Experimental Investigation of Thermal Behaviour of Phase Change Materials under Dynamical Thermal Effects

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ABSTRACT

Because we spend most of our time in enclosed spaces, thermal comfort of buildings rose increasingly and then energy consumption correspondingly is increased, aggravating the pollution of natural environment. Integrating phase change materials (PCM) into building walls is a potential method of reducing energy consumption in passively designed buildings. However, there is a strong need for experimental data to evaluate the capacity of PCM to stabilize the internal environment when there are external temperature changes and solar radiations: that is the purpose of our article. The material tested, a product designed by DuPont and the product looks like a flexible panel of 5mm thickness. The experiments have been carried out with two identical boxes called MICROBAT which dimensions are (0.62m, 0.62m, 0.62m). In one of the two boxes, the walls are covered with the PCM product. The external temperature is regulated by an air treatment system. The solar radiations are simulated with the help of spotlights; they enter in the box via the glass façade. The internal and external temperatures are measured with radiations shielded thermocouples. The spotlights and the air treatment system are dynamically controlled, allowing us to simulate the external thermal solicitations of a day. The comparisons concern the two boxes, one with PCM product and the other one without PCM product, submitted to the same thermal solicitations. The results show that the heat storage of the PCM covered walls effectively stabilizes the internal environment.

KEYWORDS

Phase Change Material, comfort, experiment, thermal dynamical effects.

INTRODUCTION

Today emerge a true need to solve the problems of thermal mass in the light structures. The climatic warming up announced (the heatwave of 2003 is an example) as well as the obligation to reduce the consumptions of energy to the world level, requires that the research in efficient solutions succeed quickly in commercial products that will allow each to live more comfortably, while consuming less energy and while contributing to the reduction of emission of C02 gases.

The use of PCM materials in building envelop is subject to considerable interest in the last decade, and a bibliographical review can be found in Tyagi and Buddhi (2006). Their main interest is that they can store latent heat energy, as well as sensible energy. As the temperature increases, the material change phase from solid to liquid. The chemical reaction being endothermic, the PCM absorbs heat. Similarly,

when the temperature decreases, the material change phase from liquid to solid. The reaction being exothermic, the PCM desorbs heat.

A new product has been achieved by the DuPont de Nemours Society: it is constituted of 60% of PCM, of which the temperature of fusion has been chosen to 22°C. The figure 1 shows the experimental heat capacity measured by differential scanning calorimetry system and the experimental thermal conductivity. This product is like a polymeric membrane, relatively flexible, of 5 mm thickness.

The use of PCM in the building is a relatively old concept that could be ever exploited really because of the inherent difficulties of setting such materials. The novelty in this case is constituted by encapsulation of an important quantity of active matter in a thermoplastic polymer that, after transformation in a relatively thin membrane, permits a practical installation in all type of envelope of the building.

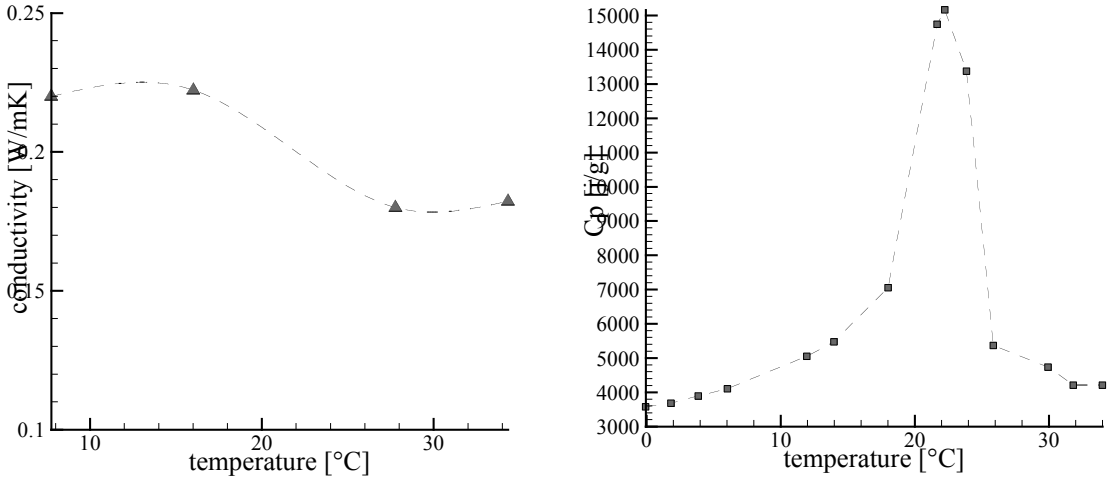

Figure 1: Measured PCM material thermal conductivity (left) and heat capacity (right)

In order to show the efficiency of this PCM made of a 5 mm thickness, we have made a comparative measurement in two test cells called MICROBAT. Very few experimental data under controlled external conditions exist. These one make it possible to be used as reference for numerical simulations, mainly in the case of solar radiations.

PRESENTATION OF THE EXPERIMENT

The experiment is composed of two test boxes which name is MICROBAT. The external dimensions of each box are 0.62mx0.62mx0.62m according to the schematic view of figure 2. Five of the box faces are identically built and the last face is composed of glass. The wall is composed of insulated material and plaster, the difference between the two boxes being the addition of the PCM material according to the figure 2.

The two MICROBAT cells are placed in a climatic chamber where the temperature is dynamically controlled. Moreover, a battery of spotlights makes it possible to simulate

an artificial sunning (gas-discharge lamps with metal halides which spectrum is similar to the sun one). With this methodology, the two test cells are subject to the same external conditions concerning the temperatures and the radiative fluxes entering via the glass face.

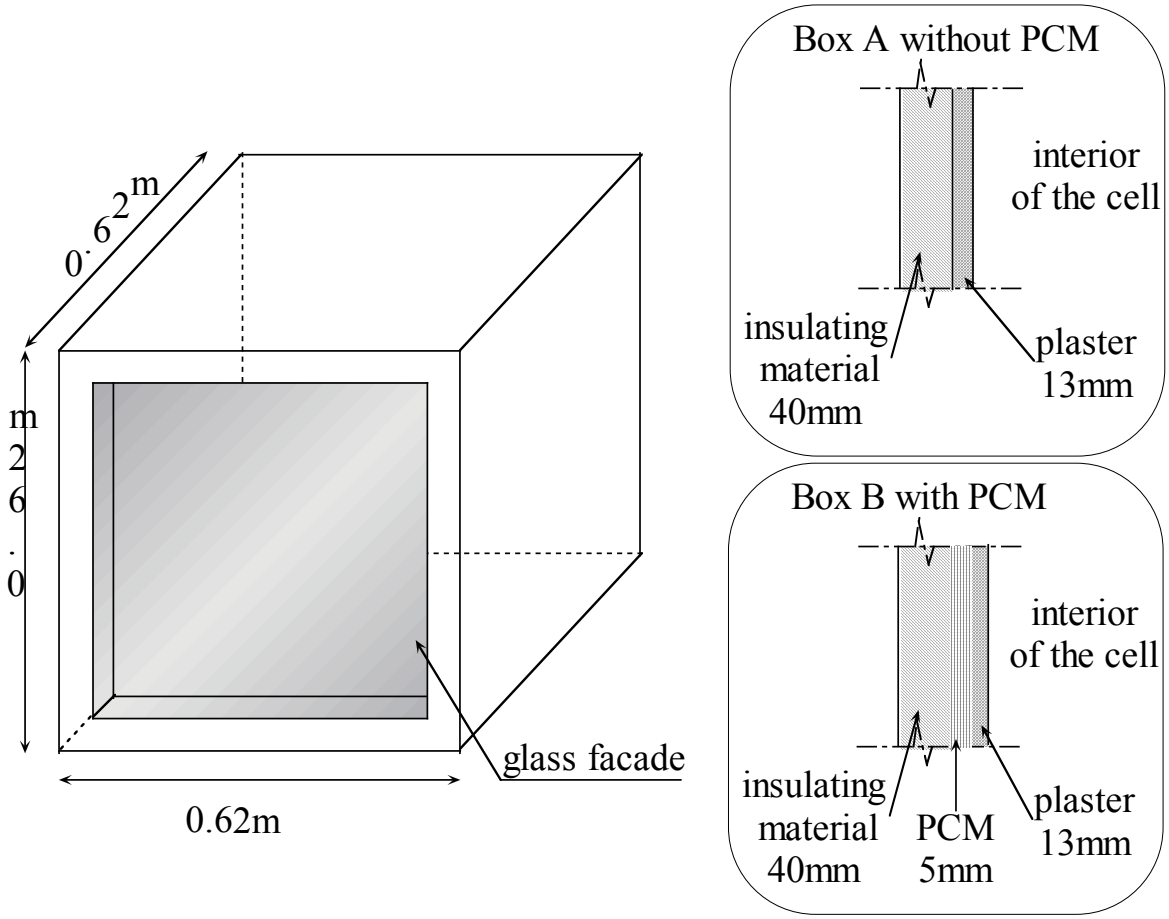

Figure 2: Description of the experimental test cells

In each box the measurement probes are the same. The temperatures are measured by the means of thermocouples; the measurements concern:

- the internal faces temperatures,
- the air temperature (using a radiative shielded thermocouple),
- the black ball temperature (in order to have the mean radiative temperature).

The picture of the figure 3 shows the interior of the test cell equipped with the various measurement probes described above.

EXPERIMENTAL RESULTS

Temperature Step

The first case concerns the study of the PCM material effect when the test cells are submitted to an external temperature step. It consists in an increase from 26°C to 35°C concerning the climatic chamber temperature.

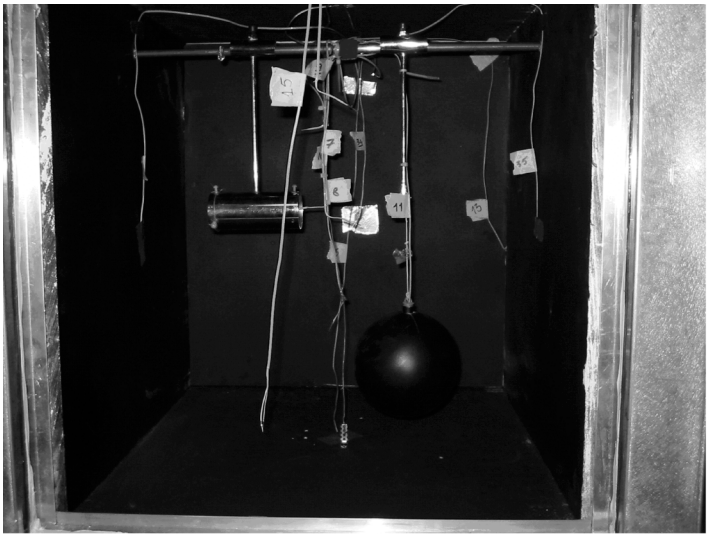

Figure 3: Measurement probes inside MICROBAT

The figure 4 shows the results obtained for the various temperatures measured. Concerning the air temperature, there is a difference of 5°C for the maximum value between the two cells, the PCM material box having a lower temperature maximum. The black ball temperature evolution shows that the wall surface temperatures are lower for the case with PCM, which is confirmed by the mean surface temperature curve: the difference between the two cases reaches 6°C for the maximum temperature value.

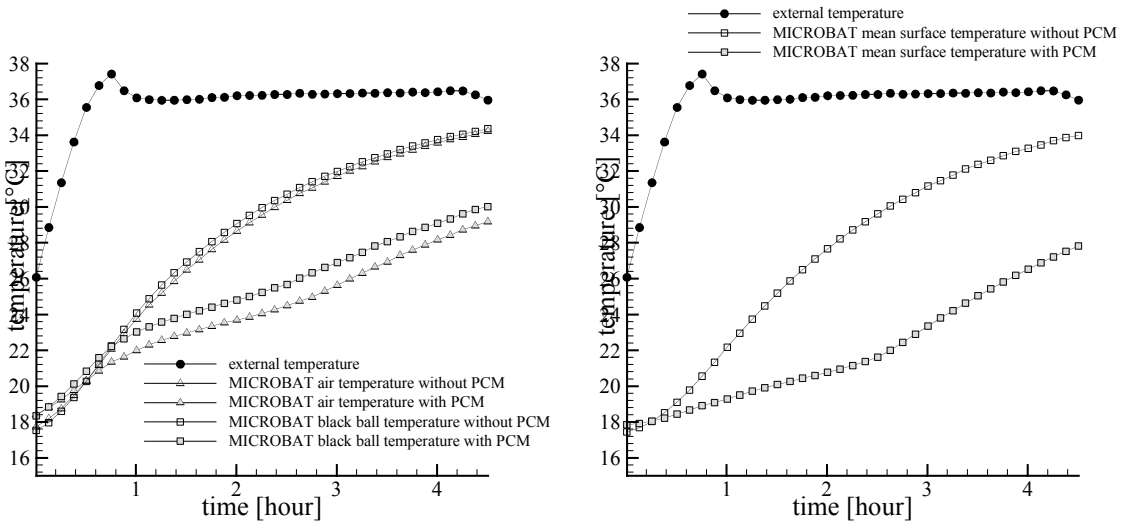

Figure 4: Results obtained for the temperature step: air volume temperature (left) and mean surface temperature (right)

This first experimental case shows demonstrates two effects of the PCM material on comfort: first, a reduction of the maximum air temperature and second, an increasing in thermal comfort due to lower wall surface temperature and than lower mean radiative temperature.

Temperature and solar radiative effects

The second test consists in coupling temperature variations with solar radiative effects. The external temperature variation is shown on figure 5. The spotlights are turned on during four hours and the radiative flux measured normally to the glass face is equal to 124W/m².

The figure 5 presents the curved obtained for the boxes air temperature, with and without PCM wallboards. The PCM effect is to reduce the maximum air temperature: the difference between the two boxes is 8°C. This reduction is mainly due to the energy stocking/desctocking effect.

In order to evaluate the PCM material energy effect, the test case is used to evaluate the difference between the two boxes concerning the energy needed to reach the measured air temperature. The total energy saving, calculated during the test presented on figure 5, is 4,2kJ which means 3.36kJ/m² of PCM walls.

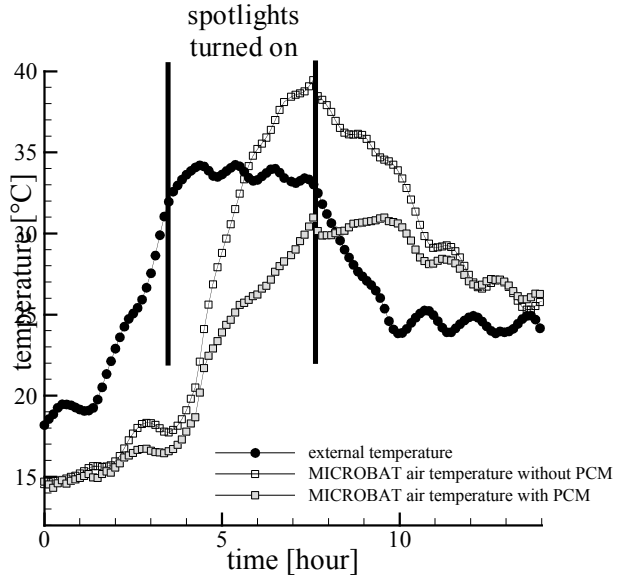

Figure 5: Results obtained under temperature and solar radiative effects

Conclusions

This paper presents experimental results concerning the effect of PCM material included in walls. The experiments are carried out in order to investigate the effects of temperature fluctuations and simulated solar radiations.

Including the PCM wallboard reduces the air temperature maximum in the room. It can be seen that the overheating effect is lower with PCM. The walls surface temperatures are reduced using PCM material, enhancing the thermal comfort by radiative effects.

In order to validate the use of PCM wallboard for light weight building envelop, further investigations are needed. Actually, a full scale test room, MINIBAT located at the

INSA of Lyon, is used to evaluate the effect of PCM. This controlled experiment allows replicating real external climatic conditions including solar radiations (Virgone and Kuznik (2006)). Numerical simulations must be carried out too, in order to investigate the total gain for real buildings. We think that the results described in this article can then be used as reference test-case for validations of numerical codes. We also need to look at modifications of the PCM wallboard position to enhance storage effects.

References

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