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Improving Thermal and Mechanical Property of Lightweight Concrete Using N-Butyl Stearate/Expanded Clay Aggregate with Alccofine1203

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P A P E R I N F O

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A B S T R A C T

Phase change material (PCM) as n-butyl stearate (n-BS) was immersed in expanded clay aggregate (ECA) by two methods, direct immersion at room temperature and immersion at elevated temperature (30ºC, 40ºC and 50ºC). ECA after 90min of immersion with n-BS at 40ºC came to standby in its weight proportion (increased by 24%). After immersion, these aggregates (40ºC) were mixed in cement slurry for preventing leakage and homogenous mixture with concrete. Oozing circle a leakage test was conducted on all the ECA with and without cement slury coating (room and elevated temperatures). ECA with cement slurry coating gave a reduction in leakage of ECA-PCM by 45%. Alccofine1203 was partially replaced (10% and 20%) by cement to improve mechanical properties in lightweight aggregate concrete. Compressive, flexural, thermal conductivity, DSC analysis and leakage test on aggregate and concrete specimens were conducted on all the mixes. Compressive strength for 10% replacement gave 31.7 kN/m^2 and 32.8 kN/m^2 for 7th day and 28th day, respectively. Similarly, flexural strength gave 6.12 kN/m^2 for 28 days. DSC analysis of pure PCM (n-BS) gave 30.42ºC and 23.25 ºC for its melting and freezing temperature with 134.2 J/g and 129.3J/g as enthalpy for its melting and freezing points, respectively. Thermal conductivity for mix-3 (10%PCM-ECA +10% alccofine1203) gave the lowest value of all the mixes i.e, 13% less than the reference mix. There was no leakage or any stain marks were observed on the filter paper till 10% incorporation.

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NOMENCLATURE

R	Radius	K	Thermal Conductivity
I	Latent heat	W_t	The dry weight of ECA before submersion
W_i	Weight of ECA after submersion at any time	Q	The heat flow rate in the specimen, Watts
A	Specimen area, m^2	T_h	Hot plate temperature, °C
T_c	Temperature of Cold plate, °C	L	The thickness of the specimen, m

1. INTRODUCTION

Energy consumption has increased rapidly to provide a comfortable environment for humans worldwide. Buildings play a crucial part in the usage of a significant part of energy resources. Consumption in India is almost doubled since 2000 and energy demand per capita is 40% out of which 33% contribute to the global emission of greenhouse gases. On an average India's consumption in energy is increased by 2.4 to 3.2% per year from 2015 to 2040 [1].

Energy savings in the residential or commercial sector using different materials for thermal energy-efficient buildings has given a new scope for research. A general idea amidst the energy-efficient building design strategies is to increase the thermal mass of the building materials which can store the thermal energy during day time and release the energy at night. This can ultimately save energy consumption in building sectors and reduce

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the peak temperature and temperature fluctuations indoor [2-3]. In the last few years, many construction solutions have been proposed to improve the thermal performance of building envelope by either increasing the material mass and/or increasing the heat capacity of the construction material [2-4]. Phase changing materials (PCMs) are the materials with good heat-storage capabilities, good energy conservation performance and promising building materials [5]. There have been numerous research attempts to use PCMs through direct mixing, immersion and impregnation in building envelopes [6, 7]. There are also functional challenges when combined with elements of the structure, for example mortar, concrete gypsum sheets, wall-covering fabrics, etc.

Some of the safest PCMs are organic paraffin wax for use in concrete as it has excellent thermal consistency, not quite alkaline [8]. Other good aspects of paraffin wax, including the melting point suitable for human comfort zone, have high capacity heat, congruent melting without segregation, low or no supercooling during phase transition, lower vapor pressure, non-toxicity, non-corrosive metal containers, good chemical and thermal stability, and low cost [9-11]. Paraffin 's main limitations include its low thermal conductivity, flammability, plastics incompatibility and high volume changes

Some of the recent researches on form stable natural composite PCM impregnated with paraffin [12] based natural form stable natural PCMs into permeable materials have stood out [13, 14]. Lightweight aggregates such as expanded graphite [13, 14], expanded perlite [13-15], vermiculite [16], and expanded clay/shale aggregate [17] have been used for producing stable composite PCMs. Due, to low thermal conductivity, paraffin-based PCMs were limited, which decreases the rate of heat stored and released during melting and crystallization processes. On the other hand, paraffin was used as core material for encapsulation to form shape-stabilized composite PCM [18-21].

Incorporation of microencapsulated PCM in gypsum boards [22] resulted in a 4K reduction in the indoor room temperature [23]. Micro-encapsulation of PCM as metallic/polymeric containers in building materials is costly and may influence the mechanical quality of the structure material when get harmed during blending [24, 25]. Butyl stearate as PCM and stabilized silica sol as an economically friendly silica source (ss). Our ss-PCM boards are the first reported monoliths with high compressive strengths of 1.2 MPa at 10^{o}C and 0.7 MPa at 30^{o}C despite high PCM mass percentages up to 86 wt%. Moreover, our ss-PCMs are form-stable up to 94 wt% PCM, thermally stable up to 320^{o}C and hydrophobic, suggesting a strong weather capacity. Its latent heats vary from 85 J / g at 20°C and 100 J / g at 22°C, which are steady for at least 6000-state transformations from liquid to solid which vice versa. DSC results from the hexahydrate mixture of the encapsulated butyl stearate / calcium chloride. The temperature at which this occurs phase change occurs is 32.59^{o}C. The latent heat of fusion is 145.39 J/g. The measured thermal conductivity of regular LWA-PCM and LWA-PCM coated with carbon fiber and graphene spray was 0.1382W/mK, 0.1382W/mK, and 0.1337W/mK, respectively [26, 27].

PCMs may be blended directly into concrete matrix by means of either wet mixing or immersion / impregnation techniques [28]. During casting period in wet mixing liquid PCM is blended into the concrete mixture [28]. It means that there is no carrier / barrier between PCM and concrete mix that may increase its leakage risk and adversely affect the concrete properties. Similarly, immersion process is the procedure under which PCM is used to hold a carrier (Clay, shale, perlite .. etc) and this carrier is submerged in a liquid PCM jar from which PCM is gradually dissolved in the carrier's pores through capillary action [29].

Active inclusion of PCMs in traditional building materials [30] allows PCMs uniformly distributed and often contributes to leakage and other problems [31]. Other studies have shown that direct mixing phase change material can greatly improve the hydration cycle, but affects the mechanical properties of cement paste / concrete [32]. Alccofine1203 has improved mechanical quality properties in high intensity concrete and green concrete [32-34] with a 10% integration. Direct incorporation of PCM in concrete had been studied primarily earlier. Schossig et al. [35] commented, however, that unencapsulated PCMs are PCMs that are prone to interfere with the surrounding matrix and attempt to alter their properties, or that may have lifetime leakage issues. Therefore the immediate integration of PCM into concrete is no longer known as a functional strategy in concrete. This is probably the reason why research studies in the last decade have been scarce, in which a direct method is used to incorporate PCM into the concrete.

In the present work, to improve the thermal property of concrete, expanded clay aggregate (ECA) was used as a carrier with PCM (n-BS). The PCM (n-BS) was first kept at 50^{o}C to completely melt and then ECA was immersed at room temperature and elevated temperature (30^{o}C, 40^{o}C, 50^{o}C). Now, these aggregates were incorporated in concrete by volume-based method, 10 and 20% partial replacement of coarse aggregate in concrete. The specimens were subjected to various tests includes leakage test on ECA, compression, flexural, thermal conductivity, DSC analysis and leakage test on the concrete specimen. Alccofine1203 was partially replaced (10 and 20%) by cement to improve the mechanical properties of concrete.

2. EXPERIMENTAL PROCEDURE

2. 1. Materials

- Ordinary Portland cement of 43 grade confirming to IS: 8112 – 1989
- Locally available river sand with passing sieve no. 4.75mm to 150 microns with specific gravity 2.50 and FM = 2.36.
- Commercially available expanded clay aggregate and its properties with sieve analysis given in Table 1 and Figure 1.
- Commercially available Alccofine1203 confirming to ASTM C89-1999, physical properties and chemical composition is given in Table 2.
- Phase change material: n-BS and its properties given in Table 3.

TABLE 1. Physical properties of ECA

Properties	ECA
Specific gravity	0.54
Water absorption (%)	15
Bulk density(kg/m3)	337
Fineness modulus	7.26

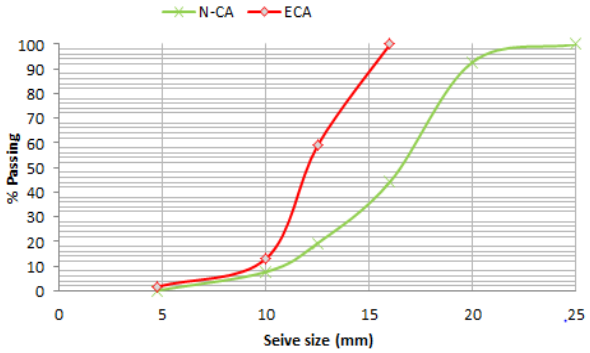

Figure 1. Sieve analysis of natural coarse aggregate (N-CA) and ECA

TABLE 2. Physical & Chemical properties of alccofine1203

Properties			Alccofine1203		
Specific gravity			2.9		
Bulk density (kg/m^3)			680		
Specific surface area (m^2/kg)			1200		
Size of the particles in the micron					
D10			1.5		
D15			5		
D90			9		
CaO	SiO_2	Al_2O_3	Fe_2O_3	SO_3	MgO
61-64	21-23	5-5.6	3.8-4.4	2-2.4	0.8-1.4

TABLE 3. Properties of PCM (n-BS)

Property	Value
Melting Temperature (°C)	27
Boiling Point (°C)	343.0
Density (25°C/4(°C)	0.854
Molecular weight (g/mol)	340.6
Molecular formula	$C_{22}H_{44}O_2$
Solubility	Insoluble in water
Color	Colorless
Physical Form	Liquid

2. 2. Preparation of PCM Aggregates The n-BS was impregnated into a lightweight aggregate (ECA) at 3 different temperatures (30°C, 40°C and 50°C). The process began with drying ECA at 105°C in the oven for 24h. After that ECA was placed in a container with liquid PCM and placed one of the containers at room temperature and other 3 containers at 30°C, 40°C and 50°C for the next 2 hours. Every 10min, the samples were taken out and weighted for its measure weight change and the degree of impregnation was calculated by the Equation (1).

$$\% \text{ Impregnation} = [(W_t - W_i) / W_i] \times 100 \quad (1)$$

where
W_t = dry weight of ECA before submersion
W_i = weight of ECA after submersion at any time.
The process continued until the highest weight impregnation was achieved with constant weight change over time. Now, these aggregates were used in preparing PCM lightweight aggregate.

2. 3 Preparing Concrete Samples The ECA-PCM aggregates were prepared using the findings obtained in section 2.2 for the shortest time period for the largest impregnation at ECA. Several trial blends for achieving the best in terms of workability (slump) and power were performed. A comprehensive proportion of the trial mix with the total number of specimens is shown in Table 4.

2. 4. Experimental Series After preparing the PCM-ECA aggregates are partially replaced by coarse aggregate with 10 and 20% with coarse aggregate. Alccofine1203 was also partially replaced with cement by 10 and 20% in concrete. All the specimens are prepared and cured for 7 and 28 days and are subjected to the series of tests. Mix proportion of M30 grade concrete with number of Specimens are given in Table 5.

1. Leakage test on ECA material
2. Compressive strength (100x100x100mm)

TABLE 4. n-BS absorption capacity in ECA at different temperature and time

Temperature / Time (min)	RT	30^{0}C	40^{0}C	50^{0}C
10	100	101	101	102
20	105	103	103	104
30	107	105	107	107
40	110	106	109	108
50	112	109	115	115
60	113	103	118	119
70	113	115	121	122
80	114	118	123	123
90	114	120	124	123
100	118	121	124	124
110	118	121	124	124
120	118	121	124	124

3. Flexural strength (100x100x500mm)
4. Thermal Conductivity (10mmx180mm dia)
5. DSC analysis
6. Leakage test on specimens (100x100x100mm)

2. 5. Thermal Properties

2. 5. 1. Thermal Conductivity (K) Thermal conductivity (K) test conducted on all the specimens using a two-slab guarded hot plate method according to IS3346 (1980). The following equation used to find the value of K

$$K = Q/2A(L/(Th - Tc)) \quad (2)$$

where;
K = Thermal Conductivity of a sample, W / m^2.k
Q = Heat flow rate in the specimen, Watts
A = Metering area of the specimen, m^2
T_h = Hot plate temperature, °C
T_c = Cold plate temperature, °C
L = Thickness of specimen, m

2. 5. 2. DSC Analysis DSC research on Pure PCM content (n-BS) was conducted. DSC analysis is a method used to measure the latent heat that is contained in the material. It is the methodology in which as a function of temperature the difference of the volume of heat needed to increase the sample pan temperature with reference pan is determined. In the DSC the temperature is regulated in such a manner that the temperature of the sample holder decreases linearly as a function of time. The experiment was conducted for both heating and cooling from -10 ^{o}C to 60^{o}C with a temperature period of as 2^{o}C. To determine the melting/freezing point and latent heat stored in material, TA Instrument with Model: DSC Q2000.

2. 6. Leakage Test on Concrete Specimens After 28 days of curing time, concrete specimens of all the mix are tested for its leakage test according to literature [26]. The specimens are completely wrapped with filter paper and weight before wrapping and after wrapping is noted. The specimens are kept in an oven at 60^{o}C for 1hour. After 1h the filter paper is weighed and the percentage of PCM leakage is determined, the filter paper is carefully examined for any stain marks on it.

3. RESULTS AND DISCUSSION

3. 1. Sieve Analysis and Chemical Composition Of Alccofine1203 Sieve analysis was conducted on natural fine, coarse aggregate and ECA using standard 4.75mm to 150-micron sieve for fine aggregate with the properties according to IS: 2386-2016, IS 383-2016. Coarse aggregate (CA) and ECA were sieved using 20mm to 4.75mm sieve and its properties are evaluated according to IS: 2386-196. Figure 1 shows the same pattern of the curve for CA and ECA. The physical and

TABLE 5. Mix proportions of M30 grade concrete

Mix designation	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Superplasticizer (lit/m^3)	ECA (kg/m^3)	Alccofine1203 (kg/m^3)	Total No of Specimens
1 Reference	410		1148		-	-	
2 (0%Alc -10% ECA)	410		1033.2		35		
3 (0%Alc -20% ECA)	410		918.4		70		
4 (10%Alc -10% ECA)	369	664	1033.2	1.75	35	41	91
5 (10%Alc -20% ECA)	369		918.4		70	41	
6 (20%Alc -10% ECA)	328		1033.2		35	82	
7 (20%Alc -20% ECA)	328		918.4		70	82	

chemical properties of ECA and alccofine1203 are given in Tables 1 and 2. The specific gravity of alccofine1203 is nearly equal to cement with a specific surface area 4 times more than cement. Chemical composition of alccofine1203, when compared with cement, is nearly the same with more percentage of Cao (61-64%), followed by SiO_2, Al_2O_3, and Fe_2O_3 by 21, 5 and 3.8%, respectively.

3. 2. Composite Absorption Characteristics

The maximum absorption capacity at room temperature and elevated temperature is found and described in section 2.2 and Table 4. Using diffusion oozing circle test leakage of these composite aggregates is found. PCM-ECA aggregates are placed on a filter paper and kept in an oven at 50°C which is above the melting point of PCM (n-BS) for one hour. Figure 2 shows that PCM-ECA without coating (WC) of cement slurry had much leakage but it was improved when cement slurry coating was applied on PCM-ECA. Up to 45% leakage was reduced with (W) Coating of the cement slurry at 40°C with 90min of immersion time.

3. 3. Mechanical Properties

3. 3. 1. Compressive Strength From Figure 2 it is clear as the percentage of ECA increased, strength decreased, and vice versa. The strength of the concrete has improved as alccofine1203 was added to concrete with partially replaced (10 and 20%) of cement. When PCM (n-BS) was incorporated into the pores of ECA from section 2.2, the strength of concrete has reduced but not less than the required strength. Most of the studies showed that LWA has an adverse effect on the mechanical properties of concrete [36-39].

When ECA-PCM composite is partially replaced with CA by 10 and 20% for 7th day compressive strength an decrease in its pattern was observed in mix-2 and mix-3 from Figure 3. Without PCM in ECA gave an increase in strength by 4.4% for mix-2 and a drastic reduction was observed in mix-3 (20% ECA only) with 46%. When alccofine1203 was added with ECA-PCM in mix-4, there was an increase in strength by 4.4% but for the same percentage (10%) of alccofine1203 and increase in ECA-PCM by 20% (mix-5) there was a reduction in strength by 7.9 and 14.9% when compared with mix-2 and reference mix., respectively. Now when alccofine1203 was increased to 20% in mix-6 with ECA-PCM (10%), strength was the same as that of reference mix. Similarly, when ECA-PCM was increased by 20% in mix-7, strength was reduced by 20.4% when compared with the reference mix. There was a drastic reduction observed in mix-4.

Different scholars hypothesized that the loss in compressive strength is largely attributable to breakage of the microcapsules (shells) and consequent leakage of PCM during the mixing or filling process [40-43], or due to chemical reactions [44] which can cause conflict with the hydration reaction of cement [45]. For 28th day compressive strength, the same pattern of the 7th-day graph was observed in Figure 4. With ECA-PCM strength was increased for all the mix except for mix-5 and mix-7. This is because of an increase in ECA

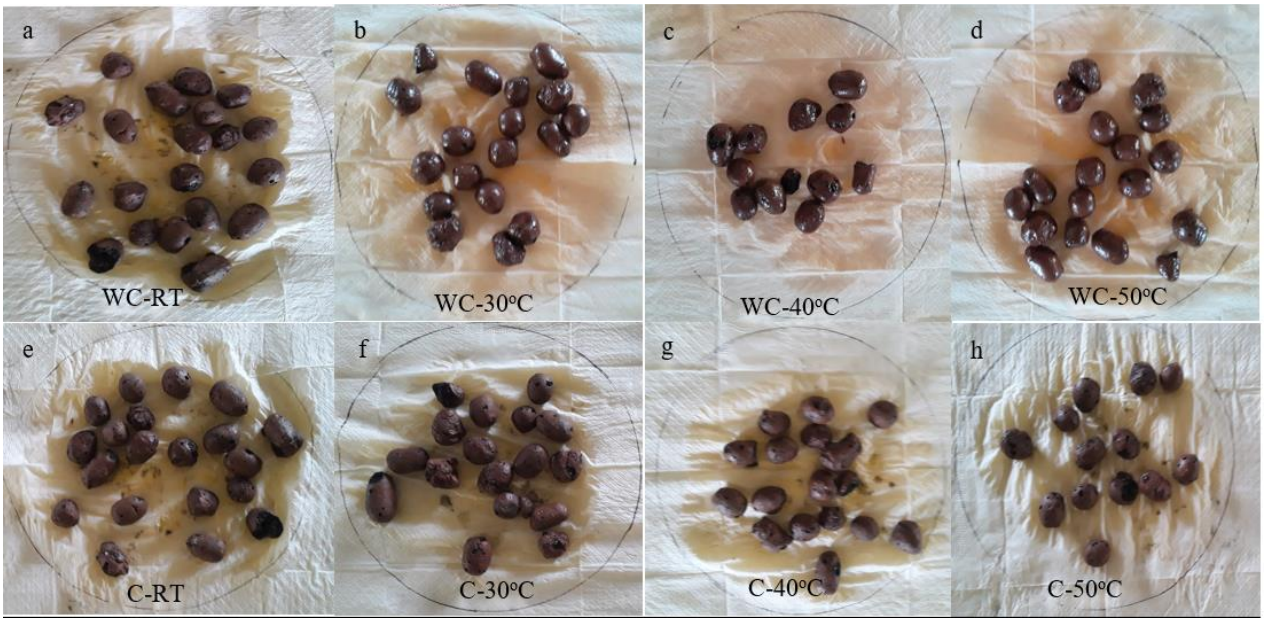

Figure 2. Diffusion oozing circle test for ECA without coating (WC) and with coating (C) a & e) Room temperature (RT), b & f) at 30°C, c & g) at 40°C, d & h) at 50°C

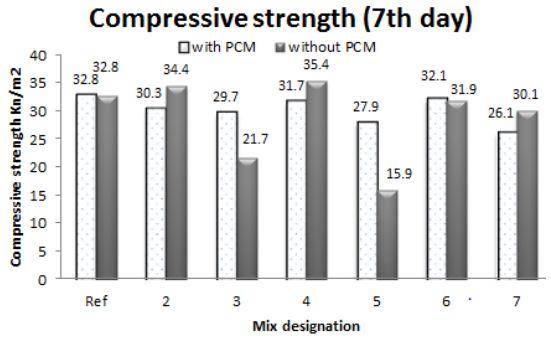

Figure 3. Compressive strength of PCM- ECA & Alccofine1203 composite (7 days)

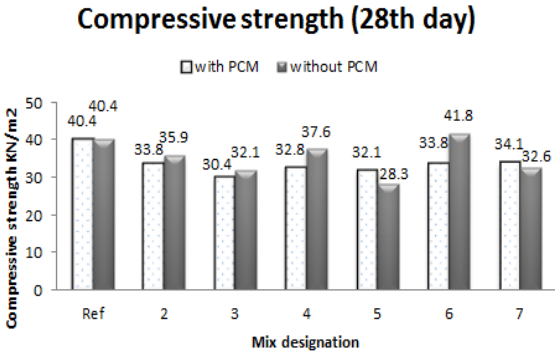

Figure 4. Compressive strength of PCM- ECA & Alccofine1203 composite 28 days

material from 10 to 20% in concrete. When ECA-PCM only was incorporated in concrete, its strength was reduced by 11.11 and 20.5% for mix-2 and mix-3, respectively when compared with reference mix. The strength improved when alccofine1203 was mixed in concrete with ECA-PCM (Mix-4) by 4.5% when compared with mix-2.

When the same amount of alccofine1203 (10%) was added with 20% of ECA-PCM (mix-5) a drastic reduction was observed in strength by 11.83% when compared with mix-3. The highest gain in strength was observed in mix-6 with 3.3% when compared with the reference mix. For ECA-PCM in mix-7, a reduction in strength by 19.3% was observed when compared with the reference mix. When alccofine1203 with ECA-PCM showed improvement in strength for mix-5 and mix-7. It is observed that mix-4 is the best combination to be incorporated in concrete.

Flexural strength of with and without PCM-ECA was evaluated after 28 days of curing in Figure 5. Without PCM the strength was increased for mix-2, mix-4 and mix-5 but similarly strength was reduced for mix-3, mix-5 and mix-6. It is observed from Figure 5 that, when ECA-PCM alone was incorporated in concrete its flexural strength was improved by 2.7% and reduced by 9.1% for mix-2 and mix-3, respectively. When only ECA material was incorporated in concrete without PCM immersion its flexural strength was reduced by 5.3 and 10.6% for mix-2 and mix-3, respectively. This is due to the density of ECA is 4 to 5 times less than natural CA. When alccofine1203 was incorporated with ECA-PCM, strength was gradually increased for mix-4 and mix-5. Strength was reduced when alccofine1203 was increased to 20% in mix-6 and mix-7 for both with and without ECA-PCM. Mix-2 with ECA-PCM gave the best result of all the mixes.

3. 4. Thermal Properties

3. 4. 1. DSC Analysis In the research conducted by Kastiukas et al. [39], a DSC experiment was used to measure the temperature difference in process and the conservation of LWA-PCM thermal energy. Pure PCM (n-BS) material was analyzed for DSC. The melting point and freezing point of pure n-BS are 30.45ºC and 23.75ºC, respectively, is evident from Figure 6. Stored enthalpy at heating and cooling, 134.2J/g and 129.3J/g were nearly similar to the data reported in literature [25]. When n-BS was impregnated with silica source, DSC analysis after 6000 heating and cooling cycles showed 85 J/g at 20ºC and 100 J/g at 2-22ºC, pure n-BS also reported 103.0 J/g and 101.8 J/g. To carry out the LWA-PCM DSC examination, the aggregates have to be compressed to a fine powder first. The latent heat stored in its purest state (RT25) is 130.5 J/g according to data reported in literature [46], while DSC analysis was conducted on LWA with RT25 being 57.93 J/g. Different test carried out by Min et al. [38], an experiment of DSC on LWA concrete was conducted to evaluate precise heat. The findings revealed that its basic heat often decreased as the PCM content rises in LWA. Despite the improvements, the ratio of LWA-PCM to cement is not significant. The specific heat measured for the temperature range from 10 to 24 ° C was 0.46 J/gK, 0.62 J/gK, 0.80 J/gK and 0.93 J/gK for 0%, 10%, 20% and 30% LWA-PCM, respectively [38].

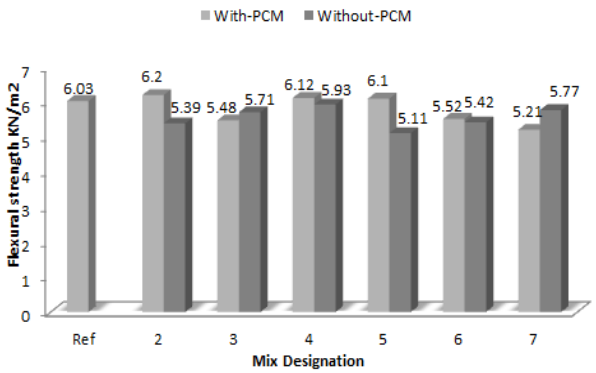

Figure 5. Flexural strength of PCM- ECA & Alccofine1203 composite (28th day)

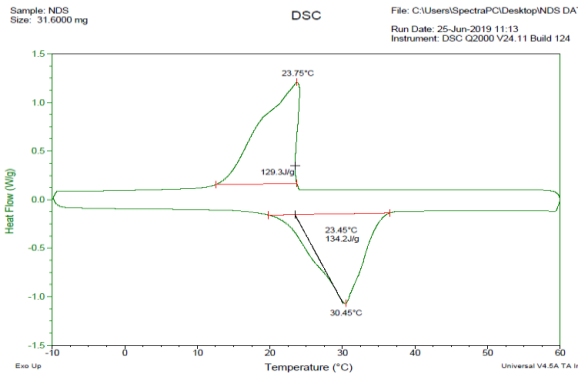

Figure 6. DSC analysis of n-Butyle Stearate

Similar to previous studies carried out by Ma et al. [37], a DSC analysis was used to find different proportions of the energy storage of concrete specimens containing LWA-PCM. Reports found that 86.40 and 82.73%, respectively in the heating cycle demonstrated the same real heat efficiency and the equivalent energy recovery of concrete with 20% LWA-PCM. Similarly in the cooling process, 60.10 and 56.94%, respectively increased the equivalent specific heat capacity and the equivalent energy storage of concrete with 20% LWA-PCM. The melting and freezing point with n-BS enthalpy is suitable for building envelopes to improve indoor temperature, because the temperature is in the comfort of humans.

3. 4. 2. Thermal Conductivity (K) In concrete materials, thermal conductivity (K) is used to determine the flow of power. From Figure 7 it is clear that its K value decreased as the percentage of PCM in ECA increased. In mix-2 the same amount of with and without PCM was found in concrete. While the amount of ECA-PCM Increased in mix-3 to 20%, its K value was significantly decreased by 13% relative to the reference combination. Adding with ECA-PCM in mix-4 and mix-5, Alccofine1203 raised the K value linearly by 20 and 40% relative to mix-3 but was lower by 13 and 8.6%,

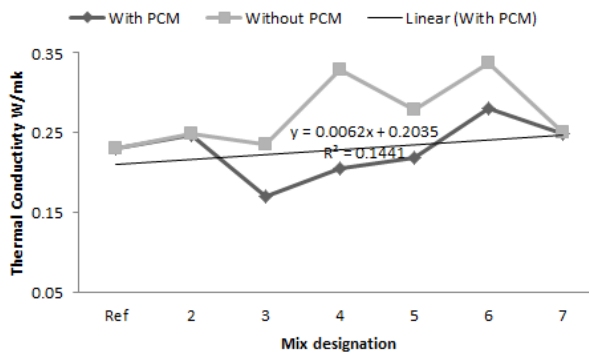

Figure 7. Thermal conductivity of ECA-PCM composite material

respectively than the reference combination. When alccofine1203 in mix-6 and mix-7 was increased to 20%, the K value increased by 14.8 and 4.1%, respectively. When only ECA was incorporated in concrete without PCM, its k value increased in all the mixes except in mix-3 which gave equal value to that of reference mix. The highest increase in k value was observed in mix-5 with 30.3% followed by mix-4, mix-5, mix-7, mix-3, and mix-2.

Data from other experiments found that the thermal conductivity of concrete mixtures treated with epoxy and adjusted cement paste LWA-PCM was approximately 0.615 W/mK and 0.738 W/mK, with an overall thermal conductivity loss of approximately 24.7 and 9.7%, respectively, for control concrete (0.817 W/mK) [47]. Heat conductivity of hardened concrete comprising LWA-PCM has also been assessed [48]. As in the analysis carried out by Memon et al. [27]. An alternative was found to increase the K value of LWA-PCM concrete composites, and Memon et al. [27] studied the addition of a conductive material as a coating for LWA-PCM. To enhance the thermal conductivity of LWA-PCM a mixture of epoxy and graphite powder was used as a coating material. Test findings found that thermal conductivity improved by 69.4, 126.9, 162.3 and 176.4% respectively for 5, 10, 15 and 20% graphite powder mass fractions. The thermal properties of the final concrete that comprises LWA-PCM coated with graphite powder have not been published.

The thermal conductivity of a hard concrete comprising LWA-PCM was also calculated by Wang et al. [26]. Similar to the analysis conducted by Memon et al. [27], the investigators observed that the addition of 1, 3, 5, 7 and 9% graphite powder improved LWA-PCM thermal conductivity by 17, 34, 55, 119 and 193%, respectively. Nonetheless, owing to the poor thermal conductivity of PCM packed in LWA pores, the thermal conductivity of concrete comprising LWA-PCM decreases with an rise in LWA-PCM content. Kastiukas et al. [39] also assessed the use of various coating materials such as carbon fibers (CF) [49] and graphite spray (GS) to improve LWA-PCM or macro-encapsulated LWA thermal conductivity. In comparison to previous studies [26, 27], the application of carbon fibers or graphite spray did not improve the LWA-PCM thermal conductivity. The standard LWA-PCM and LWA-PCM coated with CF and GS calculated thermal conductivity were 0.1382 W/mK, 0.1382 W/mK, and 0.1337 W/mK, respectively.

In the research performed by Niall et al. [36], the writers used an modified hot plate apparatus to assess the conductivity of composite LWA-PCM panels with 100% PCC and 50% GGBS. In addition, the recorded temperature data were used to determine the thermal storage behavior of the panels together with the measured densities and thermal conductivities. Research results

showed that both panels had a 47.4 and 42.8%, respectively reduction in thermal conductivity. This is induced by the low conductivity of the PCM material, according to the scientists. The authors have suggested that lower conductivity and higher heat storage potential of the PCM panels result in lower thermal diffusivity, which in effect decreases the PCM 's performance when depth rises as the heat takes longer to enter the PCM [36, 38]. By using n-BS as a PCM with ECA in concrete, the temperature inside the house can be controlled and can be maintained suitable according to the human comfort zone.

3. 5. Leakage Test on the Concrete Specimen After 28 days of curing for all the concrete specimens are taken out from the curing tank and placed in an open atmosphere for removal of moisture content. Now, the specimens are thoroughly cleaned on the surface and wrapped with filter paper on all sides. All the wrapped specimens are placed in the oven with 60^{o}C for the next 1h. All the mixes before and after oven treatment were carefully examined for its weight. It was observed that till 10% incorporation of ECA-PCM in mix-2 did not find any change in the weight of filter paper but some stain marks in mix-3 were observed. Similarly, for mix-4 and mix-5 there were no stain marks visible on filter paper. For mix-6 and mix-7 there was very little change in the weight of filter paper by 0.8 and 1.0%, respectively was observed which is considerable.

4. CONCLUSION

A novel form of the stable composite material was developed using immersing n-BS in ECA for normal room temperature and elevated temperature. Then these aggregates were immersed in cement slurry to reduce leakage of PCM in concrete. This aggregate ECA-PCM was partially replaced in concrete by 10 and 20% of natural coarse aggregate. The diffusion oozing circle test showed a decrease in leakage test of ECA-PCM aggregate by 45% for with and without coating at 40^{o}C with 90 min of immersion time. When ECA-PCM aggregate was mixed in concrete, there was a reduction in strength for both the mixes (mix-2 and mix-3). When alccofine1203 was added with ECA-PCM in mix-4, there was an increase in strength by 4.4% but for the same percentage (10%) of alccofine1203 and increase in ECA-PCM by 20% (mix-5) there was a reduction in strength by 7.9 and 14.9% when compared with mix-2 and ref mix for 7th day. The same pattern of the 7th-day graph was observed for the 28th-day compression test. It is observed that mix-4 is the best combination to be incorporated in concrete to improve the mechanical properties of concrete.

Flexural strength of concrete of ECA-PCM with alccofine1203 composite concrete was developed. When alccofine1203 was incorporated with ECA-PCM, strength was gradually increased for mix-4 and mix-5 when compared with mix-3 but was less than the reference mix. Alccofine1203 with a 10% incorporation was recommended in concrete.

DSC analysis was conducted on pure PCM (n-BS) material. Heating and cooling point was in the human comfort zone with 30.45 and 23.75^{o}C. Enthalpy stored in the PCM was 134.2 and 129.3 J/g for heating and freezing points, respectively. The thermal conductivity of ECA-PCM concrete gave much reduction in thermal conductivity value for all the types of mixes. Mix-3 had a great reduction in its thermal conductivity by 13%. When alccofine1203 was incorporated with ECA-PCM, thermal conductivity was linearly increased when compared with mix-3 but was less than the reference mix. Leakage test conducted on all the mixes showed that till 10% incorporation of ECA-PCM did not show any change in the weight of filter paper.

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Persian Abstract

چکیده

مواد تغییر فاز (PCM) به عنوان استارات n-butyl (n-BS) در مصالح رس (ECA) با دو روش ، غوطه وری مستقیم در دمای اتاق و در دمای بالا (۳۰ درجه سانتیگراد ، ۴۰ درجه سانتیگراد و ۵۰ درجه سانتیگراد) غوطه ور شد. ECA پس از ۹۰ دقیقه غوطه وری با n-BS در دمای ۴۰ درجه سانتیگراد به نسبت وزن خود آماده به کار شد (۲۴٪ افزایش یافته است). پس از غوطه وری ، این مصالح (۴۰ درجه سانتیگراد) برای جلوگیری از نشت و مخلوط همگن با بتن در دوغاب سیمانی مخلوط شدند. آزمایش نشت آزمایش نشتی بر روی کلیه ECA با و بدون روکش کاری سیمان (دمای اتاق و درجه حرارت بالا) انجام شد. ECA با پوشش دوغاب سیمانی باعث کاهش نشتی ECA-PCM به میزان ۴۵٪ شد. Alccofine1203 به طور جزئی با سیمان (۱۰٪ و ۲۰٪) با سیمان جایگزین شد تا خصوصیات مکانیکی در بتن دانه سبک را بهبود بخشد. فشار، خمش ، هدایت حرارتی ، تجزیه و تحلیل DSC و آزمایش نشت در نمونه های بتن و در تمام مخلوط ها انجام شد. مقاومت فشاری برای جایگزینی ۱۰٪ به ترتیب ۳۱/۷ کیلو لیتر در مترمربع و ۳۲/۸ کیلو نیوتن در متر مربع به مدت ۷ روز و ۲۸روز به دست آمد. به طور مشابه ، مقاومت خمشی به مدت ۲۸ روز به ۱۲/۶ کیلو لیتر در مترمربع رسید. تجزیه و تحلیل DSC از PCM خالص (n-BS) برای دمای ذوب و انجماد آن با دمای ۱۳۴.۲ J / g و ۱۲۹/۳ JJ / g به عنوان آنتالپی برای نقاط ذوب و انجماد آن به ترتیب ، ۳۰/۳۴ درجه سانتیگراد و ۲۳.۲۵ درجه سانتیگراد به دست آورد. هدایت حرارتی برای مخلوط ۳ ۱۰درصد PC PCM-ECA + 10 al (alccofine1203)کمترین مقدار از تمام مخلوط ها ، یعنی ۱۳ درصد کمتر از مخلوط مرجع است. تا ۱۰٪ اختلاط ، هیچ گونه نشتی مشاهده نشد و هیچگونه لکه بر روی کاغذ فیلتر مشاهده نشد.