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An Ample Appraisal of Phase Change Materials for Thermal Insulation

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Abstract

Energy is the evergreen topic which is having significant in all the stages & periods of Research. In the construction field, the consumption of energy is huge when compare to other engineering field. For the effective utilization and to conserve the energy resources, the implementation of new technique is the necessary one, to find the alter choice of formal materials and resources. This paper makes a complete review on the usage of phase change materials in building construction to consume less amount of energy by controlling the thermal effect in building envelope. Heat, Ventilation and Air-Conditioning is always a major concern in any of the building design to utilize less amount of conventional energy to make comfort environment. By considering the significance of HVAC, This paper also reviews the importance of HVAC implementation in buildings to make a thermal comfort building. Among the two types of PCM's the article recommends to use of organic PCM based on the benefits as mentioned in the reviewed papers. The prominent characteristics such as high thermal stability and non-corrosiveness are the major advantages of Organic PCM to recommend and utilize it in building environments when compared to Inorganic PCM.

Keywords: PCM, Energy Efficiency, Thermal Insulation, Comfort building zone

Introduction

Globally, buildings are responsible for 40% of the total world annual energy consumption which is responsible for one-third of greenhouse gas emissions around the world. A significant portion of this energy is used for lighting, heating, cooling, and air conditioning purposes in

buildings. Increasing awareness of the environmental impact of greenhouse gas emissions and CFCs triggered a renewed interest in environmentally friendly cooling, and heating technologies for buildings. Free cooling of buildings may be seen as an alternate to compressor based air conditioning systems used for the buildings. [7]

Residential buildings are mostly sensitive to climatic conditions, building envelopes work as the interface between indoor and outdoor environments, preventing heat gain in the summer ad heat loss in the winter. Proper use of energy storage technologies may reduce greatly the energy needs in residential dwellings while delivering better indoor environment quality. [1]

The importance of energy efficient buildings has assumed great urgency in light of fast depleting energy resources, energy scarcity and increasing environmental pollution. Innovative ways to cut down energy consumption are necessary. The construction industry is one of the largest energy consuming sectors. In modern buildings significant amount of energy is consumed to keep the building environment comfortable. In developing countries like India, rising population, increasing standards of living and rapid urbanization result in an increase in building construction activities. [2]

Approximately 30% of energy use in Canada is consumed in buildings. The largest component of this energy consumption in multifamily residential buildings is space heating. One of the primary functions of building enclosure is reducing space-heating energy. Although heat flow cannot be completely prevented, it can be controlled to reduce energy consumption, create a sustainable environment, and implement indoor human comfort. However, this can be achieved by constructing a thermally resistant building enclosure. [3]

Energy Efficiency

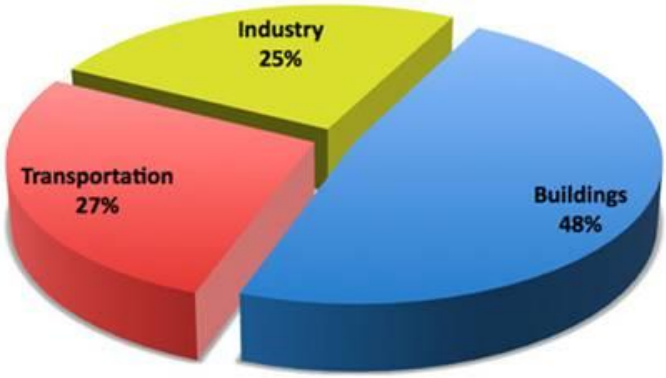

Fig.1. Energy Consumption in Canada

Energy Efficiency is nothing but an achieving the desired comfort with the least input of conventional energy. Architects and designers accomplish the task through solar passive design, use of renewable energy technology systems, and/or natural building materials. While designing such buildings, not only new building stock can be targeted but also existing buildings can be retrofitted with energy efficient and eco-friendly technologies, thereby substantially reducing energy consumption. All put together is Energy Efficient Housing. [2]

In residential sector, size and location are key factors for energy consumption. Small flats needs less energy as there is less conditioned and transfer area, and also less occupation. The amount and type of energy used in dwellings are mainly related to weather, architectural design, energy systems and economic level of occupants. By and large, dwellings in developed countries use more energy than those in emerging economies and it is expected to continue growing due to the installation of new appliances. In USA, dwellings consume 22% of the total final energy use, compared with 26% in the EU. The UK figure is 28%, well above the Spanish 15% mainly due to more severe climate and building type. For example: Predominance of independent houses over blocks. [14]

If we concentrate on energy efficiency, we can't omit the greenhouse gas emissions. The continuous increase in the level of greenhouse gas emissions and the climb in fuel prices are the main driving forces behind efforts to more effectively utilize various sources of renewable

energy. In many parts of the world, direct solar radiation is considered to be one of the most prospective sources of energy. However, the large-scale utilization of this form of energy is possible only if the effective technology for its storage can be developed with acceptable capital and running costs. One of prospective techniques of storing solar energy is the application of phase change materials (PCMs). This paper looks at the current state of research in this particular field, with the main focus being on the assessment of the thermal properties of various PCMs, methods of heat transfer enhancement and design configurations of heat storage facilities to be used as a part of solar passive and active space heating systems, greenhouses and solar cooking. [12]

Approximately 30% of energy use in Canada in consumed in buildings. The largest component of this energy consumption is in multifamily residential buildings in space heating. One of the primary functions of building enclosure is reducing space – heating energy. Although heat flow cannot be completely prevented, it can be controlled to reduce energy consumption, creates a sustainable environment and implement human comfort. However this can be achieved by constructing a thermally resistant building enclosure. [13]

Concrete and Brick walls are coated with Phase Change Materials to make a comfort building environment. Its aim is to study the influence of the integration of PCM on the thermal behavior of cells and on the thermal behavior of cells and on the improvement of thermal comfort in buildings under the Algerian climate. [6]

A building faces different kinds of problems due to thermal inefficiency such as condensation on window surfaces; some occur within our wall and roof systems. Condensation problems occur for several reasons like, elevated humidity and stagnation of air. Evaluations of thermal inefficiencies are done using visual observation, tracer smoke testing, infrared thermography and thermal analysis. Along with architectural features such as light shelves and sun shades, we have to consider about structural retrofits for stabilizing the thermal comfort.[15]

Phase Change Materials

The effect of phase change material (PCM) integration in buildings is investigated in mild climates for the entirely of the hot season. The incorporation of PCMs in building materials is particularly interesting because it allows for the thermal storage to become a part of the building structure while being completely passive. Simulations in a typical single-family home are carried out, and the effect of incorporating PCMs in different building components is analyzed. Results show an important reduction in cooling energy. [9]

In our work different kinds of materials were used as PCM. In principal materials should fulfill different criteria in order to be suitable to serve as a PCM.

- Suitable melting temperature
- High melting enthalpy per volume unit [kJ/m³]
- High specific heat [kJ/(kg.K)]
- Low volume change due to the phase change
- High thermal conductivity
- Nonflammable, Nonpoisonous, Non corrosive

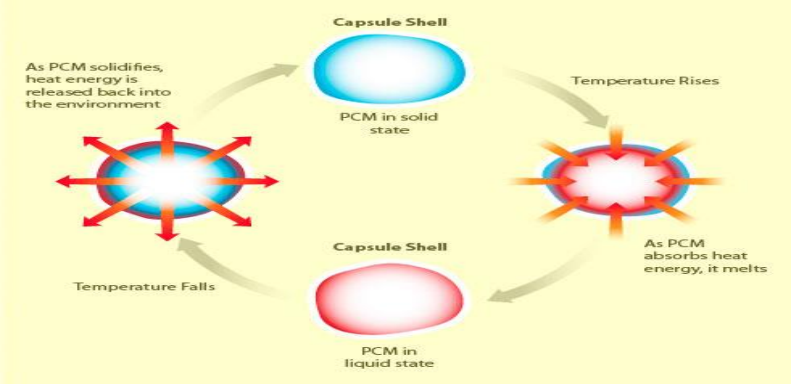

Fig.2 Phase Change Materials

Why PCM is Necessary for Energy Efficiency?

- The optimum concentration of PCM (30% PCM) wherein the composite material has a specific heat and mechanical properties well suited to the use of PCM in the building

- During the summer season, the PCM incorporated building components decrease of 2.5 C in the maximum indoor temperature and reduces the amplitude of the cells indoor temperature by 4C.
- The PCM improves the thermal comfort and increases the maximum wall temperature by 4 C in winter period. [6]

Organic PCM

These are generally stable compounds and free from super cooling, corrosion, having great latent heat of fusion. Commercial Paraffin waxes are inexpensive and have a reasonable thermal storage density of 120kJ/kg up to 210kJ/kg. Paraffin's are chemically inert and available in a wide range of melting temperatures from approximately 200C up to about 700C, of most interest in this group are the fatty acids palmitoleic acids. It is free from super cooling, volumetric change and has high latent heat of fusion. [8]

Table 1: Advantages and disadvantages of PCMs [10]

Description	**Organic PCM**	**Inorganic PCM**
Advantages	Not Corrosive	High Melting Enthalpy
	Chemically and Thermally Stable	High Density
	No or Little Subcooling	
Disadvantages	Lower Melting Enthalpy	Subcooling
	Lower Density	Corrosive
	Flammable	Cycling Stability

Overview on PCM Tasks

The Phase change materials are involved in various components of buildings to control the thermal effect and to make a comfort indoor temperature with minimal usage of energy.

Some of the tasks which are performed with the applications of PCM are studied to understand the mechanism and applications of PCM.

Some of the reviewed papers are compacted here as follows:

- The three cells are made and located in the Algiers region. Among the three cells two cells are made with PCM and by the analysis results show that the use of a gypsum plaster incorporating 30% PCM contributes to a reduction of the amplitude of indoor temperature of the cell by 4°C in the summer. The use of PCM has also improved thermal comfort and increased the maximum cell temperature by 2°C during winter. Tests of the flexural strength, compressive strength, bond strength, and hardness were performed at seven days of age on composite plaster/PCM materials. [6]
- In the present work, silica nanoparticles (30-70nm) were supplemented into cement paste to study their influence on degree of hydration, porosity and formation of different type of calcium-silicate-hydrate (C-S-H) gel. As the hydration time proceeds, the degree of hydration reach to 76% in nano-modified cement paste whereas plain cement achieve up to 63% at 28 days. An influence of degree of hydration on the porosity was also determined. In plain cement paste, the capillary porosity at 1hr is ~48%, whereas in silica nanoparticles added cement is ~35 % only, it revealed that silica nanoparticles refines the pore structure due to accelerated hydration mechanism leading to denser microstructure. Similarly, increasing gel porosity reveals the formation of more C-S-H gel. Furthermore, C-S-H gel of different Ca/Si ratio in hydrated cement paste was quantified using X-ray diffractometer and thermogravimetry. The results show that in presence of silica nanoparticles, ~24% C-S-H (Ca/Si<1.0) forms, leading to the formation of polymerized and compact C-S-H. In case of plain cement this type of C-S-H was completely absent at 28 days. These studies reveal that the hydration mechanism of the cement can be tuned with the incorporation of silica nanoparticles and thus, producing more durable cementitious materials.[11]

- In another project, thermal analysis was made by using of Finite Element Method in two dimensional analysis. The thermal efficiency was found out by comparing the wall system of with and Without PCM. The heat gain is significantly reduced when the PCM is incorporated into the brick, and increasing the quantity of PCM has a positive effect. The results show the best performance when compared to nominal wall. [4]
- The thermal properties and structural performance of variable density wall panels was investigated made with a range of Portland cement (PC) and inorganic polymer concrete mixes and using different light and heavyweight aggregates. Results from thus study found that inorganic polymer concrete produces lower thermal conductivity and volumetric heat capacity compared with PC concrete.[5]
- The usage of Phase Change Materials in residential building applications are studied by making modeling methods of PCM-embedded wall system and a new simulation program is developed to simulate the thermal performance of walls with and without PCM. Both technical and economic performances of the solution are explored. [1]

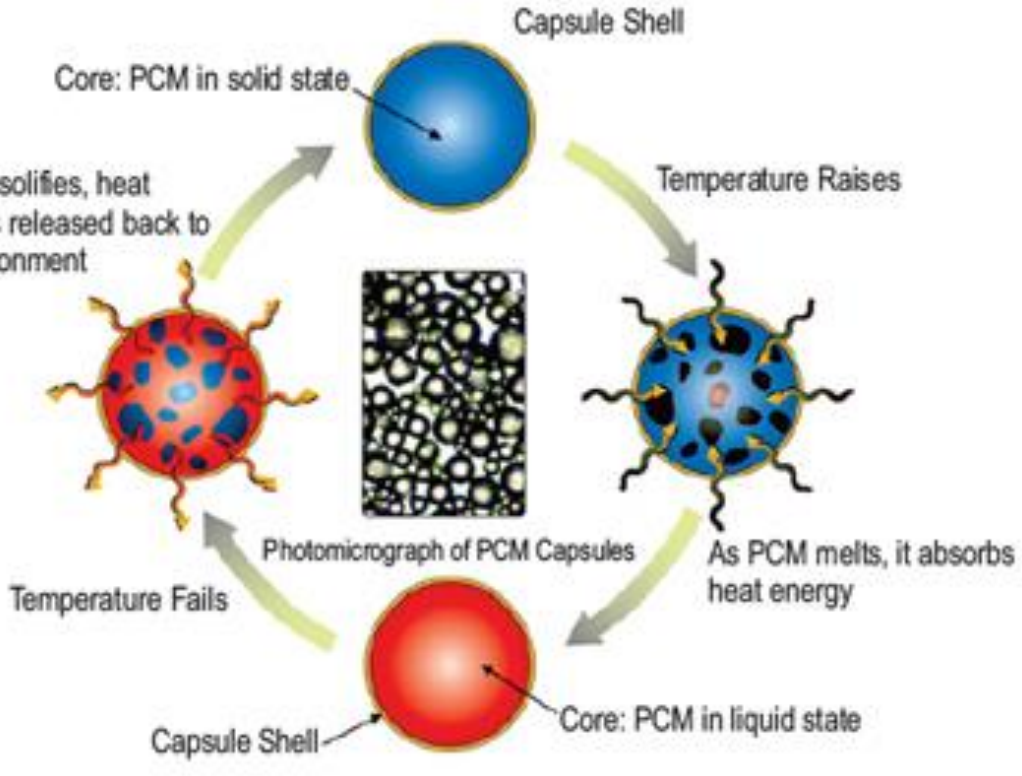

Fig.3.Photomicrograph of PCM

Conclusion

Thus the paper was concluded that the implementation of Phase Change Materials in building components will improve the thermal stability of the structure and it gives the comfort indoor temperature. The less consumption of energy and giving much benefit is the advantage of using PCM. Through the concept of HVAC we can make a comfort building envelope without causing pollution. More than that, each and every one has to aware about the Energy consumption and in every stage from planning to execution, we have to implement it by consuming optimal quantity of energy to make sustainable green environment. As compare to all other methods, PCM is the best choice for building energy efficient structures by providing comfort temperature with less amount of coolant agencies.

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