Energy Assessment of a Building with Wall Panels Incorporated with Phase Changing Materials

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***Abstract*- Construction industry is prominent sector that bestow greatly in economic & financial growth of a country. It is subjected to new innovations and techniques every year. All these innovations are to increase the longevity of the structures with a reduced cost. Abundant novel techniques are developed every year to upgrade the energy efficiency of the buildings. Energy-efficient buildings are designed to use less artificial energy and rely on natural energy more. Buildings are made energy-efficient by using many design factors and building insulation materials which prevent heat loss and makes the building airtight. Good quality design and selection of materials are prerequisites in energy-efficient building. The materials used in energy efficiency are PCM or Phase Changing Materials. Wall panels or wall boards are used in buildings to decrease the heat transfer of buildings from inside to outside. Wall boards are used to minimize the heating and cooling loads and also relax the cost of plastering and painting. The wall boards are fabricated using gypsum. Phase Changing Material can be incorporated into the wall boards by direct incorporation, immersion, shape stabilization or encapsulation. In this context, gypsum board is made by using Phase Changing Materials (PCM) like Paraffin wax in powdered form. The behavior of gypsum board with PCM is studied in this project.**

Index Terms- PCM, Gypsum, Paraffin Wax, TES, Wall board.

I. INTRODUCTION

There is huge economic growth worldwide, the overall energy consumption becomes a serious problem. The building sector's energy consumption is very high around the world with a total of 30% while comparing with other sector's energy consumption. Building energy consumption can be reduced by a lot of means but out of which utilizing solar energy is found to be very effective and promising because it is renewable and non-polluting. But there exists always a time lag between energy supply and energy demand. This is a critical issue in present world that the electrical energy produced is not sufficient to meet the demands of the people. This results in increased cost of supply and will make the whole project economic. Introducing TES or thermal energy storage can reduce this problem and reduce the electrical energy consumption.

New technologies in building construction and services are needed to reduce the big electrical energy consumption in the buildings. These techniques include various methods of controlling indoor climate. On the other hand usage of external cooling systems is increasing higher because of higher comfort requirements by the users. This makes the cost of living higher and to obtain a more sophisticated "living environment", using relatively simple strategies and avoiding extra costs.

It is possible to resolve the problem of energy consumption by using stratified light weight skins and layers, high performance materials and integration of installations, like heat pumps for example or wind turbines and enhancing the use of renewable energy sources by using devices like photovoltaic panels or solar thermal exchanger or simply by preferring natural ventilation and natural shading or re-interpreting low processing materials and using them in a tactic way.

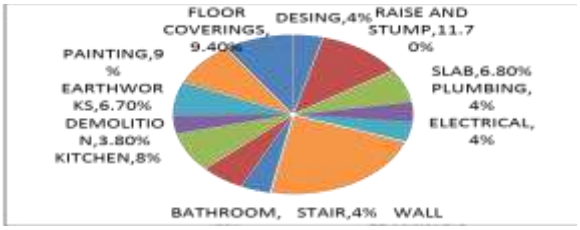

Fig.1. Energy consumption of building elements

Wall panels, wall boards and facades are examples of building envelopes. A wall panel is single piece of material, usually flat and cut into a rectangular shape that serves as the visible and exposed covering for a wall. Wall panels are functional as well as decorative, providing insulation and soundproofing, combined with uniformity of appearance, along with some measure of durability or ease of replace ability. While there is no set size limit for a piece of material fulfilling these functions, the maximum practical size for wall panels has been suggested to be 24 inches by 8 feet, to allow for transportation.

Use of wall panels can reduce construction costs by providing a consistent appearance to the paneled surface without requiring the application of paint or another finishing material. Wall panels may be finished on only one side, if the other side is going to be against a brick or concrete wall, or a comparable structure. Alternately, the panels may, if assembled to an appropriate framework, substitute for having any other kind of wall at all. Holes may be cut or drilled into a wall panel to accommodate electrical outlets and other devices coming out of the wall.

Drywall (also known as plasterboard, wallboard, gypsum panel, sheet rock, or gypsum board) is a panel made of calcium sulfate di-hydrate (gypsum), with or without additives, typically extruded between thick sheets of facer and backer paper, utilized in the construction of interior walls and ceilings. The plaster is mixed with fiber (typically paper and/or fiberglass or asbestos), plasticizer, foaming agent and various additives that can decrease mildew, increase fire resistance and lower water absorption.

A facade is generally one exterior side of a building, it is an elegant component that helps to define the unique architectural aesthetics of the building; it also has the critical role related to energy performance and interior function of a building.

Phase Changing Materials (PCM) open an alternative potential to return a part of cooling needs based upon melting and solidifying properties of some special components within a room temperature range. Thanks to this phenomenon, some degrees of additional control can be achieved. Experimental results from laboratory tests and monitoring results in two rooms of two actual buildings presented in this paper show that gypsum plaster finishing with a thin layer of 5 mm of PCM are favorable to achieve 2 to 5°C reduction in the temperature swing in rooms. -

The main objective of the measurements was to determine the actual effectiveness of the used materials and their impact on energy storage capabilities through building partitions. The light partition component containing a finishing layer of organic material undergoing a phase change was the subject of research. The heat flux and temperature distribution on individual component layers were recorded while changing the temperature conditions of the surrounding air. The article also addresses the issue of determining the parameters of material for which a very strong dependence of the specific heat and temperature exist. When used in construction materials, phase-variable thermal properties of the materials used must be accurately known, since the system efficiency depends on the thermal properties of materials. (Anna Zastawna-Rumina,*, Katarzyna Nowaka)

Glauber's salt (sodium sulphate decahydrate) is a promising phase change material (PCM) for use in the building sector, thanks to its high enthalpy of fusion associated with a proper phase transition temperature. It also offers economic and environmental advantages because it can be obtained as a byproduct from the disposal process of lead batteries. In this work, the initial thermal performances of mixtures based on Glauber's salt with different compositions are compared by using the T-history method and adopting sonication for mixing, and following the same preparation procedure for all the samples.-(Maria Gabriela De Paola 1, Natale Arcuri 1, Vincenza Calabrò 2,* and Marilena De Simone 1)

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.-(Pawan R. Ingole1, Tushar R Mohod2, Sagar S Gaddamwar2)

Phase change materials (PCMs) have been considered as an innovative technology that can reduce the peak loads and heating, ventilating and air conditioning (HVAC) energy consumption in buildings. Basically they are substances capable of storing or releasing thermal energy as latent heat. Because the amount of latent heat absorbed or released is much larger than the sensible heat, the application of PCMs in buildings has significant potential to reduce energy consumption. However, because each PCM has its own phase change temperature, which is the temperature at which latent heat is absorbed or released, it is important to use an appropriate PCM for the purpose of building envelope design. Therefore, this paper aims to investigate the energy saving potentials in buildings when various PCMs with different phase change temperatures are applied to a lightweight building envelope by analyzing the thermal load characteristics.-(Yoon-Bok Seong 1 and Jae-Han Lim 2,*)

The objective of this project is to do the assessment of energy consumption in building envelope by implementation of PCM in dry wall and producing a new dry wall using PCM.

II. MATERIALS

Phase-change material (PCM):

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. PCMs should 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 performances of PCMs. PCMs are obtained from petroleum or both from animal or vegetable sources. They are paraffin, non-paraffin and fatty acids. Inorganic materials can be classified into salt hydrates and metallic. Both organic and inorganic materials can be found with different phase change temperatures, latent heat of transition and conductivity.

III. CLASSIFICATION OF PHASE CHANGE MATERIALS

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 180°C, a freezing point of 17 ◦C and a heat of fusion of 120kJ/kg.

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.

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 ecomposition. 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.

IV. PROPERTIES OF COMMERCIALLY AVAILABLE PCM's

A phase change material (PCM) is a substance with a high heat of fusion which melting and solidifying at a certain temperature is capable of storing and releasing large amounts of energy. Heat is absorbed

or released when the material changes from solid to liquid and vice versa; thus PCMs are classified as latent heat storage (LHS) units.

Latent heat storage can be achieved through liquid→solid, solid→liquid, solid→gas and liquid→gas phase changes. However, only solid→liquid and liquid→solid phase changes are practical for PCMs. Although liquid–gas transitions have a higher heat of transformation than solid–liquid transitions, liquid→gas phase changes are impractical for thermal storage because large volumes or high pressures are required to store the materials in their gas phase. Solid–solid phase changes are typically very slow and have a relatively low heat of transformation. Initially, solid–liquid PCMs behave like sensible heat storage (SHS) materials; their temperature rises as they absorb heat. Unlike conventional SHS materials, however, when PCMs reach the temperature at which they change phase (their melting temperature) they absorb large amounts of heat at an almost constant temperature. The PCM continues to absorb heat without a significant rise in temperature until all the material is transformed to the liquid phase. When the ambient temperature around a liquid material falls, the PCM solidifies, releasing its stored latent heat.

V. INCORPORATION OF PCM IN BUILDING ELEMENTS

1 IMPREGNATION

Impregnation involves three basic steps; first step includes evacuation of air and water from the porous or light weight aggregates using vacuum pump. Next step is soaking of porous aggregates in the liquid PCM under vacuum. In the third step, the pre-soaked PCM porous aggregate functioning as a 'carrier for the PCM' is mixed into the concrete.

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.

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 1.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.

PARAFFIN WAX

Paraffin wax is a white or colorless soft solid derivable from petroleum that consists of a mixture of mixture of hydrocarbon molecules. It is solid at room temperature and starts to melt after 37°C. It is an excellent material for storing heat. This property is exploited in modified wall board for home building materials. It is infused in the wall board during manufacture so that it melts during the day by absorbing heat and solidifies again at night by releasing the heat.

Fig.2. Paraffin wax

PROPERTIES OF PARAFFIN WAX

SI NO	PROPERTIES	VALUES
1	Density	900LKg/m^3
2	Melting Point	115° F to 154 ° F
3	Specific Gravity	0.908
4	Heat Of Combustion	42 KJ/g
5	Heat Of Fusion	200-220j/g
6	Specific Heat Capacity	2.14-2.9J/$g^{-1}k^{-1}$

VI. METHODOLOGY

Model making is the main method used for the preparation of specimen. In this project gypsum powder is used for the preparation of specimen.

1. COMPRESSION STRENGTH TEST

Gypsum powder is converted into cube with the help of mould. Gypsum cube is prepared with the help of mould of size (70.6*70.6*70.6cm).

Mix proportion for gypsum plaster without paraffin
Materials used:-
Gypsum powder - 600g
Water - 300ml
According to the above proportion 600g of powder is mixed with 300ml of water without adding paraffin and poured in to the mould. After 24 hours of curing the cube is unmould.
Mix proportion for gypsum plaster with paraffin
Materials used:-
Gypsum powder - 600g
Water - 300ml
Paraffin - 60g
For adding paraffin 540g of gypsum powder is used by replacing 10% of gypsum powder and add paraffin into it. According to the mix with gypsum plaster and poured into mould. After 24 hours of curing cube is unmould.

Fig.3. Gypsum Cube

2. MOISTURE CONTENT TEST

Gypsum powder contains a finite amount of water, which is expressed as moisture content. This moisture exists within pores. To do this test 200g of moist gypsum powder is taken and is dried at 115°C in oven.

VII. RESULTS

TABLE 1 PROPERTIES OF GYPSUM

PROPERTIES OF GYPSUM	EQUIPMENT	VALUES
Compression strength test	CTM	4.714 N/mm 2
Fineness test	IS SIEVE	0.27 %
Water Absorption Test	-	5.67%
Moisture content test	-	0.01 %
Consistency test	VICAT APPARATUS	46.5%
Initial setting time test	VICAT APPARATUS	20min

TABLE 2 PROPERTIES OF GYPSUM AND PARAFFIN

PROPERTIES OF GYPSUM AND PARAFFIN	EQUIPMENT	VALUES
Compression strength test	CTM	4.23 N/mm2
Moisture content test	-	0.025%

Fig.4. Paraffin incorporated cube

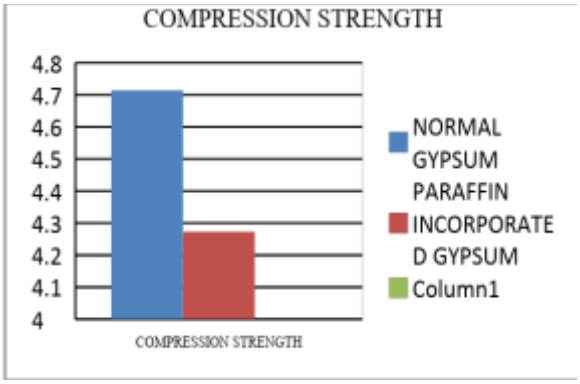

Fig.5. Compression strength comparison graph

From the graph, it is concluded that normal gypsum cube has more compression strength than paraffin incorporated cube.

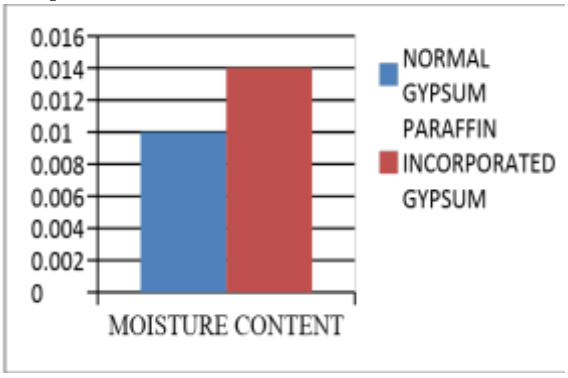

Fig.6Moisture content comparison graph

From the graph it is concluded that water penetration for both the cubes are less. But paraffin incorporated cube has a slighter higher moisture content than normal gypsum cube.

VIII. CONCLUSION

From this study it can be concluded that

Gypsum has excellent thermal holding capacity and is used as a phase changing material

Paraffin wax in addition to gypsum will act as a temperature inhibiting skin and will protect the building as a envelope.

The compression strength of Paraffin incorporated gypsum cubes doesn't vary largely when compared to normal gypsum cube.

The moisture content test also shows the same results for both the gypsum and paraffin incorporated gypsum cubes.

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