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ARTICLE

INVESTIGATION ON THE STRENGTH BEHAVIORS OF RED MUD BASED PCM MORTAR

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ABSTRACT

In the housing sector, a large quantity of energy is expended on thermal comfort which increases the energy consumption and drives up demand, thus contributing to greenhouse gas emissions. The development of smart buildings and energy-efficient construction materials can reduce energy consumption and subsequent GHG emissions. The mortar used in building envelope can be customized to contain heat storage materials for moderating indoor temperature. The inert mortar composition of Phase Change Materials (PCMs) allows the absorption of heat during thermal weather and release of heat during cold weather due to phase transition from solid to liquid and liquid to solid. In this study, expanded graphite (EG) is used to encapsulate PCM to produce red mud based PCM mortar. Locally available red-mud, quartz sand, sodium silicate and sodium hydroxide mixture was used to produce a red-mud based PCM mortar. The variation in structural properties with different ratios of red mud and quartz sand was investigated to achieve the optimum ratio. The selection and application of the optimum mix in the outer walls of the building can thus be made on grounds of porosity, thermal conductivity and strength parameters.

KEY WORDS
Red-mud, Phase change material (PCM), Energy Efficient Buildings

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INTRODUCTION

The building sector provides residential, commercial and other benefits to the community, however its contributions towards, the greatest global challenge and an indispensable requirement for sustainable development in the building sector is the reduction of greenhouse gas emissions and energy consumption and environmental degradation. In this regards, it is necessary the development and promotion of efficient, affordable, and high impact technologies, systems, and practices. The energy consumed for Heating, ventilating and air conditioning (HVAC) systems account for 60% of total energy in buildings. Phase Change Materials (PCM) integrated as building envelope materials to develop the performance of heating, ventilation and air-conditioning (HVAC) systems has been implemented as an energy efficiency measure [1]. To build Indian cities smart and sustainable, the energy consumption of building sector need to be reduced (Ministry of Urban Development, Government of India, 2015). The air-conditioning and lighting consumption can be reduced by integrating climate responsive techniques need to consider in the design [2].

The per capita energy usage defines the standards of living and economy of a country, thus, countries are focused on increasing their energy production capacity. Sun is a prime source of energy and utilization of this solar energy for building energy conservation can be a changing point in the energy storage potential of buildings. One of the techniques improving the thermal energy storage effective aspects of a building would be to adding the thermal mass of the building components by incorporating phase change materials (PCMs) within the building envelopes it helps to decreasing the temperature fluctuation and peak temperature within [3].

The working principle of the PCM is that it saving energy when liquefy and releases the energy when solidifies. The melting of the PCM happens during the daytime when the temperature due to the solar radiation is higher than the melting temperature of the PCM. Similarly, during the night solidification of the PCM happens, when the outside heat is lower than the melting temperature of the PCM. Hence, when PCM is incorporated into the building envelopes the heat storage ability of the building improves and substantially improves the indoor thermal behavior [4].

Due to the thermal features of phase change materials(PCMs), they have identified PCM integrated methods into common building envelope material, such as motor, concrete, wall, floor, ceiling and roofing tiles, boards, slate, bricks and interlocking bricks, paints, coatings and slabs are possible for thermal energy efficiency in buildings [5].

Phase Change Materials (PCMs) considered ‘‘latent’’ heat storage materials having a massive amount of heat energy stored during its phase change stage process. The thermal energy is required to change the phase of a substance is called as latent heat. There are two types of PCMs, organic and inorganic PCMs utilizing for building coated applications. Organic paraffin wax as one of the phase change material has capacity of heat absorbed or released when the paraffin wax transfers phase from solid to liquid or liquid to solid at a temperature nearly 26°C. In organic PCMs especially paraffin wax PCM, seems to be one of the more convenient latent heat storage materials able to used in building envelopes like mortar and concrete directly [6].

There are various techniques identified for the proper incorporation of PCM in building envelope material like, (a) Direct incorporation (b) Immersion (c) Shape stabilized (d) Encapsulation. Out of the above

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mentioned techniques of PCM integration, encapsulation method having massive strength, durability, good thermal stability and avoids leakage/loss of PCM during phase transformation. Thermal energy storage combined with PCM is an smart idea for improving the thermal efficiency of the buildings. PCM can be integrated in the building envelope in various ways. One of the easiest and smart methods of integrating PCM directly in building envelope material is macroen capsulation. Due to this technique improve the indoor thermal comfort behavior of the buildings, but also reduces the cooling load without or little compromising with the mechanical strength of the building structure [7].

Microencapsulated Phase Change Material (MPCM) based thermal energy storage method has the substantially control the energy consumption of the buildings, by improving the indoor thermal comfort, when incorporated directly with the building envelope materials like cement, mortar, brick, wallboard, and gypsum successfully [8].

PCM plastering mortar, concrete, brick and cubicle construction materials with integrated PCMs are meant to promotes heat saving capacity, enable stabilization of indoor thermal of buildings whereby providing the thermal comfort condition also provides stability of indoor ambient temperatures. The thermal energy saving into the walls by encapsulating PCMs relatively with conventional concrete without PCMs promoted to an improved thermal comfortless as well as lower inner temperatures [5].

In this study going to investigate PCM encapsulated red-mud, geo polymer composites, under strength properties and binding between materials for PCM mortar possibility of usage in building materials. The phase change material is paraffin wax encapsulated with graphite powder used for preparing mortar. The mechanical strength and binding performance of red mud based PCM mortar is investigated under different mix proportions.

MATERIALS AND METHODS

Red-mud, quartz sand and sodium silicate/sodium hydroxide mixture was used to produce a red-mud based PCM mortar. The phase change materials concerns paraffin wax and graphite powder were used.

Various approaches have been applied for the integration of PCM to prepare mortar; whatever, direct mixing and replacement methods are normally used. The direct mixing techniques involves the PCM capsules additional composition in the Geo-polymer composite mortar, while the replacement techniques using the PCM capsules as a substitute to displace some percentage of sand within the Geo-polymer composite mortar [9].

Planning of PCM was most important step to make red mud based Geo-polymer PCM mortar. To accomplish the ideal characteristic of PCM cases first we played out a preliminary study to get familiar with the strategy engaged with planning of PCM. Utilizing 50 grams of graphite powder and same mass of paraffin wax was taken so as to get ready PCM mix. To facilitate the mixing of graphite powder and paraffin wax, the paraffin wax was melted to fluid stage at a temperature of 100°C (as appeared in Fig. 1) and afterward infused with the graphite powder for 1h in another to allow enormous as passage of the liquid paraffin into the graphite's voids. The subsequent stage was followed cautiously that was pouring dissolved wax on graphite capacity to make it a small capsule and afterward that small capsules was changed over in little containers (as appeared in [Fig.1]). The paraffin do used expandable graphite capsules was plunged into a mix of alkali solution so as to frame a surface protection and dried an ambient temperature by the paraffin for 24 h period. To prevent the cases of PCM from getting damage or breaking because of interior pressure, these cases were plunged into a Sodium hydroxide arrangement. Sodium hydroxide is a profoundly flexible substance and it acts a defensive coat to the microencapsulated PCMs.

Table 1: Mix Proportions of Red mud based PCM mortar

Raw Materials	Mix 1 (M1)	Mix 2 (M2)
Red Mud : Quartz Sand	15:85	25:75
PCM : RM & QS Mix	10:90	20:80

Red-mud and quartz sand and were thoroughly mixed physically for 10 min to permit total mix of the mixture to guarantee homogeneity; the effectively arranged alkali solution was added the homogenous blend and mixed ceaselessly for another 5 min. Subsequently the graphite powder PCM capsules were added into the red mud and quartz sand mix and mixed for other 5 min to finish the mixing procedure and at the mean time need prevent any damage to the PCM capsules. Distinctive various mix proportions have been utilized for the testing strength properties of PCM to plan testing strength in solid cubes. Mix proportions mentioned in [Table 1]. Three sample solid test cubes were made for each mix ratios under oven curing and normal curing methods. The cube size 70mm×70mm×70 mm is used. In the PCM mortar filled into the solid cubes that are remolded after 24hrs the kept the cubes in hot air oven at the temperature 41°C for 48hrs for curing rest of the sample solid cubes are kept in ambient temperature for normal curing process [11]. Table depicts the material various mix proportions used to set up the red mud based PCM incorporated geo-polymer mortar.

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Fig. 1: PCM Preparation paraffin wax and graphite powder

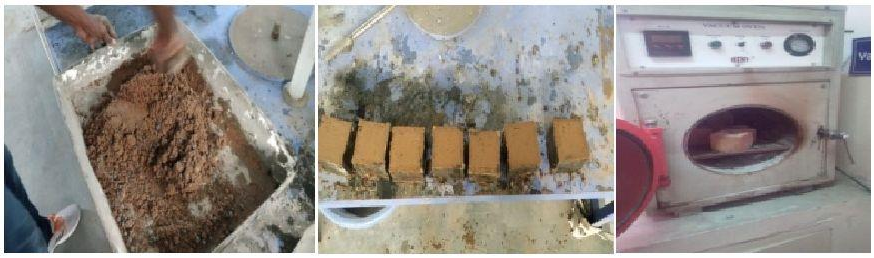

Fig. 2: Mixing, Casting and Oven Curing

RESULTS

The PCM encapsulated red-mud geo polymer composite mortar was tested using the uniaxial compressive strength. Two test samples hot oven and normal curing is utilized for the strength test. The normal cured sample cubes are specimens that were provided to natural cooling, for hot oven curing temperature of 41°C till two days then subjected into normal ambient temperature before testing. The encapsulated PCM inside the red mud geo polymer composite was in solid and a liquid state for the cold cured and hot cured respectively. Mechanical strength test of the PCM red mud geo polymer mortar was conducted at different days (7, 14 and 28) respectively. The Indian standard code (IS 650, IS 4031) was followed for the compressive test; the test was conducted in triplicate. The average of each measured experimental samples tested was recorded [10].

Compressive strength is the point of captivity of a material to withstand loads liable to diminish size, instead of versatility, which withstands loads tending to extend. Compressive strength of strong cubes test results gives an idea in regards to all of the properties of concrete diverse standard codes supports reference or strong cube as the standard model for the test. Strength of the cubes determined following by after 7 days, 14 days and 28 days for both normal and hot air oven dried samples. Compressive strength recipe for any substance is the mass loaded at the motive of inability at the cross-section territory of the surface on which load was applied [13].

Compressive Strength = Load / Cross-sectional Area

Compressive strength is normally estimated by general UTM machine. The range from little table-top arrangements to ones with in excess of 50 MN limit. Determination of compressive strength is caused on the particular evaluate procedure and states of estimation. Compressive strength is typically detailed in relationship to a particular specialized standard. A total compressive strength of a substance is that determination of uniaxial compression load applied at when the sample gets failure fully. The compressive strength is ordinarily procured probably by strategies for a strength test [15].

Table 2: Compressive strength results

Compressive Strength	7 days (in N/mm2)	14 days (in N/mm2)	28 days (in N/mm2)
A. Normal curing sample- M1	2.3	5.28	7.75
B. Oven dried sample- M1	2.34	4.93	7.63
C. Normal curing sample- M2	1.4	4.25	6.34
D. Oven dried sample- M2	1.7	4.57	6.93

The red mud based PCM encapsulated geo polymer mortar was evaluated under two different curing methods and loading conditions, inside the matrix. [Table 2] shows the average compressive strength of 2 samples these being the hot oven and normal curing sample cubes treated red mud PCM mortar surfaces respectively. Estimation of the compressive strength for sample specimens in [Table 2] showed variations in the process parameters, consisting to mechanical behavior. The compressive strength was found to increase as the curing days prolonged in both hot oven and normal curing cases [9].

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Specimen sample A and B had the highest compressive strength with 7.7 and 7.6 N/mm2 for hot oven and normal curing conditions, respectively. The quantity of PCM in the mortar design matrix was also identified to impacts in the comprehensive strength. A 31% comprehensive strength improvement was observed from day 14 days to 28 days both curing samples, In according with the shift in the compressive strength with respect to quantity fraction of the incorporated PCM into geo polymer mortar was observed on both cases. The curing duration influences on mechanical strength properties of the PCM composites: the enlarged the curing duration for both curing methods, increasing and decreasing comprehensive strengths. The pore structure appears to be enhanced because porosity decreased, thereby enhancing the expandable graphite strength because of the introduced encapsulated PCM within the geo polymer matrix. The compressive strength of the red mud based PCM mortar was mostly depended by the curing duration and the amount of PCM concentration within the design matrix. The output of strength implies, more than half of the final red mud based PCM mortar strength is improved nearly the last 28 days. This outcome is in accordance with other observations in literature is not acceptable. The difference in comprehensive strength between the hot oven and normal curing cases can be possessed to the curing temperature influence on the PCM geo polymer mortar, nevertheless no significant effects was identified for the comprehensive strength properties of the PCM geo polymer mortar at prolonged heating. Thus, it can be conclude that the phase changes from solid to liquid and liquid to solid of the PCM was not influenced in the matrix mortar.

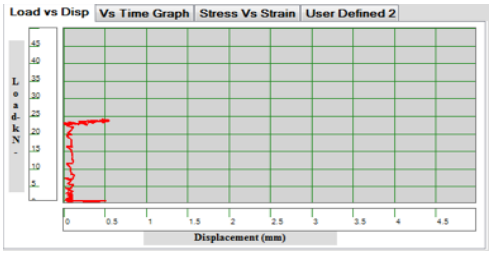

Fig. 3: Load vs. Displacement graph (14 days Oven dried cube).

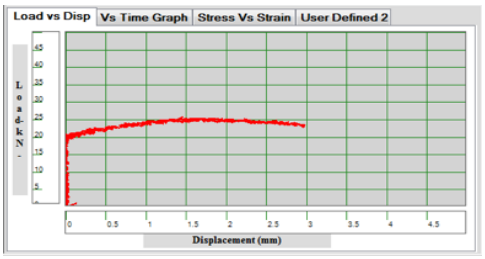

Fig. 4: Load vs. Displacement (14 days normal curing).

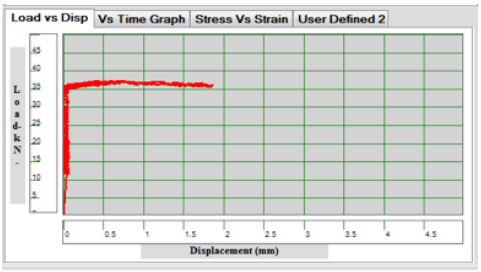

Fig. 5: Load vs. Displacement (28 days normal curing).

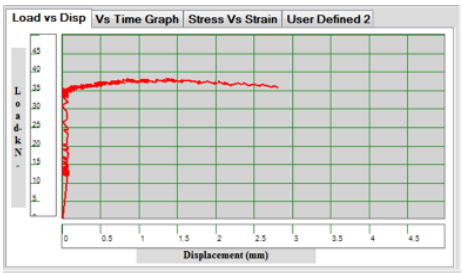

Fig. 6: Displacement vs. Time (28 days Oven dried cube).

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DISCUSSION

Direct mixing method it needs to confirm first the encapsulated PCM within a chemically and physically stable condition. This is essential to maintain the PCM in its original form and ensure no incorporation with the construction envelope materials [10].

According to this study the possibility using phase change materials for preparing red mud based PCM mortar with direct mixing method. In this concerns focused to identify the strength and bonding properties of red mud based PCM mortar was investigated for the further investigation of thermal energy managing in buildings. Based on the results of this study represents there is no issues according to the bonding behaviors in between red mud and PCM materials on different mix proportions, at the mean time to need to achieve the better binding capacity is needed for red mud based PCM mortar may make it possible to use in construction and building applications. Red mud based PCM mortar also has some undesirable properties such as lower strength comparatively standard mortar values mentioning in Indian standard codes. These undesirable properties of this PCM mortar leads unable to suggest directly applicable for building materials without evaluated from further studies, however, can be possible if appropriate PCM types and means of incorporation with better conventional materials are employed.

CONCLUSION

Another approach was successfully developed for improved building envelope materials, using PCM as paraffin wax encapsulated with graphite powder with other additives of quartz sand, red-mud and alkaline activator mixtures. The impacts of red-mud based PCM mortar with respect to the compressive strength and bonding properties was determined in this study finally the following points are highlighted from the experimental results.

1. The different in structural properties with two design matrix of red mud and quartz sand was investigated to achieve the optimum ratio incorporated with PCM from these Mix 1 represents better with other matrix.
2. Binding Property of red mud based PCM mortar as useful for both normal curing and oven dried curing red mud based PCM mortar samples. The amount of encapsulated PCM incorporation in different matrix does not affect the bonding behaviors of mortar.
3. Compressive strength of sample specimens tested following 7 days, 14 days and 28 days for both normal curing and oven dried curing red mud based PCM mortar. In view of the compressive strength outcome 28 days result was seen to be better to 14 days test result comparatively Mix 1 shows better results. Yet, the mechanical strength was not satisfied comparing standard values recommended by Indian standard codes respecting with conventional mortar already using in field.
4. To satisfy the standard recommendations for mortar, just red mud isn't sufficient for strength and furthermore there is should be another kind of binding material and another possible technique is needed for improving and achieving the better strength characteristics of red mud based PCM mortar.
5. A further investigation is required to accomplish better outcomes concerning the change for conventional materials for achieving sustainable building sector.

CONFLICT OF INTEREST

The authors declare no conflict of interest relating to the material presented in this paper.

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FINANCIAL DISCLOSURE

None.

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