Proceedings of the 6th Asian Symposium on Polymers in Concrete
Shanghai, China, October 29-30, 2009

Study of a Cement Mortar with Incorporation of PCM Microcapsules

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ABSTRACT

The incorporation of phase change materials (PCM) in construction materials contributes to the reduction of the energy consummation in the buildings. The needs of heating and cooling systems can be reduced with the adequate use of PCM. The benefits to the comfort inside buildings appear during the change of phase of the PCM. The transferences of energy that occur during the transitions solid-liquid and liquid-solid are generally the most used to help the acclimatization of the buildings. For that reason the PCM must be microencapsulated. The exterior of the microcapsules is made with a polymer. This study presents the mechanical properties of a cement mortar with the incorporation of 20%, 30% and 40% of microcapsules of PCM. The aim was to find the maximum percentage to be incorporated in a cement mortar to use in the interior coating of walls. With the incorporation of the PCM microcapsules the strength class of the reference mortar (0%) must be maintained. The results of the first series of tests showed an important decrease of the mechanical strengths and it was not possible to maintain the strength class of the mortar with PCM microcapsules. In the second series of tests the composition of the mortar was changed by the addition of 10% of cement CEM II 52,5. The results showed that incorporations of 20% and 30% of PCM microcapsules decrease the mechanical strengths but the values obtained are still inside the requisites of the European standard. The incorporation of 20 % of PCM microcapsules was possible maintaining the same strength class of the reference mortar.

KEYWORDS: microcapsules of PCM, cement mortar, energy efficiency.

1 INTRODUCTION

Phase change materials (PCM) are active materials that can modify the ambiance temperature. PCM 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 in walls, floor, ceiling and window [1].

Micro-encapsulation makes it possible to integrate PCM into conventional building materials with the advantages of easy application, good heat transfer and no need for protection against destruction. The diameter of the microcapsules can change between 0.02 mm and 2000 μm. The protecting shell is usually an organic polymer.

The use of PCM in gypsum plasters has been more investigated. For example Schossig et al [2] used a PCM with a melting range temperature of 24-26 °C. A plaster with 40% weight PCM and 6 mm thickness and another with 20% weight PCM and 15 mm thickness were studied. Results showed, in both cases a decrease in the higher temperature of around 4 °C with a delay in the maximum temperature of 1 hour. Gypsum plasters incorporating PCM have also been study by Silva et al [3]. Commercial gypsum plaster has been mixed with 25%-wt. micro-encapsulated PCM with a melting temperature around 20 °C. Results showed a reduction of about 30% in the maximum temperatures and an increase of about 10% in the minimum temperatures.

2 EXPERIMENT

2.1 Series 1

The mortar used was a commercial one, pre-composed with white cement (CEM II 52,5 N), fine aggregate and adjuvants. The PCM, a technical grade hexadecane paraffin wax, microencapsulated in a melamine-formaldehyde resin, with an average particle size between 20～30 μm, presented a melting temperature around 20 °C and a latent heat of fusion of 140 kJ/kg.

For the first series of flexural and compressive tests the PCM incorporations were 0, 20 and 40 % by weight in the cement mortar. The tests were made at 7 and at 28 days. Three prismatic specimens with 40×40×160 mm^3 were cast for each age and PCM incorporation. The flexural and compressive tests were made following the standard EN 1015-11 [4]. In order to determine the quantity of water necessary to maintain the same consistency of the different mortars the flow table test was used [5].

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 199 mm. The totality of the results is presented in Tab. 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.

Table 1. Quantities of water –Series 1

PCM (%)	0	20	40
Water (%)	18,3	33,6	38,7

The results of the flexural and compressive strengths of the mortars are showed in Fig.1 and Fig.2. 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 [6] is possible the classification of the mortars taking into account the compressive strength at 28 days. The reference mortar (0 % PCM) is from class CSIII, while the other mortars (20 and 40 % PCM) are from class CSI. As the strength class decreases significantly in the next series the cement content will be increased 10 %.

2.2 Series 2

In this series the only difference, talking about materials, was the use of 10 % more of cement content by weight of the cement mortar. As in the previous series the quantities of water were evaluated using the flow table test [5]. The results of the quantities of water are presented in Tab.2. Another changing was the consideration of a maximum of PCM incorporation of 30%. After the results of the first series, it became obvious that the incorporation of 40% was very ambitious.

The results of the flexural and compressive strengths of the mortars are showed in Fig.3 and Fig.4. With the

increase of the cement dosage the flexural and compressive strengths increased significantly compared with series 1 of tests. The average of increase for compressive strength was about 1 MPa at 7 days and about 3 MPa at 28 days. These results showed that reference mortar (0% PCM) and mortar with 20 % of PCM incorporation are from the strength class CSIII [6]. The mortar with 30% of PCM incorporation is from strength class CSII.

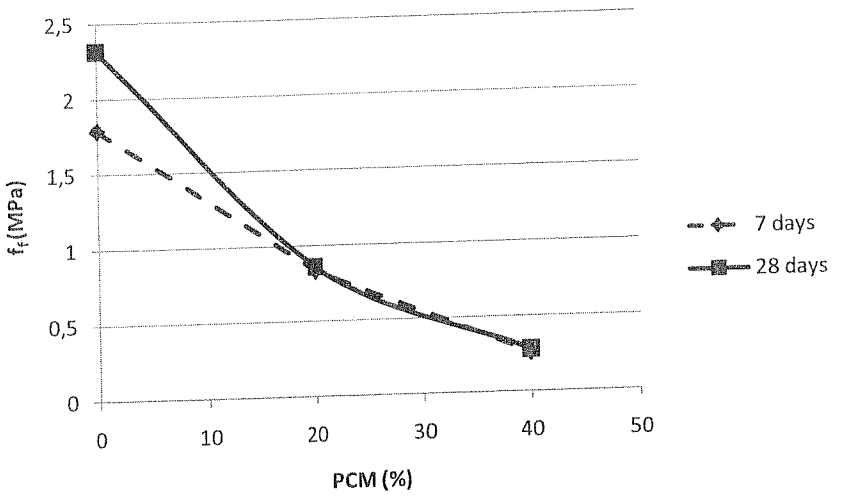

Figure 1. Influence of PCM content on flexural strength of mortars – Series 1

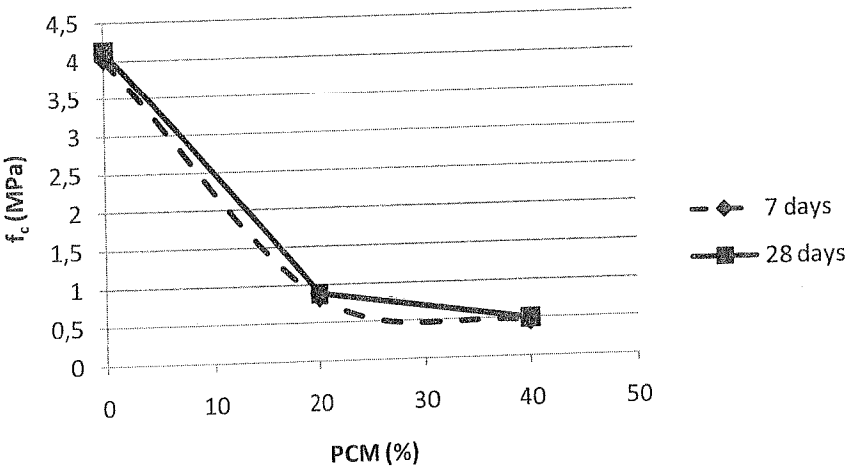

Figure 2. Influence of PCM content on compressive strength of mortars – Series 1

These series was completed with adhesive tests made in accordance with standard EN 1015-12 [7] (Fig. 5). Tab.3 shows the results obtained at 28 days. Four tests were made for all incorporations of PCM. The adhesive strengths decrease with the incorporation of PCM microcapsules. However, the value 0.1 MPa obtained for 20% and 30 % of incorporation is above the limit usually consider for plastering mortars.

Table 2. Quantities of water – Series 2

PCM (%)	0	20	30
Water (%)	18,3	26,7	30,7

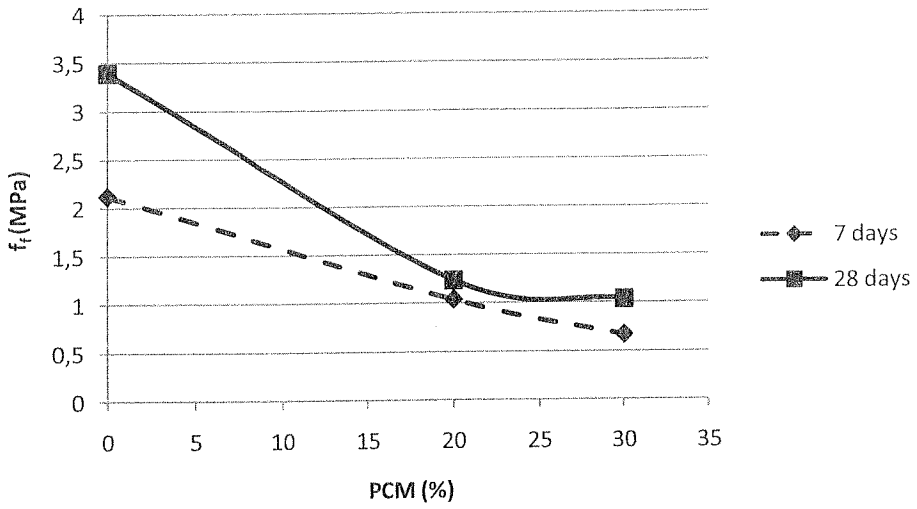

Figure 3. Influence of PCM content on flexural strength of mortars – Series 2

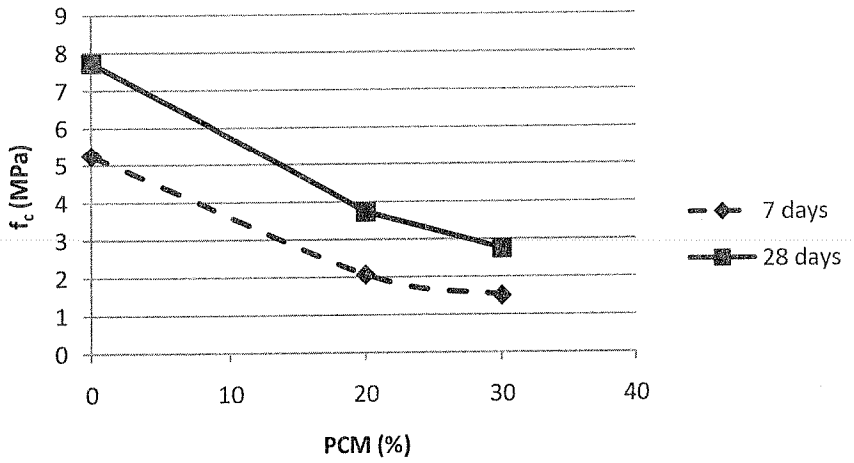

Figure 4. Influence of PCM content on compressive strength of mortars – Series 2

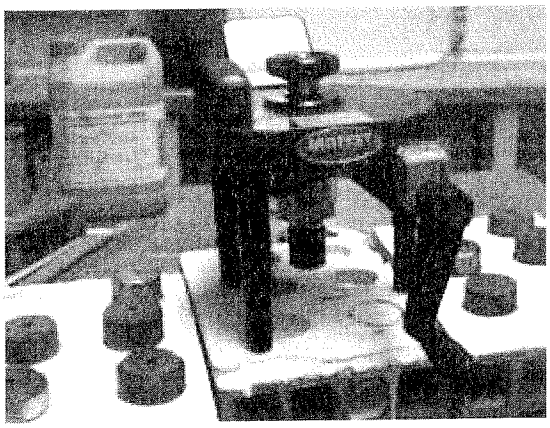

Figure 5. Determination of adhesive strength

Table 3. Results of adhesive tests

% PCM	f_u (MPa)	Failure mode
0	0,53	Adhesive
20	0,10	Adhesive
30	0,10	Adhesive

3 CONCLUSION

The incorporation of PCM microcapsules in cement mortars makes possible the storage and delivery of energy near comfort temperatures of buildings. With PCM incorporation some heating in winter and some cooling in summer, will be necessary. However, a significantly decrease in the quantity of energy necessary for buildings acclimatization, will be expected.

The incorporation of 20, 30 and 40 % of PCM microcapsules ameliorates the visual aspect of the cement mortars. Their rugosity decreases and the aesthetic quality increase. With 20 % of incorporation was possible to maintain the strength class of reference mortar (0 % PCM). The results of the adhesive tests also showed that 20 % of PCM incorporation will be possible.

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