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Experimental Evaluation of Mortar Embedded with PCM

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ABSTRACT: Due to the modern development of construction industry, buildings and other appliances is becoming the highest energy consumer in developed countries. Improvement of the energy performance of the building is the prime objective of the paper to minimize the energy consumption and to control the global warming by utilizing alternate source of materials which is having less emission of Co_2. Thus in-order to minimize the energy consumption of the building the phase change materials are used. Here the Polyethylene Glycol (PEG) and Perlite are used as a phase change material in cement mortar. The thermal behaviour of the PCM is analysed by measuring the room temperature with PCM and without PCM. The results are also showed that the range of temperature and its effects are decreased because of Latent heat characterized PCM.

KEYWORDS: Global Warming, Polyethylene Glycol, Perlite, Thermal Behaviour, PCM.

1 INTRODUCTION

Industry is the production of goods or related services within an economy. The construction industry is a major contributor towards the nation's growth, both directly and indirectly.

Energy and Environment are the two major issues facing the human comfort. Industrial developments and population boom in the past few years have resulted in an increase in energy demand with an annual increase of 2.3%. The energy consumption is the process of absorbing large amount of heat energy. This process was extensive so we were in a position where we had to ensure our efforts.

The increasing demand for energy saving and environment friendly technology is a driving the growth of the global phase change material (PCM) in the market. Nowadays the energy consumption of the building has increased in the developed and developing countries. To utilize the heat energy absorbed by the building, the phase change materials are used as the energy conservation system.

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 can be used in building walls, ceilings and floors. In building applications, they have a phase transition close to human comfort.

Thus in-order to make the energy efficient building, the PCM is used and its thermal behaviour is analysed. Here two types of PCM are used such as PEG and Perlite. These materials are mixed with cement mortar and are used as the plastering material in the concrete wall. The whole arrangements are placed in the roof terrace to get the sun light. The thermal storage in the concrete wall is found out with a particular interval of time. The temperature sensor are used to measure the temperature within and outside the concrete wall.

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2 MATERIAL DESCRIPTION

The normal ordinary Portland cement of grade 53 is used and the initial test for the cement is done such Fineness of cement, Consistency of the cement paste and the Initial and Final setting time of the cement. After that mortar cube is made and its compressive strength is calculated for 28 days curing.

2.1 POLYETHYLENE GLYCOL (PEG)

PEG is a polyether compound, which is used for various industrial purposes. It is also known as Polyethylene Oxide (PEO) or Polyoxyethylene (POE) based on its molecular weight. It is also known as Water soluble wax or Carbowax. PEGs are manufactured by polymerization of ethylene oxide and are commercially available in wide range of molecular weights from 300g/mol to 10,000,000g/mol.

Polyethylene glycols are chemically stable in air and in solution. They do not support any microbial growth. Sterilization of solid grades by dry heat at 150^0C for one hour may induce oxidation, darking and the formation of acidic degradation products.

They should be stored in well-closed containers in a cool and dry place. Stainless steel, aluminium, glass or lined steel containers are best to store liquid grades. However storage under nitrogen reduces the possibility of oxidation. PEG has low toxicity with systemic absorption less than 0.5%.

2.2 APPLICATIONS OF PEG

PEG is a successful PCM which may be used in various industries to overcome the thermal defects. Some of the Applications of PEG are listed below:

1. They act as a lubricant.
2. They are used as a plasticizer.
3. PEG esters are used as solvent.
4. They are used in wood treatment.
5. It also act as a chemical intermediates.
6. They are mainly used in industries for thermal insulations to reduce the heat.

2.3 PEG 600

Here PEG 600 is used as the phase change material in concrete wall as a phase change material. PEG 600 is a clear, colourless liquid, made from sugarcane waste. It is also a renewable source. They have an average molecular weight of 380-420. It is soluble in water and it is hydrophilic. It has various applications in various industries.

TABLE I
PROPERTIES OF PEG

Chemical Composition	Percentage
Melting Point	15 – 17^0C
Appearance	Clear viscous colourless liquid at 25^0C
PH	4 - 7
Average molecular weight	590 - 610
Hydroxyl value	176 – 200
Moisture content maximum	1.0%

2.4 PEG 600 PROPERTIES

PEG 600 consists of a distribution of polymers of varying molecular weights with an average of 600. Molecular weight has an effect on the physical properties of each product grade. Increased molecular weight results in decreased solubility in water and solvents, decreased hygroscopicity and vapour pressure and increased melting/freezing range and viscosity.

Fig. 1 PEG - 600

2.5 PERLITE

Perlite is an amorphous volcanic glass that has relatively high water content. Perlite is a white, lightweight, organic material that is used to increase the porosity for planting mixes in horticulture. It is a recyclable material that comes from diamond mines. It does not cause a reaction with waterproofing membranes. It is an industrial mineral and a commercial product useful for its lightweight after processing.

Mostly perlites are light in weight of white granular material that handles and pours easily. It can be easily provided in the masonry walls to reduce the heat transmission up to 50% or more. Due to its light weight it can be used in roof deck, floor fill, lightweight structural decks, insulation for steam and coolant lines, bases of storage tanks, sewer lines, etc.

Fig. 2 Perlite

2.6 PROPERTIES OF PERLITE

Perlite softens when it reaches a temperature of 850 – 900^{0}C. Water trapped in the structure vaporises and escapes and this cause an expansion of material upto 7 to 16 times its original volume.

2.7 CHEMICAL COMPOSITION OF PERLITE

TABLE III
COMPOSITION OF PERLITE

Chemical Composition	Percentage
Silicon dioxide (SiO2)	70 – 75%
Aluminium Oxide (Al2O3)	12 – 15%
Sodium Oxide (Na2O)	3 – 4%
Potassium Oxide (K2O)	3 – 5%
Iron Oxide (Fe2O3)	0.5 – 2%
Magnesium Oxide (MgO)	0.2 – 0.7%
Calcium Oxide (CaO)	0.5 – 1.5%
Loss on Ignition	3– 5%

2.8 PHASE CHANGE OF PCM

When the temperature is low the PCM material will be in its solid state and when the temperature increases, it starts to melt and attains the liquid state, during this process the energy is balanced by them is an effective behaviour of the PCM material. This process is called a Phase Change. This process is represented in the fig. 3. The heat absorbed by the building in the external wall is used for this process and hence the heat in the internal wall is automatically reduced and it gives a pleasant & comfortable environment inside the room.

Thus it reduce the excessive use of electronics materials such as fan, air cooler, etc.

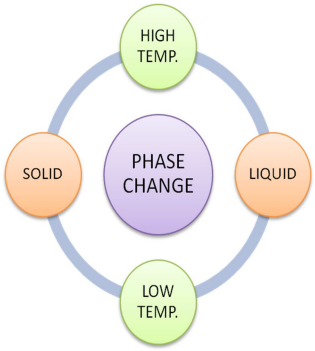

Fig. 3Process of Changing from One Phase to Another

2.9 APPLICATION OF THE PCM MATERIALS

1. To minimize the use of space conditioning.

2. To minimize the operating energy use of the building.

3. To minimize the temperature fluctuations in the building based on climatic variations.

4. To provide comfort atmosphere for the human beings by providing PCM materials with in the interior surface of the concrete.

3 TEST RESULTS

The following are the test conducted for the cement and PCM.

3.1 CEMENT

The ordinary Portland cement of grade 53 is used. The various tests such as fineness of cement, consistency of cement, soundness test of cement, initial and final setting time of the cement and compressive test for mortar after 28 day curing are done and the result details are listed below

TABLE III
PROPERTIES OF CEMENT

Sl.No	Property	Result	Range
1	Specific Gravity	3.15	3.10 – 3.15
2	Consistency	31.5%	30 - 35
3	Initial setting time	91 min	30 minimum
4	Final setting time	211 min	600 minimum
5	Compressive strength of mortar	55 N/mm^2	53N/mm^2 minimum

3.2 COMPRESSIVE STRENGTH OF PEG & PERLITE MORTAR

The cube mortar used is of the size 70.6 X 70.6 X 70.6mm. For normal cement mortar the mix proportion used is 1:3 ratio and its compressive strength is found out.

Now along with the normal cement mortar PEG is added for 1%, 2%, 3% and 4%. And also the perlite is added for 1%, 2%, 3% and 4%. The cubes were casted and its compressive strength is given below after the curing process.

3.2.1 COMPRESSION STRENGTH OF CEMENT MORTAR AND PEG

TABLE IVI
CEMENT MORTAR WITH PEG STRENGTH

Sl.No.	Addition of PEG	Compressive strength
1	1%	55.56
2	2%	58.65
3	3%	58.9
4	4%	59.17

3.2.2 COMPRESSION STRENGTH OF CEMENT MORTAR AND PERLITE

TABLE IV
CEMENT MORTAR WITH PERLITE STRENGTH

Sl.No.	Addition of Perlite	Compressive strength
1	1%	53.12
2	2%	55.08
3	3%	57.39
4	4%	58.15

From the above test results, the compressive strength of the cement mortar increases with both of the PCM. And the attained value is appreciable for 4% when compare to other percentage levels. Hence the plaster embedded with 4% of PCM is selected for thermal analysis.

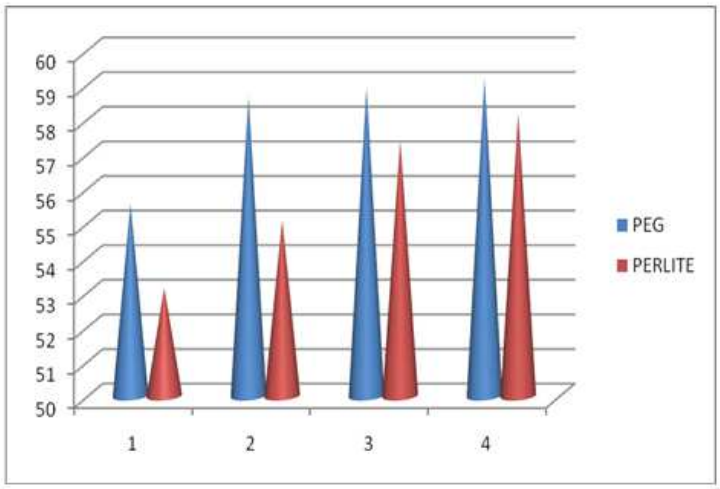

Fig. 4 Compressive Strength of cement mortar with PEG & Perlite.

3.3 THERMAL TESTING

The plastering is done along with the cement mortar with the addition of PCM materials (PEG & Perlite). The PEG and Perlite are added to the mortar is about 4%. The model wall is casted with the dimensions of 1'X1'X0.5'in the roof terrace to receive the sunlight directly.

Thus three small rooms model are made and their thermal values in the interior and exterior walls are found out. The temperature changes are measured using temperature sensor. The temperature variations are measured at 10.30 a.m, 12.30 p.m, 02.30 p.m and 04.30 p.m. and the readings are listed.

TABLE V
TEMPERATURE RANGE OF Conventional wall without PCM

Day	Temperature Range			
	10.30 a.m	12.30 p.m	02.30 p.m	04.30 p.m
Day 1	33	35.3	37.7	34.4
Day 2	33.4	35.9	36.7	34.1
Day 3	31.8	34.9	36.9	35.7
Day 4	32.4	35.4	37.9	35
Day 5	34.6	37	40	37.1
Day 6	35.6	37.1	39.1	37.7
Day 7	33.5	38.2	37.3	37.5
Day 8	34.9	35.8	36.2	33.9
Day 9	34.8	36.9	38.1	34.9
Day 10	34.5	36.4	36.5	34.8

TABLE VI
TEMPERATURE RANGE OF wall PLASTERED WITH PEG

Day	Temperature Range			
	10.30 a.m	12.30 p.m	02.30 p.m	04.30 p.m
Day 1	30.5	33.4	35.4	33.3
Day 2	30.8	33.8	34.8	33
Day 3	30.5	33.7	35	31.5
Day 4	30.4	33.9	34.7	31.9
Day 5	32	34.4	35.6	32.6
Day 6	33	35	37.3	33.9
Day 7	32	35.6	35.6	32.6
Day 8	31.2	33	33.2	31.3
Day 9	32.7	34.1	33.7	32
Day 10	32	33.5	33.9	32.4

TABLE VII
TEMPERATURE RANGE OF wall PLASTERED WITH PERLITE

Day	Temperature Range			
	10.30 a.m	12.30 p.m	02.30 p.m	04.30 p.m
Day 1	32.5	34.9	36.8	34.3
Day 2	32.8	34.8	34.8	34
Day 3	31.3	34.1	36	35.5
Day 4	31.9	34.6	35.7	34.9
Day 5	35	36.4	37.2	36.8
Day 6	34	37.1	39.3	37.5
Day 7	34	37.3	37.2	37.3
Day 8	34.2	35	34.6	33.4
Day 9	34.2	36	35.5	34.6
Day 10	34	35.5	34.6	33.4

4 CONCLUSIONS

This research developed a product that could realize important building energy savings, with the improvement of heat storage mortar, using an innovative type of phase change material called Perlite and PEG, regarding its thermal property.

The work here presented is the preparation of mortar with above mentioned PCM's for reducing the thermal defects and to control the room temperature. Some of the significant test are conducted, and the results showed that the addition of 4% of PCM gives better results of strength parameters. Among the thermal performance, the paper suggested to utilize PEG 600 because of its high thermal effectiveness.

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