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Significance of Phase Change Materials in Building Construction

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ABSTRACT:
Buildings are designed for the sole purpose of maintaining conducive living standards for the occupants. Electrical energy consumption varies significantly during the day and night according to the demand by the industrial, commercial and residential activities. PCMs are regarded as a possible solution for reducing the energy consumption of buildings. These are the materials that could store a large amount of energy in the form of latent heat at a constant temperature without any fluctuations or variations in the temperature. Buildings which have large mass will react slowly to changes in heating and cooling demands. This research is done to study the temperature fluctuations at 3 different layers of the model walls (outer face, inner face, intermediate face) throughout the day. The fluctuation of temperature taking 3 different PCMs viz. HS29, HS24 and HS34 are studied. For temperature readings, Arduino Nano processor is used with LM35 temperature sensors connected to the central IC.

Keywords: *phase change materials, latent heat, PCM, green building, thermal insulation.*

I. INTRODUCTION

In the world where there is a continuous increase in the emission of greenhouse gases into the atmosphere and increase in global temperature exponentially it is necessary to use technologies to find a way to reduce the temperature of the buildings inside. In hot and cold climate countries, the major part of the load variation is due to the air conditioning and space heating respectively. Buildings that will have large mass will react slowly to changes in heating and cooling demands. PCMs are the materials that could store a large amount of energy in the form of latent heat at a constant temperature without any fluctuations or variations in the temperature. Phase change materials (PCMs) have low temperature range and high energy density of melting – solidification compared to the sensible heat storage. This property of the PCMs finds its usage in many fields of energy conservations to a greater extent.

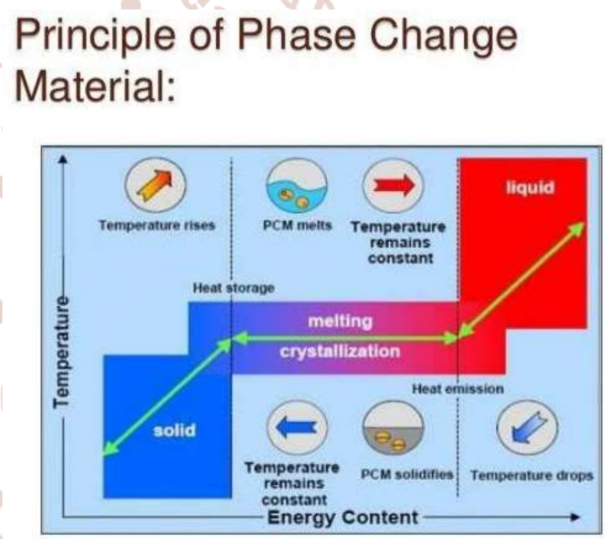


fig. 1: principle of PCMs

Table 1. Classification of PCMs

TYPE	DESCRIPTION
Organic	These are generally stable compounds nd free from super cooling, corrosion, having great latent heat of fusion E.g. Paraffin compounds, non-paraffin compounds
Inorganic	PCMs exhibit properties of good thermal conductivity, affordability and non-flammability. However, most of them are corrosive to most metals, undergo super cooling and undergo phase decomposition E.g. salt hydrates, metallic.
Eutectics	the mixtures having low melting point of multiple solids and its volumetric storage density is slightly higher than that of organic compounds. E.g. Organic-organic, Inorganic-inorganic, Organic-inorganic.

Table 2: Properties of PCMs

No.	Property	Selection Criteria
1.	Thermal Properties	a. Suitable Melting Temperature b. High Latent Heat of Fusion c. Good Heat Transfer Rate
2.	Physical Properties	a. Favourable Phase Equilibrium b. High Density c. Small Volume Change
3.	Chemical Properties	a. Long Term Chemical Stability b. Compatibility with Construction Materials c. Non-Toxicity
4.	Economica l Properties	a. Cost Effective b. Abundant in Nature c. High Scale Availability

Table 2: Advantages and disadvantages of PCMs

Advantages	Disadvantages
Available In Large Temperature Range (From Approximately 20°C Up To About 70°C)	Under go super cooling during freezing
Chemically inert	Under go phase segregation during transition
Have low vapour pressure in the melt form	Corrosive to most metals
Reasonabe latent heat of fusion (120J/gupto210J/)	Irritant
Non-corrosive, however, fatty acids are mildly corrosive	Have high vapour pressure
High volumetric latent heat storage and high latent heat of fusion	May show long term degradation by oxidization, hydrolysis, thermal decomposition and other reactions
High thermal conductivity	Exhibit variable chemical stability
Non-flammable	High volume change

II. Objectives

To reduce the energy consumption of buildings which can be considered in construction of sustainable and energy efficient buildings. To store thermal energy in building walls at peak temperature hours and use it at the low temperature hours.

III. Experimental setup

1. Materials and equipment specifications:

- Hollow concrete blocks of size 35x20x20cm^3 with two cavities each of 15x15x18cm^3
- PCM packaging is done by small packets of polythene which are filled with 140 ml of PCMs and then sealed by thermal sealing machine.

- The model size is 125x125cm^2 which stands 66cm in height. Sealed PCM packets are placed with sand in the cavities.
- Out of total 36 bricks, 9 are filled with HS24, HS29 and HS34 respectively. The remaining bricks are not filled with any material.
- A temperature sensing apparatus is built using Arduino Nano processor and 12 LM35 temperature sensors on IC CD4051.

Fig. 3: hollow concrete block filled with PCM packet and crushed sand

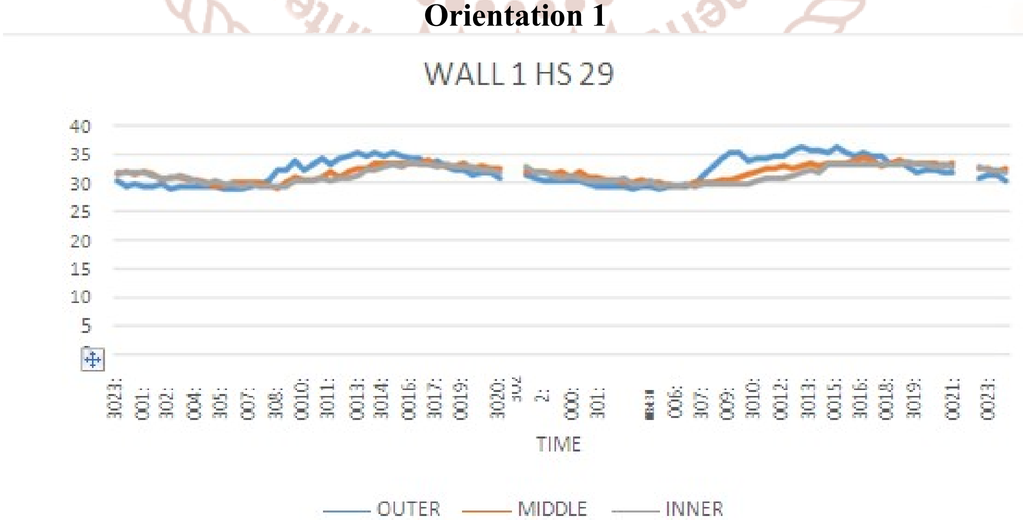
2. Casting and curing:

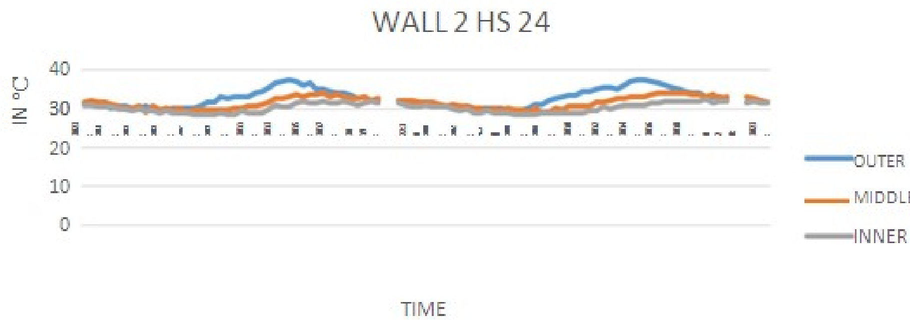
A small room like structure is constructed of size 125x125x66cmThe structure is casted on a movable steel trolley with 9 bricks on each side of structure. Structure is constructed of English bond with temperature sensors in three different lateral layers fitted in position. This structure is casted with keeping the side of wall with reference facing to north direction. These temperature sensors are fitted in between 2nd and 3rd vertical layer of bricks. The structure is casted and cured for 3 days

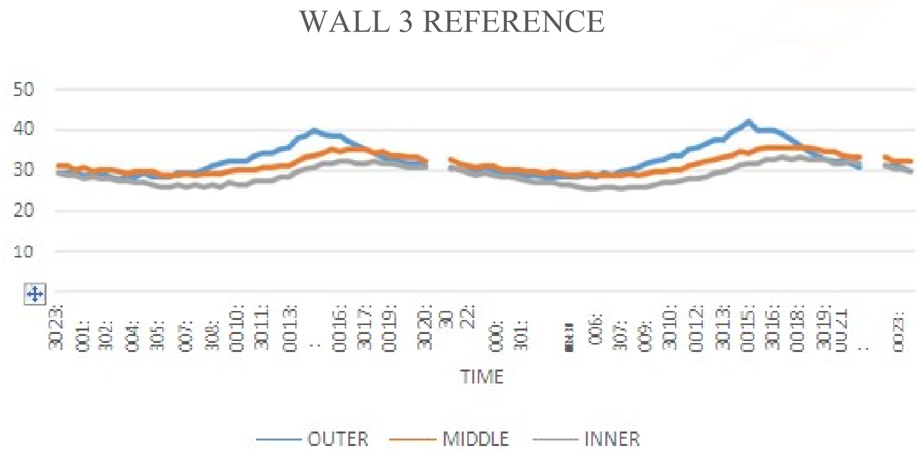
3. Testing:

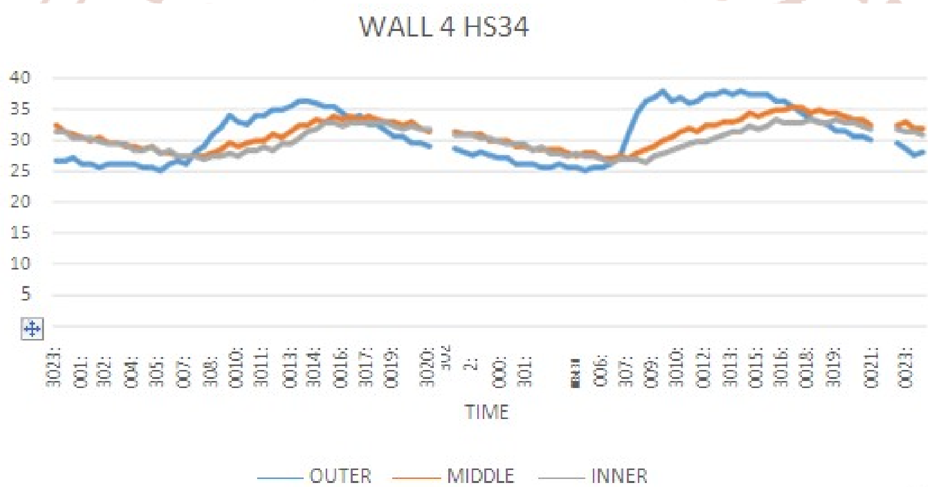
The temperature readings of different layers for every half hour interval is recorded in the memory card installed on the central IC. The readings are taken from 28st May 2018 to 30th May 2018 (orientation 1). After this the readings are taken by rotating the model by 180^0 from 3rd June 2018 to 5th June 2018 (orientation 2). Graphs of temperature versus time is plotted and shown below for 28th-30th may 2018 and 3rd-5th June 2018.

Orientation 1

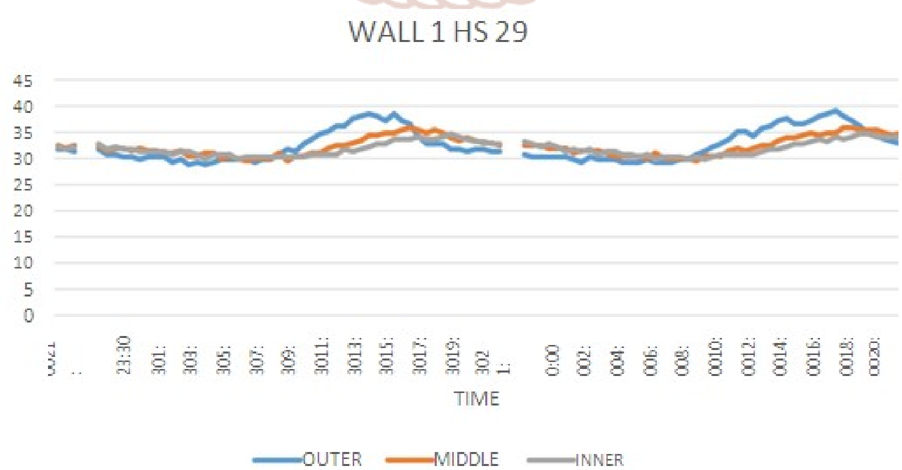


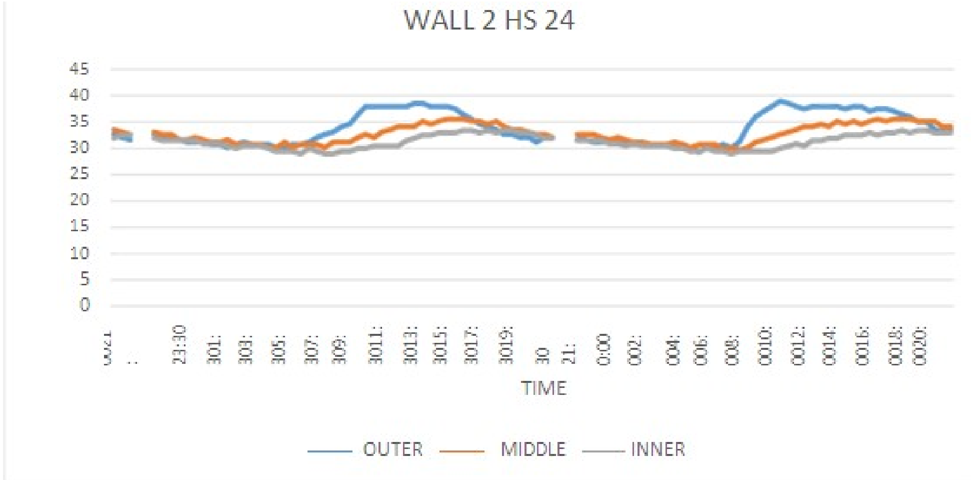


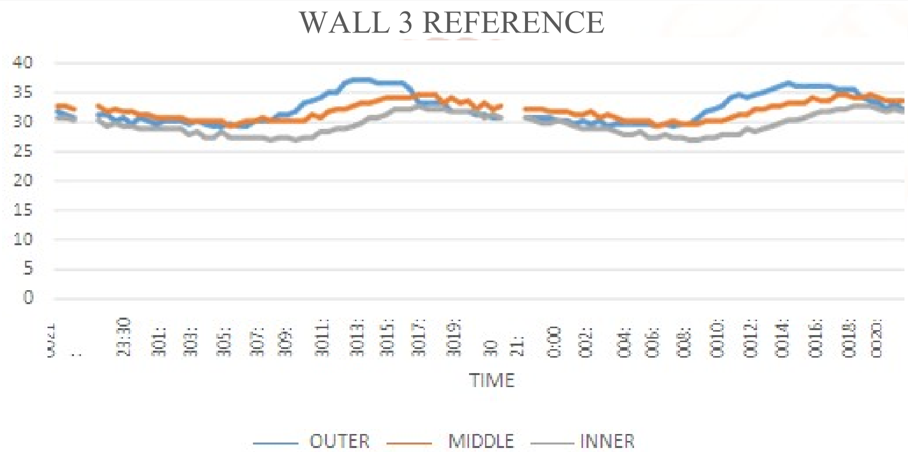


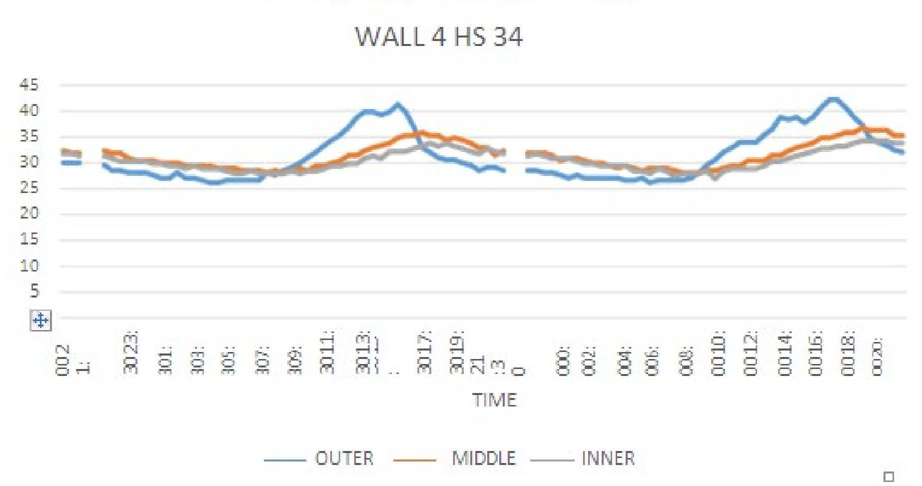


Orientation 2









In orientation 1 (28th May 2018 to 30th May 2018), Wall 4 (HS34) shows insulating properties, which shows a temperature difference of 6°C at peak hours with respect to Wall 3 (REFERENCE).

In orientation 2 (3rd June 2018 to 5 th June 2018), Wall 4 (HS34) shows insulating properties, which shows a temperature difference of 4°C at peak hours with respect to Wall 3 (REFERENCE). But here reference wall is restricted from direct sunlight exposure.

IV. Future scopes:

For finding the effectiveness of PCMs the model should be tested in different weather conditions. Encapsulation method of PCM can be improved to increase the contact area. Expected life of PCMs is 10 years so further research on PCMs can help in increasing the life cycle of PCMs. Further research can be done for developing concrete friendly PCMs. Strength analysis can be done. Effects of combination of two or more PCMs can be studied.

V. Conclusions:

After the study of temperature fluctuations in the walls we can thereby conclude that, the orientation of structure and direct exposure to sunlight are important factors while evaluating the effectiveness of PCM. The melting range of PCM need to be decided considering the local temperature conditions. The above experimental study shows a temperature drop of 5-6°C in orientation 1, and 4-5°C in orientation 2. Due to ambient weather conditions and cloudy weather, the results are quantitatively less effective than predicted.

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