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Introduction

In France, buildings represent 24% of CO₂ emission and 44% of the final energy consumption. The trend is worsening: the buildings energy consumption increased to 30% over the last thirty years. Improving the energy efficiency of buildings is an effective solution for reducing energy consumption in this sector. The latter gives to the envelope of the building the capacity to store thermal energy and release it when necessary. Therefore, thermal storage methods in the building are one of the effective responses to reduce our dependence on fossil fuels and contribute to an energy efficiency which respects environment.

Mathematical model

The enthalpy formulation for the conduction-controlled phase change :

$$\partial H / \partial t = \nabla \cdot \text{div}(k \nabla T)$$

Total enthalpy

$$H = h + fL$$

Liquide fraction

$$f = \begin{cases} 1 & \text{if } T > T_m \\ 0 & \text{if } T < T_m \end{cases}$$

The general governing equation

$$\frac{\partial h}{\partial t} = \nabla \cdot (k \nabla T) + S$$

Source terme

$$S = -\rho L \frac{\partial f}{\partial t}$$

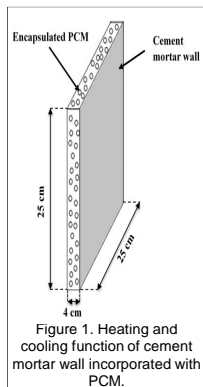


Figure 1. Heating and cooling function of cement mortar wall incorporated with PCM.

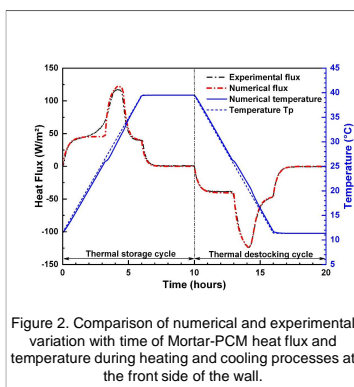


Figure 2. Comparison of numerical and experimental variation with time of Mortar-PCM heat flux and temperature during heating and cooling processes at the front side of the wall.

Abstract

Recourse to the use of phase change materials (PCM) for thermal storage is one of the most interesting energy technologies in improving the energy efficiency of buildings. The present work describes the thermal behavior of a mortar wall incorporating PCM microcapsules and physical validation of numerical results. Our numerical model is based on the enthalpy formulation. To validate the numerical model, the transient behavior of the wall incorporating PCM microcapsules is simulated in both phases of solidification and melting and has been validated using experimental data from the literature.

Results

- Our numerical model allows us to monitor the transfer of heat flow over time. The coupling of the evolution of heat flow and the liquid fraction as a function of temperature imposed on the sample surface enables us to accurately determine the end of the latent heat storage process and the end of destocking of latent heat.
- We find that the faster the heat transfer rate further augment the end of the transition cycle solid/liquid moves to high temperatures, but the profile of the heat flux is the same. This can be explained by the fact that the temperature gradient increases as the heating rate.
- On the same temperature ramp, the mortar without PCM stores an amount of energy 1,942 kJ while mortar incorporating PCM microcapsules sometimes it has stored 2,689 kJ therefore 39%. This result shows the benefit of using the integration of phase change materials in building materials.

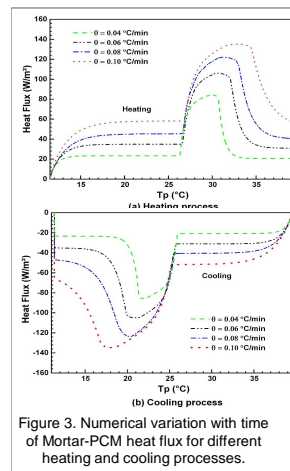


Figure 3. Numerical variation with time of Mortar-PCM heat flux for different heating and cooling processes.

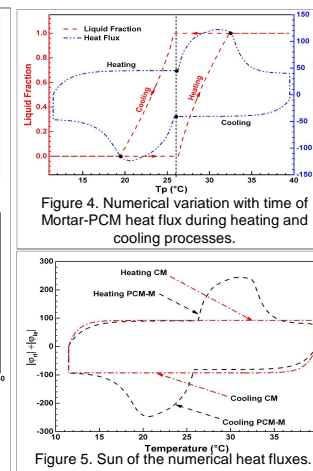


Figure 4. Numerical variation with time of Mortar-PCM heat flux during heating and cooling processes.

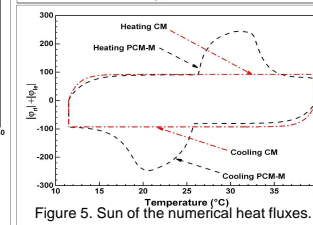


Figure 5. Sum of the numerical heat fluxes.

Discussion and Conclusions

We have presented here the thermal behavior of cement mortar incorporating PCM microcapsules. A numerical model based on the enthalpy method was developed which allows to numerically simulate the behavior of this type of composite material. Its numerical validation was obtained by comparing our numerical results with recent experimental results from the literature, and a very good agreement has been observed, be it gold Pendant heating cooling of the PCM-M.

The thermal behavior of the PCM-Mortar was studied by looking at the amount of heat stored or removed from storage in the liquid fraction, the exchanged heat flow and the rate of heating/cooling. We have shown that the rate of heating/cooling had no influence on the profile of heat flow.

This numerical study has shown the value of combining the phase change materials with conventional building materials.

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