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IMPACT OF PARAFFIN AS PHASE CHANGE MATERIAL IN CONCRETE CUBES FOR ENHANCING THE THERMAL ENERGY STORAGE

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ABSTRACT

In this present work, the impact of paraffin as Phase Change Material (PCM) on M20 grade concrete cubes is studied through an experiment. The addition of different weight percentage (0.5, 0.75, 1.0 and 1.25 wt. percentage of cement) of paraffin as PCM with concrete cubes were tested. Trying out on concrete cubes was done for X-ray diffraction pattern (XRD) analysis, compressive strength and thermal energy storage measurement. The XRD pattern of the cast concrete cube revealed the presence of paraffin without any chemical reaction with cement. To evaluate the strength of the M20 grade concrete cubes with the addition of PCM, the compressive strength test was performed. The optimum percentage of PCM to be added for giving maximum thermal energy storage in concrete cubes is obtained from the experimental results. There is reduction in temperature to improve the thermal comfort also evident from the results.

Keywords: PCM, XRD, M20 & TEC.

1. INTRODUCTION

Trend for contributing energy efficiency buildings are increasing to cater the demand of increasing electricity demand in the fast growing nations [1, 2]. If we really look at the major consumer of energy resources are construction industries i.e. about 40% of consumption in overall production [3]. Thermal energy storage (TES) is having the capability to store energy for later stage use with the aid of either sensible TES materials or latent heat storage materials [4]. Latent heat is the energy required to change the phase of the material [3-5]. Steel, masonry and water are some of the TES materials presently adopted in the construction industry and they stores thermal energy when there is a rise in the temperature of the materials. Materials with latent heat property are mostly referred as phase change material (PCM) which is with solid-liquid phase changes [5-7].

By high heat of fusion which by melting and solidifying at a certain temperature, a PCM is having the capacity to store and release large quantity of energy. When the material property changes from solid to liquid vice-versa, it is ascribable to the heat absorbed or let go by the material [8-9]. Thereby PCMs are come under the classification of latent heat storage (LHS) materials. To increase the thermal storage capability of the building envelope PCMs can be incorporated. PCMs are having the ability to store energy at constant or approximate temperature, which is experienced as the phase transition temperature of the PCM. When cementious material are utilized as construction material in a building which causes a high potential in producing high performing storage material [10, 11]. The heat transfer behaviour and thermal properties of this composite material can be characterized in concrete by the simulation of thermal energy storage in concrete [12, 13].

To reduce internal temperature change by storing latent heat in the solid-liquid or fluid-gas phase change of a material in the build environment, the PCMs can be used [14, 15].When compared with the conventional thermal storage materials PCMs are capable to store 5 to 14 times more thermal energy per unit volume [16]. Heat is absorbed and released almost isothermally and is used to reduce the energy consumed by conventional heating and cooling systems by reducing peak loads [17-19]. Organic and inorganic PCMs are the two types of PCMs used for construction applications. Organic PCMs are sub-classified as paraffin and non-paraffins [20, 21]. These organic PCMs are having better properties of cohesion, chemical stability, non-reactivity and recyclability as their advantages [22-27]. But these organic PCMs are comparatively low heat conductivity in the solid state. But inorganic compounds have a high latent heat absorbing capacity and also non-flammable. Inorganic PCMs have high thermal energy store and are cheaper than organic PCMs [28, 29].

In this present work paraffin is selected as the phase changing material for enhancing the thermal comfort of the building. XRD analysis was carried to find out the presence of PCM in the concrete cubes with and without PCM. Paraffin is available at cheap cost and applying this as PCM reduces the price of energy efficient constructions.

2. EXPERIMENTAL PROCEDURE

2.1 M20 grade cement concrete mix design

For M20 grade concrete the proportion of the component parts of concrete was calculated based on ISO: 10262:2009 methods. From a volume of 1 $m^3$of concrete the quantity of material is taken as 382 Kg of cement, 644 Kg of fine aggregate, 1240 Kg of coarse aggregate and 181.6 liter of water. For enhancing the thermal comfort property of the concrete cube, paraffin is selected as PCM admixture. Addition of paraffin is chosen in terms of various percentages (0.5, 0.75, 1.0 and 1.25 in quantity of cement) and then the mixture is added to the aggregates for the preparation of concrete cubes. Homogeneous mixing of paraffin with cement was ensured during the preparation of concrete.

2.2 Positioning of thermocouple in concrete cube

For evaluating the temperature variation inside the concrete cubes 'K-type' thermocouple was fixed in the centre and side of the mould before the casting of concrete blocks as shown in Figure-1. The temperature was assessed using an indigenously fabricated digital thermometer which has a digital LED display with 7 segments as shown in Figure-1.Manufacturing is done in such a manner that it is possible to assess the temperature inside the concrete cube.

Figure-1. Manufactured concrete cubes with K-Type thermocouple inserted and temperature measurement set-up.

2.3 Preparation of concrete cubes

The measured quantity of cement, fine and coarse aggregate and different weight percentage of paraffin was mixed with water to prepare the concrete cubes. The prepared concrete was placed inside the mould, where the 'K-type' thermocouple was already fixed. The concrete blocks were made as per the IS code standard. The number of concrete cubes prepared for the testing purpose was 9 numbers with thermocouple for temperature measurement and 12 numbers of concrete cubes for compressive strength test with varying weight percentage of paraffin as PCM and normal concrete without the addition of PCM.

2.4 Preparation of specimen for XRD test

From the prepared concrete cubes for varying weight percentages of PCM added concrete and normal concrete specimen were taken for X-ray Diffraction analysis for distinguishing the presence of PCM in the concrete cubes cast. Powder from each concrete cubes were collected by breaking down the concrete cubes using the compressive strength testing machine on 30th, 60th and 90th day after water curing.

2.5 Preparing the specimen for compressive strength

The cast concrete cubes were removed from the mould after 24 hours and water cured for 28days. Compressive strength test was carried out on a compressive strength testing machine as per IS: 516:1959 procedure on cast samples on 7th, 14th and 28th day for three specimens, for each pile of cast concrete curbs.

2.6 Temperature measurement

The cast cube specimen was held under water curing for 28 days. The cast specimens with 'K-type' thermocouples were tested visually for cracks or damages. After leaving the specimen for drying, from the 30th day onwards the temperature was assessed along the specimen using specially fabricated digital thermometer shown in Figure-1. Specimens are held in an open, uncovered place under natural ambient condition and temperature readings are held on each lot of specimens prepared for each pile of concrete and put down.

3. RESULTS AND DISCUSSIONS

3.1 XRD Analysis of concrete/paraffin

The paraffin as phase change material added to concrete cubes casted with M20 Grade was tested for the presence of paraffin. Concrete powders were collected from the concrete cubes from crushed concrete cubes using the compressive strength test machine on 30th, 60th and 90th day for XRD analysis. The XRD pattern of the cast concrete specimen with and without PCM is shown in Figure-2. The XRD peaks from the pattern clearly indicate the presence of paraffin in concrete and intensity of diffraction peak increases as paraffin content increased in the concrete. It is apparent from the Figure-2 that diffraction peak of PCM incorporated concrete, slightly shifted to lower value compared to the normal concrete. The observation leads to conclude that the integrity of paraffin is preserved during the casting of concrete cubes and thermodynamically stable during the casting of concrete cube specimens. It is too apparent from the XRD pattern that after 30, 60 and 90 days the integrity of the paraffin as PCM has been saved.

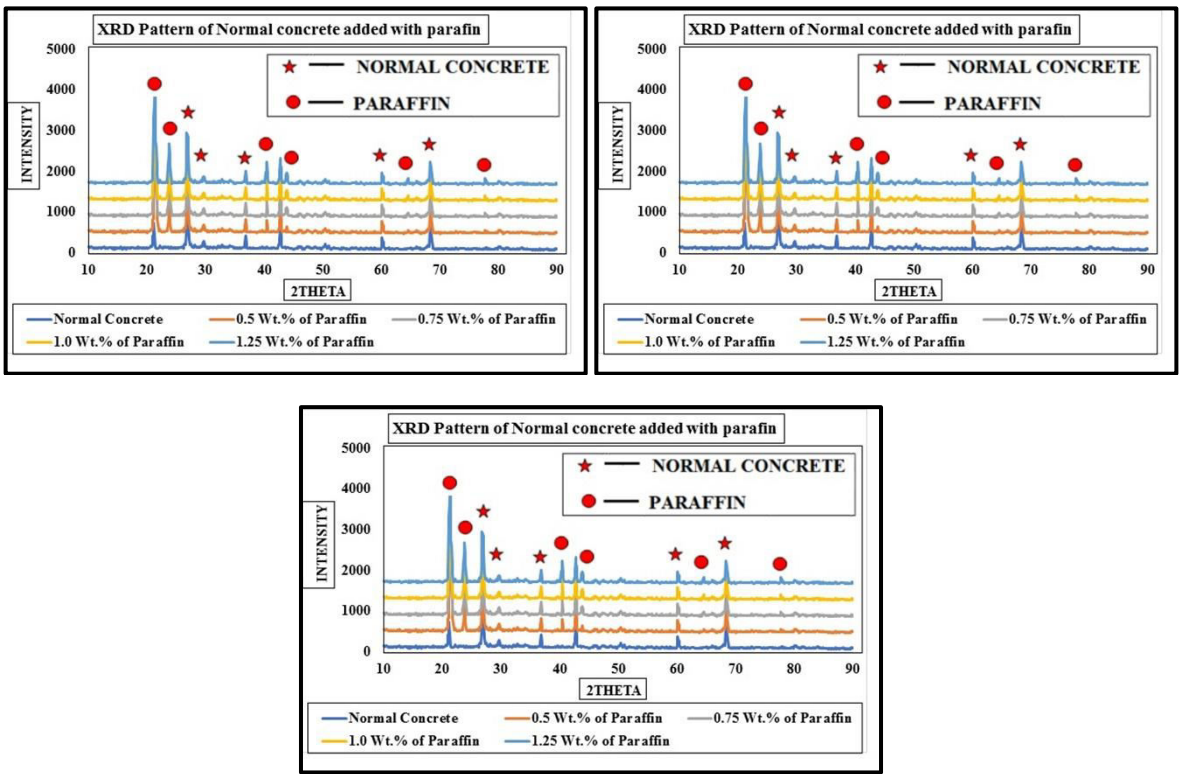

Figure-2. XRD Pattern of (A) Concrete/Paraffin after 30 days (B) Concrete/ Paraffin after 60 days (C) Concrete/ Paraffin after 90 days.

3.2 Effect of PCM in concrete

The Figure (3-6) shows the results of the effect of PCM added in M20 grade casted concrete cubes. From the Figure (3-6) it is evident that the concrete added with varying weight percentage of Paraffin (PCM) (0, 0.5, 0.75, 1 & 1.25 Wt. Percentage of PCM) and latent heat storage capacity of the PCM are recorded utilizing the indigenous fabricated thermocouple which is depicted in the Figure (3-6). From the Figure (3-6) it is apparent that due to the addition of paraffin, atmospheric temperature absorbed by the concrete block, stored as a latent heat in the pith (kernel) and cuts the temperature along the lateral side of the concrete blocks [30]. The concrete cube added with 1 percentage by weight of Paraffin stored maximum latent heat and reduces the temperature on the lateral sides up to1 to 3 degree centigrade which is shown in the Figure-5 which was measured for 30th, 60th and 90th day.

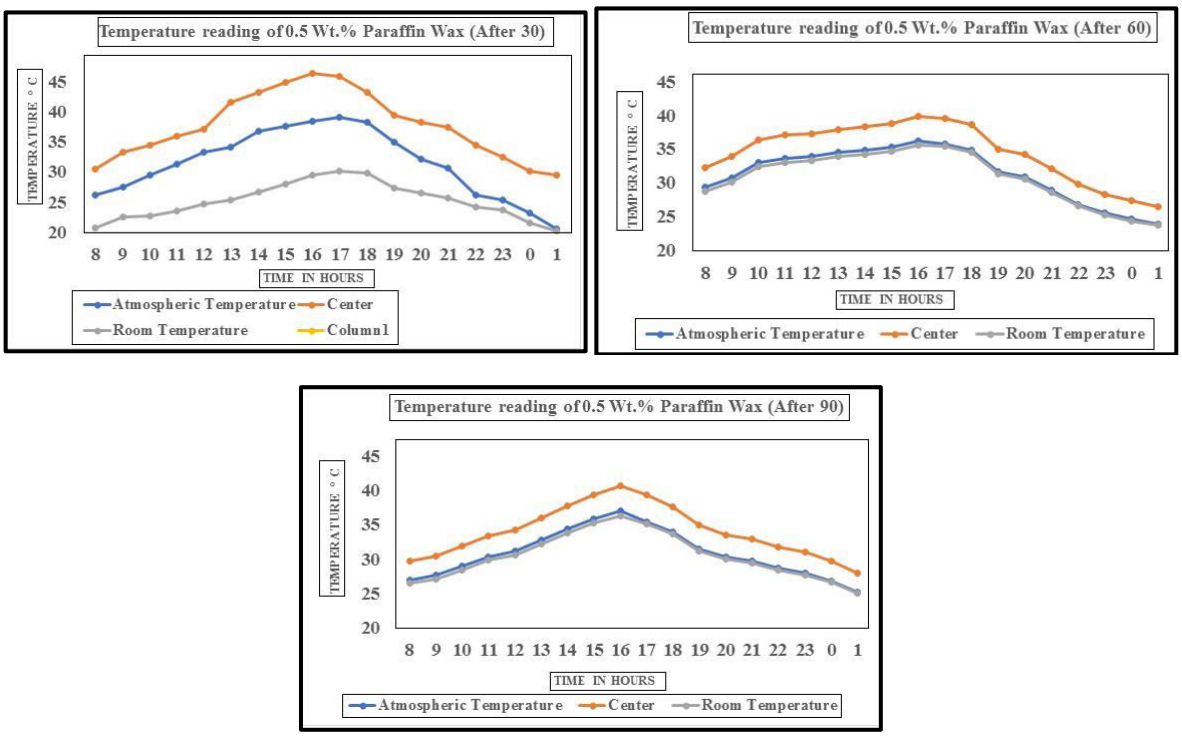

Figure-3. Temperature reading on 0.5 wt.% of (A) Concrete/ Paraffin after 30 days (B) Concrete/ Paraffin after 60 days (C) Concrete/ Paraffin after 90 days.

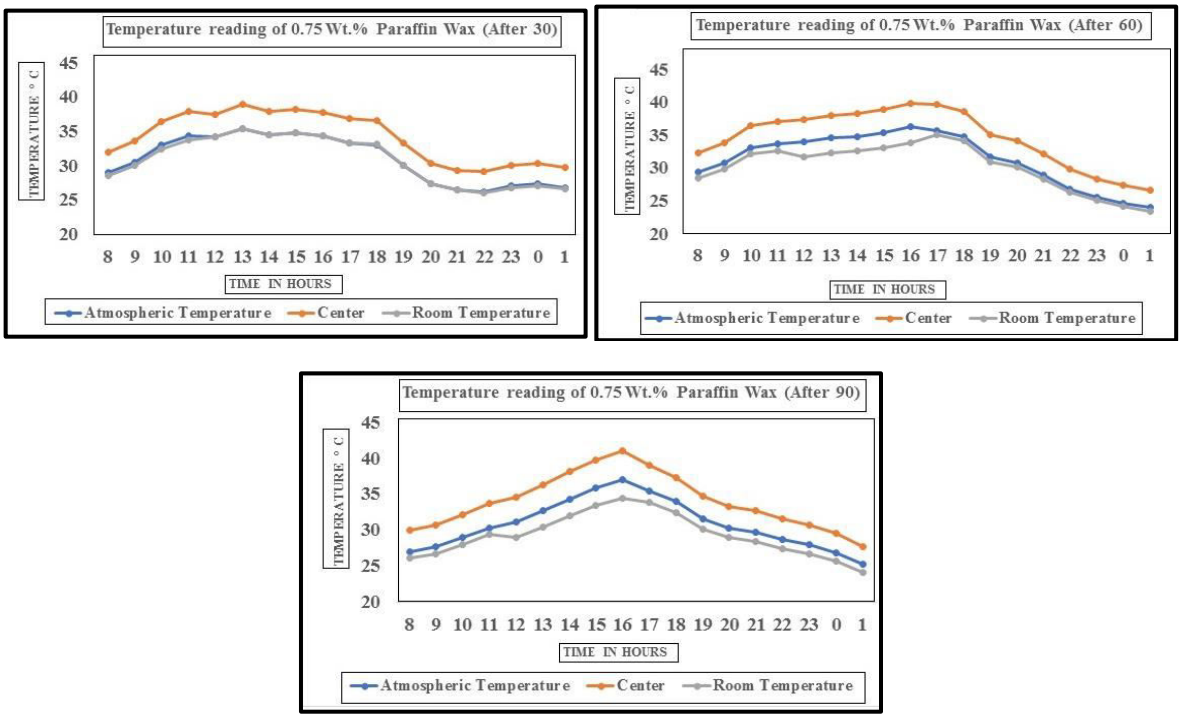

Figure-4. Temperature reading on 0.75 wt.% of (A) Concrete/ Paraffin after 30 days (B) Concrete/ Paraffin after 60 days (C) Concrete/ Paraffin after 90 days.

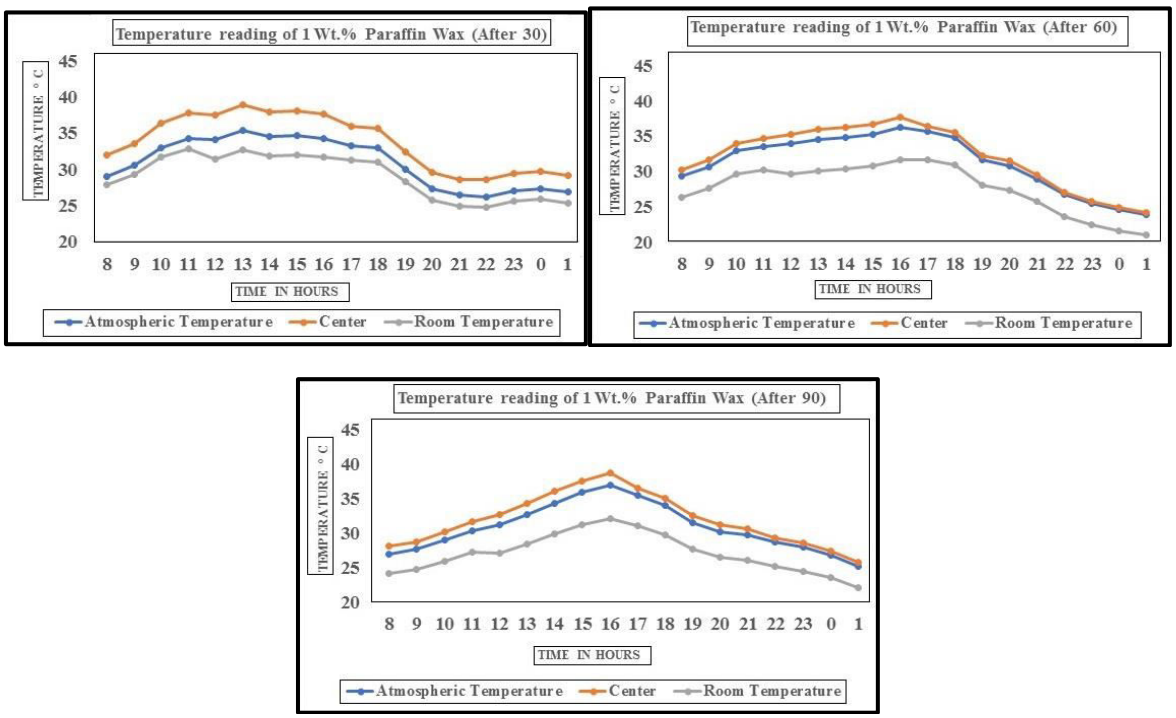

Figure-5. Temperature reading on 1.0 wt.% of (A) Concrete/ Paraffin after 30 days (B) Concrete/ Paraffin after 60 days (C) Concrete/ Paraffin after 90 days.

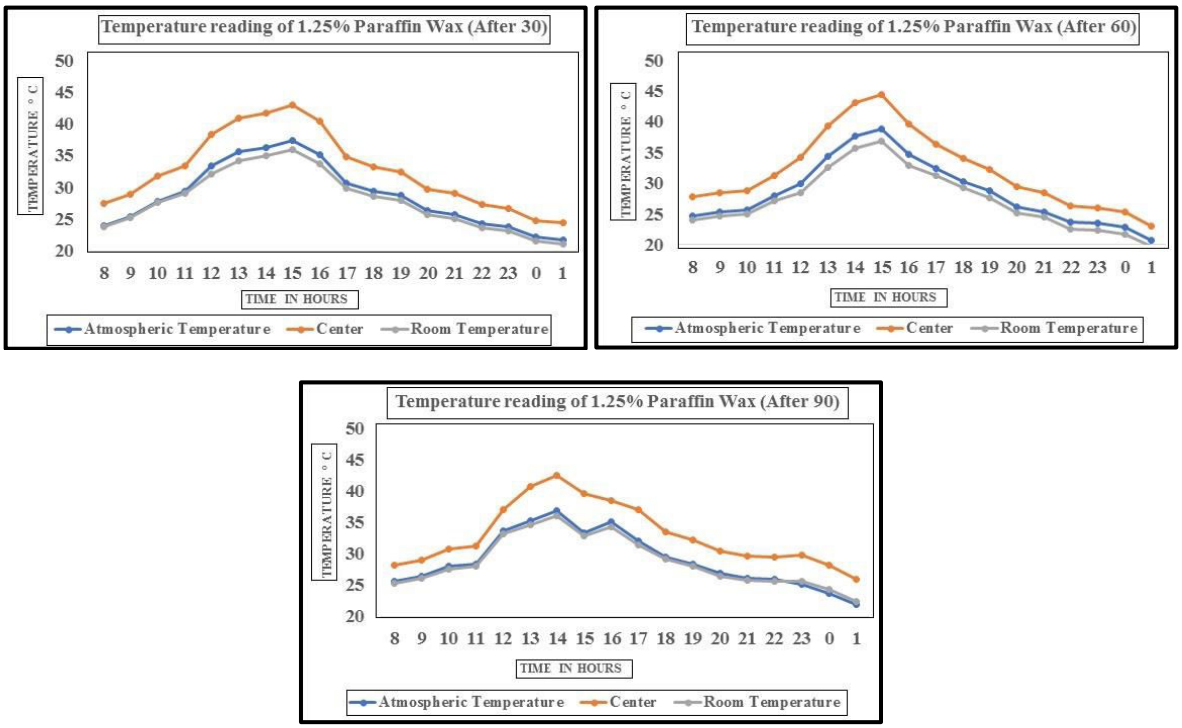

Figure-6. Temperature reading on 1.25 wt.% of (A) Concrete/ Paraffin after 30 days (B) Concrete/ Paraffin after 60 days (C) Concrete/ Paraffin after 90 days.

Referable to the addition of paraffin to concrete cubes the strength of the concrete is not affected and it is apparent from compressive strength of the concrete cube which is shown in Figure-8. The XRD analysis of specimen with concrete/paraffin also clearly exposes the presence of paraffin and integrity was preserved after 30, 60 & 90 days which is shown in Figure-2. It was brought out that the effect of cooling has enhanced by the addition of paraffin as PCM in the concrete blocks. The paraffin absorbs the heat and changes it to latent heat, the converted latent heat is stored in the nucleus or heart of the concrete cube and it is plain from the shown Figure (3-6).

In Figure-7. It is evident that 1.0 weight percentage addition of PCM enhances the cooling effect on side walls has proven for the 30th day.

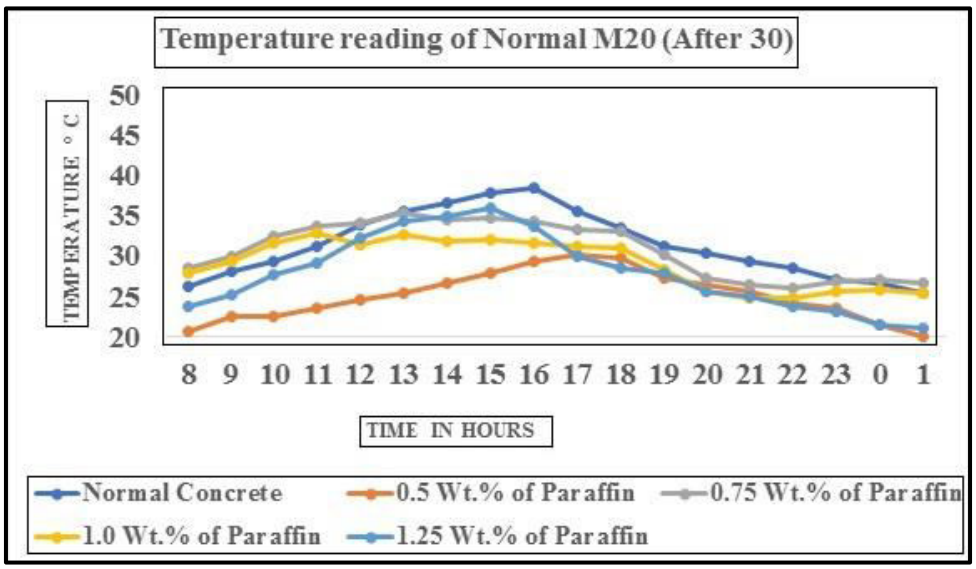

Figure-7. Comparing the temperature reading on PCM effect on side of concrete cubes on varying wt.% of Concrete/ Paraffin after 30 days.

3.3 Compressive strength

The values of the compressive strength test are shown in Figure-8. A comparative analysis of compressive strength in terms of the percentage of added PCM is shown in Figure-8. It is evident from Figure-8, the compressive strength of the concrete is not affected by the addition of paraffin as PCM in different weight percentages when compared with the normal concrete. The compressive strength of the cast concrete cubes was tested on 7th, 14thand 28th day. The compressive strength of the PCM added concrete cubes gradually increases by the 28th day over the normal concrete.

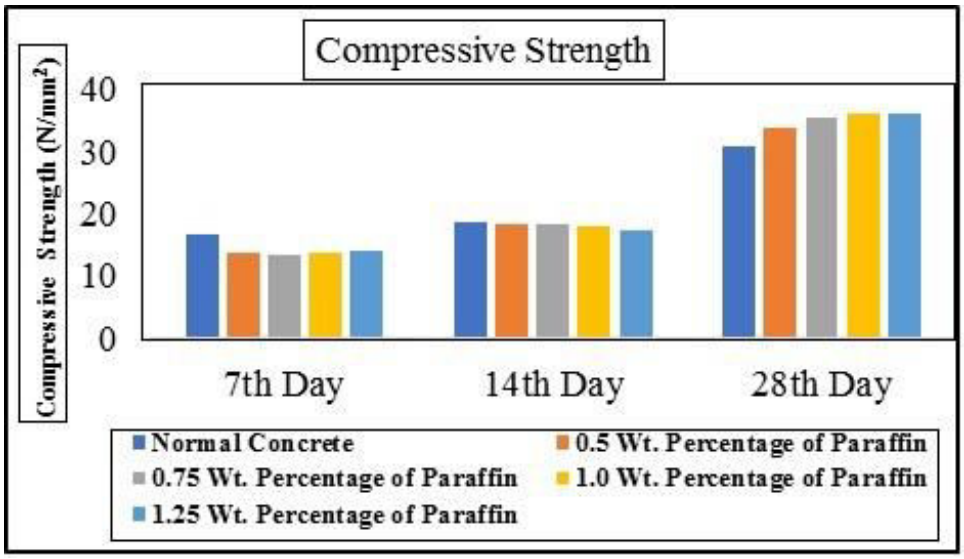

Figure-8. Effect of addition on paraffin content to concrete on compressive strength.

CONCLUSIONS

The addition of paraffin as PCM to normal M20 grade cement concrete cube proves to be effective latent heat storage material in producing an effective thermal storage system in concrete. The addition of paraffin was added to normal concrete by varying the weight percentage (0.5, 0.75, 1.0 & 1.25 in measure of cement), from the experimental result was found that 1 weight percentage of paraffin added to normal concrete is effective in storage of maximum latent heat and provide good thermal comfort in the outer walls. The presence of paraffin in concrete cubes is also supported by the XRD pattern and when the paraffin weight percentage increases the peak of PCM is also slightly changed. The

compressive test results on concrete cubes also prove that the addition of paraffin to concrete does not touch on the compressive force.1.0 weight percentage of paraffin is effective enough to trim the outer wall temperature up to 3-6 degree centigrade in the cast cement concrete blocks.

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