Comparison of different dosages of PCM incorporated wall panels

R R Lakshan¹, A M Rosini¹, K Sathiyan¹, Dhanya Sathyan¹, K M Mini¹* and D Gangadharan²

¹Department of Civil Engineering, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, India.
²Department of Sciences, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, India.

Email: lakshan.raaj@gmail.com

Abstract: In the modern world of development and technology, sustainable development is of greater need. One of the main factors that cause global warming is due to the usage of the artificial air conditioner in buildings. This study is the development of an eco-friendly wall panel for buildings which can reduce the usage of artificial air conditioner and to improve the thermal comfort in buildings in a sustainable way. To achieve this, PCM materials is used in mortar wall panels to regulate the temperature. PCM absorbs heat at higher temperature and releases the absorbed heat at lower temperature. In this study PCM were encapsulated to prevent them from being affected by the chemical environment. The encapsulated PCM were incorporated in mortar cubes and were made into wall panels. The PCM incorporated specimens were tested for compressive strength and thermal conductivity to study the hardened property and the heat transfer. The obtained results were compared with the control specimen to conclude the effect of PCM in mortar wall panels. The PCM incorporated specimens showed improved results compared to the control specimen.

1. INTRODUCTION

The construction industry is the second largest industry of the country after agriculture. The construction industry plays a key role for governments in both developed and developing economies. New energy saving concepts are required to build a sustainable environment. One of the most developing area in modern world is building construction. Concrete is the most used material in the modern world. Keeping cool indoors when it is hot outdoors is a major problem in construction sector. The sun beating down on buildings causes indoor temperatures to rise to uncomfortable levels. Air conditioning provides some relief. But the initial costs of installing an air conditioner and the electricity costs to run it can be high. In addition, conventional air conditioners use refrigerants made of chlorine compounds, suspected contributors to the depletion of the ozone layer and global warming. But there are alternatives to air conditioning.

Sustainability in concrete is achieved by different energy saving materials[6]. One such material used to enhance the sustainability of concrete is PCM, which absorbs and releases heat at particular amount at different thermal conditions[8]. PCM reduces the thermal conductivity of the concrete thus increasing the sustainability of concrete. PCM reduces the number of freeze thaw cycles, improving the indoor thermal condition by eventual liberation or retention of thermal energy. For example, PCM is incorporated in concrete immediately after mixing to reduce the peak heat of hydration.
PCM materials are generally distinguished into organic, inorganic and eutectic groups. The organic PCM materials are further divided into paraffin based and non-paraffin based materials \[3,5,9\]. In this study a non-paraffin based PCM material is studied under different thermal conditions to assess the efficiency of the given material. PCM are incorporated in wall panels made of OPC and PPC mortar mixes. Such PCM materials that are incorporated in wall panels can be exposed to different chemical environment that may change the properties of the PCM leading to reduction in its efficiency. The solution for this problem is to encapsulate the PCM with an outer shell that is inactive to the external chemical environment and also transfers heat inside and outside the shell efficiently[10]. The encapsulation also protects the PCM to be preserved in its original position during its molten state, thereby saving a large amount of dissipation of PCM.

Encapsulation of PCM in suitable shell material is done using different methods. In the present work suspension polymerization is used to encapsulate the PCM into its outer passive wall. Different materials were encapsulated and one of the materials that could sustain its stability at peak temperature of hydration of concrete was selected. PCM was encapsulated and then cubes made of new mix of mortar with incorporation of encapsulated PCM were tested for compressive strength. Wall panels made of mortar mix with incorporation of PCM was tested for thermal conductivity at different temperatures[1,11,13].

2. PREPARATION OF PCM

PCM are materials that change its phase according to the atmospheric temperature. PCM used in this study is non-paraffin based material. The PCM is to be encapsulated to ensure the resistance towards external chemical environment and to avoid the leakage of PCM into mortar mix.

The selected PCM is encapsulated using suspension polymerisation[5]. The PCM materials in the compound form was suspended in liquid phase to get an encapsulated PCM beads. The PCM materials were taken as micro sized particles and all the particles of the PCM were encapsulated. Few encapsulated PCM were tested for the resistance towards the heat of hydration. The PCM beads were prepared and stored in liquid phase before incorporation in mortar wall panels. The PCM beads were also incorporated in mortar cubes for compressive strength.

PCM incorporated mortar were cast in cubes of dimension 5x5x5 mm. 3 cubes were cast for 0,3,5 percentage of PCM incorporation in each respectively. The castcubes were cured for 28 days and compressive strength was tested using Compression testing machine. PCM incorporated mortar wall panels were cast in numbers of two for each percentage of 0,3 and 5 percentage respectively and tested for thermal conductivity[2,4].

3. EXPERIMENTAL INVESTIGATION

PCM incorporated panels are expected to perform better in conditions where there is a deviation in temperature. Tests have been performed on PCM integrated cement mortar panels to evaluate the thermal resistivity and the compressive strength.

3.1.Compressive strength

Compressive strength is the governing property which attribute to the hardened strength . This test has been carried out on the hardened (cement-sand) mortar cubes. The strength of the mortar cubes gives us the direct measure of quality control of cement.

Compressive strength test was performed to determine the load-bearing capacity of the mortar cubes. Compression testing machine which has a total capacity of 2000kN was the instrument used to carry out the test. Specimen of size 5cmx5cmx5cm was removed after 28 days from curing tank. It was also
ensured that the excess water has been removed from the specimen. The cube was placed in such a manner that the load is applied in the direction opposite to the cube cast. The axis of the specimen was aligned with the centre of thrust of the spherically seated platen. The load was applied increasingly at a rate of 140 kg/cm² per minute until the cube collapsed. The maximum load at which the cube cracks was noted.

\[ \text{Compressive strength} = \frac{\text{Maximum load applied to samples}}{\text{cross section of samples}} \]

3.2. Thermal conductivity

Thermal conductivity of the material is the property which determines the amount of ease at which it can transfer or conduct heat. The instrument used to execute the thermal conductivity test is the guarded hot plate apparatus as shown in Figure 1, which aids in determining the thermal resistance to insulation.

The instrument consists of guarded main heater plate, two samples, two cooling plates, two auxiliary heater plates which is isolated from the external environment by an outer guard. The panel was fixed firmly within the two plates. The temperature is adjusted in the instrument preceded by turning on the water supply which acts as the key in maintaining the temperature of the plates. The passage of heat through the plates is not similar but has variation such that the temperature of one plate ascends or descends in comparison to another plate. Readings were noted down at regular intervals until the temperature stabilised.[14,15]

![Figure 1. Guarded Hot Plate Apparatus](image)

4. RESULTS AND DISCUSSION

The results obtained from the tests are discussed below.

4.1. Compressive strength

Study has been carried out on 5cm cube using Compression testing machine of 2000kN capacity. Three samples were tested for each specimen and the average value was calculated. Test results are presented in Figure 2.
From the test results it has been observed that the panels incorporated with PCM have reduced compressive strength in comparison with the panel without PCM. This may be due to the increased porosity developed in the concrete due to the addition of PCM. The extra pores developed due to the addition of PCM made more voids in concrete which drastically reduces the Compressive strength. In OPC, compressive strength reduction of 38.7% and 76.4% were obtained for 3% and 5% of PCM added respectively[7,12]. In case of PPC, the reduction in strength corresponds to 33.2% and 77.6% for 3% and 5% addition of PCM respectively.

4.2. Thermal conductivity
Thermal conductivity tests were carried out on panels of size 45cmx30cmx2cm using hot guarded apparatus at a temperature of 45°C-50°C. Test results are represented in Figure 3 and Figure 4.
From Figure 3 and 4, it was evident that a reduction in thermal conductivity was obtained on addition of PCM. It is observed that in both the cases a reduction in thermal conductivity is observed up to 3%. Further increase in PCM increases the thermal conductivity. In OPC, a reduction in thermal conductivity of 22% was recorded on the addition of 3% PCM whereas when 5% was added the thermal conductivity decreased to 12.82%, both in comparison with the control specimen. In PPC, a decrease of 17.8% and a decrease of 7.8% of thermal conductivity was observed on addition of 3% and 5% of PCM respectively. Hence it can be concluded that the addition of small quantity of PCM in concrete reduces the thermal conductivity which makes it as a suitable construction material for tropical countries where the temperature variations are high. It is also observed that the results are in concurrence with the initial study carried with 3% PCM at a temperature of 60°C-65°C. [16]

5. CONCLUSION

Based on the study conducted the following conclusions were arrived at:

- The reduction in compressive strength tends to become higher on increased addition of PCM. In OPC, a reduction of 39% and 76% was observed for 3% and 5% addition of PCM respectively. In PPC, a reduction of 33% and 78% has been noted on 3% and 5% PCM addition respectively.
- On addition of 3% PCM, thermal conductivity has been reduced by 22% and 18% in OPC and PPC respectively. On addition of 5% the reduction in thermal conductivity is reduced. The reduction is only 13% and 8% in OPC and PPC respectively.
- On addition of 5%, thermal conductivity has been increased by 12% and 11% for OPC and PPC respectively in comparison with 3% PCM.

Considering the physical strength and thermal conductivity aspect it is concluded that 3% PCM incorporation is effective.

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