International Journal of Scientific Engineering and Research (IJSER)
www.ijser.in
ISSN (Online): 2347-3878, Impact Factor (2015): 3.791

Experimental Study on Performance of Smart Material in Structures

S. Abinaya[1], S. Amutha[2], N. Deepika[3], M. Rinisha Kartheeshwari[4], S. Dharmar[5]

[1, 2, 3, 4] U.G Scholars, Department of Civil Engineering, P.S.R. Engineering College, Sivakasi, India

[5]Associate Professor, Department of Civil Engineering, P.S.R. Engineering College, Sivakasi, India

Abstract: ***Smart Materials are introduced to fulfill the demand of high performance building. Among the different types of smart materials predominantly fascinating towards energy efficiency of buildings are Phase Change Materials (PCM), able to retort to thermal stimuli with a reversible transition between solid, liquid and gaseous states. Marco Casini [1] The PCM was installed longitudinally in to the cavities of hollow blocks with Expanded Polystyrene as filler by the process of Macro-encapsulation. The experimental set up consists of two nominally identical model house having a dimension of 6' x 4' x 5'.The thermal performance of two identical model house was evaluated experimentally with and without PCM by using Temperature sensor. The experimental result showed that using PCMs in model house sustain the inside temperature closer to the desired temperature for a longer time.***

Keywords: Smart material, Phase Change Material, En-capsulation, Model house

1. Introduction

The Energy consumption in buildings varies significantly during the day and night according to the demand by business and residential activities. [2] Karthik Muruganantham. In order to limit the energy requirements of building smart material are introduced. Particularly Phase Change Material are used to maintain the room temperature by absorbing or releasing heat (called latent heat) without increasing their internal temperature. PCMs can work under the principle of passive energy storage to save thermal energy in the buildings. In order to increase the thermal inertia of a building's components, Phase Change Materials (PCMs) can be used in wall panels, roofs, tiles, ceiling insulations and other components of a building as internal energy storage. Naser P. Sharifi *et.al* [3]. The main advantage of setting a PCM in wallboards and incorporating it into the interior side of the exterior envelope of a building is to have a large surface in contact with the indoor air. Bouguerra E.H*et.al* [4] the use of PCM did not significantly reduce the overall ecological impact under the experimental conditions considered. However, for some theoretical scenarios, the ecological benefits achieved by the PCM are enhanced (12–14% reduction in comparison with no PCM). Albert Castell *et.al* [5]

The most common solution for implementing PCMs into buildings so far are by installing PCM enhanced wall boards towards the interior side of the building envelope. And implementing PCMs on the roof will be able to absorb the incoming solar energy and the thermal energy from the environment to reduce warmth fluctuations on the inside. Simen Edsjø Kalnæs Bjørn Petter Jelle [6] .From a practical point of analysis, only the phase change solid-liquid is used in building encase. The material can be a pure substance, a eutectic mixture or non-eutectic mixture. F. Kuznik et.al [7]. For Experimental analysis, the External walls were set with hollow concrete brick (400 x 200 x 200 mm). There is a possibility for increasing the thermal resistance of the Hollow concrete block by filling the enclosures with Phase Change materials (PCMS) such as Calcium chloride Hexahydrate ($CaCl_2.6H_2O$) with Expanded polystyrene pellets as filler by the process of Macro-encapsulation. The Macro-encapsulation not only provides a self-sufficient structure of PCM and detach the PCM from thermal fluids but also enhances the warm transfer rate. Swetha Pendyala[8]. Macro capsules which comprises the addition of PCM in some form of package such as pouches made by thin aluminium foil sheet.

This paper summarizes the Experimental results on performance of thermal balance of two identical Model houses; it was found that the high temperatures of the walls and roofs will be reduced during summer and better the occupants comfort was achieved in the Model house constructed with PCM.

2. Experimental Setup

2.1 Model House

The location of the site is at the P.S.R Engineering College in Sivakasi. There the locality preferred was at the back of civil department where all the indispensable traits for the passive solar design is accessible. Since all the necessities are about to be satisfied, the location was selected. Model house is the one which is to monitor the thermal performance practically. Here two model houses of size (6'x 4'x 5'), one with PCM and the other without PCM were made by using the hollow concrete blocks of size (400 x 200 x 200 mm). The model house with PCM consists of stuffed Calcium Chloride Hexahydrate with expanded polystyrene pellets as filler along the walls and the roof. Direct incorporation of PCMs in building materials are not well suited for long-term applications. So that encapsulation process is carried out for PCM buildings. Özonur et al. [9]

Figure 1: Two identical Model House with and without PCM

2.2 En-capsulation

The objective of encapsulation is the material containment, to prevent changes in its chemical composition and to avoid interactions with the environment. The process also leads to increased compatibility with the surrounding materials. There are two including macro and micro, among them macro encapsulation was implemented here. Macro differs from micro encapsulation by the material size used for capsulation, whose size must be more than 1cm. Here the encapsulation material is an aluminum foil pouch which comes under macro since its size. Nearly 400 encapsulated pouches were made with each pouch consists of 125g of the PCM material and the remaining space was filled with expanded polystyrene pellets which have good emissivity.

Figure 2: Macro encapsulation of PCM integrated into hollow block

2.3 Calcium Chloride Hexahydrate (PCM)

Calcium Chloride Hexahydrate is a inorganic salt that behaves as a typical ionic halide, being solid at room temperature and extremely soluble in water. Calcium Chloride Hexahydrate can store/release up to 193 kJ/kg on entire phase transition. Kenneth and Gates [10]. This huge increase of thermal storage capacity for PCMs and their almost isothermal expulsion could be used to stabilize ambient temperatures within the buildings. Bouguerra E.H *et.al* [4] The Phase change behavior of this material is suitable for heat storage with a low degree of integration in order to evaluate their long-term reversibility. The following tabulation shows their properties

Table 1: Properties of Calcium Chloride Hexahydrate

S. No.	*Properties*	
1	Chemical formula	$CaCl_2.6H_2O$
2	Crystal structure	Trigonal
3	Heat of fusion	171 KJ/Kg
4	Melting point	30 °C (86 °F;303 K)
5	Specific heat capacity	300.7 J/mol·K

2.4 Temperature Sensor

The sensor used for temperature detection is of type LM 34. These devices are precision integrated- circuit temperature sensors, whose yield voltage is linearly proportional to the Fahrenheit temperature. The LM34 device has a benefit over linear sensors calibrated in degrees Kelvin, because the user is not required to subtract a large stable voltage from its yield to obtain convenient Fahrenheit scaling.

Figure 3: Temperature Sensor

The LM34 device does not necessitate any exterior calibration or trimming to provide typical accuracies of ±1/2°F at room temperature i.e.−50°F to 300°F temperature range. The features of the LM34 device make it suitable for many general temperature sensing applications. Multiple pack up options expand on flexibility of the device. Due to its simplicity and handy the sensor is adopted here.

Table 2: Parameters of Temperature Sensor

S. No.	*Parameter*	*LM34*	
		Max	*Min*
1.	Accuracy	-2	+2
2.	Non linearity	-1	+1

3. Mechanism of PCM

The mechanism of PCM in building as seen in figure 4.For better mechanism it is necessary to have solar passive buildings. These buildings have the ability to provide thermal comfort and have the potential to reduce energy demand by 5 to 20%. They have the control system which collects the solar energy and distributed without active devices by radiation, convection or conduction. Thus the project was implemented by using the solar passive building. At the transition temperature (i.e. 30ºC) the encapsulated PCM undergoes phase change which leads to the convection process. Convection is the behavior of emitting the temperature which is possible when there is the molten state over the solid state occurs. Through this the interior temperature will be sustained and this will be absent at the Model house without PCM.

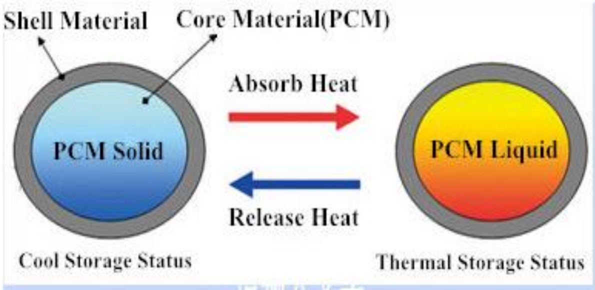

Figure 4: Principle of PCM

4. Experimental Data Observation

The temperature variation of a month during the various working hours of a day was measured, and recorded in the Table-2. In which the outdoor temperature, indoor temperature with PCM and indoor temperature without PCM were measured by using temperature sensor. Average readings were taken for every week of month and their respective graphs were plotted in figure 5 & 6.

Freezing and melting are the change of state from liquid to solid and from solid to liquid. For any given pure chemical they occur at a specific temperature, which is the same for freezing and melting. Melting is also called fusion, and the energy requisite to bring about this transform of state is called the heat of fusion or the enthalpy of fusion. The purity of the compound can influence the temperature at which the solid-liquid change takes place. In morning the thawing of the PCM will be partial and the complete liquefaction process will be terminated at afternoon. It again solidifies when the temperature less than transition temperature attains

Table 3: Temperature Variation Profile

Weeks	Datum	Temperature variation TIME (hours)						
		9	10	11	12	13	14	15
1	A	36.8	38.4	39.3	40.1	42.5	41.4	40.0
	B	35.2	35.9	36.1	37.3	39.5	38.2	36.6
	C	33.4	34.3	34.2	35.1	37.2	35.8	34.8
2	A	38.8	39.5	42.2	45.0	46.2	44.5	41.9
	B	35.3	36.2	36.6	40.9	41.9	40.8	39.4
	C	33.6	34.2	37.3	38.8	39.7	38.8	35.9
3	A	42.8	45.3	48.9	54.4	58.1	52.6	48.7
	B	40.1	41.8	44.9	50.6	52.7	48.5	45.3
	C	37.7	39.1	42.4	47.5	49.9	45.2	42.3
4	A	43.2	45.7	50.1	53.5	57.5	53.6	48.7
	B	40.7	43.2	46.5	50.6	53.9	50.7	45.7
	C	38.0	40.3	44.2	47.1	50.8	47.3	42.7

From Table 3 A, B, C refers; A – Exterior temperature, B – Interior temperature of model house without PCM, C – Interior temperature of model house with PCM.

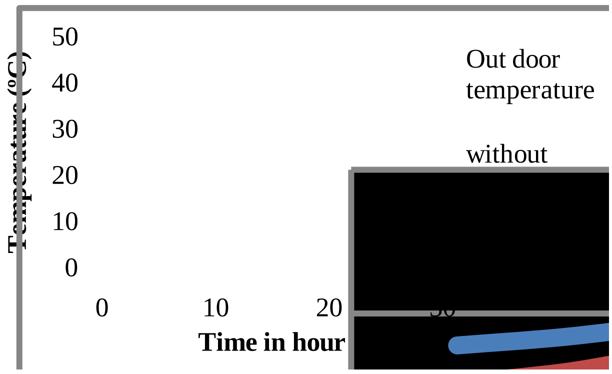

Figure 5: Comparison of temperature variation between with and without PCM

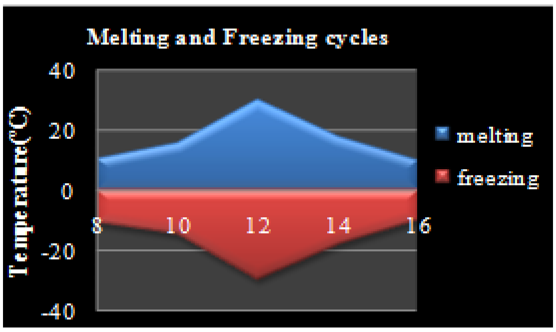

Figure 6: Phase change interface

5. Results and Discussions

This paper discussed about the simulation result of PCM integrated model house with non PCM integrated model house constructed by Hollow concrete blocks. Using PCMs in buildings increases the thermal inertia of the structures and not only prevents rapid changes in the inside temperature, but also saves more energy by decreasing the energy needed to heat up and cool down the structure. Naser P. Sharifi *et.al* [3] The experiment was conducted to measure the thermal performance of the two identical model house constructed with and without PCM. Table-2 shows the temperature variation profile for one month. The thermal effect from a conventional house and PCM house were calculated for every day per hour during the month February to March. Monitoring of the experimental system has provided positive results. The report shows a total reduction of needed heating load for the building of around 10% when utilizing PCMs in the building.

6. Conclusion

From the Experimental analysis, the results are obtained and graphs are also plotted to show the temperature variation between with and without PCM integrated model house. The integration of PCM in the exterior walls of the building shown that there is a maximum reduction in temperature up to 4^{o}C. The proposed model house would really beneficial in smart material construction with increasing demand. These reduce the usage of air conditioning system and reduction of CO_2 gas emissions. Thus it can be concluded that this concept gives a great solution to sustain the occupant comfortable temperature by absorbing a large amount of heat during a period of hot days. From the result it has been perceived that:

- The number of comfortable hours has been sustained with the PCM's integrated building than the non integrated building.
- The PCM have a energy storing capacity and act as environmental friendly.

References

[1] Marco Casini, "Smart materials and nanotechnology for energy retrofit of historic buildings, " Journal of Advances In Civil, Structural And Construction Engineering, CSCE 2014.
[2] Karthik Muruganantham, "Application of Phase change Material in Buildings: Field Data vs. Energy Plus Simulation, " November 2010.
[3] Naser P. Sharifi and Aaron Sakulich, "Application of Phase Change Materials in Structures and Pavements"
[4] Bouguerra E. H et.al, "Performance of Phase Change Materials for Cooling of Buildings in Mild climate", In the proceedings of 30th International Plea conference, December 2014.
[5] Albert Castell, Karim Menoufi, Alvaro de Gracia, Lídia Rincón, Dieter Boer, Luisa F. Cabeza " Life Cycle Assessment of alveolar brick construction System incorporating phase change materials, " Journal of Applied Energy, 101 (2013), 600–608.
[6] Simen Edsjø Kalnæs Bjørn Petter Jelle, "Phase Change Materials for Building Applications: A State-of-the- Art Review and Future Research Opportunities, Energy and Building, " 2015.
[7] F. Kuznik, D. David, K. Johannes, J.-J. Roux "A review on phase change materials integrated in building walls, " Journal of Renewable and Sustainable Energy Reviews, Elsevier, 15 (1), pp. 379-391, 2011.
[8] Swetha Pendyala, "Macro encapsulation of Phase Change Materials for Thermal Energy Storage," Journal of University of South Florida, Scholar Commons citation, January 2012, Graduate Theses and Dissertations.
[9] Kenneth I. and J. Gates, "Thermal Storage for Sustainable Dwellings," Journal of International Sustainable Building proceedings, Maastricht, Netherlands, 2000.
[10] Y.Özonur, M.Mazman, H.Ö. Paksoy and H. Evliya, "Microencapsulation of coco fatty acid mixtures for Thermal energy storage with phase change material" Journal of International Journal of Energy Research, 30, 741-749, 2006.