ANALYZING THE THERMAL PERFORMANCE OF A PCM MATERIAL UTILIZED IN BUILDINGS

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Abstract

In the present work investigations have been carried out by simulation to study and examine the roof of a building incorporating PCM for thermal comfort in residential building. Two models were used and the theoretical performance of both is compared by considering one as the reference case. A PCM integrated roof has the potential to maintain a fairly constant temperature within the room due to its huge heat absorbing and storing capacity in a passive manner. Whereas, the ceiling temperatures always fluctuate in a Non-PCM room (RCC room) throughout the day and every day. The results of ceiling temperatures, heat flux and heat transfer rate in the Non-PCM and PCM room were observed and better results are found for PCM Room.

Keywords : Phase Change Material – PCM, Latent Heat of Fusion – LHF, Sensible Heat - SH

I. Introduction

PCMs are components with a high latent heat of fusion. It can store latent heat throughout the transition phase. A PCM retains thermal energy and stores it at some stage in a solid-to-fluid phase transition, enabling the temperature to be kept up close to the melting point. Latent heat storage is useful as it requires a smaller temperature difference between the storage and releasing features than smart heat, making PCMs ideal for preserving up temperatures within a temperature limit [III].

PCMs are utilized because of their high latent heat capacity; they can maintain up inner temperatures at whichever temperature is wanted. Because of the increasing center of attention on environmental alternate and the utilization of renewable energy,
PCMs have been researched and developed a lot over the recent decade. This is because of PCMs' capacity to maintain up interior temperatures without the utilization of gasoline or fuel. They have a massive power storage density, which is available within a slender temperature range. There are many types of section alternate substances which all have their blessings and disadvantages. The three predominant types of PCMs are inorganic, natural and bio-based [IV][VII].

II. Literature Survey:

| Author                          | Important findings                                                                 |
|---------------------------------|-------------------------------------------------------------------------------------|
| Haoshan Ge, et.al., [III].      | The primary reason behind deciding on inorganic PCM is that they are not flammable and will have greater heat conductivity. |
| Sari A et.al., [VIII].          | During solidification process no subcooling is occurred, the latent heat is 182.7 J/g and LA–SA mixture as a PCM is acceptable for the thermal storage system. |
| Mondal S. [V].                  | PCM Material plays a keyrole in textile industry for clothing in cold session and thermal comfort for humans. |
| Kandasamy R et.al., [IV].       | In the die injection molding, by utilization of PCM the required temperature is maintained inside the die. |
| Tgagi.VV et.al., [IX]           | In thermal energy storage applications, the PCM plays a prominent role to store the energy and reduced the super cooling problems occurred. |
| Santamouris M et.al., [VII]     | The building temperature is reduced during summer by applying cool material on the walls and roofs. |
| Arkar C et.al., [II]            | Utilization of PCM in buildings, low energy is consumption and overall cooling efficiency is increased compared to normal buildings. |
| Agyenim F et.al., [I]           | The results explained that, by using PCM low heat loss occurred and to fabricate the equipment is also easy. |
| Pasupathy et.al., [VI]          | To reduce the load during summer session, PCM can act as a temperature moderation |

III. Modeling in Creo 2.0

The RCC model is designed in Creo and assembled as per the requirements. The given figure is the drawing of RCC Roof with and without PCM.
Fig: (a) without PCM (b) With PCM

IV. Boundary Conditions

Through there are various methods of incorporating PCM in the building envelope. An attempt is made in the present research for the modeling and simulation of a PCM integrated roof and a simple RCC roof as shown in fig. the RCC roof is considered as a reference case to compare the performance of a PCM integrated roof. Initially the theoretical thermal performance of two roofs is studied.

As real time problem, two equal test rooms for simulation have been constructed to study the thermal performance of the two roofs. Two test rooms of identical sizes of 120*120*120 cm$^3$ are constructed to conduct simulation with the size of the two roofs were taken as 120*120 cm$^2$ area.

Roof - 1 : simple RCC roof 10 cm thick

Roof –2 :PCM integrated roof {PCM panel 4 cm thick between of 3 cm of RCC} of thick 10 cm.

The temperature distribution inside the roof is analyzes in the Ansys 2019R2 by finite element analysis. The parameters are shown below

| Material                        | Density (kg/m$^3$) | Thermal Conductivity (W/mK) | Specific Heat (J/kg K) |
|---------------------------------|--------------------|-----------------------------|------------------------|
| Concrete Slab (RCC)            | 2300               | 1.279                       | 1130                   |
| Roof top slab (mixture of Brick + lime) | 1300               | 0.25                        | 800                    |
V. Results and Discussions

The assembled model in Creo is renewed into STEP file and imported to ANSYS. To get accurate results in the mesh element size should be minimum. Hexagonal fine mesh is applied to the assembled body. The boundary conditions are mentioned above, are applied to the RCC Roof.

![Fig: (a) imported model from the Creo modeling software (b) Hexagonal meshed body.](image)

From the statistics, it is measured that the total nodes are 833760 and elements are 239869.

The element quality is mention in given table.

| Mesh metric       | Element quality | Aspect Ratio | Skewness  | Orthogonal Quality |
|-------------------|-----------------|--------------|-----------|--------------------|
| Min               | 0.12421         | 1            | 1.30e-10  | 5.44e-2            |
| Max               | 1               | 16.046       | 0.94559   | 1                  |
| Avg               | 0.92732         | 1.3557       | 9.976e-2  | 0.89967            |
| Standard Deviation| 0.11548         | 0.56134      | 0.16725   | 0.16721            |
Fig: boundary conditions are applied to the RCC

Fig: Temperature distribution inside the RCC Room
From the above figure, the results stated that temperature for ceiling with PCM is maintained low temperature compared with without PCM. The PCM material is rejecting the temperature from the surroundings and keeping low temperature inside the room. The temperature difference between with and without PCM is approximately 6-8°C. By considering this result, the human can stay comfortable inside the PCM Room. Similarly, the results are noted for the 2PM and it mentioned in below figure.

**Fig:** Temperature of the RCC - with and without PCM at different days at 2PM
VI. Conclusion

A PCM integrated roof has the potential to maintain a fairly constant temperature within the room due to its huge heat absorbing and storing capability in a passive manner. Whereas, the ceiling temperatures always fluctuate in a Non-PCM room (RCC room) throughout the day. The temperature variation between with and without PCM shows a significant difference, with PCM maintaining a more stable temperature. This can lead to improved comfort levels for occupants, especially during hot weather conditions.

*Fig: Heat flux (W/m²) - with and without PCM at different days at 1&2PM*

From the above figure, the simulation results stated that very low heat is transferred to the RCC room by using PCM. With these results, the human can stay comfortable during summer.
without PCM is approximately 6-8°C. The heat flux entering the PCM rooms is observed to be 10-18 w/m² and for non-PCM Room 140-160 w/m².

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