing significant differences between the two materials. While lightened earth is characterized by its low thermal conductivity, ensuring good thermal insulation, wattle and daub has a capacity for hygrometric regulation, enabling better moisture management. The study of coupled heat and moisture transfers has highlighted the importance of heat and moisture flows in the energy performance of walls. A numerical model was developed to simulate these transfers in different wall configurations and validate experimental observations. The simulations showed that interior insulation leads to greater energy loss than exterior insulation, although it also provides better hygrometric storage, contributing to interior humidity stability and reducing the risk of condensation. The addition of PCM to the wadding modified its thermal and hygrometric properties. The PCMs helped to reduce thermal conductivity and increase heat storage capacity, thus improving the thermal inertia of the walls. At the same time, they play a key role in the absorption and restitution of humidity, limiting hygrometric fluctuations and improving interior comfort. Performance evaluation of walls incorporating PCMs revealed that their composition and layout directly influence their energy efficiency. Three wall configurations were studied. The first configuration, consisting solely of a structural layer and insulation, offers the most limited performance in terms of thermal and hygrometric regulation. The second configuration incorporates 20% PCM in the structural layer, providing a significant improvement in moisture absorption and desorption. Finally, the third configuration combines an Energain panel with MCP, a structural layer and insulation, effectively reducing thermal and hygrometric fluctuations. This last solution proved to be three times more effective than the first in terms of thermal stabilization. By combining two approaches, experimental and numerical modeling, this research contributes to the improvement of biosourced construction strategies, proposing innovative solutions to enhance the energy efficiency of buildings while promoting more sustainable and environmentally-friendly construction.