Effect of PCM in Internal Temperature: Experiments in the Test Room MINIBAT

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Summary: *PCM (Phase Change Materials) have been performed by DuPont de Nemours Society in flat plates of 5 mm thickness). These one have been inserted between insulation and plaster panel of the walls of our experimental cell MINIBAT.*
We propose to present the results issuing from this full-scale test room (3:1mx3:1mx2:5m). Five of the room walls are maintained at a fixed temperature. A glass façade isolate the room from a climatic chamber. The temperature in the climatic chamber is imposed dynamically to create a triangular temperature profile. A lighting allows us to simulate the sun radiative effects. The experimental set-up simulates a complete day with dynamical effects, and the climatic conditions can be reproduced. The results concern a summer day without air conditioning system and a comparison is made between the case with PCM and the case without PCM. The results show a good improvement in thermal comfort in this case of a weak thermal inertia of the dwelling.

Key words: *thermal comfort, PCM, experimental results*
Category: *Indoor climate*

1 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, require 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.
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. The figure 2 presents 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.

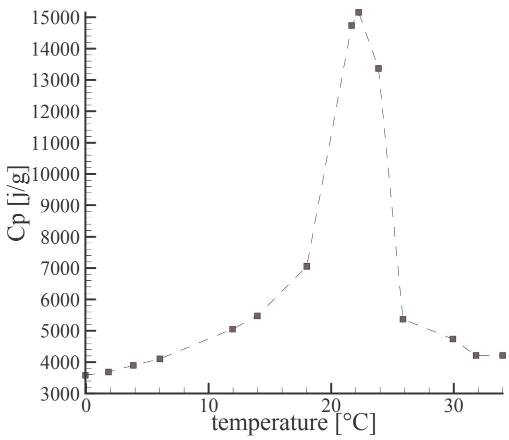


Figure 1: Experimental PCM material heat capacity measured for several temperatures

In order to show the efficiency of this PCM made of a 5 mm thickness, we have made a comparative measurement in our experimental cell MINIBAT. 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.

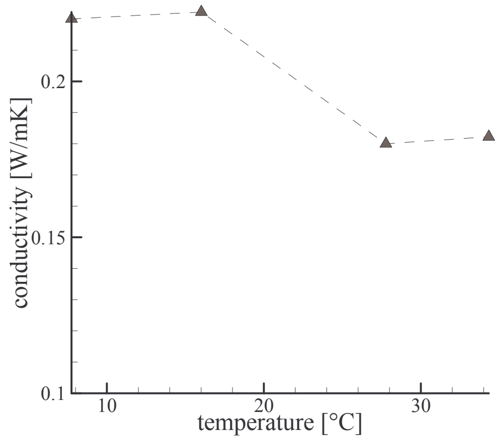
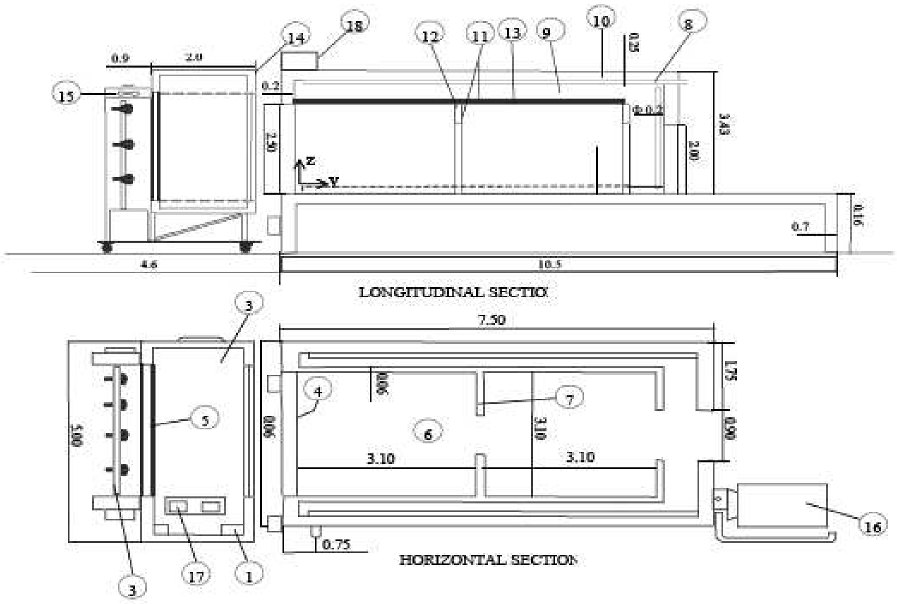


Figure 2: Experimental PCM material thermal conductivity measured for several temperatures

The first part of our article presents the experimental test cell. The experimental set-up simulates a complete day with dynamical effects, and the climatic conditions can be reproduced. The second part presents the results of a summer day without air conditioning system and a comparison is made between the case with PCM and the case without PCM. The results show a good improvement in thermal comfort in this case of a weak thermal inertia of the dwelling.

2 Presentation of test cell MINIBAT

The experimental cell MINIBAT, presented figure 3, is composed of two identical parts which dimensions are 3.10mx3.10x2.50m respectively to (x, y, z). We will use in our study only the cell 1 which will be called experimental test cell. In our studies, cell 2 is not distinct from the thermal guard because the communication door between these two entities is open. The composition of the walls is given in table I. Three of the walls (which location are given figure 4) have been covered with PCM material for the tests. The glazed façade separates the cell from a climatic chamber whose temperature is controlled and can vary between -10°C and 40°C. A thermal guard allows keeping the five others faces at a constant temperature, which can vary between 5°C and 30°C. During our tests, the thermal guard temperature was kept constant at 19°C.



(1) cold conditioner; (2) spotlights; (3) climatic chamber;
(4) simple glass; (5) double glass; (6) experimental room; (7) door;
(8) air pipe; (9) thermal guard; (10) insulated concrete;
(11) plaster plate ; (12) wood plate; (13) wood plate;
(14) insulated chamber; (15) light ventilator;
(16) thermal guard air treatment system;
(17) climatic chamber air treatment system; (18) test room air treatment system

Figure 3: Experimental test cell MINIBAT

Wall	Material	Thickness (mm)
Floor	concrete	200
Wall	plaster plate wood plate	10 50
Ceiling	plaster plate insulated material wood	10 55 25
Glazed facade	glass	10

Table I: Composition of the walls

A battery of 12 spotlights, of 1000W each one, makes it possible to simulate an artificial sunning (gas-discharge lamps with metal halides which spectrum is similar to the sun one). The spotlights are placed on 3 horizontal lines (see figure 4), each line being tilted of an angle α: for line A α=0°, for the line B α=25° and for the line C α=50°. The radiative flux thus created penetrates in the cell via the glazed wall. The control makes it possible to dynamically control the temperature of the climatic chamber as well as the entering level of radiative flux, by the means of the number of lit spotlights.

All the faces temperatures are measured using thermocouples of resolution ±0.4°C, each face with 9 thermocouples. The temperatures of the climatic chamber and the various parts of the thermal guard are measured using Pt100 probes of which the resolution is of ±0.3°C. The globe temperature is measured using a thermocouple inside a black ball centred in the experimental cell. The temperature of the air is measured using shielded Pt100 probes: the first one is positioned at the middle of the room and at a height of 85cm (the soil being at height 0cm); the second one is at a height of 170cm. The various levels of radiative fluxes are measured using a pyranometer.

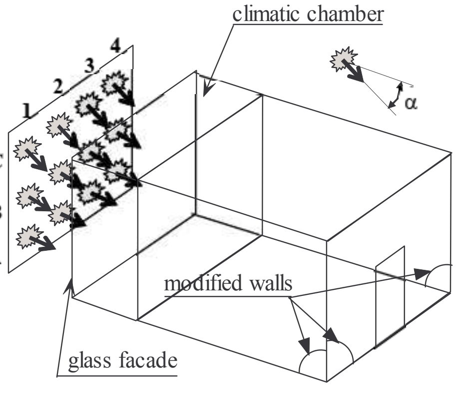


Figure 4: Isometric diagram of the climatic chamber with the projectors and location of the 3 modified walls

The acquisition of the various parameters is done by the means of a multiplexer-multimeter connected to a PC. The control of the whole of the apparatuses, except control, is made using software LABVIEW. The time step chosen between two series of measurement is 10mn and the duration of each test is three days.

The tests presented in this article correspond to summer tests, for which the temperature of the climatic chamber varies between 15°C and 30°C.

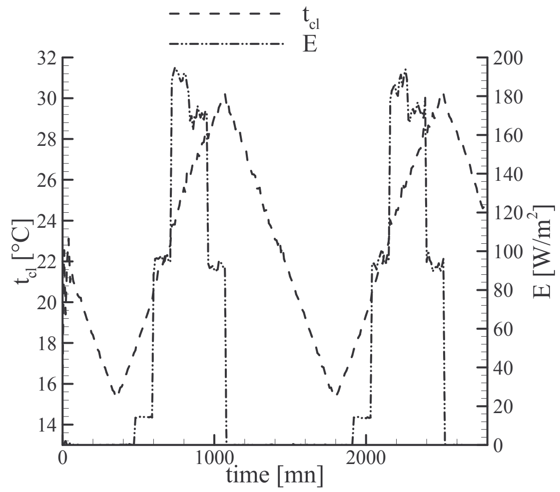


Figure 5: Experimental conditions for the summer case

The climatic chamber temperature (t_{cl}) and the radiative fluxes (E) are shown for the two test cases on figures 5. We can notice the good repeatability of the controls of the climatic chamber temperature and lighting of the projectors. With regard to the latter, it is necessary to notice inertia during their lighting and their extinction, illustrated by discontinuities of values during measurements.

In conclusion, the experimental methodology permits us to obtain a complete boundary conditions description and the temperature inside the test cell, all the values being dynamically measured.

3 Results

The results concern the different temperature mesured during the two experiments. The figure 6 shows the evolution of the air temperatures for the two different height positions (85cm and 170cm). The differences between the two cases tested concern mainly the temperature evolution maximum and minimum With PCM, the temperature maximum is about 32°C when without PCM this value is about 36°C. Concerning the temperature minimum, the differences between the two cases is about 1°C, the PCM case being higher than without PCM (20°C with PCM and 19°C without PCM). The gain concerning the air temperature is clearly shown for the summer case.

It is interesting to note that a thermal stratification exists in the case without PCM (a difference of 1°C for the temperature maximum between the two probes) which doesn't happen for the PCM case. This is mainly due to higher natural convection effects because of the lower vertical walls temperatures. This improve the thermal comfort and has never been observed before.

The figure 7 shows the evolution of the globe temperature measured with a thermocouple in a black ball. The main difference concern the temperature maximum wich is lower of about 2°C for the PCM case. This measure shows that the PCM material enhanced the thermal comfort for which the globe temperature is an indicator.

4 Discussion and conclusion

In this article experiments are carried out in a test cell and in controlled external conditions with solar contributions which is new in the literature.

According to the comparisons presented in this paper, the PCM composite walls allow to enhance the thermal comfort of the room in the summer case. The maximum air temperature is decreased by about 4°C and the minimum increased by about 1°C. This free regulation is obtained only by using PCM material. Another notable effect is the natural convection enhancement allowing to have a better mixing concerning the air in the room and decreasing the thermal stratification.

The globe temperature evolution confirms the enhancement of the thermal comfort because of the PCM used.

Further investigations are needed in order to have more results concerning various external conditions. These results will be used to validate numerical codes for the prediction of energy consumptions of such systems.

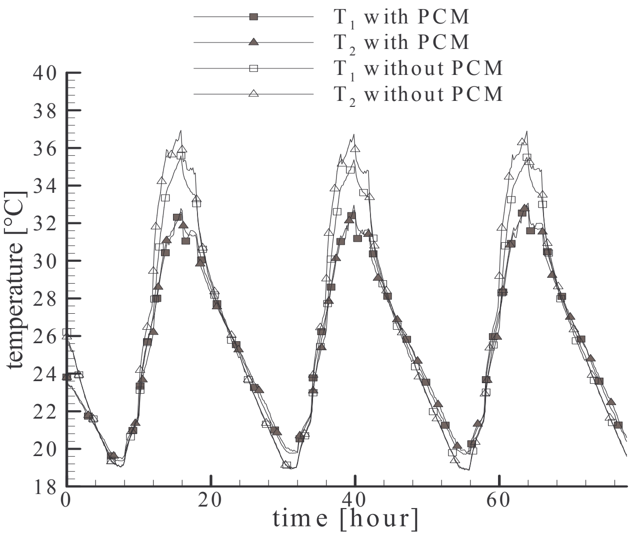


Figure 6: Room air temperatures T_1 and T_2 measured respectively at a height of 85 cm and 170 cm

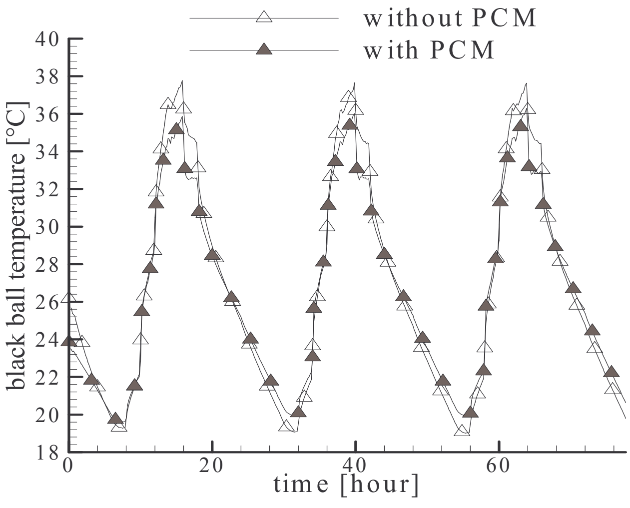


Figure 7: Globe temperatures for the cases tested