ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Issue 4, April 2018

Experimental Investigation of Encapsulated Phase Changing Material in Incorporated Concrete

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Abstract*:* Phase changing material (PCM) incorporated in concrete absorbs the heat when the material incorporated is in the liquid state and release the same heat when the material incorporated is in the solid state. Due to this property, if it is incorporate in the concrete. It can provide good thermal comfort inside the room.An experimental investigation is carried out to analyse the thermal comfort of PCM incorporated concrete. Various proportions of PCM were incorporated in concrete (10%,20%,30%)by replacing volume of water). The compression strength of the PCM incorporated material concrete was also investigated. The temperature variation analysis was carried out.Compression strength was conducted on the cube of size 150*150*150 mm. compression strength was found to assess whether the initial properties remain the same after incorporation of PCM. The specimens were cured and tested at 7 and 28 days.Based on compressive strength result, cubes with 30% PCM by volume of water showed a decrease in compressive strength. On the other hand 10% and 20% PCM by volume of water shows marginal change in compressive strength when compared to control concrete cubes.Hence cubicle specimens were cast for 10%, 20% PCM because for 30% PCM, there was decrease in compression strength.For temperature variation analysis two cubicles of size 450*450*550 mm and thickness of 75mm were cast with PCM. Control cubicles without PCM were also cast. The temperature variation was analysed at regular interval of 1hour**Keywords**: HSI, RSAD, Anomaly, MATLAB.

I. Introduction

World is searching for an innovative technique to discover alternative sources of energy, It has become essential to save the existing energy.To save the existing energy, there are various technique and methods which can results in various saving of energy, one of the innovative methods for energy is the incorporation of Phase changing materials. The phase changing materials have wide application for energy saving in various fields.The phase changing material can be used as a part of construction material and make a great deal in the conservation of energy as it provides a good thermal comfort inside the room. As a consequence, the usage of air condition and other warming equipment's are minimized. PCM can act as a green building material in construction because of its energy efficiency. A phase changing material is a substance with a high heat of fusion which can result in melting and solidifying at a certain temperature and is capable of storing and releasing large amount of energy. Heat is absorbed or released when a material change from solid to liquid state and vise versa. Hence PCMs are classified as latent heat storage units

II. Literature Review

Adem.et.al (2012), 'A review on thermal energy storage system with phase changing materials in vehicles' analysed previous works on TES system with solid –liquid phase change and provided an insight to recent effort to develop new type of TES system with PCMs for use in vehicle . it is found that the development of such device will suit the regions with a cold climate.

Amitha jayalath. et. al. [2] (2008), 'applications of phase change materials in concrete for sustainable built environment' investigated the effort of using PCM in concrete. They found that concrete incorporating PCM improves the thermal mass of the building which reduces the space conditioning energy consumption and extreme temperature fluctuations within the building. the heat capacity and high density of concrete coupled with latent heat storage of PCM provides a novel energy saving concept for sustainable built environment. Microencapsulation is a latest and advanced technology for incorporation of PCM in to concrete which creates finally dispersed PCMs with high surface area for greater amount of heat transfer. Numerical modeling of composite concrete have done. However most of the existing TES system have been explored with wallboard and plaster materials and comparatively a few researches have been done on TES system using cementitious materials.

C. Castellon, M. Nogues, J. Roca, M. Medrano, L. F. Cabeza Departament d'Informàtica I Eng. Industrial, University **de Lleida Pere Cabrera s/n, 25001** – Lleida In the literature, development and testing were conducted for prototypes of PCM wallboard and PCM systems to enhance the thermal energy storage (TES) capacity of

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standard gypsum wallboard with particular interest in peak load shifting and solar energy utilization. The thermal inertia seen in all the experiments suggests that all the PCM included in the sample walls freezes and melts in every cycle. These results also showed that night cooling is important to achieve this full cycle every day.

Belen zalba.et.al.[4] (2003), 'review on thermal energy storage with phase change: materials, heat transfer analysis and applications' studied the heat transfer in thermal energy storage with solid- liquid phase change by carrying out different simulation technique. The problem in the lorn term stability of the materials are studied and the materials are classified according to their different applications.

Muthing F.et.al[8] 'research framework for an experinmental study on phase change materials in scaled models of duch dwellings' measured the possible savings, an experinmental research facility was set up. In this field setup, modern dutch dwellings are simulated by using scaled models with and without PCM in the concrete floors. These models are provided with sensor measuring inside temperature and the incoming solar irradiation. As a reference, a weather station collects data on the outside temperature, humidity, solar irradiation and wind speed.

Yuli S. indartonol.et.al.[9] 'thermal characteristics evaluation of vegetables oil be used as phase change material in air conditioning system' carried out the experiment with a mixture of vegetables oil and biodiesel, as phase change material in secondary refrigerant were evaluated. Some thermal characteristics such as freezing and melting temperature and also latent heat of the oil are studied. The result were found that the mixture of vegetables oils and biodiesel were inexpension than trimethylolethane trihydrate.

III. MATERIAL PROPERTIES

Table 1 Chemical Properties of cement

Chemical Properties	Constituent (%)
SiO_2	**21.04**
Al_2O_3	**5.02**
Fe_2O_3	**3.12**
CaO	**62.11**
MgO	**2.44**
K_2O+Na_2O	**1.04**
SO_3	**3.12**

- Cement type - Ordinary Portland Cement
- Grade of cement - 53 grade
- Name of the company - ACC Cement
- Size of Coarse aggregate - 10 to 12 mm
- Specific Gravity - 2.7
- Fineness Modulus - 5.51
- Water Absorption - 2.5 %
- Bulk Density - 1410 kg/m^3
- Nature of sand - Normal river sand
- Specific Gravity - 2.6
- Fineness Modulus - 2.47
- Water Absorption - 2 to 3 %

3.1. PHASE CHANGE MATERIAL

Solar energy applications require an efficient thermal storage. Hence, the successful application of solar energy depends, to a large extent, on the method of energy storage used. The latent heat of melting is the large quantity of energy that needs to be absorbed or released when a material changes phase from solid state to liquid state or vice versa. The magnitude of the energy involved can be demonstrated by comparing the sensible heat capacity of concrete (1.0 kJ/kg K) with the latent heat of a phase change material (PCM), such as calcium chloride hexahydrate CaCl2 _6H2O (193 kJ/kg).

"Thermal energy storage can be accomplished either by using sensible heat storage or latent heat storage".

IV. TEST ON PCM

Micro encapsulated PCM was used which has a phase changing temperature. The physical and chemical properties are given

Table 2 properties of pcm

Appearance	Transclucent, viscous semi-solid, near phase changing temperature 20c above
phase changing temperature	18c -24c
Specific gravity	1.48-1.5
Latent heat practically	175 joules/g
Specific heat	2 joules/g degree C
Thermal conductivity	1watt/ g degree C
Congruent melting	Yes
Hazardous	No
Flammability	No
Thermal stability	Greater than 10000cycles
Maximum operating temperature	100c

V. CONCRETE MIX DESIGN

The mix design of M_{20} grade of concrete is done by using the IS: 10262-1982 method.

Design Stipulations

(i) Characteristic compressive strength required in the field at 28 days: 20 MPa.

(ii) Maximum Size of aggregate : 20 mm.

(iii) Degree of Workability: 0.9 Compaction factor.

(iv) Degree of quality control : Good.
(v) Type of Exposure: Mild.

Water: Cement: fine aggregate: coarse aggregate
192.5: 383 : 541.91 : 1242.38
0.5 : 1 : 1.42 : 3.24

VI. CONCRETE MIX PROPORTIONS

Control concrete mixture was designed as per IS: 10262- 1982 to have 28days compressive strength of 20 MPa. The mix proportions with and without PCM are given below

MIXING	MC	M1	M2
CEMENT(kg)	45	45	45
FA(kg)	63.9	63.9	63.9
CA(kg)	145.8	145.8	145.8
PCM(%)	0	10	20
PCM(litres)	0	2.25	4.5
W/C ratio	0.5	0.5	0.5
Water(litres)	22.5	20.25	18

TABLE 3 CONCRETE MIX PROPORTIONS

Fig 1. PREPARATION OF MODELS

MOULD

The size of the project model is 450*450*550mm and 75mm thickness the required mould is not available readymade in markets, so we decided to prepare the moulds for our required dimension. We prepared the wooden mould for casting the models to proceed the project work further. The outer cover dimension of the mould is 450*450*550mm and the dimension of the inner cover of the mould is 375*375*450mm.Materials used to erect the mould is plywood sheet. Our model is in the shape of sample which enclosed by six sides. The five sides of the sample is designed and erected monolithically and the sixth side which is the top cover of the sample is designed and casted separately. Same set of procedure is carried out for the three models in a project.

Fig 2 IMAGE OF MOULD

CASTING OF COVER SLAB

Sample model shown below is a conventional sample model which is made up of 0% PCM and the mould is removed after a day of casting the sample. A curing is done for 28 days to achieve the maximum strength without affecting the basic properties of concrete.

OBSERVING TEMPERATURE.

As we already said RCC model is erected to check the temperature variation inside and the outside of the sample model by using the digital thermometer. We designed and made the sample model of different proportion of mixes which are conventional concrete, 10% and 20% PCM of water to check the temperature difference between the sample model of conventional concrete, 10% and 20% PCM of water.

VII. RESULT AND DISCUSSION

TESTS ON FRESH CONCRETE

S.NO	CONCRETE MIXES	W/C RATIO	SLUMP VALUE	NATURE OF COLLAPSE
1.	MC	0.5	90	SHEAR
2.	M1	0.5	95	SHEAR
3.	M2	0.5	100	SHEAR
4.	M3	0.5	105	SHEAR

Table 3 Slump test

Compaction Factor test:

Concrete Mixes	W/C Ratio	Partially Compacted Concrete (Kg)	Fully Compacted Concrete (Kg)	Compaction Factor
MC	0.5	10.63	11.82	0.9
M1	0.5	10.67	12.13	0.88
M2	0.5	10.62	12.22	0.87
M3	0.5	10.28	12.54	0.82

Table 4 Compaction factor test

COMPRESSIVE STRENGTH TEST

The compressive strength of mix proportion of PCM replacing volume of water were tested. It was found that the mixes M1 and M2 showed a marginal increase in

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Vol. 5, Issue 4, April 2018

compressive strength at 7 and 28 days. On the other hand, mix M3 shows a decrease in compressive strength. So the mix M2 was chosen among the other mixes as for 30% PCM, there was decrease in compression strength.

Concrete mix	Concentration of PCM	Compressive strength at 7days (N/mm^2)	Compressive strength at 28days (N/mm^2)
MC	0	12.61	21.86
M1	10%	12.63	21.97
M2	20%	12.68	22.13
M3	30%	11.72	19.65

Table 5 Compressive strength test

Fig 3 Chart showing compressive strength of different proportion of concrete at 7 days

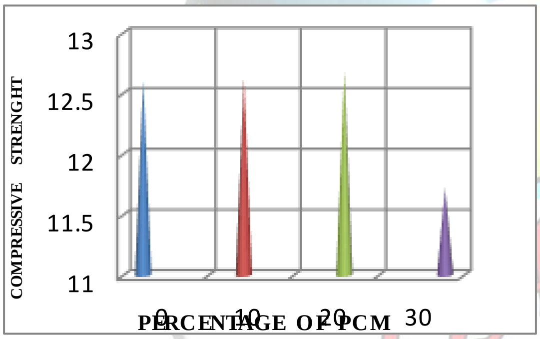
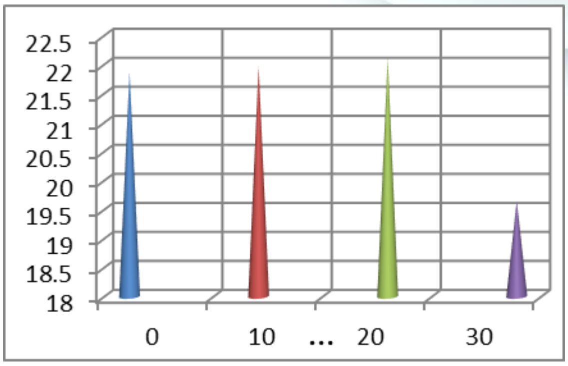


Fig 4 Chart showing compressive strength of different proportion of concrete at 28 days



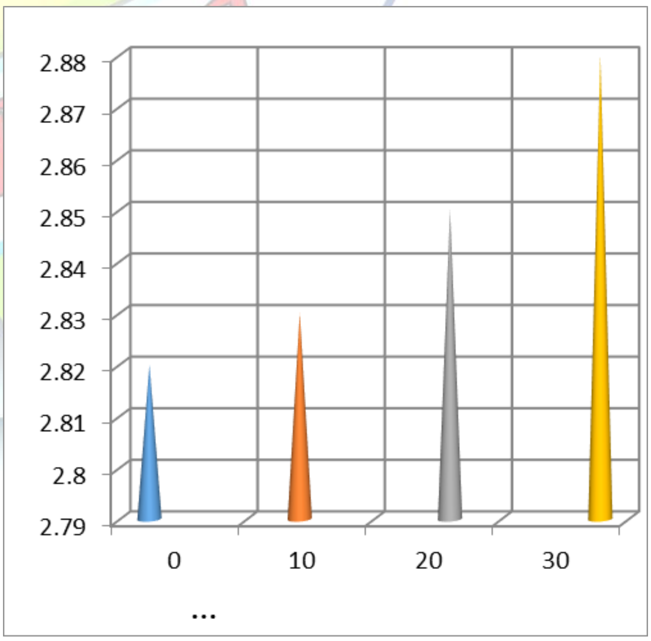
SPLITE TENSILE STRENGTH TEST

The split tensile strength of the concrete cylinders were tested for both control concrete mix (MC) and PCM incorporated in concrete mix of M1, M2, M3. The mixes of M1, M2, M3 showed a marginal increase in split tensile strength than the control mix. So the initial characteristics have not changed.

Table 6 Split tensile strength test

S.No	Concrete mix	Concentration of PCM in %	Split tensile strength at 28days (N/mm^2)
1	MC	0	2.82
2	M1	10%	2.83
3	M2	20%	2.85
4	M3	30%	2.88

Fig 5 Chart showing split tensile of different proportion of concrete at 28 days



FLEXURAL STRENGTH TEST

The mixes showed only a marginal increase in flexural strength than the mix. So the initial characteristics have not change.

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S.no	Concrete mix	Concentration of PCM in %	Flexural strength at 28days (N/mm^2)
1	MC	0	1.82
2	M1	10%	1.85
3	M2	20%	1.86
4	M3	30%	1.88

TABLE 7 FLEXURAL STRENGTH TEST

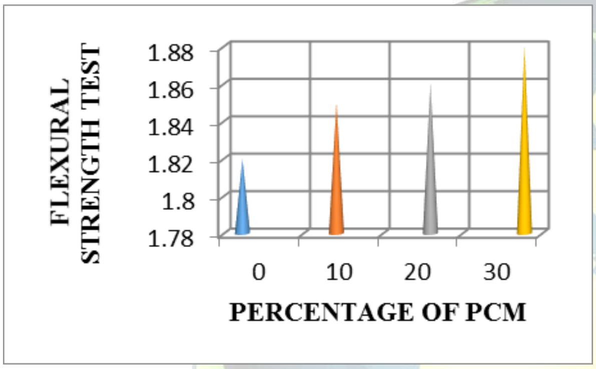

FIG 6 FLEXURAL STRENGTH OF CONCRETE AT 28 DAYS

TEMPERATURE VARIATION TEST

While comparing the temperature variation in experiment, it was found that the temperature is about 4 to 5°C. the maximum temperature difference with phase changing material appear after 2hours. The result showed that there was decrease in temperature as time passes.

First Day

Time	Temperature in MC (°C)	Temperature in M1 (°C)	Temperature in M2 (°C)
11 am	30	28	26
12 pm	34	31	29
1 pm	36.5	35	32.5
2 pm	36	34	32
3 pm	33.5	31	29

TABLE 9.6 TEMPERATURE VARIATION IN MC, M1, M2 FOR FIRST DAY

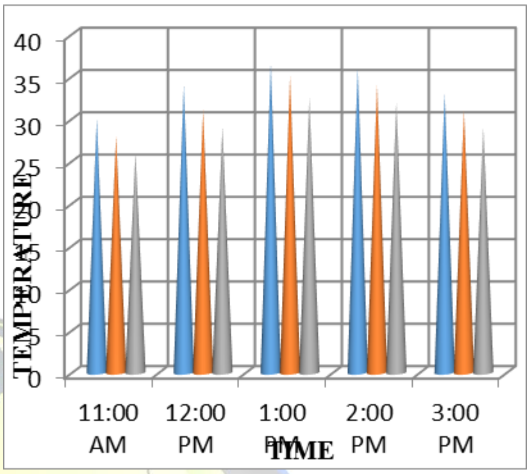

FIG 7 CHART SHOWING TEMPERATURE VARIATION OF DIFFERENT PROPORTION OF CONCRETE IN FIRST DAY

Second Day (21-03-2014)

Time	Temperature in MC (°C)	Temperature in M1 (°C)	Temperature in M2 (°C)
11 am	32	30.5	29
12 pm	34.5	33	30
1 pm	35	34	30.5
2 pm	36.5	35.5	32.5
3 pm	33	31.5	28

TABLE 8 TEMPERATURE VARIATION IN MC, M1, M2 FOR SECOND DAY

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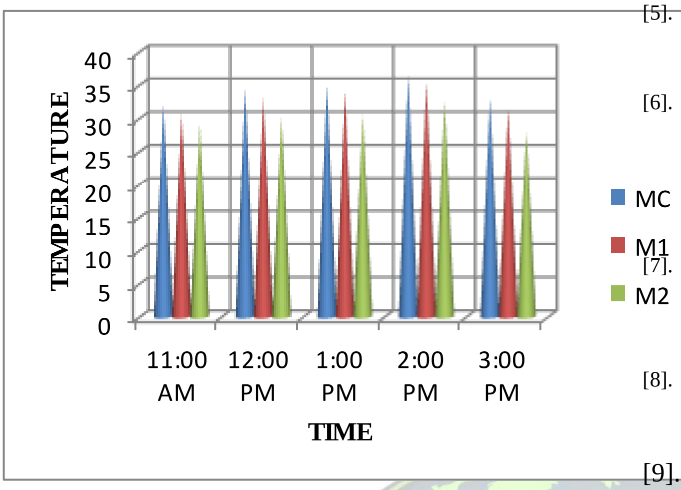

FIG 8 CHART SHOWING TEMPERATURE VARIATION OF DIFFERENT PROPORTION OF CONCRETE IN SECOND DAY

VIII. Conclusion

By conducting the temperature variation analysis, it was found that there was decrease in temperature when PCM was incorporated in concrete. It was found that the temperature is about 4 to 5°C decrease. The maximum temperature difference will appear after 2 hours. The result showed that there was decrease in temperature as time passes. By conducting the test in compressive strength, split tensile strength and flexural strength, it was found that the physical properties of concrete cubes remained the same without losing any of its initial characteristics.

It was found that the optimum proportion of PCM incorporated in concrete was 20% as beyond 20% replacement, there was decrease in compressive strength.

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Bibliography

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