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Use of Phase Change Materials in Construction of Buildings: A Review

Pawan R. Ingole[1], Tushar R Mohod[2], Sagar S Gaddamwar[2]

[1]Asst. Professor, Dept. of Mechanical Engineering, J.D.I.E.T. Yavatmal, S.G.B.A. University, India

E-mail- pawaningole5@gmail.com

Abstract— 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. In this paper, recent development in the field of using different types of PCMs with concrete, their incorporation and the influence of PCMs on the properties of concrete at the different stages are reviewed.

Keywords— Eutectic, Immersions, Impregnation Paraffines, Phase change materials.

INTRODUCTION

Phase Change Materials exhibits Thermodynamic property of storing large amount of latent heat during its phase change. PCM solidifies on drop of ambient temperature giving off its latent heat of fusion. As compared to conventional materials PCMs have the property of storing high amount of latent heat giving more heat storage capacity per unit volume. PCMs are implemented in Gypsum wall boards, plasters, textured finishes due to its thermal energy storage application. Chemical composition Of PCMs yields to three basic sub-categories namely (i) organic compounds, (ii) inorganic compounds and (iii) inorganic eutectics or eutectic mixtures. PCMs should be desired to have high latent heat of fusion and good heat transfer rate. It mainly depends upon desired comfort temperature and ambient temperature. Super cooling influences the performance of PCMs. Incorporation of PCMs in construction work and to provide information on their characteristics are the main aim of this paper.

1. CLASSIFICATION OF PHASE CHANGE MATERIALS

1.1 EUTECTICS

Eutectic mixtures or eutectics are the mixtures having low melting point of multiple solids and its volumetric storage density is slightly higher than that of organic compounds. The eutectic binary systems showed melting points between 18 and 51 ◦C and freezing points between 16 and 51 ◦C, with a heat of fusion between 120 and 160kJ/kg. The organic eutectic capric mauric acid is the most suited for passive solar storage since it has a melting point of 18 0C, a freezing point of 17 ◦C and a heat of fusion of 120kJ/kg.

1.2 ORGANIC PHASE CHANGE MATERIALS

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. Paraffins 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 or palmitoleic acids. It is free from super cooling, volumetric change and has high latent heat of fusion.

1.3 INORGANIC PHASE CHANGE MATERIALS

PCMs exhibit properties of good thermal conductivity, affordability and non-flammability. However, most of them are corrosive to most metals, undergo super cooling and undergo phase decomposition. Highly crystalline polymer for example high density polyethylene (HDPE) is advantageous if it is rendered stable by cross linking when 98% of the heat of fusion is used by transition. Most of them occur at higher unfavorable temperatures ranging from 30 ◦C to 600◦C.

Table1: List of Main Phase Change Materials

Organic	Paraffins	Inorganic
Polyglycol E400	Paraffin C14	H_2O
Polyglycol E 600	Paraffin C15–C16	LiClO3·3H2O
Polyglycol E 6000	Paraffin C16–C18	Mn(NO3)2·6H2O
Dodecanol	Paraffin C13–C24	LiNO3·3H2O
Tetradodocanol	Paraffin C16–C28	Zn(NO3)2·6H2O

Biphenyl	Paraffin C_{18}	$Na_2CO_3 \cdot 10H_2O$
HDPE	Paraffin C_{20}–C_{33}	$CaBr_2 \cdot 6H_2O$
Propianide	Paraffin C_{23}–C_{50}	$Na_2S_2O_3 \cdot 5H_2O$
Dimethyl-sulfoxide		$Ba(OH)_2 \cdot 8H_2O$
Capric acid		$Mg(NO_3)_2 \cdot 6H_2O$
Capricinic acid		$(NH_4)Al(SO_4) \cdot 6H_2O$
Laurinic acid		MgCl2·6H2O
Miristic acid		NaNO3
Lakisol		KNO3
Palmitic acid		KOH
Stearic acid		MgCl2

2. PCMS INCORPORATIONS IN CONCRETE

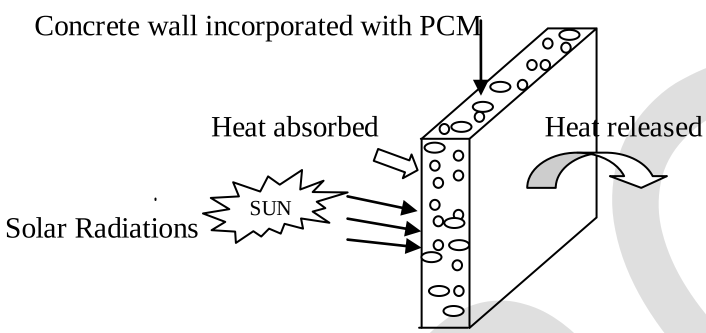

Figure1. Heating and cooling function of concrete wall incorporated with PCM.

2.1 IMPREGNATION

Impregnation consists of three basic proceedings; first step includes evacuation of air and water from the porous or light weight aggregates with the help of vacuum pump. Soaking of porous aggregates in the liquid PCM under vacuum ends second step. Lastly, in the third step, the pre-soaked PCM porous aggregate functioning as a 'carrier for the PCM' is mixed into the concrete.

2.2 IMMERSIONS

Soaking of the porous concrete products in a melted PCM (named immersion PCM-concrete) is called as immersion technique which was first introduced by Hawes. It is the immersion of porous concrete products in a container already filled with the liquid PCM. The effectiveness of emersion process mainly depends on absorption capacity of the concrete, temperature and types of PCM being employed.

2.3 DIRECT MIXING

PCM must be first encapsulated within a chemically and physically stable shell before directly mixing it with concrete. Encapsulation can be done by interfacial polymerization, emulsion polymerization, in situ polymerization as well as spray drying. For direct mixing, the shell hardness of the PCM microcapsules should be sustainable and indestructible to avoid any damage during the concrete mixing.

3. APPLICATIONS OF PCMS

3.1 BUILDING APPLICATIONS

To improve the performances of technical installations such as hot water heat stores, pipe insulation and cool thermal energy storage and latent heat thermal storage systems, PCMs can be incorporated. In addition, the improvement of double facades with PCMs has been achieved for better control of the cavity temperature.

3.2 PCM ENHANCED CONCRETE

PCM enhanced concrete (thermo-concrete) is another possibility for applying PCMs in building constructions. To produce low cost storage materials with structural and thermostatic properties, thermo-concrete is an appropriate PCM with a concrete matrix or open-cell cements.

3.3 THERMAL ENERGY STORAGE AND COOLING POWER POTENTIAL

For efficient energy storage in connection with the two-phase heat transfer fluid water/steam, high-temperature PCM is a key component. Necessary power density demands for specific applications can be met by nitrate salts used for high-temperature PCM storage. A design development of radially finned tubes by DLR is applied in a 700 kW h PCM thermal energy storage demonstration modules.

4. RECENT WORK IN THE FIELD OF PCMs

M. Ravikumar et al. (2012) analyzed the heat transmission across three roof structures viz., bare RCC roof, RCC roof with weathering coarse and RCC roof with PCM above RCC. It was concluded that the thermal inertia of roof is very high, moderate and lowest with PCM, WC and RCC roofs respectively. Thus the roof structure below the PCM layer is not affected much by the external climatic variation.

Gang Li et al. (2012) reviewed the recent development of available cold storage materials for subzero applications. Absorption and adsorption storages are mainly discussed for their working pairs, heat transfer enhancement and system performance improvement aspects.

Lin Qiu, et al. (2012) analyzed the reality melting and solidification of PCM set up the PCM heat transfer model which considering liquid-phase natural convection in this paper and exploits CFD software to carry out numerical simulation.

Mario A Medina, et al. (2013) presented results of the potential thermal enhancements in building walls derived from using phase change materials. For the frame walls, the PCM encapsulated within reflective foil sheets yielded the highest reductions of 52.4% (peak) and 35.6% for a PCM concentration of about 15%, producing more stable wall temperatures.

Amarendra Uttam, et al. (2013) presented the application of phase-change energy storage in air conditioning applications. It was concluded from the results that during day time temperature of air coming to the room is decreased by 2-4 K. The effectiveness of system is highly dependent on local climate.

Guohui Feng, , et al. (2013) showed that compared to normal fresh air system, the phase change solar energy fresh air thermal storage system has a significant improvement in energy saving and indoor comfort level and will play an important role in the energy sustainable development.

Tung-Chai Ling, , et al. (2013) investigated that PCM-concrete has some useful characteristics such as better latent heat storage and thermal performance. The inclusion of PCM in concrete yields a significant improvement in the thermal performance of the concrete.

Jessica Giro-Paloma et al. (2013) suggested that the use of microencapsulated PCM has many advantages as microcapsules can handle phase change materials as core allowing the preparation of slurries. It was concluded that stiffness depended on the temperature assay and particle size, which showed an important decrease in elastic properties at 8000C.

Doerte Laing, et al. (2013) analyzed that a high-temperature PCM is a key component for storing latent heat. The 700 kWh PCM storage has been tested successfully in a combined storage system for DSG. The operation of this PCM storage module for evaporating water in constant and sliding pressure mode was succeeded.

Camila Barreneche et al. (2013), showed that the Phase change materials can be presented as materials with high thermal energy storage capacity due to the latent heat stored/released during phase change, reducing the energy demand of buildings when incorporated to construction materials. The benefit from extending the PCM addition up to 15 wt% is better for gypsum samples than for Ordinary Portland cement matrixes.

Servando Álvarez, et al. (2013) investigated that more the contact area between PCM and air by a factor of approximately 3.6, increase the convective heat transfer coefficient significantly, allowing the cold stored usage.

M.R. Anisur et al. (2013) emphasized that opportunities for energy savings and green house-gas emissions reduction with the implementation of PCM in TES systems. It was concluded that about 3% of total CO2 emissions by fuel, projected in 2020 could be reduced with PCM applications in building for heating and cooling.

Jisoo Jeon, et al. (2013) highlighted that the proper design of TES systems using a PCM requires quantitative information and knowledge about the heat transfer. He reviewed the development of available latent heat thermal energy storage technologies and discusses PCM application methods for residential building using radiant floor heating systems.

5. CONCLUSION

PCMs work as a store house of thermal energy and deliver it as and when required due to its high latent heat of fusion/fission, thus aids to energy saving. Wide applications of PCMs in buildings do not seem optimal but improvements in thermal heat storage (THS) of PCMs make them implementable on wide range. Among all PCMs, Organic compounds particularly Paraffin waxes are most suitable for latent heat storage (LHS) due to their compatibility with human comfort temperature range of about 26^0C with their affordability.

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