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APPLICATION OF LATENT HEAT THERMAL ENERGY STORAGE IN CEMENT MORTARS

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Using Phase Change Materials (PCM) for thermal energy storage is an effective solution both for more efficient use of energy and its consumption reduction. The needs of heating and cooling systems can be reduced with the adequate use of PCM. The objective of this study was the development of new interior cement mortar with thermal enhanced properties by incorporating microencapsulated PCM. The compositions were fixed in order to fulfill the mechanical properties standard requirements. Thermal performance in Passy's test cells was carried and showed that the use of a cement mortar with PCM microcapsules contributes to easily obtain the comfort temperature.

1 INTRODUCTION

One of the main causes of energy‘s consumption increase in buildings is related with higher comfort needs by the users. In developed countries, lightweight construction has been used as a way to reduce the environmental impact of natural resources exploitation for building materials use. However, most of the comfort needs have been satisfied by the use of air conditioning apparatus.

The importance of energy's consumption and CO_2 emissions reduction, has led, in the last twenty years, to several research programs that aim energy conservation by thermal storage, through new materials and building techniques. Focusing on materials development, one of the major fields of study has been phase change materials (PCM) that have been used both for solar passive storage, integrated in construction materials and as cooling or heating medium in active systems such as air conditioners[1].

PCM are active materials that can modify the ambience temperature. These materials can store thermal energy during the phase change process. This energy is called latent heat. PCM have been incorporated in construction elements for more than 30 years now. Major applications of PCM in buildings include systems for walls, floors, ceilings and windows[2,3].

Micro-encapsulation makes possible the incorporation of PCM into conventional building materials with the advantages of easy application, good heat transfer and no need of protection against destruction. The diameter of the microcapsules can change between 0.02

and 2 mm. The protecting shell is usually an organic polymer.

In Portugal, high thermal mass buildings are still very common, as part of the construction method mainly for dwellings. These buildings are usually plastered with cement or gypsum. However, temperature fluctuations can be high mainly during the heating season. Therefore the idea of incorporating PCM seemed to be a way to save indoor energy[1,3,4].

By choosing the adequate phase transition temperature of the PCM, one can, to some extent, thermo regulate indoor environment, contributing not only to a decrease on energy consumption but also to peak shift the heating loads to periods when energy is less expensive.

Zhou et al.[5] performed a simulation of a direct gain passive solar house in Beijing that incorporated PCM plates as walls and ceiling interior lining. In their study, during the heating season, an external heat source was used in order to maintain indoor temperatures above 18 °C. Results showed that up to 47% energy could be saved during the peak hours with a total of 12% energy saved during winter.

Schossig et al.[6] conducted a study where they used gypsum plaster for interior lining in lightweight (gypsum plasterboard, wooden slats with insulation and 14 cm thick polyurethane foam) test buildings facing south. In this study, two different plaster systems were tested: a 40%-wt. PCM, 6 mm thick plaster and a 20%-wt. PCM, 15 mm thick plaster. Results showed a 4 °C difference in the maximum temperature, with a time delay of 1 hour.

2 EXPERIMENTAL PROGRAMME

The experimental programme for the complete research work was planned to evaluate both mechanical and thermal properties. The programme was divided into two main stages. The PCM microencapsulated is presented as a group of particles composed by paraffin wax involved by a polymethylmethacrylate polymer. It has a particle size distribution between 1.1 and 10.5 μm and average size of 6.2 μm, presented a melting temperature around 23 °C (Fig. 1).

The first experimental stage was the evaluation of the mechanical properties of the cement-PCM mixture. The mortar used was a commercial one, pre-composed with white cement (CEM II 52,5 N), fine aggregate and adjuvants. For the flexural and compressive tests the PCM microcapsules incorporation were 0, 20 and 30 % by weight of the cement mortar. The tests were made at 7 and at 28 days. Three prismatic specimens with 40x40x160 mm^3 were cast for each age and PCM microcapsules incorporation. The flexural and compressive tests were made following the standard EN 1015-11[7]. In order to determine the quantity of water necessary to maintain the same consistency of the different mortars the flow table test was used[8].

For the reference mortar (0 % PCM) and with the water quantity recommended by the supplier of the mortar (18,3 % by weight) the flow was 207 mm. The totality of the results is presented in Table 1. The quantities of water significantly increased with the incorporation of PCM microcapsules. These are due to the smaller size of the microcapsules compared with the size of the other components of the mortar.

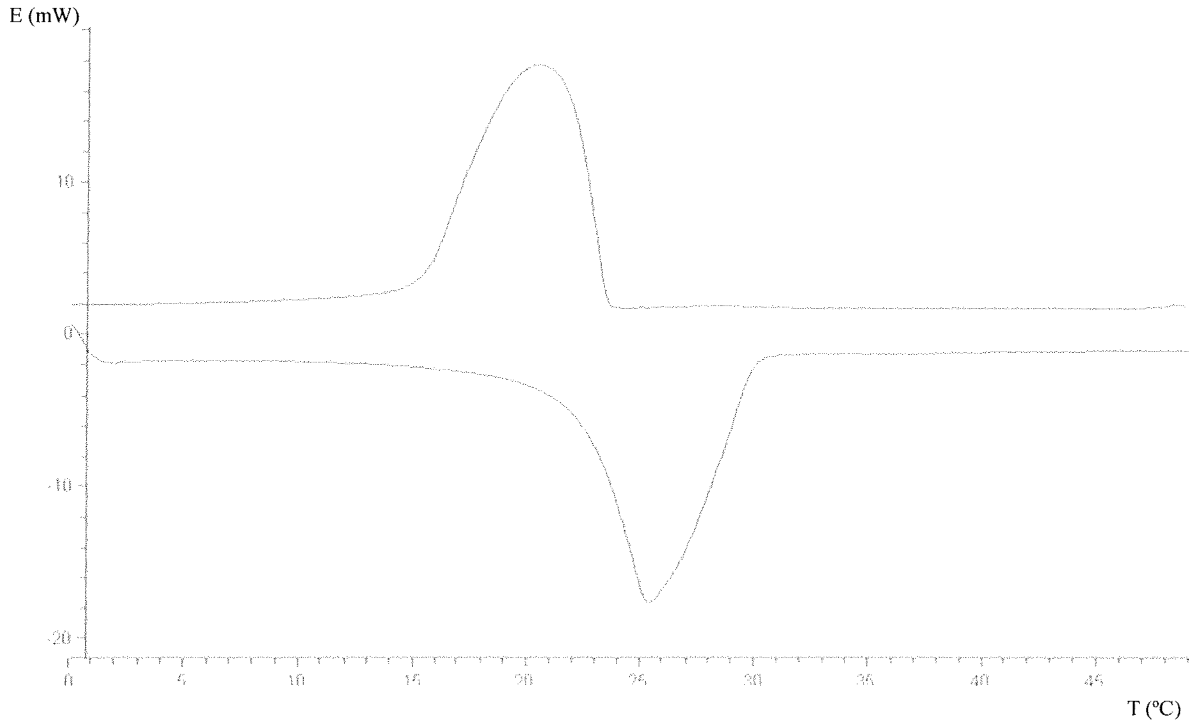

Figure 1: Results of DSC of microcapsules of PCM

PCM microcapsules (%)	0	20	30
Water (%)	18,3	37,5	55,2
Flow (mm)	207	215	206

Table 1: Quantities of water

The results of the flexural and compressive strengths of the mortars are showed in Figures 2 and 3. The flexural and compressive strengths of the mortars significantly decreased with the incorporation of PCM microcapsules. These are due to higher quantity of water and smaller cement content compared with reference mortar. With the standard EN 998-1[9] is possible the classification of the mortars taking into account the compressive strength at 28 days. The reference mortar (0 % PCM) and the mortar with 20 % PCM are from class CSIII, while the mortar 30 % PCM is from class CSII.

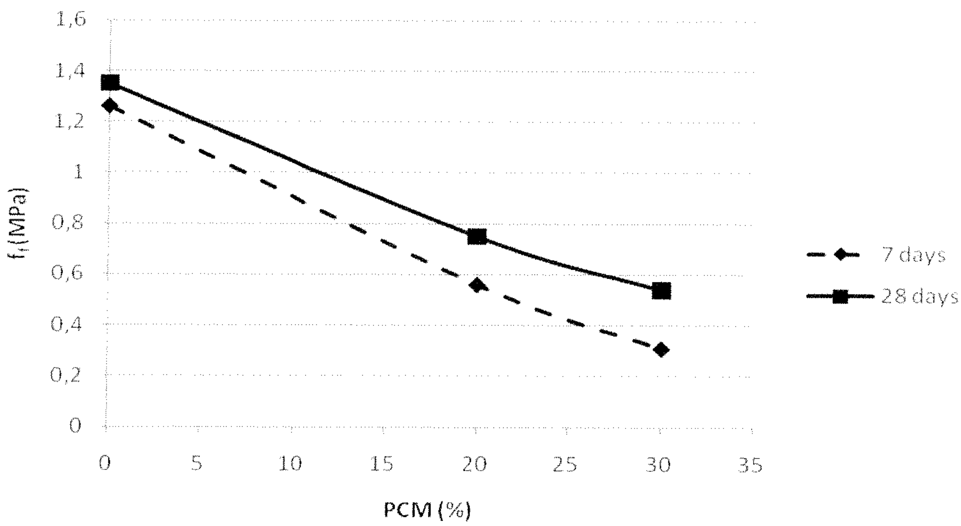

Figure 2: Influence of content of PCM microcapsules on flexural strength of mortars

The second stage of the experimental campaign consisted in the comparison between the thermal performance of two rooms, in a Passy's test cell, of the selected plaster and the commercial cement mortar. The mentioned cell (Fig. 4), located at the Building Physics and Technology Laboratories of Civil Engineering Department at the University of Minho in Guimarães, north to south oriented, is 4.24 m length, 2.58 m wide and 3 m high and presents the following constructive characteristics: south façade made of a hollow polycarbonate sheet (10 mm thick) mounted in a wood frame (2.83 m high and 2.03 m wide) and glass door (55 cm wide) mounted in a wood frame; inner north wall made of cement bonded particle board (12 mm thick) and expanded polystyrene (10 cm thick). In this wall, two particleboard doors (2.20 m high and 59 cm wide) allow access to the room; inner west wall made of adobe bricks and expanded polystyrene (20 cm thick); inner east wall made of mortar layer (2 cm), hollow brick (11 cm), mortar layer (2 cm) and expanded polystyrene (20 cm thick); floor made of cement bonded particle board (12 mm thick), air box (10 cm), of cement bonded particle board (19 mm thick) and expanded polystyrene (25 cm thick); roof made of particleboard (5 cm thick), cement bonded particle board (12 mm thick) and expanded polystyrene (30 cm thick).

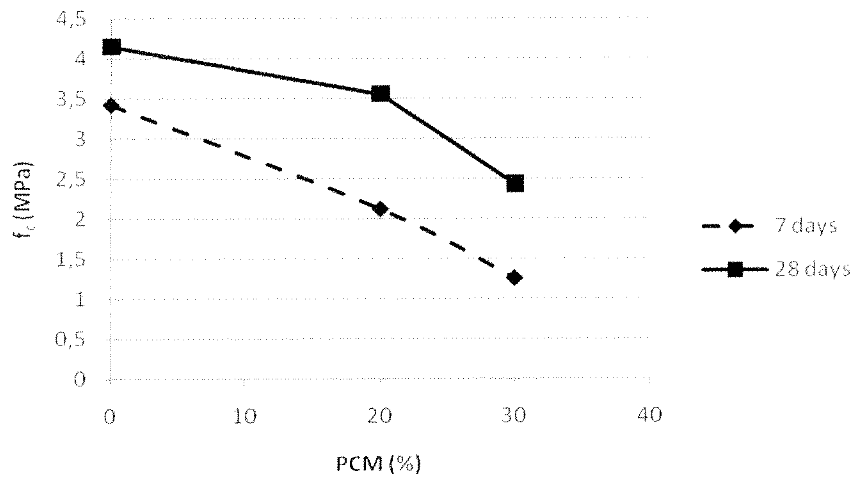

Figure 3: Influence of content of PCM microcapsules on compressive strength of mortars

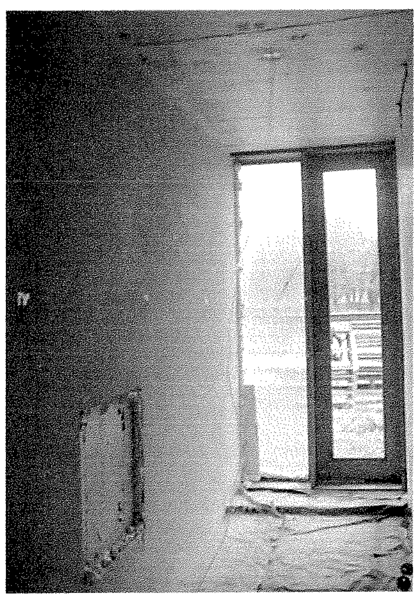

Figure 4: West room of the Passy's test cell.

A hollow ceramic brick (11 cm thick) wall was built, dividing the cell in two rooms (east and west). To allow plastering, instrumentation and maintenance of the east room, an aperture was left (this opening was then closed with a double layer of expanded polystyrene 5 cm thick plates and polyurethane foam). Each surface of the wall was then covered manually with cement mortars. In the West façade cement mortar with 20 % of PCM microcapsules was used as the solution in study (Fig. 4), while in the East façade cement mortar was used as Reference solution. Both rooms were instrumented with temperature sensors and thermocouples were installed in the different places in order to give the ambiance temperature, the superficial temperatures on the walls and the interior temperatures in the walls. Monitoring was carried between the 3rd and the 23th October, 2009.

The three coldest days occurred between the 20th and the 22nd October, 2009. During this period the interior temperature in the reference room changed between 14°C and 17°C, while the interior temperature in the PCM room changed between 14°C and 22°C. The biggest difference between the two rooms occurred at the 22nd October, 2009 and was 6°C more in the PCM room.

The three warmest days occurred between the 5th and the 7th October, 2009. During this period the interior temperature in the reference room changed between 20°C and 22°C, while the interior temperature in the PCM room changed between 20°C and 23°C. The biggest difference between the two rooms occurred at the 7th October, 2009 and was 1°C more in the PCM room.

3 CONCLUSIONS

The incorporation of PCM microcapsules in cement mortars decreases the compressive and flexural strengths. However, with the incorporation of 20 %-wt. it was possible that the obtained cement mortar maintained the class strength of the reference mortar (0 % PCM microcapsules).

The results obtained in Passy's test cell showed that the presence of PCM microcapsules bring the interior temperature, during some periods, to the level of comfort without any heating or cooling system.

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