Journal of Harbin Engineering University
ISSN: 1006-7043

Vol 45 No. 11
November 2024

Effect of Hydrated Salt-24 Inorganic Phase Change Material in Lightweight Concrete via Diverse Study Procedure

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Abstract: Here the endeavor concentrates to rise the thermal as well as mechanical features of Light Weight Aggregate Concrete (ECAC) considering Expanded Clay Aggregate (ECA) being transporter of inorganic Phase Change Material (PCM) (Hydrated salt-24 (HS24) holds 24 °C melting value for M30 standard concrete. Since Phase Change Matters attached with concrete, so diminishes mechanical aspects and again elevated on mixing of an ultrafine slag called alccofine1203.The cement was partly substituted by Alcofine1203 of magnitude of 10 to 20 percent as well as Manufacturing sand i.e. M-sand being substituted absolutely with fine aggregate. Expanded Coarse Aggregate become merged inside liquid PCM by 3 number of distinct temperatures (40 °C, 50 °C and 60 °C) meant for 28 h, to control the extreme absorption volume of ECA, with these masses being partly substituted (10% and 20%) with coarse masses. Later dipping practice, these combinations once more submerged inside cement slurry for subsequent 2hours to evade loss of Phase Change Materials out of ECA. Outflow of PCM-ECA masses being taken considering dispersion oozing circle trial. The instant of cement slurry covering being introduced upon PCM-ECA matters; outflow decrease an amount of 40% on behalf of each combination. There are 7 number of combinations were considered with 175 samples along with standard combination. There are distinct trials have been carried to estimate its diverse aspects like mechanical, thermal, durability, outflow of ECAC.

Keywords: HS24, PCM, Expanded Clay Aggregate, Alcofine1203, DSC.

1. Introduction

In this work, it has used expanded clay aggregate as a carrier to PCM (HS24) with cement slurry coating on ECA material to prevent leakage of PCM from the voids of ECA. As the PCM is not directly in contact with the concrete, there is no effect on strength and durability property. The PCM-ECA composite is replaced with coarse aggregate in concrete by volume. The preparation of form-stable PCM composite is explained in chapter 3, section 3.3. After preparation of PCM-ECA Composite, the natural coarse aggregates (NCA) are partially replaced with the composite up to 20% in LWAC by volume batching. To improve the mechanical property of LWAC, cement was partially replaced with alccofine1203 up to 20%. Manufacturing-sand is used as fine aggregate (FA), which passes through a 4.75mm sieve is used in the preparation of LWAC. Different tests conducted are; Absorption characteristics of PCM-ECA composite, water absorption, 1000 thermal cycle test on pure inorganic PCM-HS24, compressive strength, flexural strength, and leakage test on the hardened concrete specimen. Differentially Scanning Calorimetry investigation also being carried out to assess the internal heat energy reserve & melting/freezing point concern to the phase change materials. There each complete organic & inorganic PCM matters being encloses through this analysis point of concern.

2. Composite absorption characteristics

The highest absorption capacity of PCM in ECA is calculated, according to Ramakrishna et al., 2015.The maximum absorption capacity of PCM in ECA at distinct temperatures and time is given in the underneath Table-1. To prevent loss of PCM out of ECA, a coating of cement slurry was given on the surface of ECA. The leakage after and before the coating is determined, according to Ramakrishna et al., 2015.The diffusion oozing circle method was used to find the PCM-ECA composite leakage test.

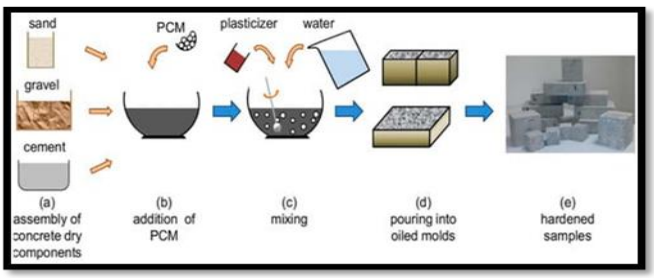

Figure 1. MPCMs and Microencapsulated PCMs in concrete sample preparation

A leakage test was conducted at different temperatures to find the percentage of leakage at a given temperature; four different temperatures, such as ambient temperature, 40°C, 50°C and 60°C, were selected. Some

PCM-ECA composite is placed on the 150mm diameter filter paper and is placed at different temperatures (40°C, 50°C and 60°C) in the oven. After one hour of the heating process, the filter paper is taken out. Itis examined for its weight change and leakage diameter. It is observed that after cement slurry coating, the loss was much reduced at all the temperatures, i.e., at room temperature, 50% reduction was observed; similarly, at higher temperatures (40°C, 50°C and 60°C), 45%, 42% and 40% reduction in leakage was observed respectively.

Table-1 Absorption ability of HS24 inside ECA maintaining at distinct temperature and time

Temperature / Duration(h)	Weight of PCM-ECA (grams)			
	AT*	40^{0}C	50^{0}C	60^{0}C
2	502	505	505	505
4	505	507	510	515
6	507	510	515	520
8	508	510	522	522
10	510	512	525	530
12	515	525	530	537
14	525	540	550	553
16	535	560	595	599
18	550	590	632	635
20	575	595	635	635
24	580	600	637	637

AT*=Ambient Temperature

From Table-1, it can be concluded that the maximum absorption after 18h of immersion at 50^{0}C was 20.89%; similarly, after 18h of immersion at 60°C, the percentage of immersion was 21.26% which was slightly higher than 50^{0}C. So, the aggregates after 18hof immersion are taken out and are dried outside for 30minutes and then placed inside a previously prepared slurry cement slurry for the subsequent two hours to prevent loss of PCM out of ECA. After cement slurry coating, now the PCM-ECA composite is ready to use in LWAC.Thermal energy storage lightweight aggregate concrete (TES-LWAC) was prepaid using NCA's partial replacement with PCM-ECA composite up to 20%. The composite used was immersed in PCM for 18h at 50°C, which gave maximum absorption capacity.

3. Leakage test

Against the hardened concrete specimens, there one leakage trial carried out for every mix. Following of curing work to 28 days, samples become dried at ambient temperature for 2h. All the samples then rolled through filter paper, where the filter paper is weighted previous to wrapping. Then the samples kept inside an oven maintaining at excited temperature, i.e., at 50°C for the following 2hour. After the oven drying process, all the specimens are taken out. Then filter paper weight is accounted, following to observing the stain marks upon the filter paper.

Only for the 2ndmixture, there an observation of weight proportion alteration by4% during the application of cement slurry without coat. However, it diminished to 1.5% along with the application of a cement slurry coat. Remaining all the mixes expressed no change in the filter paper's weight, and significantly fewer stain marks were visible. This concludes that the PCM from ECA is leak-proof, which can be used in building sectors for improving the thermal property of concrete.

4. Water absorption on LWAC

There was a water absorption trial carried out upon each mix with organic and inorganic PCMs in LWAC. The mix designation is given in the Table-3, where reference mix is conventional LWAC, mix-1 as well as mix-2 are usually of 10%, 20 % with PCM-ECA replacement in LWAC, mix-3 and mix-4 are 10% alccofine1203 with 10% PCM-ECA and 20% alccofine1203 with 10% PCM-ECA, accordingly. In the same way, for mix-5 and mix-6 are 10% alccofine1203 with 20% PCM-ECA & 20% alccofine1203 with 20% PCM-ECA. Thereafter the water absorption trial is carried out upon each mixes following to 28days of curing in freshwater.

Fig.2 shows that with and without PCM in the mixes, the maximum water absorption being noticed with in mix-2. It contains 20% ECA, and the value recorded was 17.05% without PCM-ECA incorporation compared with the reference mix. However, during PCM-ECA being associated in LWAC, water absorption enhanced by 5% compared with without PCM in LWAC. Similarly, for 20% incorporation of ECA with and without PCM, mix-4 & mix-6 gave water absorptionof2.35% &1.76% for without PCM in LWAC, respectively, for mix- 1and mix-3expressedwater absorptionof4.11% &3.23%, respectively. Onlymix-5expresseda degradation in water absorption via an amount of3.82% when compared with the reference mix.

Alccofine1203, when partially replaced by 10% in LWAC without PCM ,was reduced by 17.33%. However, when the same percentage of alccofine1203 was used in LWAC with 20% ECA without PCM, water absorption was enhanced by 5.45%. Similarly, for mix-5 & mix-6, there was an increase in water absorption by 3.51% & 6.53%. When alccofine1203being associated in LWAC, the water

absorption become reduced for each of the mixes due to its fineness.

5. Differential Scanning Calorimetry (DSC) analysis of inorganic PCMHS24

DSC study being implemented to determine the latent heat storage & melting/freezing point in the PCM material. The experiment has been carried upon every absolute organic & inorganic PCM matters. To perform the DSC analysis, very little material(5gmto10gms) is placed in the pan. It is cooled to -10°C and then heated up to +60°C (according to the type of PCM) with a temperature recess of 0.1°C for mutually the heating as well as cooling cycle.

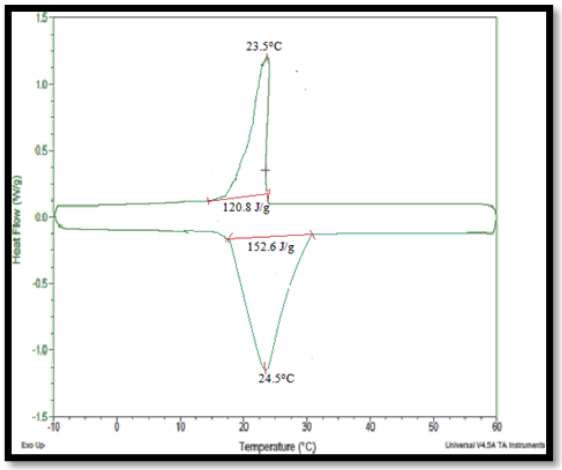

Fig. 3DSC study concern to HS24 inorganic PCM

From Fig.3 it is noticed that inorganic PCM, i.e., HS24, the melting and freezing point was24.5°Cand25.9°C, respectively. The enthalpy deposited at melting and freezing point being noticed to an amount of 152.60J/g & 120.80J/g, respectively.

6. Compressive strength test

Compressive strength was determined on all the mixes according to IS 516 1959. The values of compressive strength for with and without PCM for the 14and 28numbers of days are given in Table-3 and Fig.-4.

When ECA was partially replaced by 10% and 20% in mix-1 andmix-2 without PCM incorporation, compressive strength was reduced by 8.65%& 42.17% on the7thday.Similarly, for mix-3,as alccofine1203 was partially replaced by 10% with ECA percentage as 10%, the strength was more than conventional concrete and was increased by 4.3%. For some portion of ECA, with an increase in alccofine1203 to 20%, it showed the lowest compressive strength value by 15.97MPa for the 14th day without. Similarly, mix-5 and mix-6, which contain 20% of ECA with 10% and 20% of alccofine1203, showed a reduction in compressive strength by 15.12% & 20.16%, respectively, on the 14thday without PCM.

Table-3 Mix proportion sand mechanical property of PCM-ECA composite in LWAC

				Compressivestrength MPa				Flexuralstrength MPa	
	Al (%)	ECA (%)	Slump (mm)	14days		28days		28days	
Mix				With PCM	Without PCM	With PCM	Without PCM	With-PCM	Without PCM
Ref	-	-	90	37.68	37.68	42.74	42.74	6.03	6.03
1	0	10	85	30.39	34.42	33.44	26.67	5.39	6.8
2	0	20	80	29.71	21.79	32.1	18.68	5.71	5.48
3	10	10	85	31.77	39.39	37.61	27.83	5.93	6.12
4	10	20	80	27.95	15.97	28.36	32.09	5.11	6.8
5	20	10	90	26.08	31.98	48.69	24.35	5.42	5.52
6	20	20	90	32.09	30.08	29.92	34.11	5.77	5.21

Al=Alccofine 1203 and ECA=Expanded Clay Aggregate

Similarly, for the 14th day, when PCM-ECA was partially replaced with NCA in preparation of LWAC, mix-3 (10%alccofine1203 &10% PCM-ECA) produces the most suitable outcome among all the mixes. For 10% and 20% PCM-ECA i.e.; mix-1 & mix-2 gave lower in compressive strength via an amount of 19.34% & 21.1% correspondingly when matched with reference mix. The instant when alccofine1203 was partly substituted 10% (Mix-3) with cement in LWAC, the compressive strength was improved by4.3% associated with mix-1, still the strength become reduced compare to the standard mix on the 7th day. For 20% (mix-4) replacement of alccofine1203 with cement, the strength being diminished via a magnitude of25.80% linked with the standard mix.

As the density of ECA is significantly less, its compressive strength will also be less. As the percentage of ECA increases in the mix, its compressive strength decreases and vice versa. After28daysof curing ,all the mixes without PCM showed are duction in compressive strength. Though, the maximum decrease being noticed for mix-3, i.e., 20%ECA and the value was 18.68MPa compared with the reference mix. When alccofine 1203 being moderately substituted by 10% in mix-3 and mix-4 with partial replacement of ECA by 10% and 20%, it gave a slight increase in strength by 27.83MPa 32.61MPa respectively. The same mix-3andmix-4wereobservedinmix-5andmix-6, andthevaluewas24.35MPaand 34.11MPa.

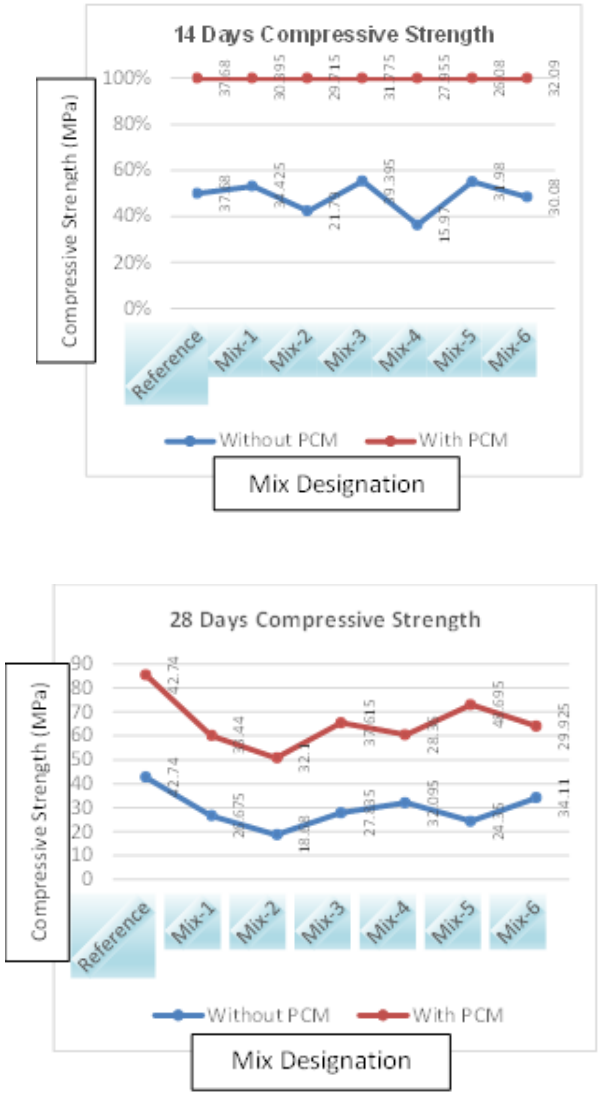

Fig. 4 Distinct mix compressive strength maintained at a) 14th days and b) 28th days of PCM-ECA composite in LWAC

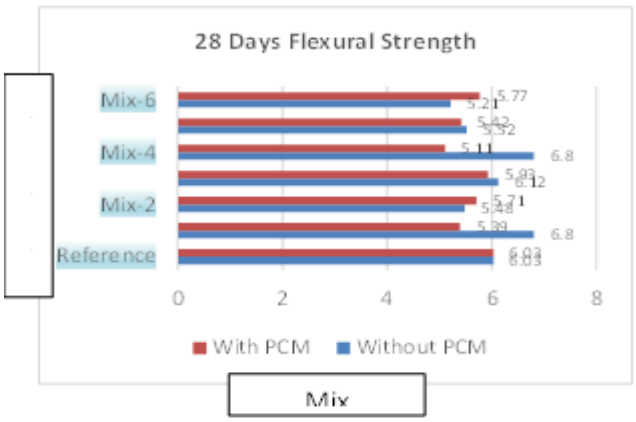

Fig.5 Concrete Flexural strength considering with and without PCM

When PCM-ECA composite was partiallyreplaced with NCA without alccofine1203 in mix-1 and mix-2, the strength became diminishing to that of reference mix. The highest compressive strength was observed when 20% alccofine1203 with 10% PCM-ECA was mixed in LWAC, and the value was 48.69MPa.

5.1.1 Flexural strength test

The flexural strength test trend was different from compressive strength where each mix through PCM reduced strength. The highest reduction in power being noticed in mix-3 by 15.2% for fractional replacement of ECA through PCM. Mix-2 gave substantially equal strength that of standard mixsucceededviamix-5along with mix-1 by4.3%as well as5.3%decreaseinstrength for ECA by PCM. The flexural strength within mix-1 and mix-5, was increased via 4.1% as well as 10.7% compared with and without PCM. However, rest mix gave a considerable reduction in flexural strength. Mix-3 showed one radical decrease of around 24.8% for with and without PCM combination.

The trend against without PCM being completely distinct when compared with PCM. The mix-1, 3 and 4 strengths being enhanced through 12.7%, 1.4% and 12.7% respectively succeeded through reduction in strength of magnitude 9.1%, 8.4% and 13.5% corresponding to mix-2, mix-5 and mix-6 respectively. Mix-2 showed nearly the equal strength against with and without PCM. There being noticed that when the proportionofalccofine1230 rises from10%to 20%in mix- 4 and mix-5, strength became enhanced from 5.11 KN/m^2 to 5.42 kN/m^{2,} correspondingly. FromTable-3 and Fig.5, it can be expressed that mix-3 being the appropriate matter in strength goods point of concern with and without PCM incorporation by alccofine 1203.

6. Conclusion

Influence concern to PCM-ECA within LWAC against mechanical, thermal, longevity as well as leakage characteristics have been accomplished.

ECA become layered with cement slurry, and its seepage being diminishes by 60 percent at 50° C in dispersion oozing circle trial. There being noticed leak-proof in each of the mixes. In mix-2 a fraction alteration in screen paper being monitored by 4% during uncovering of cement slurry being introduced yet it become decreases to an amount of 1.5 percent including a Cement slurry layer concern to ECA. DSC test pointed out a significant magnitude for the aspects like melting, freezing and internal heat content. There a 10 percent ECA including 10% alccofine 1203 (mix-3) become one influential matter (60%) on behalf of refining thermal possessions within concrete.

- Compressive strength expressed a standard feature with 10% PCM-ECA as well as 10% alcidine 1203 (mix-3) by48.69 MPa strength by the side of 28 days.
- Flexural strength against 10%PCM-ECA by 10% alccofine1203 produces the maximum amount i.e. 6.8 MPa.

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