Analysis Of Thermal Energy Storage System With Different Phase Change Material

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Abstract - *This review paper comprises the use of phase change materials (PCMs) in various types of heating/cooling systems as an effective means of blocking energy and maintaining temperatures within the well-being zone. PCMs have been widely used in a variety of systems for heat pumps, solar engineering, and thermal control. During the last decade, researchers have looked at the usage of PCMs in heating and cooling applications. PCMs are abundant and melt and solidify at a wide range of temperatures, making them useful in a variety of applications. This study also discusses the investigation and analysis of Phase Change materials utilised in various heating/cooling systems and their applications.*

***Key Words*: PCMs, ANSYS, Meshing, Thermal Energy Storage Analysis, house cooling**

1. INTRODUCTION

Due to rising global energy consumption associated with the growth of civilization and the concomitant depletion of conventional energy sources, several countries are implementing technological solutions to minimise energy consumption in different areas, including construction. Scientific research is currently being conducted in a number of research institutes across the world in order to develop material and technology solutions that will allow rooms to maintain adequate thermal comfort throughout periods of low or high outside air temperatures. Simultaneously, solutions related to the possibilities of employing energy from renewable sources, including in the case of building partitions, thermal energy from solar energy conversion, are being researched. To increase thermal comfort in building rooms, phase change material is increasingly being employed, which lowers temperature changes on the interior surface of the partition due to its heat storage capabilities. This material is used to reduce the amount of energy required to cool or heat rooms in a building by incorporating it into passive or active systems. In passive systems, phase change material (PCM) is used in many construction components. The goal of this approach is to collect thermal energy from a variety of sources and then direct that energy toward Lower temperatures. Wall partitions are commonly utilised regardless of the building's structural architecture, although they can also be found in floors and roof elements. The application procedure for phase change materials is determined by the type of PCM and its location. It's most commonly used in microcapsule form in concrete elements. PCM is added to the concrete mix, which is then used to make concrete wall elements, and the samples were utilised to determine the thermal properties of composites. Varied computational methods were used to characterise the heat flow through the tested materials with various concentrations of PCM in the sample and heat capacity.

Phase change material is used in a variety of building items, including ceramic components. Filling existing gaps in finished masonry using phase change material is one of the options for modifying these features. A separate PCM layer on the inside or outside of the ceramic partition, or between the partition layers, is another option. Modification of phase change material for items used as indoor interior cladding is also being researched. The goal of this alteration is to absorb excess thermal energy inside the space, which can come from a variety of sources, including solar radiation coming through the building's major glazed surfaces or the operation of electronics inside the room. Research confirms the beneficial effect of phase change material on the stabilisation of temperatures on the internal surface of the partition, regardless of the location of the PCM and the partition structure in which it was used, during periods of significant temperature fluctuations and room overheating.

There is an issue with the basic thermal parameters for these composites when developing customised parts or multilayer construction partitions. We frequently receive fundamental physical and mechanical attributes for prefabricated pieces prepared by the manufacturer (parameters). Obtaining thermal parameters needs the use of available research methods, such as experimental, computational, or computer simulations, despite the fact that the element or partition is made up of numerous materials. In many research facilities, studies are conducted using a single method or a combination of methodologies, with the results compared. Experiments on a single building component or a modified multilayer building partition can be carried out using the experimental approach.

These studies are conducted in a laboratory setting or in (outside) field settings under natural climate conditions. The authors of the research conducted tests in a laboratory chamber on a PCM modified wall to investigate the effect of temperatures on the effective thermal conductivity of this partition. These experiments were conducted in a constant state, demonstrating a good link between thermal conductivity and growing temperature. Thermal characteristics of building components were also studied in the next papers. Available statistical programmes can also be used to analyse the results of laboratory tests. More information regarding the physical and mechanical properties of newly built composites or redesigned building partitions can be gathered as a result of such study.

2. MATERIALS AND METHODS

2.1 Phase Change Materials (PCMs)

A phase change material (PCM) is a substance that releases/absorbs enough energy to generate useful heat/cooling at phase transition. In most cases, the transition will be between one of the first two fundamental states of matter, solid and liquid. The phase transition may also occur between non-classical states of matter, such as crystal conformance, in which the material transitions from one crystalline structure to another, which may have a higher or lower energy state.

2.2 Materials

For the analysis, a model with a base dimension of 7.31m*7.31m*0.005 m and a surface area of 53.43m^2 was used. On this foundation, a room model with four walls, one roof, two glass windows, and one door was built. The room's dimensions were 5.18m*4.87m*5.18m, resulting in a volume of 31.856m^3. The model was then examined after various PCMs were applied to the inside surfaces of the walls.

Five variants of the PCM models were used for the purpose of the research.

- Variant 1(V1) - no PCM
- Variant 2(V2) - PCM used is Sodium Metasilicate Pentahydrate.
- Variant 3(V3) - PCM used is n-Hexadecane.
- Variant 4(V4) - PCM used is save OM 65.
- Variant 5(V5) - PCM used is A70 PlusICE.

Because of the ongoing research using a modified masonry element in collector and accumulation walls, the aforementioned PCM layer system was postulated. The phase change material's position on the inside will block solar radiation from entering the living space, preventing energy from being used in cooling.

2.3 Selection Criteria

The phase change material should possess the following thermodynamic properties:

- Melting temperature in the desired operating temperature range
- High latent heat of fusion per unit volume
- High specific heat, high density, and high thermal conductivity
- Chemical properties
- Chemical stability
- Complete reversible freeze/melt cycle
- No degradation after a large number of freeze/melt cycle
- Non-corrosiveness, non-toxic, non-flammable and non-explosive materials
- Economic properties
- Low cost
- Availability

3. PHASE CHANGE MATERIAL (PCM) INTEGRATED IN WALLS

3.1 Encapsulation

Since PCMs transform between solid–liquid in thermal cycling, encapsulation naturally became the obvious storage choice. Following are some of the encapsulation technique that are used for the encapsulation of PCMs -

- Macro-encapsulation
- Micro-encapsulation
- Molecular-encapsulation

In this technique, PCM has to be encapsulated before being used into construction elements. Here, the microencapsulation is summarised. The process that PCM particles are contained in a thin and stable shell (ranging from 1 -m to 1000 -m) is known as microencapsulation.

Due to these advantages of preventing the leakage of PCM and high heat-conduction ability. Therefore, its chances of being incorporated into various construction materials are increased greatly.

The Project is completed with the encapsulation of different phase change materials placed in the walls. The setup is made with fewer joints to decrease the wastage.

3.2 Product Development

Many decisions need to be made in order to produce the most desirable and affordable product to make the highest profit and most unique devices. There are three distinct phases: The concept phase, the study phase, and the production phase. During the concept phase, we defined the problem of storing thermal energy for a long duration. We then conceptualised in different ways by cascading of PCMs in different layers by using different types of PCMs.

Through research and customer surveys, we entered the study phase knowing consumer preferences.

After reviewing our results, we hypothesised how we would enter the production phase. Because this product would be produced in bulk, we took into account the price of machinery, storage, labour, etc.

After all of those costs were accounted for, we analysed potential if the task could be achieved practically.

4. STEADY STATE THERMAL ANALYSIS BY ANSYS

Steady-state thermal analysis is evaluating the thermal equilibrium of a system in which the temperature remains constant over time. In other words, steady-state thermal analysis involves assessing the equilibrium state of a system subject to constant heat loads and environmental conditions. The simplest form of steady-state analysis is linear steady-state analysis in which input parameters, such as material properties, are prescribed independent variables.

The following figure shows the steady state thermal analysis setup. We have created 2 models which are-

- Non PCM based model
- PCM based model consisting of different PCM material analysis

4.1 Specifications of the model

Following physical specifications were considered for the purpose of the analysis -

- Length Of Room = 5m
- Breadth Of Room = 5m
- Height Of Room = 5m
- Area Of Plot = 7.31m*7.31m=53.43m^2

4.2 Materials Used

The following materials were considered during analysis –

- Concrete
- Oak Wood
- Glass
- Wood
- Sodium Metasilicate Pentahydrate (Thermal Conductivity – 0.1 W/m .ºC)
- N-hexadecane (Thermal Conductivity – 0.154 W/m .ºC)
- Save Om 65 (Thermal Conductivity – 0.19 W/m .ºC)
- A70 Plus ICE (Thermal Conductivity – 0.23 W/m .ºC)

4.3 Meshing

A mesh is a representation of a larger geometric domain by smaller discrete cells. Meshes are commonly used to compute solutions of partial differential equations and render computer graphics, and to analyse geographical and cartographic data. A mesh partitions space into elements (or cells or zones) over which the equations can be solved, which then approximates the solution over the larger domain. Element boundaries may be constrained to lie on internal or external boundaries within a model. Higher-quality (better-shaped) elements have better numerical properties, where what constitutes a "better" element depends on the general governing equations and the particular solution to the model instance. A mesh is considered to have higher quality if a more accurate solution is calculated more quickly.

4.4 Meshing Specifications of the Model

Table 4.3.1 Meshing details of the model

Properties	Values
Element Size	0.33 m
Element Order	Linear
Number of Nodes	5266
Number of Elements	13835
Smoothing	Medium

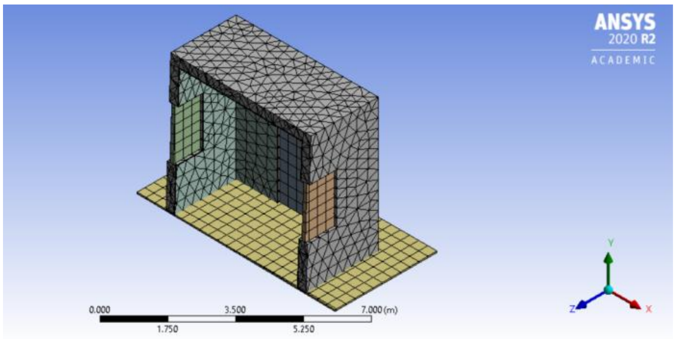

Fig. 4.3.1 Meshing Of the model

5. RESULT

The Project is completed with the encapsulation of different phase change materials placed in the walls. The setup is made with fewer joints to decrease the wastage. Four types of PCMs are placed in the walls. The temperature of the room from inside increases as the thermal conductivity of the PCM is increased.

Temperature increases sharply until it reaches the melting zone of respective PCMs.

5.1 Wall without PCM

Temperatures from the analysis shows following result -

- Maximum Temperature - 39.991 °C
- Minimum Temperature - 37.132 °C
- Average Temperature - 38.531°C

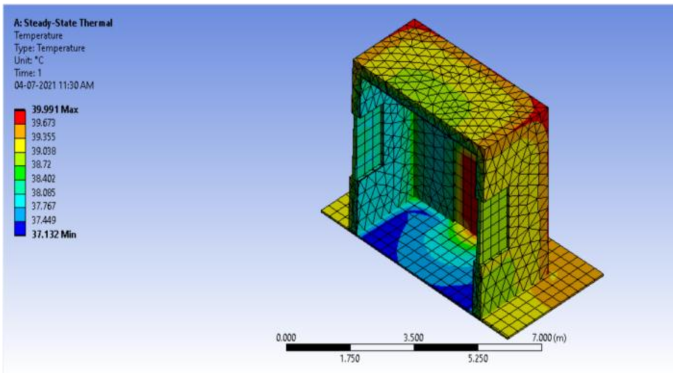

Fig 5.1 Variation of Temperature in the Room without Use of PCM

5.2 Wall with PCM used is Sodium Metasilicate Pentahydrate

Temperatures from the analysis shows following result -

- Maximum Temperature - 41.234 °C
- Minimum Temperature - 34.649 °C
- Average Temperature - 38.566 °C

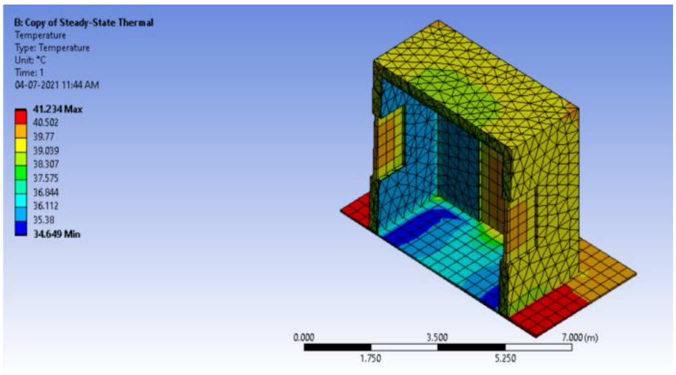

Fig 5.2 Variation of Temperature in the Room with use of Sodium Metasilicate Pentahydrate

5.3 Wall with PCM used is n-Hexadecane

Temperatures from the analysis shows following result -

- Maximum Temperature - 40.755 °C
- Minimum Temperature - 35.359 °C
- Average Temperature - 38.692°C

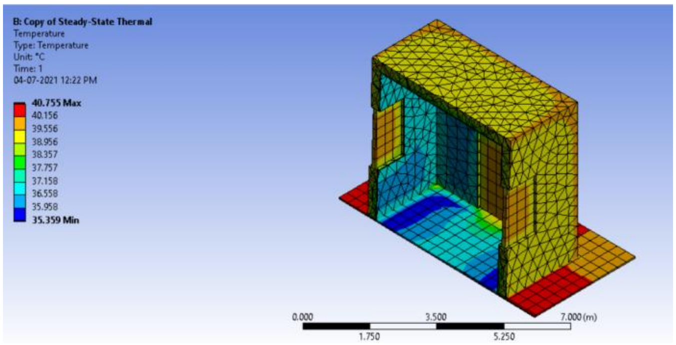

Fig 5.3 Variation of Temperature in the Room with use of n-hexadecane

5.4 Wall with PCM used is savE OM 65

Temperatures from the analysis shows following result -

- Maximum Temperature - 40.582 °C
- Minimum Temperature - 35.657 °C
- Average Temperature - 38.736 °C

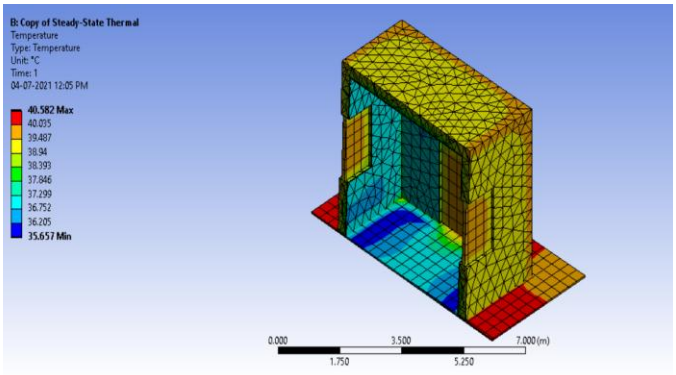

Fig 5.4 Variation of Temperature in the Room with use of savE OM 65

5.5 Wall with PCM used is A70 PlusICE

Temperatures from the analysis shows following result -

- Maximum Temperature - 40.437 °C
- Minimum Temperature - 35.902 °C
- Average Temperature - 38.77 °C

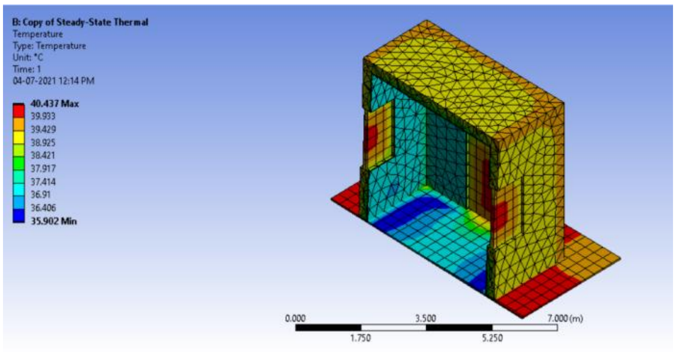

Fig 5.5 Variation of Temperature in the Room with use of A70 PlusICE

6. CONCLUSIONS

Table 5.5 Comparison of Various Results

PCM Used	No PCM	Sodium Metasilicate Pentahydrate	n-hexadecane	savE OM 65	A70 PlusICE
Thermal Conductivity (In W/m .°C)	Nil	0.1	0.154	0.19	0.23
Maximum Temperature (Outside wall)	39.99 °C	41.234 °C	40.755 °C	40.582 °C	40.43 °C
Minimum Temperature (Inside Wall)	37.13 °C	34.649 °C	35.359 °C	35.657 °C	35.90 °C

With the conclusion of the analysis, the project comes to a close. The test results are listed in the tables above.

- The test was conducted to confirm that PCM may be used in our construction process to lower the amount of energy required to cool/warm the room to a human comfortable temperature.
- Using the various PCMs, it can be seen that as the Thermal Conductivity of PCMs increases, so does the temperature inside the room.
- As a result, a PCM with poor heat conductivity should not be employed to get the most out of this approach.
- If we use a Sodium Metasilicate Pentahydrate (Thermal Conductivity – 0.1 W/m .°C) the minimum temperature dropped from 37.132 °C to 34.649 °C which is a 8 % drop in temperature.
- If we use a n-Hexadecane (Thermal Conductivity – 0.154 W/m .°C) the minimum temperature dropped from 37.132 °C to 35.359 °C which is a 5 % drop in temperature.
- If we use a SavE OM65 (Thermal Conductivity – 0.19 W/m .°C) the minimum temperature dropped from 37.132 °C to 35.657 °C which is a 4.1 % drop in temperature.
- If we use an A70 PlusICE (Thermal Conductivity – 0.23 W/m .°C) the minimum temperature dropped from 37.132 °C to 35.902 °C which is a 3.4 % drop in temperature.

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