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A Contribution to The Thermal Insulation of Building using Phase Change Materials in Taif, Saudi Arabia

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Abstract

An increased attention is recently turned to the increase of the building energy performance in Saudi Arabia in order to achieve the required indoor thermal comfort and to improve the global energy saving strategy. Consequently, different insulation materials are applied for the purpose of walls and roofs insulation. Phase change materials (PCM) can be considered as a new technology for the insulation of building in Saudi Arabia. In the present study, experimental measurements for the effect of using phase change material in roof insulation for small models of a single room according to the atmospheric conditions of Taif city, Saudi Arabia are performed. Two test models are designed form refractory bricks (20x20x40cm), type ND40, (ASTM-C416), with internal volume of 1m3. The external roof of one test model is covered by PCM; namely, Paraffin Wax, while the other test model is remained without insulation material. The external as well as the internal air temperature are measured simultaneously using Extech RHT20: Humidity and Temperature Datalogger. It should be pointed out that, the present experiment has been performed in Faculty of Engineering, Taif University, Saudi Arabia. The results showed that a decrease in the internal air temperature during the sunshine time and an increase of such temperature after sunset time in comparison with the external air temperature. This indicates the effectiveness of Phase Change materials in obtaining a thermal comfort atmosphere in the whole day.

Keywords: Building, Energy saving, Experimental measurements, Phase change materials, Thermal comfort, Thermal insulation

INTRODUCTION

The thermal design of residential building envelope assemblies is based on steady-state energy flows. Actually, building envelopes are subjected to varying environmental conditions according to the local area atmospheric conditions. The application of the conventional insulations may not always be the most cost-effective energy solution for improving the thermal performance of the building envelope [1]. Consequently, advanced insulation materials have been introduced for the insulation of residential building in recent years [2]. The integration of Phase Change Materials (PCMs) in building envelopes is a way to enhance heat storage capacity of buildings and thereby to rationalize the use of energy for heating and cooling of buildings [3].

Phase Change Materials (PCMs) are substances which melting and solidifying at a certain temperature. Such materials are capable of storing and releasing large amount of energy. Different types of PCMs can be found and applied for many purposes [4].

During the last decade, the number of articles regarding the integration of PCMs in buildings to improve their energy efficiency has been increasing. Before 2003 only 2 review articles on this subject are found in the literature.

During the last years more comprehensive and particular reviews of PCM latent heat systems and their applications have been made, and more than 20 extensive review articles about the potential of integrating PCMs in buildings were published, allowing to conclude that interest in the subject is rising [5]. However, during the last years more specific issues were reviewed and its foreseeable that the article reviews concerning the problem of integrating PCMs in buildings, to meet the demand for thermal comfort and energy conservation/savings purpose [6].

Different challenges are, however, arisen when using PCM in buildings, including the variety of materials available, safety, cost and economic feasibility, design configurations, integration with other sustainable energy technologies, impact on thermal and energy performance [7]. As a result, computational modeling and experimental measurements are often used as effective tools to quantitatively understand and help resolving this optimization problem [8].

The PCMs are found to have a wide range applications in a wide array of areas such as in building energy efficiency, thermal energy storage, waste heat recovery, spacecraft thermal systems, microelectronics thermal protection, solar power plants and food product cooling. Phase change processes involve transforming of a material from one phase (solid, liquid, or gas) into another. For example, melting of ice into liquid water or boiling of liquid water into water vapor is classified as a phase change process. During a phase change, molecules rearrange themselves, causing a change of entropy of the material system.

Thermodynamics requires that the material absorb or release thermal energy or heat because of this entropy change, and this heat associated with the unit mass of the material is defined as the latent heat of the material. The latent heat is released by a material during melting and evaporation; it is absorbed during freezing and condensation phase change processes. In short, a phase change process involves a large amount of heat transfer at a constant temperature, and both are attractive features for heating, cooling, and temperature stabilization applications [9].

PCMs have been tested as a thermal mass component in the insulation of buildings for the past 10 years, and most investigations have found that PCMs enhance building energy performance. Some associated problems, such as high initial cost, loss of phase change capability, corrosiveness, and PCM leaking have hampered widespread adoption. Paraffinic hydrocarbon PCMs generally perform well, but they increase the flammability of the building envelope. Accordingly, for these reasons, more attention is now paid to PCMs based on fatty acids or inorganic salt hydrates. Traditionally, PCMs were used to stabilize interior building temperature. In older applications, then, preferable locations for PCM were interior building surfaces such as walls, ceilings, and floors [10].

At the same time, concentrated PCM applications require more precise selection of the PCM's functional temperature range, location, and heat storage density. Because these systems are complex, though, they are difficult to analyze using existing whole-building energy simulation tools. As a result, experimental measurements are particularly valuable for energy performance and cost analyses before sufficient computer tools are developed and validated for these technologies.

Most of previous PCM-investigations are dealt only with experimental studies dedicated to the development and evaluation of PCM walls only [11]. That can be referred to such systems are relatively complex, though, they are difficult to analyze using existing whole-building energy simulation tools [12].

EXPERIMENTAL MODEL

The experimental models constructed in the present investigation consist of two similar rooms with internal volume of $1m^3$. The two rooms are constructed from refractory bricks (20x20x40cm), type ND40, (ASTM-C416).

The external walls are covered with plastic sheets in order to reduce heat transfer through room walls. One room's roof is covered with the phase change material, selected in the present research as Paraffin Wax contained in a wood frame, while the other roof remained empty, as shown in Figure1.

Figure 1. The designed rooms for the present experiments

The woody frame is filled with PCM (Paraffin Wax), with height of 10 cm, as shown in Figure 2. The amount of phase change material used is about 10 kg of Paraffin Wax. The woody frame is covered with a thin plastic cover to prevent the dust particles from the phase change material.

Two similar instruments for measuring temperature and humidity ratio outside and inside test models were used of the type Extech RHT20: Humidity and Temperature Datalogger, shown in Figure 3. The specifications of such instrument can be shown in Table 1 and it can also be found in [13].

The applied Datalogger requires USB software, which is a program for collecting data from the DATA LOGGER when it is connected to a PC or notebook computer. The data may be displayed graphically, as Excel or similar programs.

Figure 2. The phase change material in the woody frame during the experiment.

Figure 3. Extech RHT20: Humidity and Temperature Datalogger

Table 1. Specifications of the RH20 Datalogger

	Range	Accuracy
Relative Humidity	0 to 20% and 80 to 100%	±5.0%
	20 to 40% and 60 to 80%	±3.5%
	40 to 60%	±3.0%
Temperature	14 to 104°F	±1.8°F
	-13 to 14°F and 104 to 158°F	±3.6°F
	-40 to -13F	±8°F typical
	-10 to 40°C	±1°C
	-25 to -10°C and 40 to 70°C	±2°C
	-40 to -25C	±4°C typical

RESULTS AND DISCUSSION

The air temperature and the relative humidity are measured inside the designed room equipped with PCM and the results are compared with the values measured outside the room.

Figure 4 shows the comparison between the values measured on a selected day of 02.03.2016 from 10:36 am to 07:55 pm. The results showed that the air temperature inside the designed room with PCM is less than the outside air temperature during the sunshine period and is higher than the outside temperature at the rest of the day to the sunset time.

The trend of the temperature variation indicates that thermal comfort has been obtained during the day. It should be pointed out that, the higher temperature measured inside the room is referred to the closed as well as insulated walls of the designed models, where no openings were designed.

In order to check the accuracy of the previous results of Figure 4, the same experiment has been repeated on the next day of 03.03.2016 form 14.05 pm to 10.05 am. The results are illustrated in Figure 5. It can be shown that the same results is obtained even over the large period considered.

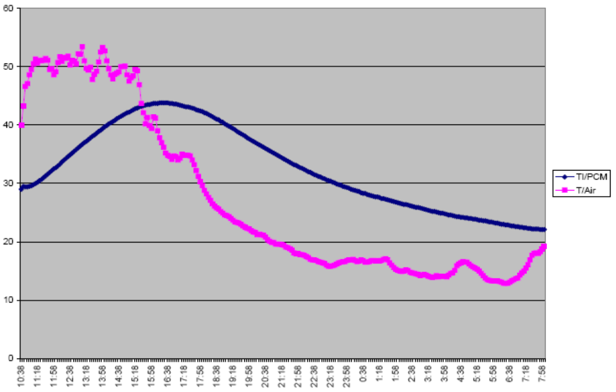

Figure 4. Comparison of inside and outside air temperature for the designed room with PCM, 02.03.2016..

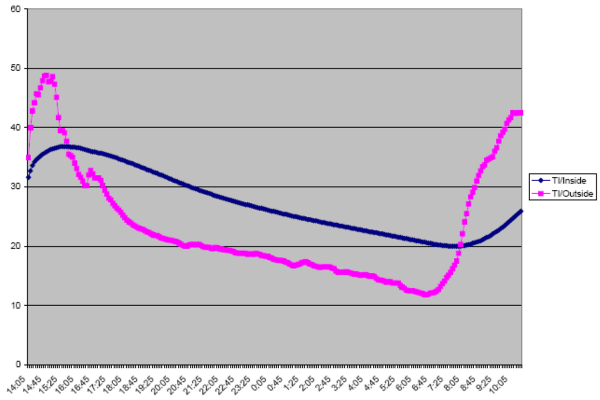

Figure 5. Comparison of inside and outside air temperature for the designed room with PCM, 03.03.2016.

In order to compare the two designed rooms, the inside air temperature and the relative humidity were measured inside the two rooms (one with PCM and the other without PCM). The results were measure on 04.03.2016 from 9:43 am to 18:40 pm, and illustrated in Figure 6.

Figure 6 showed that, although of the rapprochement of the relative humidity inside the two designed rooms, the inside air temperature showed a little variation in such a manner that the air temperature inside the room with PCM is higher than that measured in the room without PCM. This indicates that warming of air inside the room with PCM was occurred due to the rejection of some of latent heat towards the interior of the room. That can be also explained as that PCM has worked as an insulation material and has prevented the heat transfer from the interior of the room to the exterior domain.

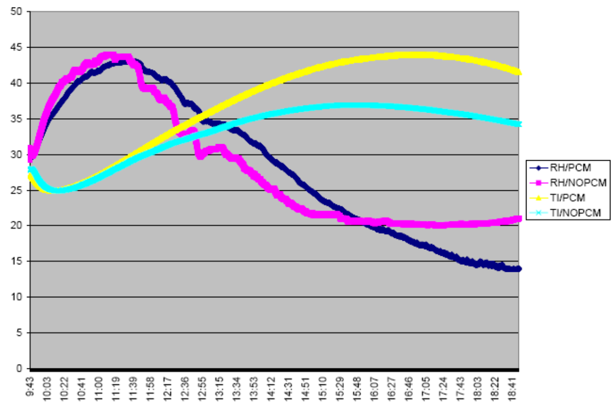

Figure 6. Comparison of inside air temperature and the relative humidity for the two designed rooms, 04.03.2016.

CONCLUSION

In the present paper, experimental measurements of temperature inside a designed room model equipped with phase change material (PCM) have been performed. The measured values are compared with those measured outside the room and inside another designed room that not equipped with PCM. In comparison with the outside air temperature, the internal temperature in the room with PCM showed that thermal comfort temperature is obtained during the whole day.

Moreover, in comparison with the room that not equipped with PCM, the results showed a nearly agreement of relative humidity, however, an increase of inside temperature in PCM-room. That refereed to the insulated walls of both rooms. Finally, it should be concluded that further experimental measurements should be performed in different days and with other phase change materials. Such performing experiments can show the effectiveness of using PCM in building insulation in Taif city, Saudi Arabia.

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