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# Experimental study of using PCM in brick constructive solutions for passive cooling

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ABSTRACT

This work presents the results of an experimental set-up to test phase change materials with two typical construction materials (conventional and alveolar brick) for Mediterranean construction in real conditions. Several cubicles were constructed and their thermal performance throughout the time was measured. For each construction material, macroencapsulated PCM is added in one cubicle (RT-27 and SP-25 A8). The cubicles have a domestic heat pump as a cooling system and the energy consumption is registered to determine the energy savings achieved. The free-floating experiments show that the PCM can reduce the peak temperatures up to 1 °C and smooth out the daily fluctuations. Moreover, in summer 2008 the electrical energy consumption was reduced in the PCM cubicles about 15%. These energy savings resulted in a reduction of the $CO_2$ emissions about 1–1.5 kg/year/m$^2$.



## 1. Introduction

Energy consumption for thermal comfort in buildings has grown a lot in few years because of increasing users demand for comfort conditions and the associated market penetration of more cooling systems. This increase of energy consumption and the increase of the fuel price and $CO_2$ emissions are promoting a new policy of more sustainable buildings.

Phase change materials (PCM) have been studied for thermal storage in buildings since before 1980 [1–5]. Those systems provide a higher thermal inertia to the building that, combined with thermal insulation can reduce the energy consumption of the building by absorbing the heat gains and reducing the heat flow. During daytime the PCM can absorb part of the heat through the melting process, and during night the heat is released by the solidification of the PCM, resulting in a lower heat flow from outdoors to indoors.

In first step, development and testing were conducted for prototypes of PCM wallboard and PCM concrete systems to enhance the thermal energy storage (TES) capacity of standard gypsum wallboard and concrete blocks, with particular interest in peak load shifting and solar energy utilization. Several researchers have investigated methods for impregnating gypsum wallboard, concrete and other architectural materials with phase change materials [6,14]. Different types of PCMs and their characteristics are described. The manufacturing techniques, thermal performance and applications of gypsum wallboards and concrete blocks which have been impregnated with phase change materials as well as concrete with microencapsulated PCM have been presented and discussed previously [7–12].

All those systems used microencapsulated PCM, presenting some important problems that reduced the chances to reach a commercial state. Such problems are the high investment cost and the degradation of the mechanical properties of the material. In this work the use of macroencapsulated PCM is considered, reducing the investment cost and overcoming the mechanical problems. Using macroencapsulated PCM avoids the over cost of the microencapsulation process and does not present any mechanical problem since the material is not integrated in the construction material. The encapsulation system is resistant by itself and does not reduce the strength of the wall.

Although many research has been done studying the incorporation of PCM in several construction materials, almost no work has been carried out on brick constructive solutions, widely used in Mediterranean countries. Alawadhi [13] studied numerically the introduction of PCM in bricks, obtaining good results and a theoretical reduction of the heat flux entering the indoor space in summer. However, the model used was not validated. No experimental work has been done up to the date and no real data is available for this kind of constructive solution. Therefore, this study can provide very useful data for demonstrating the concept and contributing to the integration of PCM in typical Mediterranean construction.

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**Fig. 1.** Demonstration cubicles in Puigverd de Lleida.

In this work macroencapsulated PCMs were tested with typical Mediterranean constructive solutions. A new experimental set-up consisting of several cubicles (using conventional brick and alveolar brick) was built. Macroencapsulated PCM is added in one conventional brick and in one alveolar brick cubicle (CSM panels, containing RT-27 and SP-25 A8, respectively) and the thermal behaviour of the cubicles is studied.

Moreover, all the previous works found in the literature were either theoretical or they did not measure the real energy savings achieved by the PCM. Only the temperature profile was analyzed, presenting estimations of the energy savings based on the temperature difference achieved by the PCM. However, these estimations did not consider the dynamic schedule and operation of the building and its HVAC system. In this work a step further is done and a heat pump is installed in the cubicles to measure the real energy consumption. These results will provide real data for the energy savings and to determine the reduction of $CO_2$ emissions considering the dynamics of the building.

## 2. Experimental set-up

Five different cubicles were built using different Mediterranean typical constructive solutions. To be able to compare the results obtained with the concrete cubicles studied previously [7], the internal dimensions of the new cubicles are the same as the old ones (2.4 m × 2.4 m × 2.4 m). The cubicles are located in Puigverd de Lleida (Fig. 1), which represents a typical Spanish continental climate, with cold winters and warm and relatively dry summers. The important temperature oscillations during day and night make it very suitable for the PCM operation since the material can be melted during the day and solidified during the night. The PCMs tested were designed for cooling applications.

### 2.1. Brick cubicles

The walls consist of perforated bricks (29 cm × 14 cm × 7.5 cm, Fig. 2) with an insulating material (depending on the cubicle) on the external side, an air chamber of 5 cm and hollow bricks. The roof was done using concrete precast beams and 5 cm of concrete slab. The insulating material is placed over the concrete, protected with a cement mortar roof with an inclination of 3% and a double asphalt membrane.

Three cubicles using different insulating solutions are compared:

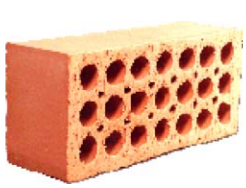

**Fig. 2.** Hollow brick.

**Table 1**
Physical properties of polyurethane.

| Property | Polyurethane |
|---|---|
| Thermal conductivity (W/m K) | 0.028 |
| Density (kg/m$^3$) | 35 |

1. Reference cubicle (Reference): This cubicle has no insulation.
2. Polyurethane cubicle (PU): The insulation material used is 5 cm of spray foam polyurethane (Table 1).
3. PCM cubicle (RT27 + PU): The insulation used is again 5 cm of spray foam polyurethane and an additional layer of PCM. CSM panels (Fig. 3) containing RT-27 paraffin (Table 2) are located between the perforated bricks and the polyurethane (in the southern and western walls and the roof).

Figs. 4–6 show the demonstration cubicles built with brick, polyurethane, and RT-27 PCM and polyurethane, respectively, during construction.

### 2.2. Alveolar brick cubicles

Two different cubicles were built with alveolar brick:

1. Reference cubicle (Alveolar): The alveolar brick (Fig. 7 and Table 3) has a special design which provides both thermal and

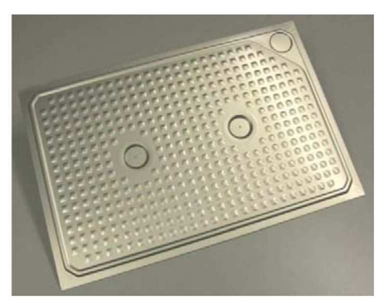

**Fig. 3.** CSM panel containing the PCM.

**Table 2**
Physical properties of PCM.

| Property | RT-27 | SP-25 A8 |
|---|---|---|
| Melting point (°C) | 28 | 26 |
| Congealing point (°C) | 26 | 25 |
| Heat storage capacity (kJ/kg) | 179 | 180 |
| Density (kg/L) | | |
| Solid | 0.87 | 1.38 |
| Liquid | 0.75 | |
| Specific heat capacity (kJ/kg K) | | |
| Solid | 1.8 | 2.5 |
| Liquid | 2.4 | |
| Heat conductivity (W/m K) | 0.2 | 0.6 |