Proceedings of the 7th International Conference on Safety and Durability of Structures
ICOSADOS 2016
May 10 - 12, 2016, UTAD, Portugal

Passive solar system applied in *trombe* walls

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Keywords: PCM, thermal mortar, *trombe* wall, testing models.

Introduction

A phase-change material (PCM) is a substance with a high heat of fusion, with the capability of melting and solidifying at a certain temperature, and is capable of storing and releasing large (certain) amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa. Thus, PCMs are classified as latent heat storage (LHS) units.

The PCM may be classified as organic, inorganic and eutectic mixtures. The organic compounds are further divided into non-paraffinic and paraffin, the inorganic compounds can be classified into hydrated salts and metal [1].

The idea to use PCMs for the purpose of storing thermal energy is to make use of the latent heat of a phase change, usually between the solid and the liquid states, for thermal control purposes in construction. Since a phase change involves a large amount of latent energy at small temperature changes, PCMs are used for temperature stabilization and for storing heat with large energy densities in combination with rather small temperature changes in that materials.

The successful usage of PCMs, is by one side a question of a high energy storage density, but by another side hand it is very important to be able to charge and discharge the energy storage with a thermal power, like sun, that is suitable for the desired application [2].

Materials likely to be used for phase change thermal energy storage that have been studied during the last 40 years are hydrated salts, paraffin waxes, fatty acids and eutectics of organic and non-organic compounds. A eutectic mixture is a composition of two or more components that melt congruently forming and crystallizing a mixture of compounds crystals [3].

The PCM’s have countless applications in different areas, initially being used in the textile, footwear and automotive industry, but can now be used for thermal energy storage in buildings. The use of PCM's is primarily aimed at increasing the thermal comfort of human being, particularly in the construction industry. With their use a decrease of energy consumption is to be expected [4, 5, 6, 7].

The PCM´s are introduced in construction through his incorporation in building materials such as concrete and gypsum, in order to change the thermal characteristics of those materials. It should be noted that the incorporation of PCM's in common building materials does not lead to an additional cost other than the cost of manufacturing the microencapsulated PCM's. In construction, the PCM's can be placed on roofs, walls, ceilings, floors, glazing, ventilation systems, and building materials (bricks, concrete).

The work presented here is related to the study of a passive solar system applied in facades with *trombe* wall, which is a construction technology that allows reducing the energy consumption of buildings [8]. In particular, the effect of the incorporation of phase changing materials (PCM's) was assessed using namely a PCM based on paraffin and another one based on octadecane.

This study is primarily based in the execution, experimental analysis, and comparison of results obtained in test models.

For this purpose, an experimental campaign conducted at Bragança Polytechnic Institute was performed, firstly, to evaluate the blending mode of all the constituents of the mortar, the content of PCM to incorporate in the mortar, as well as the involved water quantity. These early studies included the mechanical characterization of the mortar with and without PCM. The obtained data indicate that the best results were achieved with the addition of 30% of PCM in the mortar.

The second part or current work was devoted to the study of six test models built using cement mortar and an appropriate geometry. One of the models served as a reference, another sample model was tested considering that the main facade will simulate a window, while the remaining models were executed as a main facade using the *trombe* wall building system. Trombe walls were built with four different materials: cement mortar, cement mortar with octadecane, cement mortar with paraffin. All models have been developed with the ability of the wall to be ventilated. All models were monitored and tested in terms of thermal behaviour. Three of the walls testing samples were tested simultaneously under the same conditions, during four days. The differences between the test's layouts are related to the granite wall colour and the ventilation surrounding the models. During the monitoring of the models it was possible to obtain temperature records and thermal conductivity of the main facade elements in 10 to 10 minutes intervals. Also, a direct comparison between the tested models was established.

Main conclusions of this work are that the incorporation of PCM's into thermal mortars can bring benefits in terms of thermal comfort, greater efficiency, and sustainability to buildings, as well as improve the efficiency of *trombe* wall building system.

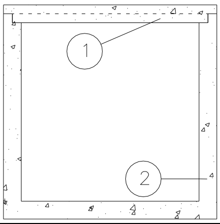
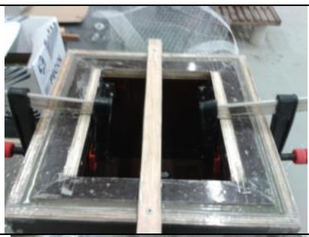
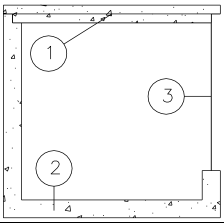
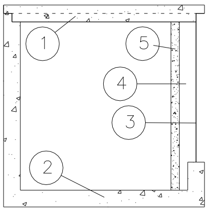
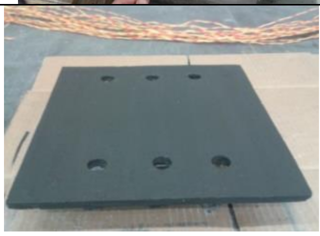
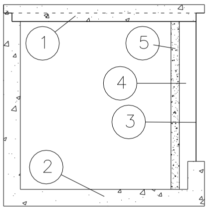
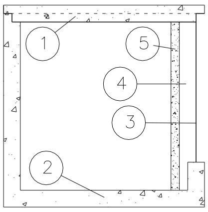
Experimental program

Six *trombe* wall models were conducted to study a passive solar system applied in facades with *trombe* wall, which is a construction technology that allows reducing the energy consumption of buildings. Model 1: all model are in concrete without *trombe* wall, just for comparison; Model 2: one of the facades are in acrylic with 2.5 mm thick; Model 3: with *trombe* wall made in concrete painted with black colour; Model 4: *trombe* wall were built in concrete with the incorporation of octadecane PCM; Model 5: *trombe* wall were built in concrete with the incorporation of paraffin; Model 6: *trombe* wall were in grey granite stone, Table 1, [8]. The models 2 to 6 have one of the facades in acrylic. To analyse the temperatures at different points inside the models were placed on type K thermocouples, Fig. 1.

Thermal conductivity is a specific characteristic of each material, and depends strongly on both the purity and the temperature at which it is found (especially at low temperatures). In general, the conduction of thermal energy in the material increases as the temperature increases. The temperature values of the indoor air and outdoor surface, relative humidity, and thermal conductivity of a given element are obtained by means of the testo 435-2 equipment, a multi-function measuring instrument, used according to ISO_9869-1994 [9], Fig 2.

Once assembled, the models were placed on the school's roof, with the main facade orientated south, Fig. 3. Different tests were performed using several cycles of numerous days each. Testing variables like main facade painting, openings in main façade, and different thermocouples locations were studied (Table 1). The monitoring task took place in May, June and July.

Table 1 – *Trombe* walls models

Models	scheme	construction details	
Model 1	 1 – cover 2 – concrete facade		
Model 2	 1 – cover 2 – concrete facade 3 – acrilic facade		
Model 3	 1 – cover 2 – concrete facade 3 – acrilic facade 4 – air box 5 – black trombe wall		
Model 4 and 5	 1 – cover 2 – concrete facade 3 – acrilic facade 4 – air box 5 – PCM trombe wall		
Model 6	 1 – cover 2 – concrete facade 3 – acrilic facade 4 – air box 5 – granity wall stone		

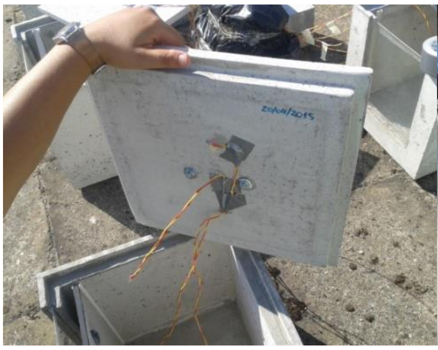


Fig. 1 – type K thermocouples placed on cover

Fig. 2 – Surface temperature sensor

Fig. 3 – Models provided on the school roof

Experimental results

Fig. 4 shows the variation of the interior temperature of the test models, the outside temperature, and the radiation incidence on the models. Fig. 5 shows the temperature change at facade south-orientated, outside temperature, and the radiation incident in the models. Fig. 6 shows the temperature variation of the air-boxes of models with *trombe* wall, the outside temperature and incident radiation in the models.

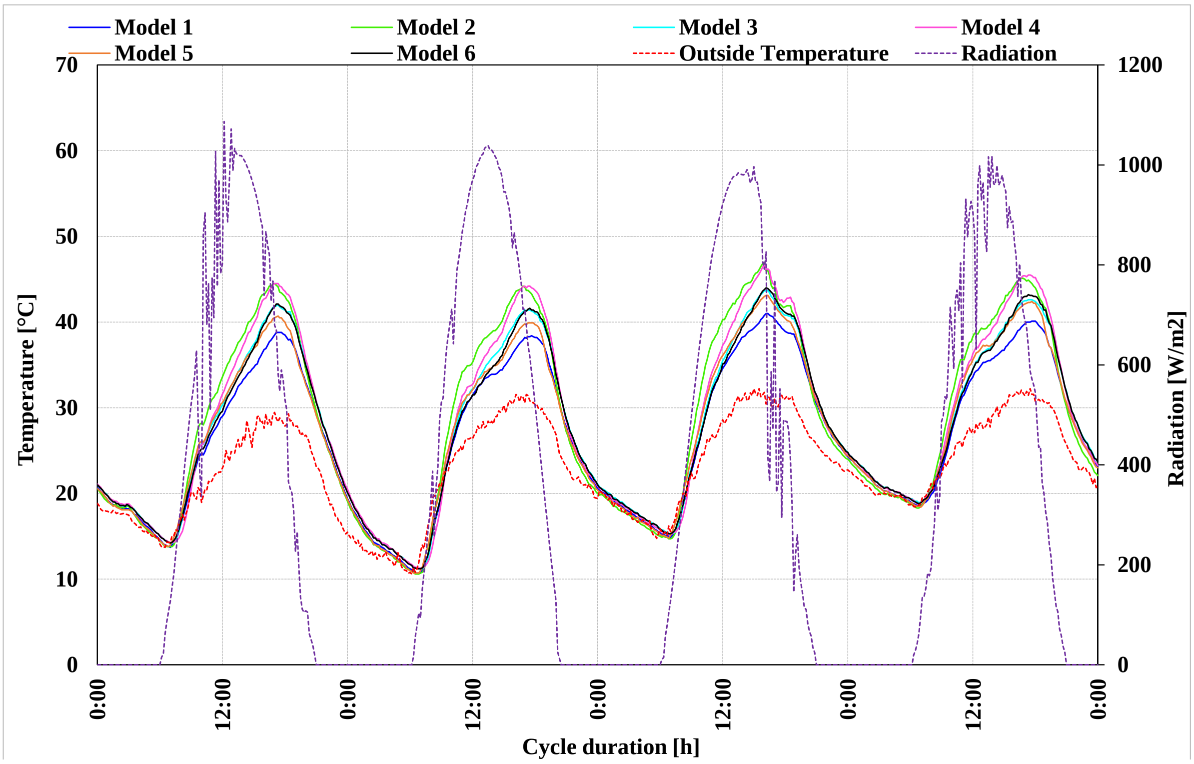


Fig. 4 – Variation of air temperatures inside the models

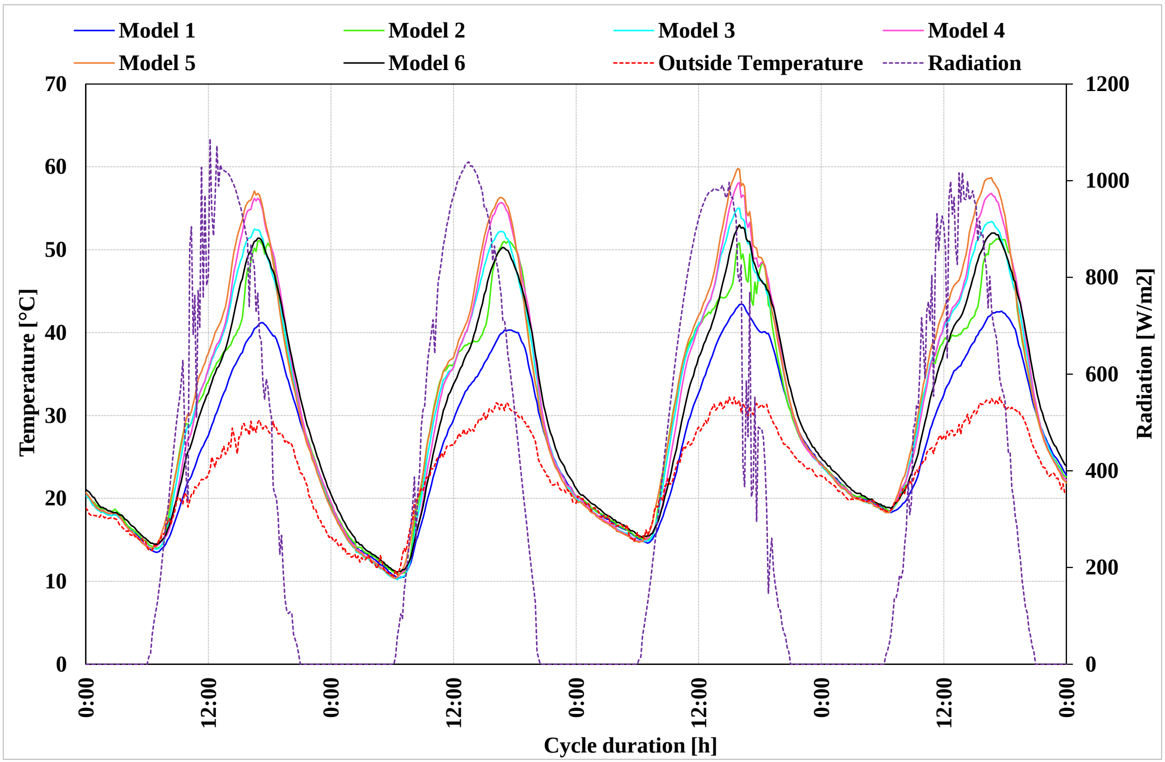


Fig. 5 – Surface temperatures at south-orientated facade

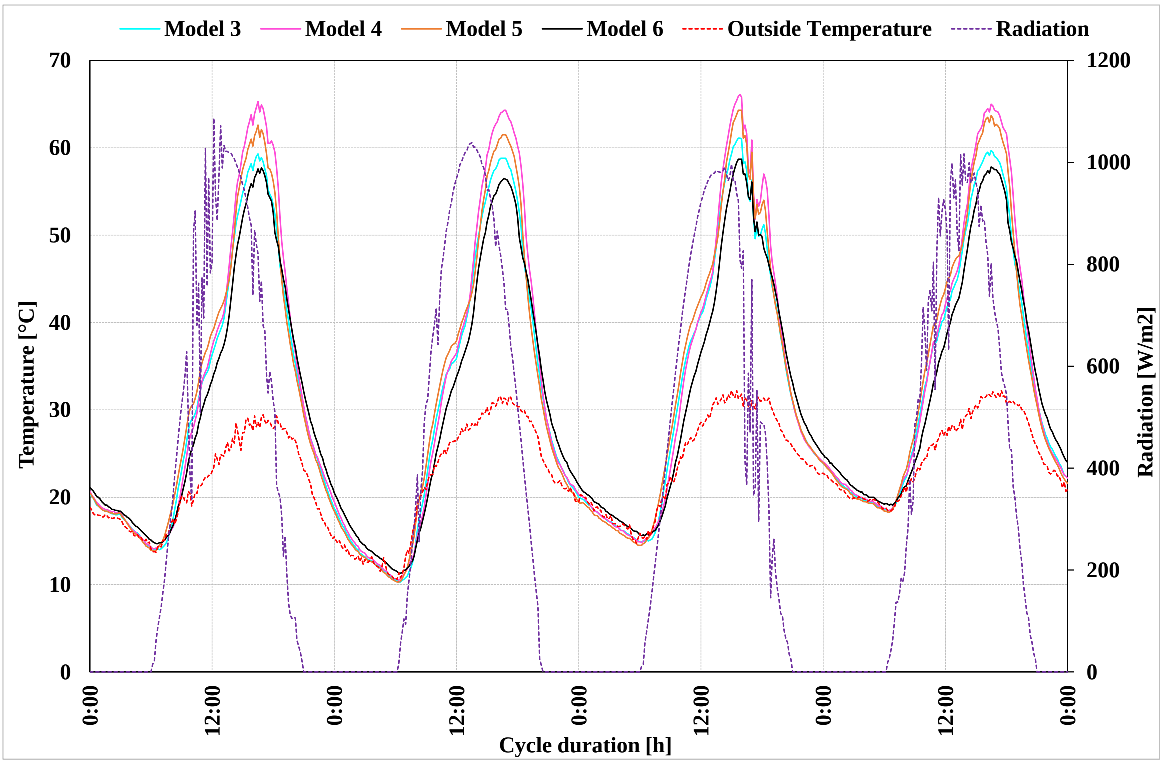


Fig. 6 – Temperatures variations in air box

Analysing the temperatures inside the models (Fig. 4) it was found that the *trombe* wall with 1.5 [cm] thick mortar PCM has a behaviour very close to the *trombe* wall with 2 [cm] thick granite. During the day, the PCM wall heats least and during the night cooling similarly to the wall of granite stone.
In the south-orientated facade with (Fig. 5) one obtains de higher values on the models, as expected. From the analysis of the air temperatures in air box during the day (Fig. 6), it was found that granite and mortar with paraffin heats less than the other surfaces due to its properties, while granite remains longer hot overnight.

Conclusions

The experimental research presented in this work aimed to observe the behaviour of PCM incorporated into the mortar applied to the building system *trombe* wall, when subjected to typical temperature cycles of heating season.
The use of PCM brings advantages in terms of thermal comfort, economically and socially. Brings more efficiency and sustainability to the buildings.
The construction system is more efficient if the *trombe* wall has a dark colour and has ventilation.
A *trombe* wall with 1.5 [cm] thick mortar with 30% PCM can work the same way with the same wall 2 [cm] thick granite stone.
In terms of thermal conductivity, a granite wall is better than the wall mortar with 30% PCM, which in turn is better that the wall of cement mortar.

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