Experimental Heat Transfer Analysis of Different PCM Material used in Concrete Wall

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Abstract— A phase-change material (PCM) is a substance with a high heat of fusion which, on melting and solidifying at a certain temperature, is capable of storing and releasing large amounts of energy. PCMs are regarded as a possible solution for reducing the energy consumption of buildings. For raising the building inertia and stabilizing the indoor climate, PCMs are more useful because of its nature of storing and releasing heat within a certain temperature range. Phase change materials (PCM) are “latent” thermal storage materials possessing a large amount of heat energy stored during its phase change stage. The energy required to change the phase of a substance is known as latent heat. In this paper we are using PCM integrated into building materials for thermal energy storage applications, and much attention has been given to works concerned with the achievement and assessment of applying PCM in concrete wall. Because concrete have high specific heat capacity as well as the thermal conductivity which will eventually affect their thermal performance. In this we are using two PCM material integrated into concrete namely paraffin wax and beewax. After that we take reading of temperature by using temperature sensor. We are also comparing temperature of modes operating in series or parallel.

Key words: PCM, Paraffin Wax, Digital Temperature Sensor

I. INTRODUCTION

Phase Change Material (PCM) plays an important role as a thermal energy storage device by utilizing its high storage density and latent heat property. One of the potential applications for PCM is in buildings by incorporating them in the envelope for energy conservation. During the summer season, the benefits are a decrease in overall energy consumption by the air conditioning unit and a time shift in peak load during the day. Heat transfer through the building wall material using different phase change materials. We are using the concrete blocks as the building wall material. The objective of using the PCM’s is to be utilized its high latent heat of fusion to reduced heat gain by absorbing the heat in the concrete blocks through the melting process before it reaches the indoor space.

II. HEAT TRANSFER ANALYSIS

Heat transfer is the transition of thermal energy from a hotter mass to a cooler mass. when an object is at a different temperature than its surroundings or another object, transfer of thermal energy, also known as heat flow, or heat exchange, occurs in such a way that the body and the surroundings reach thermal equilibrium, this means that they are at the same temperature. Heat transfer always occurs from a higher temperature object to a cooler temperature one as described by the second law of thermodynamics or the Clausius statement. Where there is a temperature difference between objects in proximity, heat transfer between them can never be stopped, it can only be slowed. Heat transfer may occur by conduction, convection and radiation. For heat transfer to take place, temperature difference must exit. (This is as per second law of thermodynamics), conduction heat transfer takes place by molecular energy exchanges or by flow of valence electrons in conducting medium. Convection heat transfer takes place by motion of a fluid. If the convection is induced by density difference resulting from temperature difference within the fluid, it is known as natural convection. However, if fluid motion is aided by a pump or fan, then the process is called forced convection. Radiation heat transfer does not depend on any material medium, but takes place by means of electromagnetic waves which are propagated at a velocity comparable to that light. In actual practice, heat transfer takes place by a combination of modes operating in series or parallel.

III. CLASSIFICATION OF PCM

A. Organic PCMs:

Paraffin, Fatty acids, Lauric acid, O-Cresol, Brij 35 etc. is the example of organic PCMs.

   – Advantages
   1) Availability in a large temperature range and freeze without much super cooling.
   2) Ability to melt congruently and self-nucleating properties.
   3) Compatibility with conventional material of construction and no segregation.
   4) Chemically stable and high heat of fusion.
   5) Safe and non-reactive and recyclable.

   – Disadvantages
   1) Low thermal conductivity in their solid state. High heat transfer rates are required during the freezing cycle and volumetric latent heat storage capacity is low.
   2) Flammable. This can be easily alleviated by a proper container and due to cost consideration only technical grade paraffin’s may be used which are essentially paraffin mixture and are completely refined of oil.

B. Inorganic PCM:

Salt hydrates are the examples of inorganic PCM.

   – Advantages
   1) High volumetric latent heat storage capacity and Low cost and easy availability
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(IJSRD/Vol. 3/Issue 02/2015/392)

2) Sharp melting point High thermal conductivity
3) High heat of fusion, low volume change and non-flammable
   – Disadvantages
1) Change of volume is very high.
2) Super cooling is major problem in solid-liquid transition Nucleating agents are needed and they often become inoperative after repeated cycling.

IV. SELECTION CRITERIA
Thermodynamic properties, the phase change material should possess

1) Melting temperature in the desired operating temperature range, high latent heat of fusion per unit volume and high specific heat, high density and high thermal conductivity
2) Small volume changes on phase transformation and small vapour pressure at operating temperature to reduce the containment problem and congruent melting.

A. Kinetic Properties:
1) High nucleation rate to avoid super cooling of the liquid phase and high rate of crystal growth, so that the system can meet demands of heat recovery from the storage system.

B. Chemical Properties:
1) Chemical stability, complete reversible freeze/melt cycle and no degradation after a large number of freeze/melt cycle
2) Non-corrosiveness, non-toxic, non-flammable and non-explosive materials

C. Economic Properties:
1) Low cost and large-scale availability.

V. MATERIALS
Material used for thermal analysis

A. Concrete Block:
Concrete block is the types of Building wall material. It is made by the mixture of cement, water and concrete. Concrete block can be used like any other masonry unit to build foundation walls, archives and corbels, etc. a typical concrete block is equivalent to 4.5 bricks. Thus construction is faster than with other machinery units. The mortar used is also less which result in cost saving. Concrete blocks have been extensively used in combination with conventional roofing systems like RCC, RBC, GI SHEET, ACC SHEETS etc. they are also compatible with other materials like fired bricks. Dressed stone and compressed earth blocks for composite wall construction. We have used this as the building wall material. Size of the concrete block is given below:

Fig. 1: Concrete Block (400mm X 200mm X 100mm)
Different properties of the Concrete block are listed below:
- Block Size 400mmX200mmX100mm
- Average Compressive Strength at 28 50-110 Kg/sq. mm
- Mix Proportion 1:12-14(1 part cement: 12-14 parts sum graded aggregates)
- Water absorption in 24 hr. Less than 10% by weight of Block
- Thermal Conductivity 1.7 W/mk
- Heat of fusion 150 KJ/kg

We have filled the concrete block with the different phase change materials in the centre hole which is shown in the diagram

Fig. 2: Concrete Block Integrated With Paraffin Wax

Fig. 3: Concrete Block Integrated With Beewax
B. Paraffin wax:
Paraffin wax is a white or colourless soft solid derivable from petroleum, coal or oil shale that contains a mixture of hydrocarbon molecules containing between twenty and forty carbon atoms. It is solid at room temperature and begins to melt above approximately 37 °C (99 °F). Its boiling point is >370 °C (698 °F). Common applications for paraffin wax include lubrication, electrical insulation, and candles. It is distinct from kerosene, another petroleum product that is sometimes called paraffin wax is mostly found as a white, odourless, tasteless, waxy solid, with a typical melting point between about 46 and 68 °C (115 and 154 °F), and a density of around 900 kg/m³. It is insoluble in water, but soluble in ether, benzene, and certain esters. Paraffin is unaffected by most common chemical reagents but burns readily. Its heat of combustion is 42 kJ/g.

C. Beewax:

1) Wax Content Types and Its Percentage:
- Hydrocarbons 14%, Monoesters 35%, Diesters 14%, Triesters 3%, Hydroxymonoesters 4%, Hydroxypolymers 8%, Acidesters 1%, Acid polymers 2%, Free fatty acids 12%, Free fatty alcohols 1%, Unidentified 6%.

Beeswax is a tough wax formed from a mixture of several compounds an approximate chemical formula for beeswax is C15H31COOC30H61. Its main components are palmitate, palmitoleate, and oleate esters of long-chain (30–32 carbons) aliphatic alcohols, with the ratio of triacontanyl palmitate CH3(CH2)29COO(CH2)14CH3 to cerotic acid CH3(CH2)24COOH, the two principal components, being 6:1. Beeswax can be classified generally into European and Oriental types. The saponification value is lower (3–5) for European beeswax, and higher (8–9) for Oriental types. Beeswax has a relatively low melting point range of 62 to 64 °C (144 to 147 °F). If beeswax is heated above 85 °C (185 °F) discoloration occurs. The flash point of beeswax is 204.4 °C (400 °F) and Density at 15 °C is 958 to 970 kg/m³.

D. Digital Temperature Sensor:

- Specification
  1) Temperature range: -50 to 300°C
  2) Resolution: + - 0.1°C/°F
  3) Power supply: 1.5 volt

VI. EXPERIMENTAL SETUP

Experimental setup has made by the plywood, concrete block, wax and the digital temperature sensor, the different procedure for Preparation of Setup Box, first we prepared...
the Plywood box, which is packed around three sides and one side, is open. After this we prepared the electronic kit which has used for the temperature observation. Concrete block (400mmX200mmX100mm) has kept inside the open side of plywood. And fully air packed with the thermocol sheet. The plywood box made in such way that it can be open and close by back side for taking reading on back side by fleep type cover arrangement. We packed the whole setup box. We filled up the centre hole of the concrete block with the different PCM material.in one concrete block we filled up the paraffin wax PCM material and in other block we filled up the beewax PCM material. Setup Box has shown in the diagram which is kept in the sun light for taking reading. Setup box has kept in the sunlight as that position and direction where the concrete block got the direct sunlight for the Natural Convection process. Firstly we take surface temperature reading by digital temperature sensor as (T1) and inside temperature reading as (T2) as shown in observation table below. We have taken the observation reading for the different phase change material (paraffin wax and beewax) in the different days, from 11:00 am to 4:00pm in the sun light the observation table has shown in the table.

VII. RESULT AND DISCUSSION

Observation Table for the Hollow Concrete Block

<table>
<thead>
<tr>
<th>SR.NO</th>
<th>TIME</th>
<th>SURFACE TEMP (T1)</th>
<th>INSIDE TEMP (T2)</th>
<th>TEMPERATURE DIFFERENCE (T1-T2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11:00 AM</td>
<td>42.2</td>
<td>39.5</td>
<td>2.6</td>
</tr>
<tr>
<td>2</td>
<td>12:00 PM</td>
<td>44.2</td>
<td>40.2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>1:00 PM</td>
<td>43.3</td>
<td>40.5</td>
<td>2.8</td>
</tr>
<tr>
<td>4</td>
<td>2:00 PM</td>
<td>43</td>
<td>39.9</td>
<td>3.1</td>
</tr>
<tr>
<td>5</td>
<td>3:00 PM</td>
<td>42.7</td>
<td>39.7</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>4:00 PM</td>
<td>41.3</td>
<td>38.9</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Table 1: for the Hollow Concrete Block

<table>
<thead>
<tr>
<th>SR.NO</th>
<th>TIME</th>
<th>SURFACE TEMP (T1)</th>
<th>INSIDE TEMP (T2)</th>
<th>TEMPERATURE DIFFERENCE (T1-T2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11:00 AM</td>
<td>41</td>
<td>36.3</td>
<td>4.7</td>
</tr>
<tr>
<td>2</td>
<td>12:00 PM</td>
<td>43.6</td>
<td>36.9</td>
<td>6.7</td>
</tr>
<tr>
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<td>4</td>
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<td>37.1</td>
<td>6.4</td>
</tr>
<tr>
<td>6</td>
<td>4:00 PM</td>
<td>40.9</td>
<td>36.8</td>
<td>4.1</td>
</tr>
</tbody>
</table>

Table 2: For Paraffin Wax

VIII. CONCLUSION

1) Graphs have been drawn between Time and two different PCM.
2) Two PCM materials have been compared with concrete block.
3) Graphs have been drawn for comparing paraffin wax and bee wax with concrete block.
4) The average temperature difference for hollow concrete block, paraffin wax and bee wax is observed to be 2.9, 5.98 and 4.93 respectively.
5) From the experimental analysis it is conclude that reduction in temperature is observed in paraffin wax than bee wax in comparison with hollow concrete block.

REFERENCES


