Experimental Investigation of Thermophysical Properties of Plaster of Paris Incorporating Phase Change Materials

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Abstract- Phase change materials (PCMs) are high thermal energy storing materials. Adding PCMs into building materials is reported to give high thermal mass which gives higher energy efficiency. Researches show that effective thermal conductivity of concrete reduces with increasing PCM content in concrete. Energy efficiency and heat capacity of PCM-concrete are reported to be higher than plain concrete. In this paper thermal properties of PCM-concrete product are reviewed along with some mechanical properties. Incorporating PCM into concrete is found to lower the peak temperature and retards the time of occurrence of this peak temperature. PCM absorbs high heat which reduces cooling as well as heating load in building which in turn reduces the risk of thermal cracking. This review paper assembles thermal properties of PCM-concrete with mechanical properties to understand the complete behavior of concrete when PCMs are employed.

Index Terms- Phase change materials (PCM), Thermal energy storage, Thermal properties, Thermal cracking, building materials

I. INTRODUCTION

Phase change materials (PCMs) are thermal energy storing materials which store energy in the form of both sensible and latent heat. Many researches show that adding PCM in building elements like concrete [6], gypsum board [4], plaster [5], increases thermal mass of building due to which energy efficiency of the building is increased [11,15] and so energy demands for cooling and heating is decreased [13,14]. Thermal energy storage in PCM can be classified in two ways: first as sensible heat storage system heat is stored/released with temperature change and the phase remains same, hence a large volume needs to be handled whereas for latent heat storage system heat is stored/released as heat of fusion or heat of solidification, hence a large energy can be stored[1]. Different techniques of incorporation of PCMs are described in various works. These practices have their individual advantages and limits. Use of microencapsulated PCM, available in powder form is getting attention from few years. Inserting microencapsulated PCMs in cementitious composites is beneficial not only for energy budget but also for avoiding thermal cracking [7,10]. Various researches have been carried out to find out energy efficiency, thermal properties, strengths etc. by integrating PCMs in building material composites. Also, different incorporation practices have been checked for their effects in these properties by numerous researchers. The purpose of the study present here is to check thermal properties like thermal conductivity and heat capacity of plaster of Paris (POP) composites. Different PCMs like paraffin wax, capric acid etc. are direct mixed with POP composites to find out these thermal properties.

II. PHASE CHANGE MATERIALS (PCMS)

A phase change material (PCM) is an ingredient which liquifies and solidifies at a certain temperature and it has a large heat of fusion. It can store and release large quantities of energy. Heat is absorbed or free when the material transforms from solid to liquid phase and vice versa; therefore, PCMs can be named as latent heat storage (LHS) units.

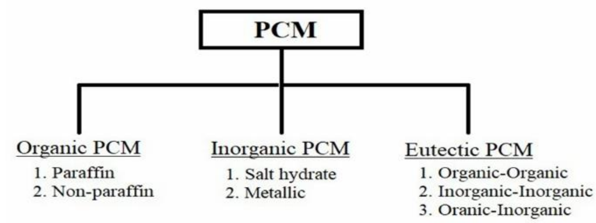

Fig 1.1 Classification of PCM

Criteria For Pcm Selection

The important PCMs are categorized as pronounced above. Selections of PCMs are done by filling various criteria such as: economic, thermal, kinetic, chemical etc. Some significant characteristics must pay attention while choosing PCMs for any application, such as:

- No corrosiveness.
- No degradation later long number of cycles, no leakage.
- No toxicity and flammability.
- Melting temperature.
- High latent heat of fusion per unit volume.
- High specific heat.
- Small volume change on phase change.

Objectives of the presented research work are as follows:

- To find out the thermo-physical properties of POP samples incorporated PCM at different temperature ranges.
- To find out effective thermal conductivities of plaster of Paris (POP) containing PCMs.

III. LITERATURE REVIEW

Chaoen Li et al. [1] performed experimental investigation of thermal performance of microencapsulated PCM-contained wallboard by two measurement modes. They found that incorporation of PCM (paraffin wax) in gypsum wallboard decreases the thermal conductivity of wallboard and concluded that inclusion of PCM in wallboard increases thermal inertia of wallboard.

Likesh kumar sahu et al. [3] compared the thermal characteristics of concretes and Cementous composites containing PCMs by directly mixing PCMs in to concrete and cement composites.

Erman Yig˘it Tuncel et al. [2] performed investigation on sustainable cold bonded lightweight PCM aggregate production and Its effects on concrete properties and they found that PCM reduced the palletization tendency while duration of the production process increased

U. Stritih et al. [4] Integrated the passive PCM technologies for net-zero energy buildings and concluded that the cooling requirements of building are affected by the wall material.

IV. PROBLEM IDENTIFICATION

Demand of thermal comfort of building and energy consumption is rising day by day. Thus, energy demand in the world is growing endlessly. It has observed that building is one of the leading energy consumption areas. Energy consumption in air conditioning, ventilation, heating is increasing due to demand of thermal comfort. Therefore, the thermal energy storage systems are gaining attention. The thermal energy systems have possibility to save energy in buildings. As mentioned earlier, thermal energy storage systems store energy in two ways i.e. by storing sensible heat and latent heat. The phase change materials (PCMs) are latent heat storage system which have a high heat storage density and have a capability of storing large quantity of heat during phase change procedure. Hence the incorporation of PCMs in building elements is a means of energy saving.

Thus, the problem of energy crisis in buildings is essential to be resolved. This wants a lot of investigation work to be conducted to accurately analyze the thermal performances of building elements along with using the phenomenon of energy storage systems. PCM embedded building elements have high potential to save energy hence research for these kinds of composites are of emerging requirements.

V. METHODOLOGY

Plaster of Paris (POP) mortar samples were incorporated by direct PCMs. Three samples of POP were made by direct mixing of PCMs in their solid powder form. The mass fractions of PCMs were kept 0.2 for each sample. Conventionally, POP is used as a wall cladding due to its plasticity, thermal and sound insulation. Therefore, we selected high-quality plaster powder as the construction material. The model ratio of the PCM/POP mortar is 20% and the water/POP ratio is 40%. Firstly, PCM and POP mortar were mixed to homogenize components. Then, water was added into the compound. Finally, the mixture was placed into a mold, and the dimension is 100 mm ×100 mm ×20 mm. The specimen remained dehydrated in the test center for some days till the weight of the samples didn't change. In this study, three samples were fabricated, including paraffin wax as PCM, capric acid as PCM and common POP sample. Eventually, after the drying process, the mass percent-age of MPCM in the sample is about 16%. The material used in test specimen and the final test samples are shown in below figure 6.1 and figure 6.2 respectively.

Fig.6.1 material used to make specimen

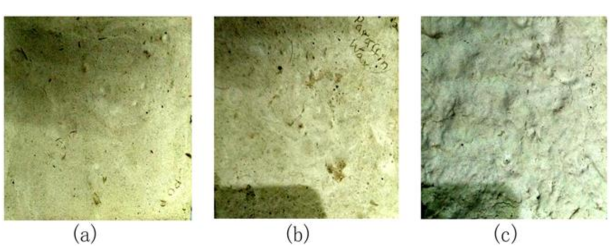

Fig. 6.2 material used to make specimen: (a) POP; (b) POP with paraffin wax; (C) POP with capric acid

Density measurement of cementitious composites was done by simply measuring the volume of sample (V) and the mass (m) at room temperature. Then the density of sample was calculated by:

$$\rho = m / V$$

To measure operative thermal conductivity of the sample, an arrangement was made as heat flow meter arrangement is illustrated in figure. In this apparatus a specimen and a heat flux transducer (HFT) are inserted between two flat plates. These flat plates are controlled at unlike temperature to produce a heat flow from the specimen. A reproducible compressive load is applied between plates to ensure reproducible contact resistance between specimen and plates. To reduce lateral heat flow a guard covers the test specimen and plates which is maintained at a uniform temperature of two plates. The test specimen arrangement is shown in figure 6.3 and figure 6.4.

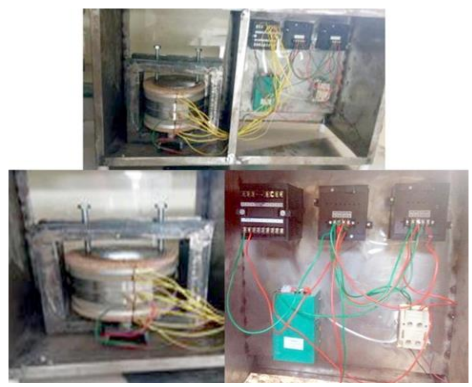

Fig.6.3 Experimental setup of heat flow meter for thermal conductivity test.

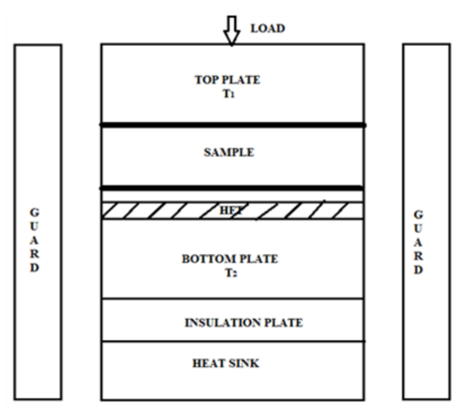

Fig. 6.4 Arrangement of apparatus.

To measure the specific heat capacity of POP mortar sample Differential scanning calorimeter (Model-Q20™ TA instruments, USA) designated as per ASTM E1269 [64] was used. Arrangement of DSC is shown in figure 4.5. The components of the device are: Test chamber- The test chamber of the device contains: (a) furnace, which provides a controlled and uniform heating/cooling of the sample and reference to the desired temperature range; (b) Temperature sensor for sensing sample temperature; (c) Differential sensor, which sense heat flow difference between the specimen and reference; (d) A means to keep inert environment in test chamber by purge gases like air, argon, helium, nitrogen or oxygen.

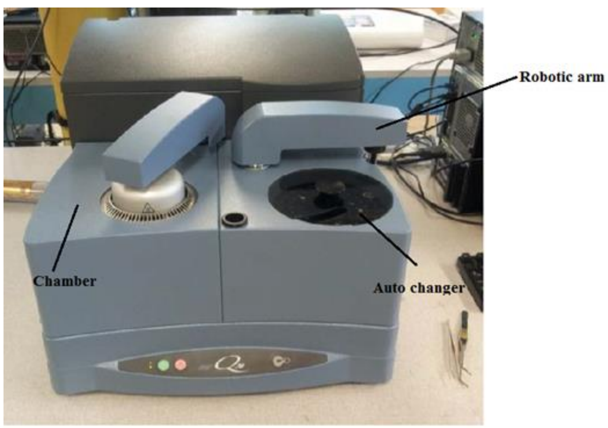

Fig. 4.5 DSC apparatus

VI. RESULT AND DISCUSSION

The thermal conductivity measurement for POP mortar samples containing paraffin wax and capric acid as phase change materials has been carried out in the temperature range of 15-55 ˚C in four sub points. All the samples have been examined after aging 7 days. The outcome shows that thermal conductivity of samples varies very less with temperature change.

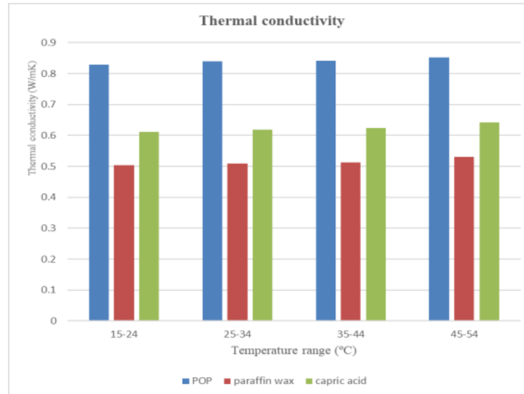

Chart 7.1 Thermal conductivity trend of POP samples

Higher the specific heat capacity, higher will be the thermal mass and hence higher will be the thermal comfort in building. Incorporating phase change material is reported to increase specific heat capacity and hence the thermal mass.

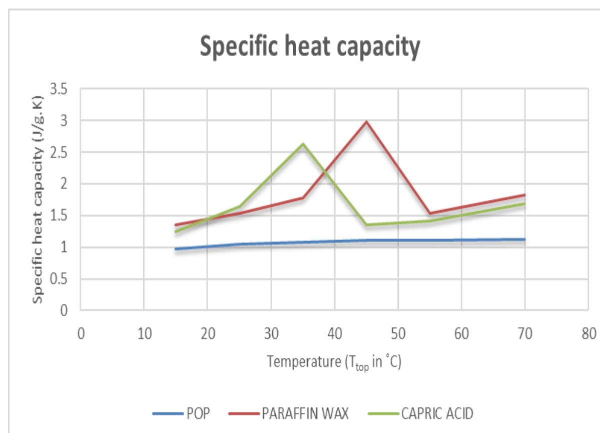

Chart 7.2 Specific heat capacity versus temperature plot.

VII. CONCLUSION

Finally, we can conclude that for common plaster of paris sample, the thermal conductivity grows linearly with temperature increase and for PCM-contained samples, the addition of the PCM into the POP would decrease the thermal conductivity due to the decrease of density and the conductivity of the PCM lower than that of plaster of Paris. The apparent specific heat capacity of the composite PCMs sample is much larger than that of POP sample.

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