Abstract- Phase change materials (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. This property of the PCMs finds its usage in many fields conserving energy to a greater extent. The major application of the PCMs is in the building construction where it is used in several ways to maintain either a constant temperature in the interior of the building or to store a large amount of solar radiation as a latent heat energy in it. In this paper a building construction model is suggested and analyzed using Fluent 6.3 and the results were discussed. The main consideration was made on the regulation of inner temperature fluctuations along with the maximum energy of solar radiation that could be stored and retrieved later. A detailed literature survey of all the researches that were done previously using PCMs in buildings was done.

Keywords- Phase change materials, Buildings, Fluent, Temperature fluctuations, Energy storage.

I. INTRODUCTION

In the world where there is a continuous increase in the emission of green house 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. Phase change materials (PCMs) or latent heat storage materials are suggested to be used along with the insulators in the building construction to reduce the inflow of heat into the building. PCMs are the materials that stores a large amount of energy in it by undergoing a phase transformation like solid to semi-solid, solid to liquid or liquid to gas. Thus it stores a large amount of energy at a given temperature corresponding to the melting point of the PCM by the conversion of its phase. It has a large amount latent heat storage capacity in it when compared to the available sensible heat storage (SHS) material. In general latent heat storage materials are based on the heat absorption or release when a storage material undergoes a phase change from solid to liquid or liquid to gas or vice versa. Unlike conventional SHS, however, when PCMs reach a temperature at which they change phase (their melting temperature) they absorb large amounts of heat at an almost constant temperature. The total heat storage in a material [1] is given by

\[ E = mc\Delta T_1 + mL + mc\Delta T_2 \]

Where \( \Delta T_1 \) is the difference between the melting point temperature and the initial temperature \( \Delta T_2 \) is the difference between the final temperature and the melting point temperature and \( mL \) is the latent heat storage (Energy storage considering the phase transformation) of solid-solid transformation heat is stored as the material changes from one crystalline structure to another. So small latent heat is involved and also there is only a small volume change that occurs. So it has less stringent container requirements and design flexibility than solid-gas or liquid-gas[2]. Solid-gas transformation though have a larger latent heat capacity has a greater volume change that makes designing process a complex one[3]. Solid-liquid PCMs though have higher volume change when compared to the solid-solid phase change materials, is more economical.

The PCMs to be used should have thermal properties including suitable phase-transition temperature, High latent heat of transition, good heat transfer and other properties including small volume change, low vapor pressure etc. The phase change materials are classified into three categories namely organic, in-organic and eutectic. Depending upon the application and the properties required, the PCMs are chosen accordingly. The organic materials include paraffins (like octadecane) mostly straight chain n-alkanes CH3–(CH2)–CH3. The in-organic materials include salt hydrates and metallics.

Several researchers have worked on with the PCMs and its properties that could be be used in building constructions for human comfort. Studies have been made on PCM used as trombe walls, wall boards, under floor heating, shutters etc. In this paper the properties of n-octadecane and paraffin wax was studied and a fluent analysis was made on the proposed model for the building wall construction and the results obtained were studied. The best orientation of the PCMs for the building wall is found using the fluent software.

II. LITERATURE REVIEW

Swet [4], Chandra et al.,[5] and Ghoneim et al.[6] investigated the use of sodium sulfate dehydrate as
PCM for Trombe walls in building constructions and found that PCM of smaller wall thickness was more desirable than the ordinary masonry wall providing higher amount of latent heat storage. They tested with common salt hydrates and hydrocarbons and concluded that for a given amount of heat storage it is economic to use PCMs rather than using water walls or mass trombe walls making it easy for the retrofit applications of the buildings. Bourdeau[7] used chloride hexahydrate as a PCM and found that 8.1 cm PCM wall has higher thermal performance than 40-cm thick masonry wall, whereas Knowler[8] used commercial grade paraffin wax to increase the efficiency of the walls.

Kedl and Stovall [9], Neper [10], Drake [11], Peippo et al. [12], Athienitis et al. [13], Kissock et al. [14] and Feldman et al. [15,16] researched about the use of PCMs incorporated into plasterboard or by their addition in wet stage of plasterboard manufacture to provide thermal comfort of light weight buildings inside and also to improve the building structure.

Gutherz and Schiler [17] incorporated a PCM in the ceiling of the building and directed the solar radiation into the PCM so that it heats up and stores the energy of the sun and then releases the heat into the room to keep the room warm enough in the comfort region. Bruno [18] developed a ceiling board system using PCM which stores coolness in off-peak time and releases during peak times thereby reducing the cost of electricity. Kodo and Ihamoto [19] also examined the peak shaving control of air conditioning systems using PCMs for office building ceiling boards, which were enhanced by micro-capsule PCM.

Feldman et al.[20] studied the thermal properties of ester obtained from the esterification process of stearic and palmitic acid with methyl, butyl and propyl alcohols and demonstrated the ability to tailor PCMs with specific transition temperature. Strith and Novak [21] presented a model in which the paraffin wax (melting point 25-30 °C) absorbs the solar radiation and stores energy which later heats the air for the ventilation of the house. The simulation results depicts that the amount of heat energy stored has an effect on the outlet air temperature.

Athienities et al.[22] investigated the transient heat transfer in the floor heating system and focused on the influence of cover layer and incident solar radiation on floor temperature distribution while Bako[23] used the thermal mass integrated storage on floor to reduce the peak loads so that the storage of heat energy into the PCM is done during the night time when the electricity charges are low. These investigations also concluded that PCM s can provide a stable indoor room temperature without fluctuations. Lin et al.,[25] studied the under-floor heating system including the polystyrene insulation, electric heaters, PCM, air layer and wood floor. It was designed that the heaters heat the PCMs during off-time and release energy during the peak time. Nagano et al. [24] worked on the floor air conditioning system using granulated phase change material made of foamed waste glass beads and paraffin mixture.

Amar et al.,[26] discussed about the selection of materials of PCM in building constructions and also summarized about the investigations and the analysis done on the PCMs used in buildings to reduce the temperature swing inside. Pasupathy et al.,[27] gathered information regarding the earlier problems involved in the incorporation of PCM in the buildings and various methods regarding the space heating and cooling to maintain a constant temperature inside without fluctuations. Baetens et al.,[28] also studied the PCM utilization in the buildings to maintain a stable indoor temperature. Bragança et al.,[29] experimentally proved that gypsum plaster finishing with a thin layer of 5 mm of PCM are favorable to achieve a temperature swing of 2 to 5 °C.

Mehling[30] developed a concept where the PCM shutter was placed outside during the day time, where energy is stored in the shutter and during the night time, when the shutter is closed, heat from the PCM radiates the room.

Schossig et al.,[31] tried to improve the drawbacks of the macro-capsules or direct immersion process PCMs and introduced a novel approach to micro-encapsulate PCMs for the building industry. Tyagi et al.,[34] also worked on with micro-encapsulation technology presenting an overview of previous research on micro-encapsulation technology for incorporating PCMs in the building applications along with few conclusive remarks from available literature. Fang and Zhang[32] found a new composite PCM by blending an organic PCM with organic modified montmorillonite. The characteristics of the composite PCM after 1500 heating-cooling cycles showed that it has a good performance stability. The composite was used in gypsum boards had a function of cutting down energy consumption by decreasing the temperature swing inside. Fang et al.,[33] also prepared a three composite phase change material blending butyl stearate, dodecanol and RT20 with an organically modified montmorillonite (MMT) aiming in further reduction in the temperature variations.

Zhu et al.,[37] overviewed the previous research in dynamic characteristics and performance of active and passive building applications concentrating on the peak load shifting and recommendation for future works in the area was provided. Kuznik et al.,[36] discussed about physical consideration about the building envelope, PCM integration and
thermophysical property measurements and other numerical studies concerning the integration. Zhou et al.,[35] summarized previous works on latent thermal energy storage in building applications and their thermal performance analyses and also did a numerical simulation of buildings with PCMs and discussed the results. Ascione et al.,[38] investigated on the dynamic component that could contribute in reducing building cooling demand in Mediterranean climate. Analyses of an office building was made with reference to the entire cooling season (from May 1st to September 30th), in reliable conditions as regards building use, and thus internal gains, occupancy, activation of cooling systems.

François Mathieu[39] et al studied about the thermal shielding of external building walls with the help of a numerical model. In a thermal steady-state regime, a low thermal conductivity wall results in low heat gains and heat losses which are beneficial to reduce energy consumption. A finite volume code was done using genetic algorithm for the multi layer PCMs.

B.L. Gowreesunker et al.[40] investigated on the study of PCM in the clay boards using CFD. CFD analysis was done in a ventilated and a non ventilated room and the air temperature, indoor temperature distributions were obtained in the analysis results. They aimed at reducing the temperature variation.

Ye et al.,[41] demonstrated the performance of a kind of shape-stabilized PCM for Building Energy research. The performance of the PCM was also simulated in the BuildingEnergy, a software built via experimentation and evaluated the performance of the PCM via energy saving index (ESI). The ESI is the ratio of a particular material or component’s energy saving equivalent (ESE) to the corresponding value of the ideal material or component that can maintain the room at an ideal thermal state in passive mode.

III. PROBLEM IDENTIFICATION

As it could be seen in the literature review there were several researches and investigations performed in the usage of PCMs in the building applications. The main concern of most of the research papers were to reduce the fluctuations of the temperature inside so that there will be constant temperature inside the building depending upon the melting point of the PCM. If the melting point of the PCM is 28°C then it will be able to store a large amount of energy in this melting point temperature (Latent heat) thus maintaining a constant temperature in its heat addition process and also in its discharging process for a long time.

Thus the buildings in cold nations are made of PCM impregnated walls or Trombe walls to store the heat in it without losing as a waste and to maintain a warmer temperature when needed. The block diagram of the maintenance of temperature swing in in colder nations is as in Fig.1.

Also in summer, the building walls are designed such that the high temperature outside should not reach the inner side of the building. So, PCMs are used so that the heat from the exterior is stored in it at its melting temperature. Here the PCM is chosen in such a way that its melting temperature is much below the exterior temperature such that comfort temperature is maintained. Also if an insulator is placed next to the PCM as in Fig.3 during night times when the energy is discharged the insulator provides resistance for heat flow maintaining a constant temperature throughout the day. Two configurations are suggested and the configuration are modeled in Gambit and analyzed in Fluent 6.3.
IV. ANALYSIS OF THE PROBLEM

The PCM that we chose for the study was n-octadecane that has a melting point of 28.3°C lesser than the exterior temperature that was assumed to be 36°C. The model of the configuration was done using Gambit in 2D and the analyses was done using Fluent 6.3 considering unsteady state heat conduction equation.

For the first configuration as it could be seen in Fig.4. there is a total temperature drop of 8°C throughout and this temperature will be maintained constant because of the phase change material present between that absorbs heat in case of higher temperature and releases heat in the discharging condition maintaining constant inner temperature.

In the second configuration the temperature drop was about 10°C overall as it could be seen in Fig.5. This could also be possible configuration for the reduction in the variation of the temperature swing inside. The advantage of the second configuration is that the phase change material maintained at a temperature of its melting point it could store a large amount of energy in it which could be later extracted from it for other purposes. So in this configuration the PCM serves as a thermal heat storage and also as a inner temperature regulator.

V. RESULTS AND DISCUSSION

In the first configuration the drop of temperature was about 8°C whereas in the second configuration it was about 10°C. The main function of the PCM is to store a large amount of heat in it without raising the temperature maintaining it constant. But in the first configuration the PCM was maintained at a temperature below its melting point. So there will not be enough heat stored in it for retrieval or future usage. But there is a drop in temperature between exterior and interior overall. But the PCM in this configuration acts like a regulator and will store considerable amount of energy in the case of increase in temperature.

But in the second configuration the PCM is operating at a temperature at a temperature in the range of its melting point so in addition to the regulation of the fluctuation of energy it also store a large amount of heat in it that could be used for future purposes. So this configuration also serves the purpose of Trombe walls that stores the solar energy without wasting the radiation.

REFERENCES

Phase Change Materials In Building Construction To Reduce Room Temperature Fluctuations


[18]. Frank ,B. (2002),” Phase change material for space heating and cooling”. Sustainable Energy Center: University of South Australia; Presentation.


