Universidade do Minho
Escola de Engenharia

Properties of cement mortars with phase change materials (PCMs)

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INTRODUCTION

- The buildings are one of the leading sectors in energy consumption at developed countries.

- Every year, the energy powered by the sun that reaches the entire land surface is about 10 000 times higher than the actual energy consumption per year worldwide.

- In the European Union the buildings are responsible for 40% of energy consumption and 40% of carbon dioxide emission to the atmosphere.

- Thus, the need to find a way to take advantage of this natural energy source with the aim to reduce the high energetic consumption in buildings is pressing.

INTRODUCTION

It is known that the largest part of the energy consumption in construction industry, specifically in residential sector is associated with the needs for heating and cooling.

This problem is related with the excessive use of energy from nonrenewable sources, which causes serious environmental impacts.

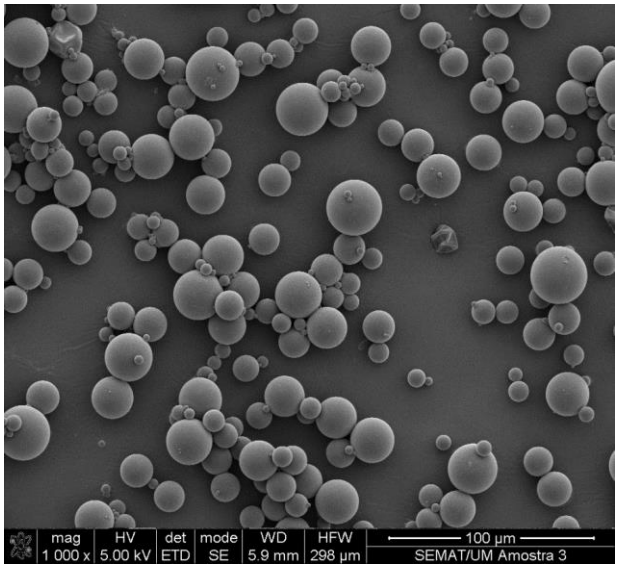
The incorporation of Phase Change Materials (PCM) in mortars appears as a possible solution in an attempt to solve, or at least minimize, the massive energetic consumption related with buildings.

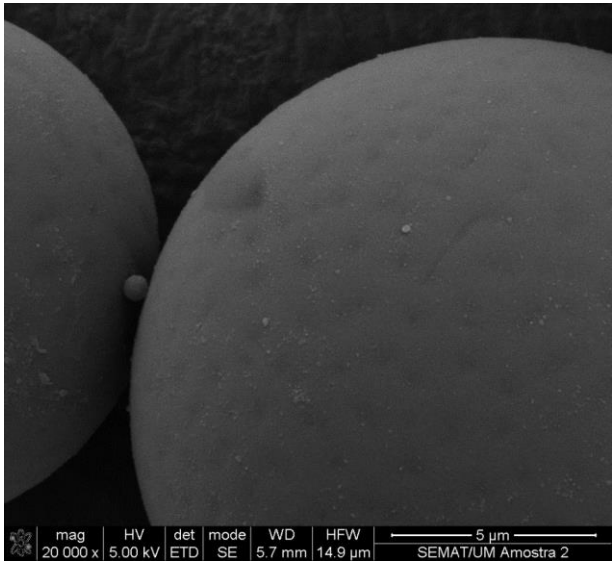
The PCM can be integrated into construction materials using diverse techniques.

- IMMERSION
- DIRECT INCORPORATION
- SHAPE STABILIZATION
- ENCAPSULATION: Microencapsulation and Macroencapsulation

Phase Change Material

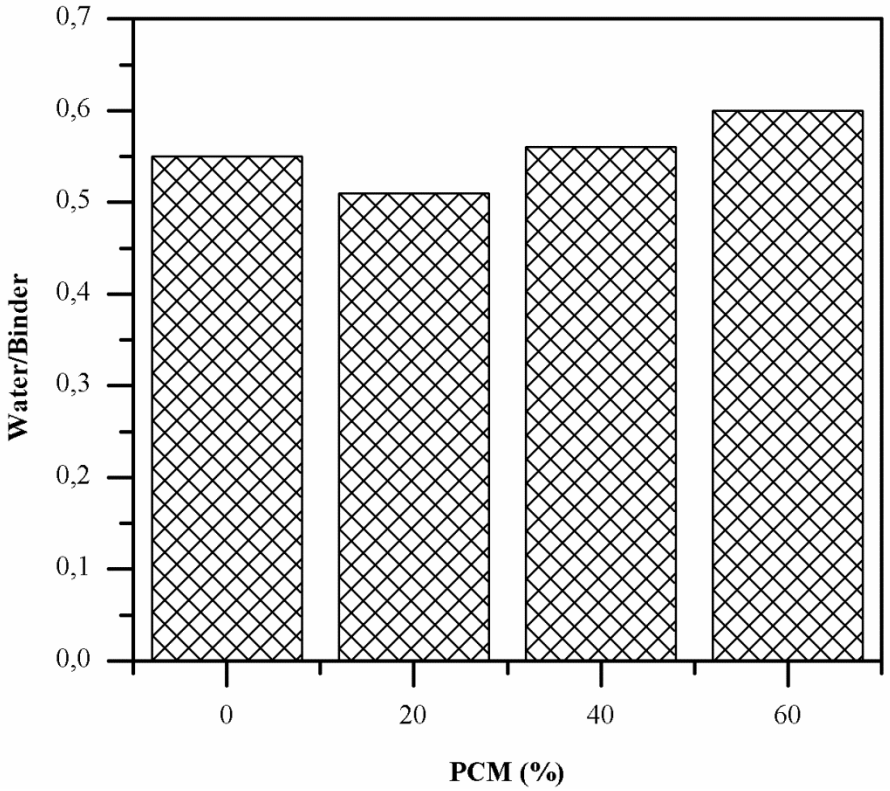
- Composed of a wall in melamine-formaldehyde and a core in paraffin;
- Transition temperature of 24 ºC in the heating cycle and 21 ºC in the cooling cycle;
- Enthalpy of 147.9 kJ/kg;
- The process of encapsulation is polycondensation by addition;
- Average particle size of 44 µm.

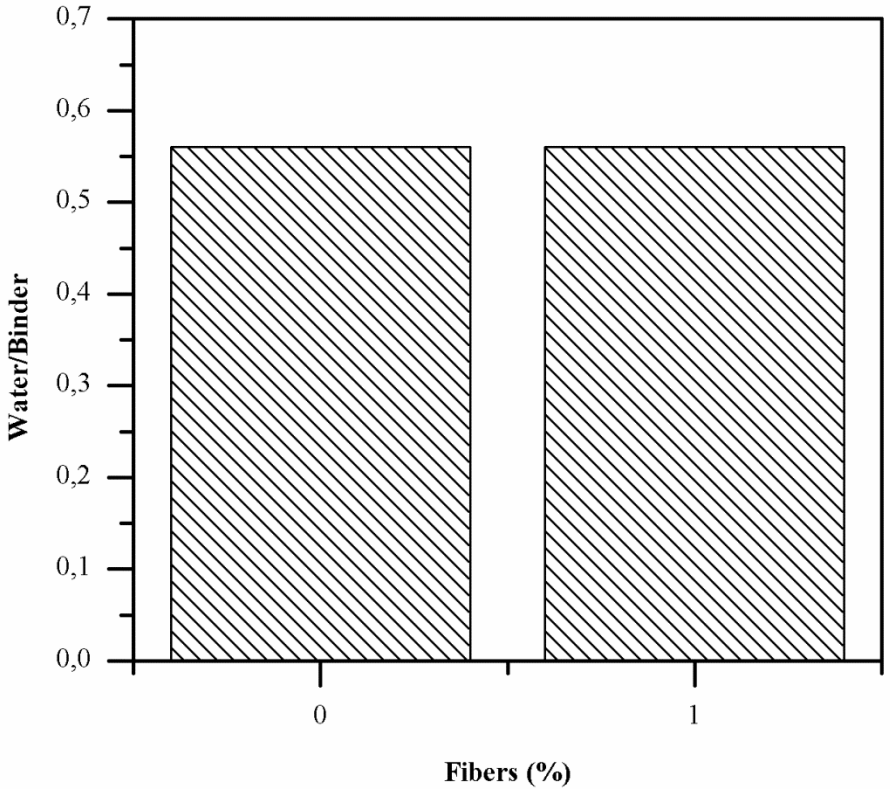




MICROENCAPSULATION: WORKABILITY

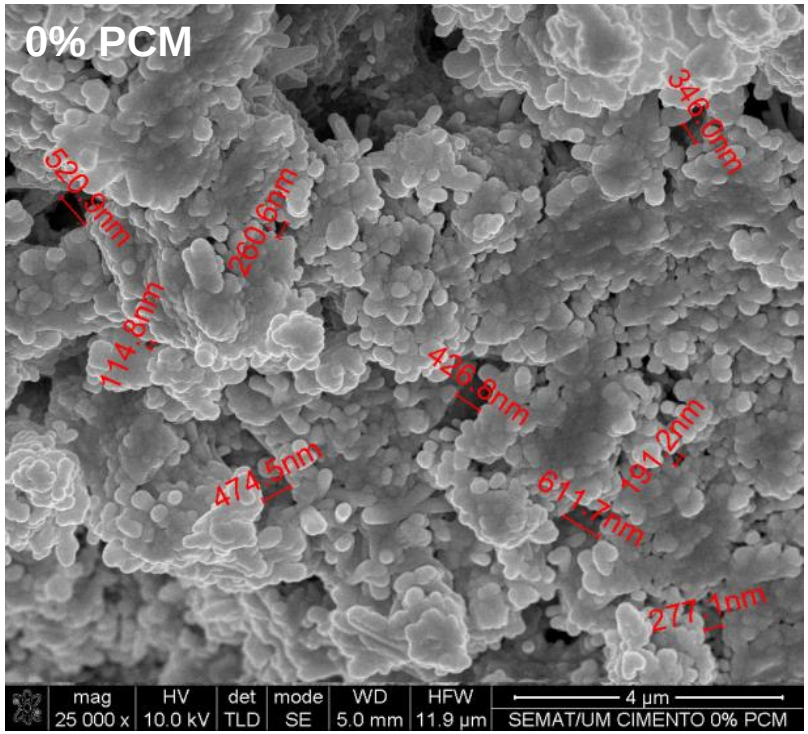
- The tests indicate an increase in the amount of water added to the mixture, with the incorporation of PCM microcapsules.
- This situation can be explained by the reduced particle dimension of the PCM.

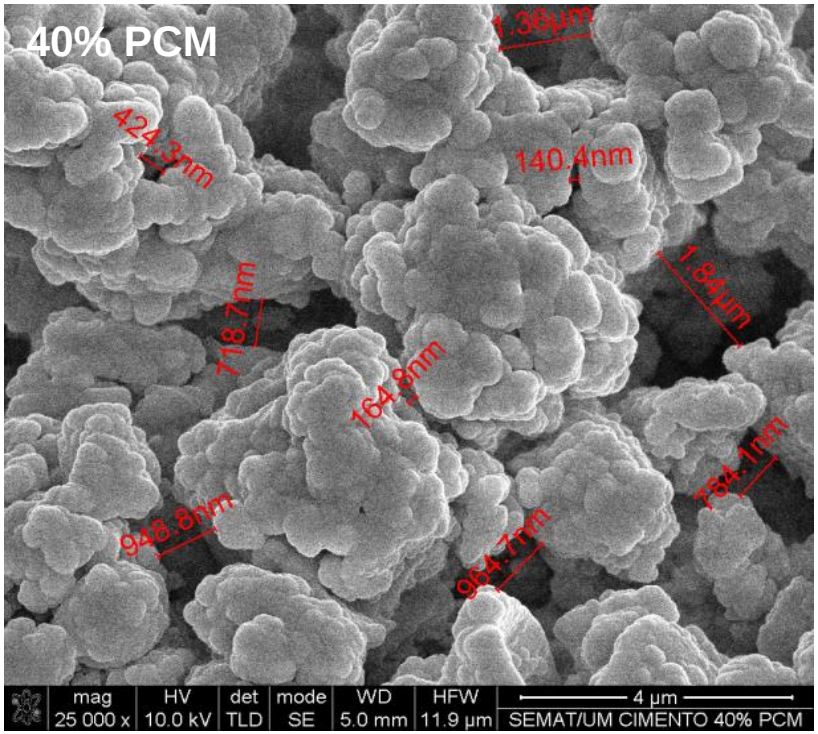




MICROENCAPSULATION: MICROSTRUCTURE

- The microscope observations reveal a good connection between the different materials evidenced by the absence of cracks in the microstructure of the mortars.
- The internal structure of the reference mortars is more compact compared with the mortars with PCM that exhibit biggest pores.

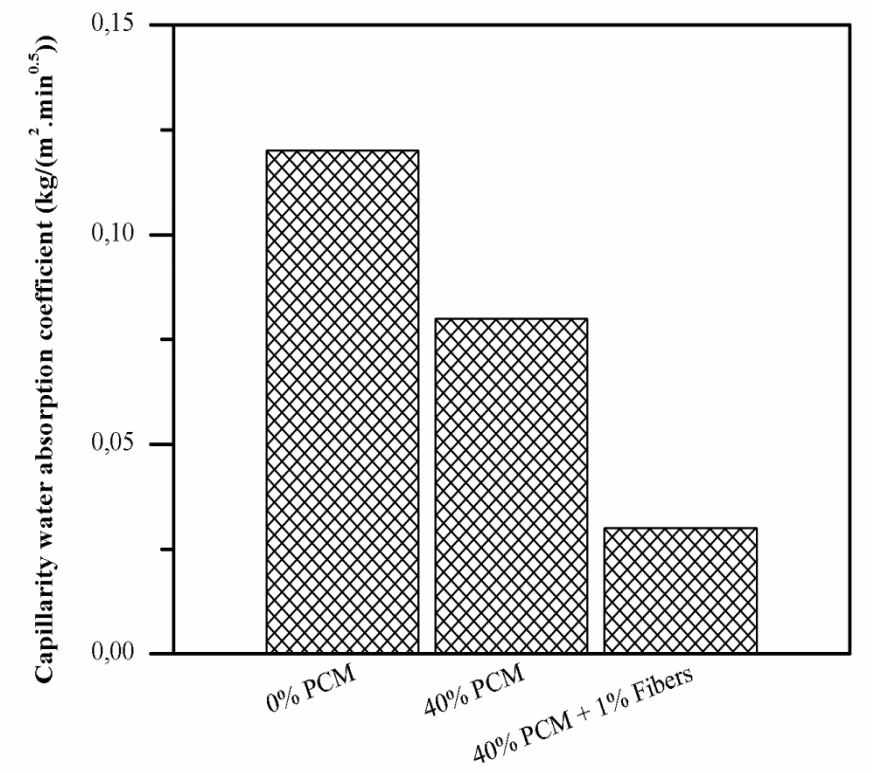


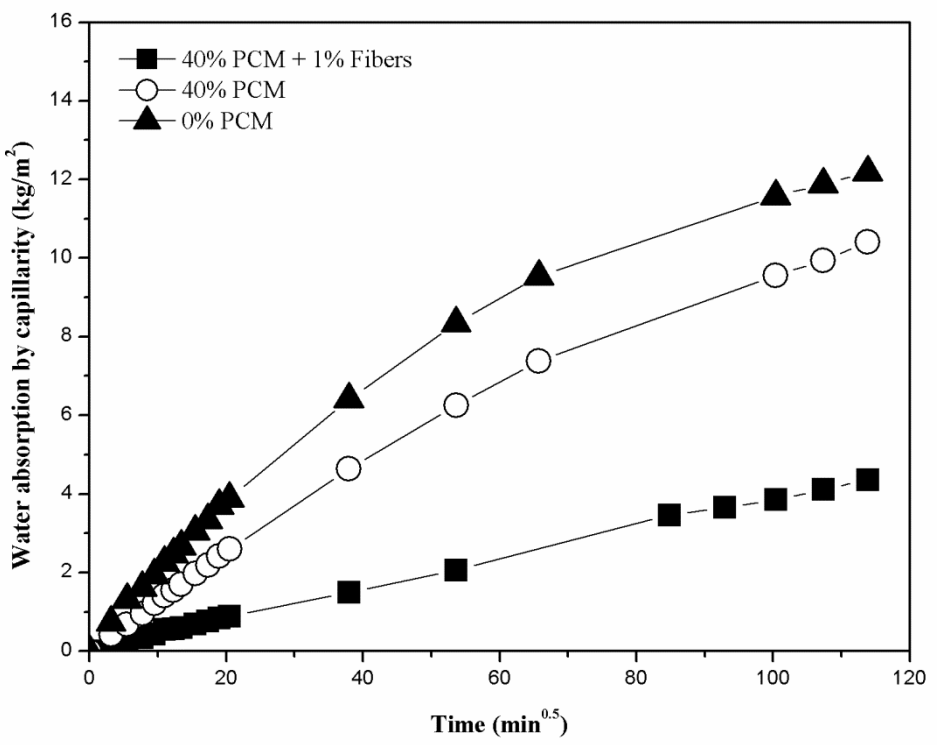


MICROENCAPSULATION: WATER ABSORPTION BY CAPILLARITY

- The incorporation of PCM and fibers leads to a decrease of capillarity water absorption coefficient.

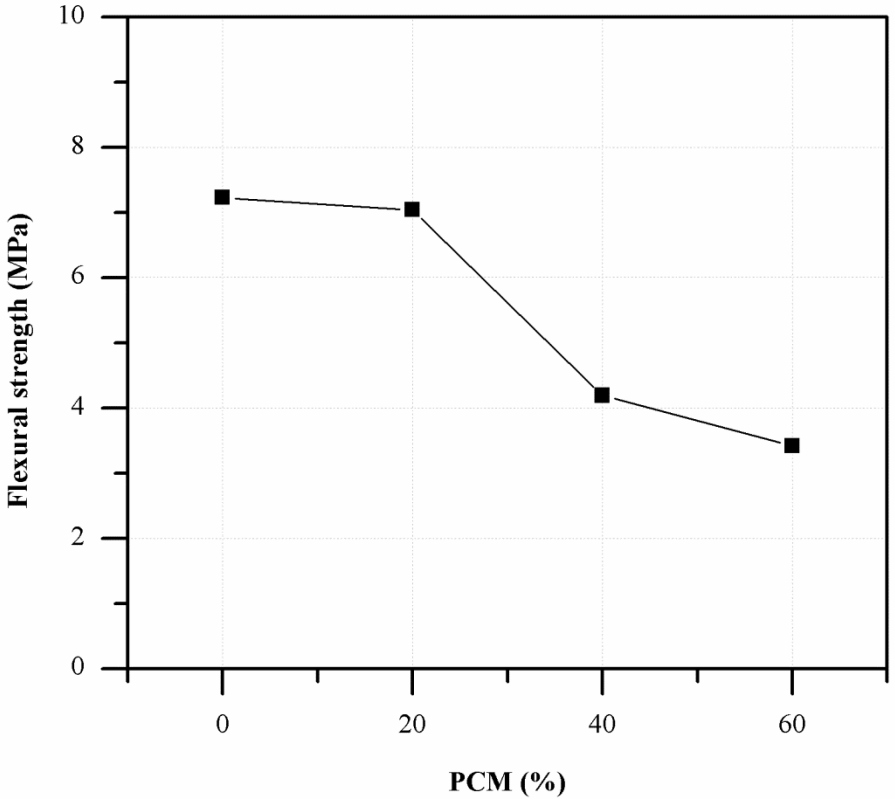
- The incorporation of PCM caused an increase in water absorbed by capillarity.

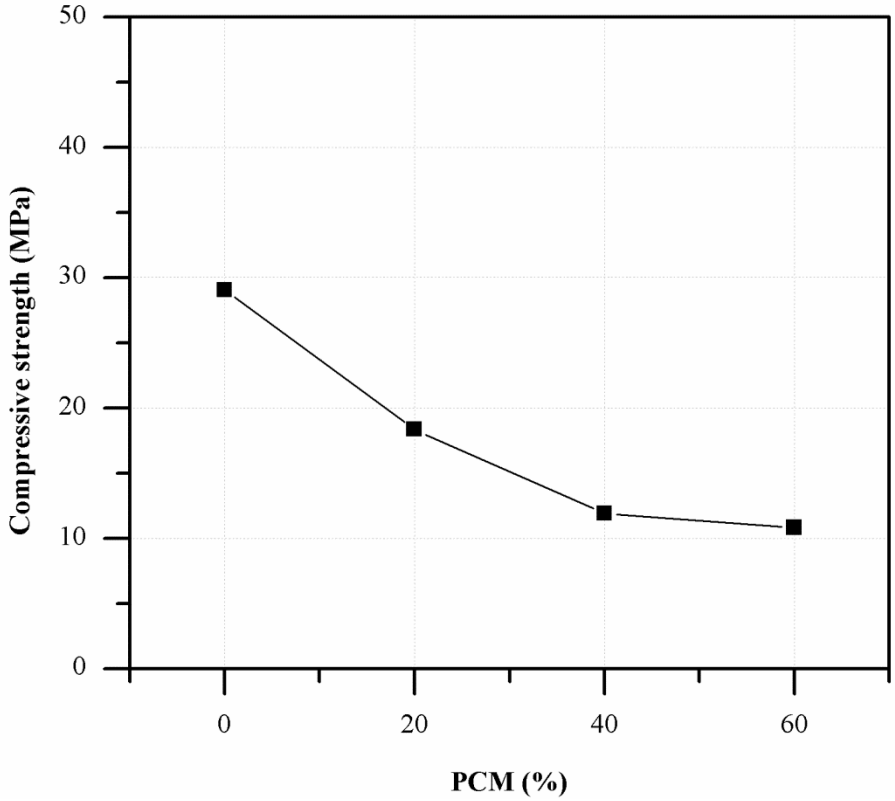




MICROENCAPSULATION: FLEXURAL AND COMPRESSIVE STRENGTHS

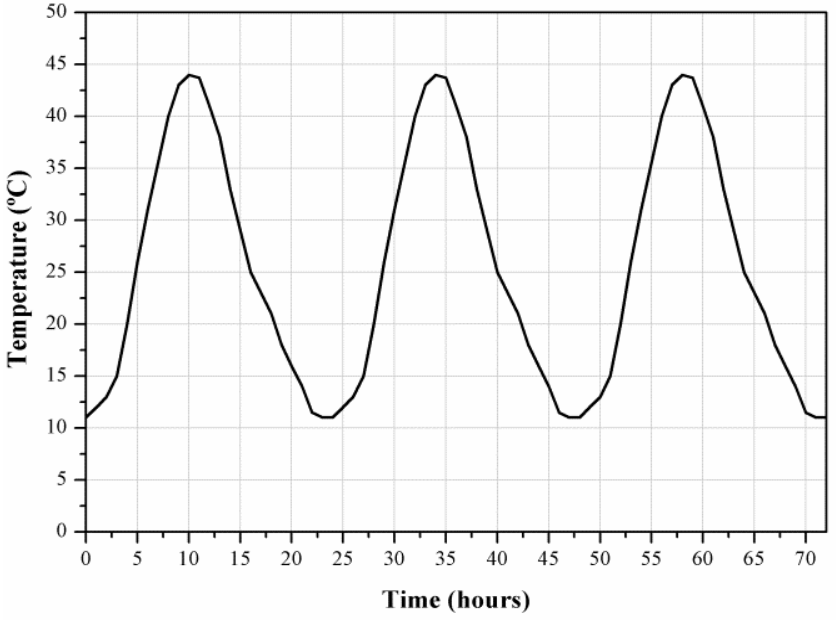
The incorporation of PCM caused a decrease in flexural and compressive strengths. This behavior is related to the presence of a greater amount of water in the formulation of the mortars.





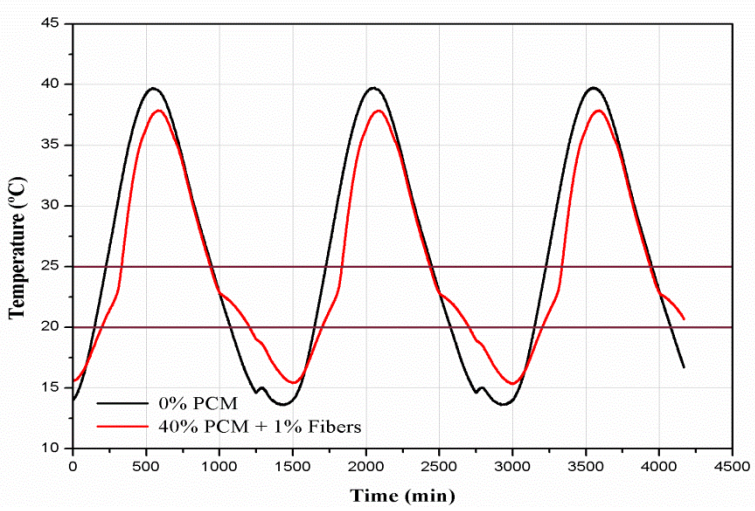
MICROENCAPSULATION: THERMAL BEHAVIOR

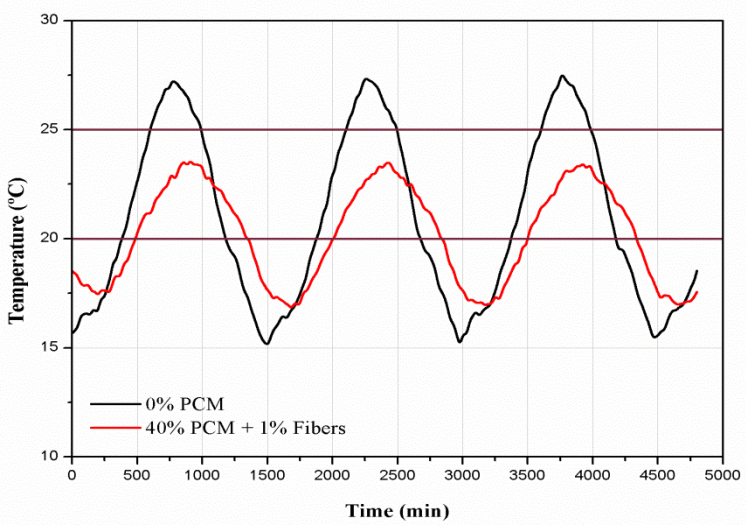
- A campaign of tests was conducted with the aim of evaluate the thermal behavior of mortars with incorporation of PCM in Portugal.
- The weather data was obtained with resource to a meteorological station installed in the University of Minho in Guimarães, Portugal.



MICROENCAPSULATION: THERMAL BEHAVIOR

- It was possible verify the positive effect of the PCM.
- Cells with PCM did not reach such extreme temperatures as the reference test cell (0% PCM). The temperature inside remains stable for a longer period.
- It was possible observe a decrease of maximum temperature and an increase in the minimum temperature. This mean a shortest operation time of HVAC systems when the composite materials with PCM are used and effective energy saving can be achieved.





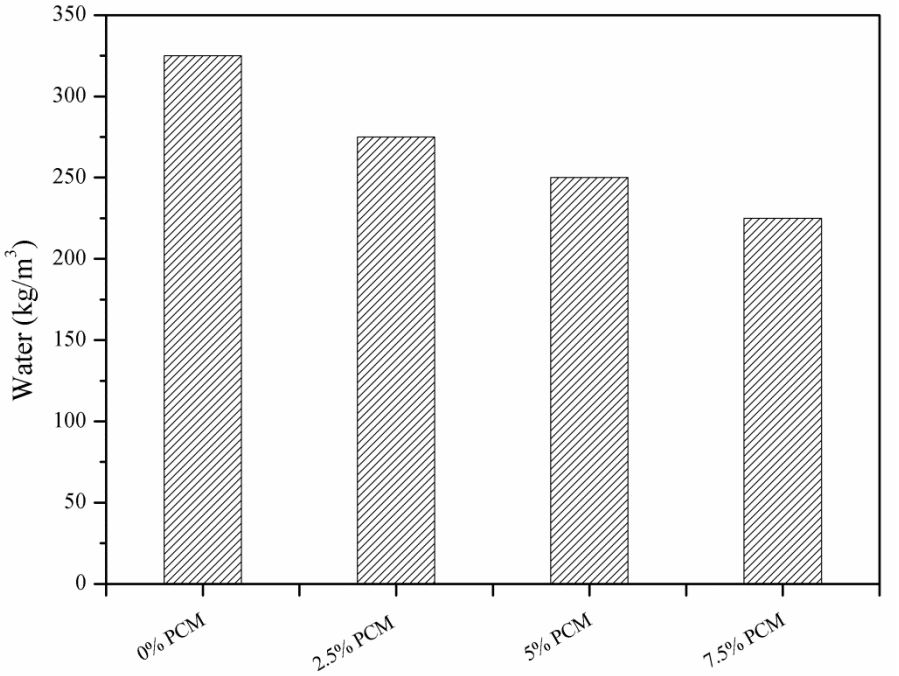
DIRECT INCORPORATION: MATERIALS

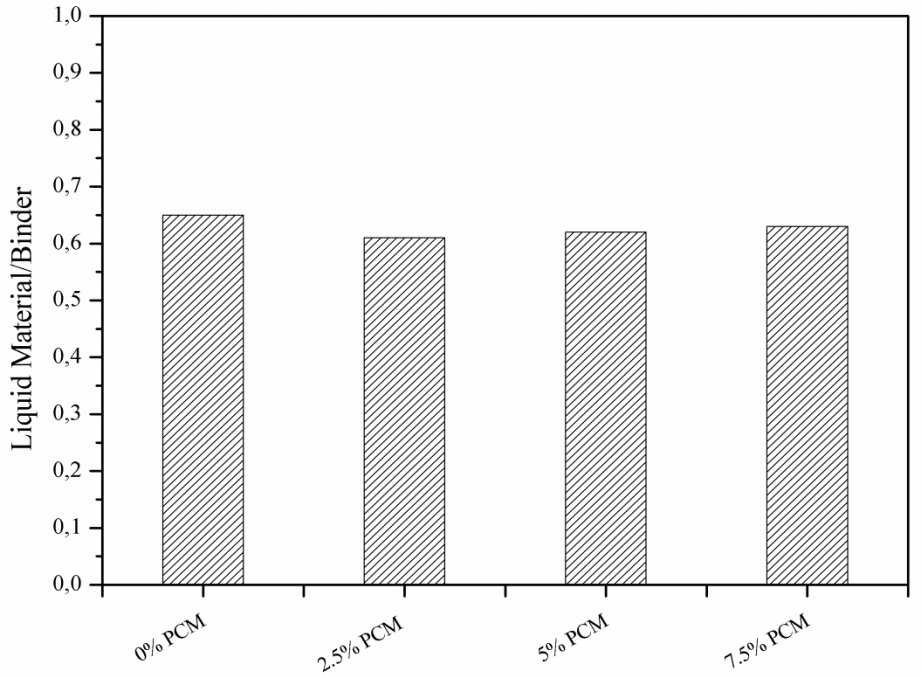
- The use of a non-encapsulated PCM, by their direct incorporation into mortar becomes very attractive and competitive, since it allows to develop mortar with thermal regulation capacity at a significantly lower cost

- The PCM used is non-encapsulated, composed of paraffin with a transition temperature between 20-23 ° C and an enthalpy of 200 kJ / kg.

DIRECT INCORPORATION: WORKABILITY

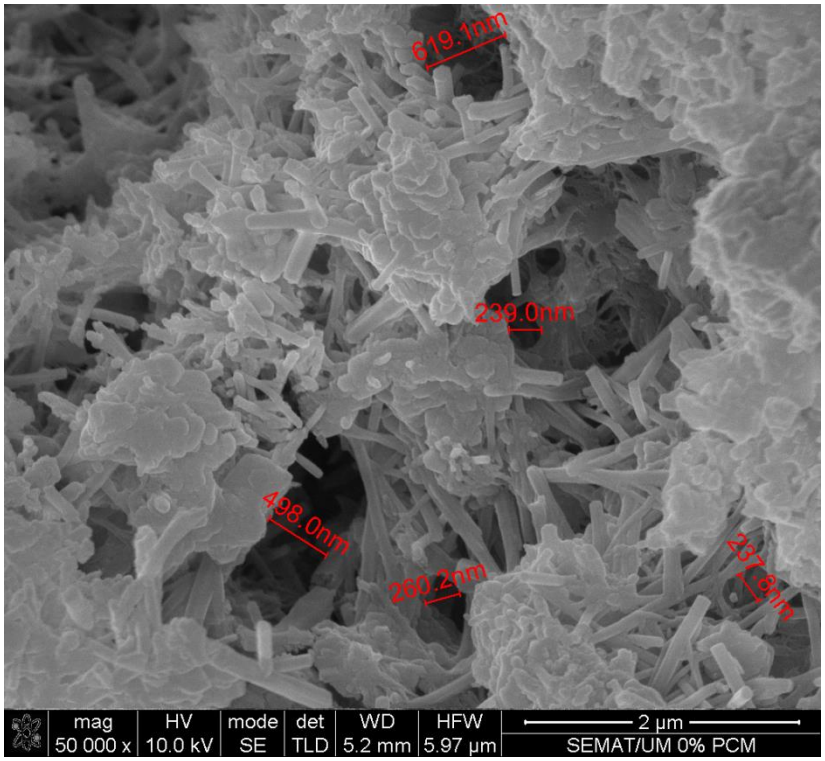
The incorporation of non-encapsulated PCM did not cause significate changes in the liquid material/binder ratio. This behavior can be justified by the utilization of the liquid PCM, which in part can operate as agent for the formation of a homogeneous mortar, replacing part of the water.

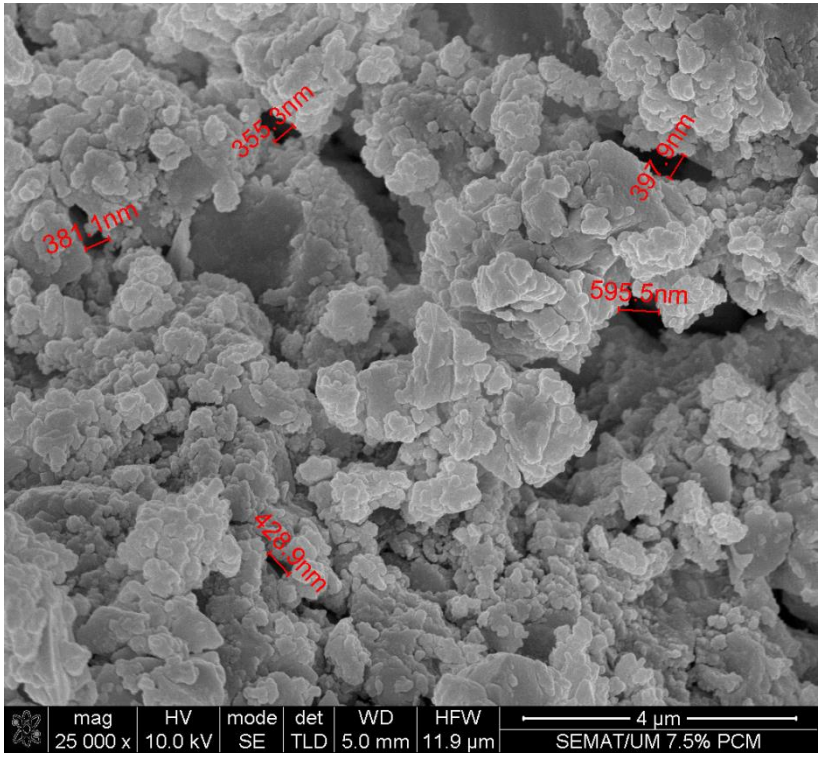




DIRECT INCORPORATION: MICROSTRUCTURE

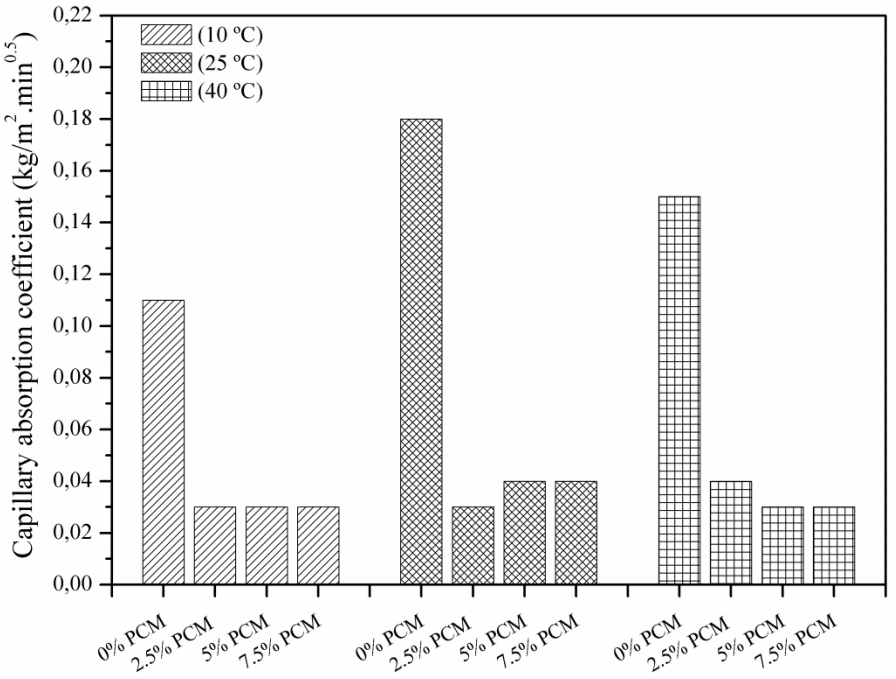
In the mortars with incorporation of PCM it was observed a decrease in the quantity of the pores and a decrease in its size. This behavior can be explained by the decrease of water content of the mortars with PCM incorporation.





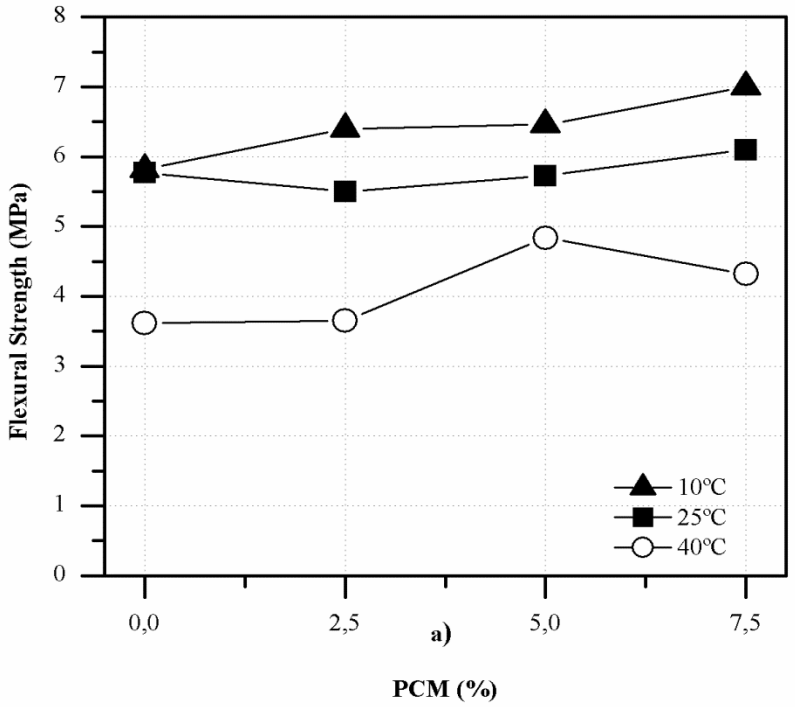
DIRECT INCORPORATION: WATER ABSORPTION BY CAPILLARITY

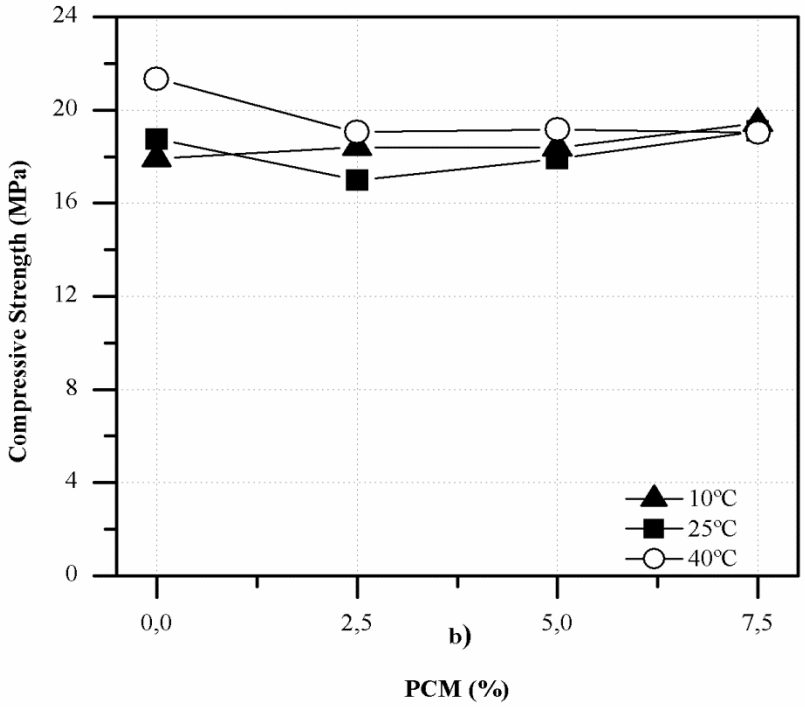
The incorporation of non-encapsulated PCM leads to a decrease in the capillary absorption coefficient. This behavior can be explained by the partial or total occupation of the mortar pores by the PCM. It was also verified that the mortars with PCM incorporation present a similar capillary absorption coefficient when submitted to different ambient temperatures, which shows that even in different states (solid and liquid) the PCM does not move to outside of the mortar matrix.



DIRECT INCORPORATION: FLEXURAL AND COMPRESSIVE STRENGTHS

The incorporation of non-encapsulated PCM did not cause significant changes in the flexural and compressive behavior. This situation can be explained by the contained PCM inside the pores, not weakening the mechanical strength.





CONCLUSION

- **It was possible to conclude that it is possible to incorporate microencapsulated and non-encapsulated phase change material in mortars for interior coating.**

- **Microencapsulated Phase Change Material:**

  - Regarding workability, it was verified that the incorporation of PCM caused an increase in the amount of water added to the mortar. This behavior is related to the small particle size of PCM microcapsules.

  - It was possible to identify a good interaction between the mortars constituents materials, evidenced by the absence of cracks in the microstructure of the developed mortars.

  - The incorporation of PCM microcapsules in mortars caused an increase in water absorption, revealing a higher porosity of these mortars.

CONCLUSION

- **Microencapsulated Phase Change Material:**

  - The study of mechanical strengths showed a decrease with the incorporation of PCM, which is a consequence of the higher porosity.

  - The incorporation of PCM did not affect the durability.

  - The incorporation of PCM microcapsules leads to a decrease of the extreme temperatures and climatization needs.

- **Non-encapsulated Phase Change Material:**

  - The incorporation of non-encapsulated PCM causes a decrease in the amount of water added to the mixture. However, the ratio liquid material/binder of the mortars is similar.

  - The incorporation of non-encapsulated PCM leads to a decrease in the microporosity of mortars.

CONCLUSION

- **Non-encapsulated Phase Change Material:**

  - Regarding the water absorption by capillarity it was observed that the incorporation of non-encapsulated PCM leads to a decrease in the capillary absorption coefficient, due to the partial or total occupation of the mortar pores by the PCM.

  - According to flexural and compressive strengths, it can be concluded that he incorporation of non-encapsulated PCM did not cause significant changes in the mortars mechanical behavior

- **It can be conclude that the utilization of PCM in interior coating mortars can reduce the energetic consumptions, reducing the energy demand, the fossil fuel depletion and the environmental impact associated with the heating and cooling systems.**

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Thank you for your attention.

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Seminar – PCMs4Buildings

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