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Effect of Phase Change Materials (PCM's) on Recycled Aggregate Concrete

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***Abstract*:- In this rapid industrialized world, recycling construction material plays an important role to preserve the natural resources. In fact, huge quantities of construction and demolition wastes are generated every year in developing countries like India. The disposal of this waste is a very serious problem because it requires huge space for its disposal and very little demolished waste is recycled or reused.**

The fast economic development around the globe and high standards of living imposes an ever increasing demand for energy. As a prime consumer of world's material and energy resources building and construction industry has a great potential in developing new efficient and environmentally friendly materials to reduce energy consumptions in buildings. Thermal energy storage systems (TES) with Phase change materials (PCM) offer attractive means of improving the thermal mass and the thermal comfort within a building. PCMs are latent heat thermal storage (LHTS) materials with high energy storage density compared to conventional sensible heat storage materials. Concrete incorporating PCM improves the thermal mass of the building which reduces the space conditioning energy consumption and extreme temperature fluctuations within the building. The heat capacity and high density of concrete coupled with latent heat storage of PCM provides a novel energy saving concepts for sustainable built environment. Microencapsulation is a latest and advanced technology for incorporation of PCM in to concrete which creates finely dispersed PCMs with high surface area for greater amount of heat transfer.

In this research work, recycled concrete aggregates (RCA) were obtained from a demolished bridge. The demolished waste is crushed to suitable size and reused as recycled coarse aggregate. Then PCM materials are added to RAC and its behavior is studied.

Our study is a part of comprehensive program wherein experimental investigations have been carried out to assess the effect of partial replacement of coarse aggregate by demolished waste and cement by PCM on workability and compressive strength of recycled concrete for the study at 7 and 28.

The aim for this project was to determine the strength and durability characteristics of high strength structural concrete by using recycled coarse aggregates and phase change materials, which will give a better understanding on the properties of concrete with recycled aggregates and PCM. The experimental investigation were carried out using detailed strength and durability related tests such as compressive strength test & split tensile strength test of cubes.

The objective of present study is to determine the sustainability of RCA as an alternate material to NCA and PCM to cement and to compare the compressive strength.

The tests were conducted by replacing the coarse aggregates in concrete mix of M25 (1:1.61:2.74) The mix designing is done for water cement ratio 0.45. Cubes are casted by replacing NCA aggregate with 0%, 30%, 50%, 70% RCA. And cement with 0%, 10%, 20%, 30% PCM

Many researchers state that recycled aggregates are only suitable for non-structural concrete application. This research, however, shows that the recycled aggregates that are obtained from Lab-tested concrete specimen make good quality concrete. The compressive strength of recycled aggregate concrete (RAC) is found to be higher than the compressive strength of normal concrete. Recycled aggregate concrete is in close proximity to normal concrete in terms of split tensile strength. The slump of 100% recycled aggregate concrete is Zero and that can be improved by using saturated surface dry (SSD) coarse aggregate.

Keywords: Recycled Concrete Aggregate (RCA); Natural coarse aggregates (NCA); Saturated surface dry (SSD); Thermal energy storage systems (TES); Phase change materials (PCM); latent heat thermal storage (LHTS); Recycled aggregate concrete (RAC) Phase change material (PCM)

INTRODUCTION

Enhancing the environmental sustainability of human activities and industrial processes is a common challenge in various branches of modern research and technology. Being characterized by huge demand of both energy and raw materials and by a significant contribution to the global emission of greenhouse gases, the construction industry is fully concerned by this challenge. Particularly, since concrete s the most widely used construction material, several solutions are nowadays under investigation to reduce the environmental impact of its production processes. They often consist of partially replacing "natural" constituents (i.e. aggregates, cement, water, fibers) with recycled ones, n view of the two fold objective of reducing both the demand of raw materials and the amount of waste to be disposed n landfills.

Building and construction industry is a prime consumer of world's material and energy resources which accounts nearly for 40% of usage. Nevertheless limited conventional fossil energy sources produce harmful emissions which are accountable for environmental pollution. in an effort to conserve energy, thermal energy storage systems (TES) can be regarded as a convenient solution. Thermal energy storage is capable of storing energy for later usage with either sensible heat storage materials or latent heat storage materials. Current TES materials employed in the building industry includes sensible heat storage materials like steel, masonry and water, where thermal energy s stored by raising the temperature of the material. Although sensible storage has been used for centuries as a passive thermal storage, latent storage materials provides more effective storage of heat with comparatively very small amount of material. Latent heat storage materials are referred to as

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phase change materials (PCMs) preferably with solid liquid phase change. Integration of PCM n to building fabric can increase the thermal storage capacity of the building envelope. PCMs are capable of storing energy at constant or nearly constant temperature which s referred as the phase transition temperature of the PCM. Cementitious materials as the most widely used construction materials n buildings has a great potential n developing high performance thermal storage material. Numerical modeling of composite material with PCM is very important for optimal material selection and optimal designing of the systems. Simulation of thermal energy storage n concrete characterizes the heat transfer behavior and thermal properties of this composite material.

Phase change Materials

The smart materials constitute a large variety of materials: magnetic shape memory, self-healing materials, piezoelectric materials, etc Materials that have one or more properties which can be significantly changed in a controlled fashion by external stimuli, such as stress, moisture, temperature, pH, electric or magnetic fields. This research focuses on phase change materials (PCMs) as a type of smart materials. PCMs exhibit a high enthalpy of fusion. Indeed, compared with sensible heat storage materials, latent heat storage materials present a higher energy storage density, per unit of temperature gradient, while requiring less mass of material. Over a limited temperature range, a PCM can change its physical state. Even some PCMs are suitable for building incorporation (thermal insulation, building envelope, walls, slab ceiling. Building's temperature ranges between 0◦to55◦ approximately depending on the geographic location. Many research projects focused on the application of PCMs in building construction.

Review of literature

Alam et al., (2016) studied characteristic strength of recycle aggregate concrete with partial replacement of cement with silica fume. They reported that adhered mortar on recycled coarse aggregate produces porous and rough nature of surfaces, which help in developing better bond. But for achieving required workability, the water absorption for recycled coarse aggregate is more than natural aggregate, they further reported that the recycled aggregate concrete has less workability as compared to the concrete made of natural aggregate; this is due to the porous and rough surfaces of the recycled aggregate.

Corominas and **Etxeberria** (2016) studied effects of using recycled concrete aggregates on the shrinkage of high performance concrete. They reported that the plastic and drying shrinkage became higher as the quality of RCA decreases.

Laneyrie et al., (2016) studied the influence of recycled coarse aggregates on normal and high performance concrete subjected to elevated temperatures of 750 °C and reported that the residual performances for the recycled concretes were generally similar to but slightly worse than those observed for the reference concretes. Also the presence of non-cementations impurities accelerates the damage of concretes with temperature.

AmithaJayalath (2017) states that Latent heat storage materials with solid liquid phase change or Phase Change Materials (PCMs) provide a promising solution in developing efficient thermal storage systems for buildings. The thermal mass of the building structures can be increased with the incorporation of PCMs into building materials. it will enhance the occupants comfort and reduce the consumption of energy for space conditioning.

ZakariaDakhli (2019) states that phase Change Materials (PCMs) integration in building materials reduces the need for air conditioning use in summer and brings comfort and well-being throughout the seasons. This research study proved that PCM incorporation in cement material enhances its thermal efficiency by adding a new feature: "thermal absorption feature". The latter absorbs energy to restore it when needed (day vs. night).

S.No.	Physical property	NCA	RCA
1	Water absorption (%)	1.49	6.05
2	Specific gravity	2.63	2.35
3	Impact test	13.68	11.6
4	Aggregate crushing test	43.80	40.56

MATERIALS AND METHODS

Materials used

- **Aggregates**
- **Coarse aggregate**
  - i) ***Natural coarse aggregate***
  - ii) ***Recycled coarse aggregate***
- **Fine aggregates**
- **Cement:**
- **Water**
- **Phase change materials**

Method

The Concrete is prepared by replacing normal coarse aggregates with different percentages of recycled coarse aggregates and checked for various strength parameters. Then we replace cement with different percentages of PCM in 50% RAC and study various strength parameters like Compressive strength, Flexure strength, tensile strength etc.

Testing of materials:

Physical properties of NCA and RCA:

To compare the physical properties of RCA with virgin aggregates various test has been done on (water absorption test, specific gravity, impact test, aggregate crushing) and following table shows the comparison between natural

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coarse aggregate NCA and Recycled coarse aggregate RCA.

Table 12: Physical properties of NCA and RCA

SLUMP TEST

Grade of concrete	Mix Proportions (cement:sand:coarse aggregate)	% of natural Aggregate (NCA)	% of recycled Aggregate (RCA)	w/c ratio	Slump (mm)
		100	0		77
M 25	1 : 1.61:2.74	70	30	0.45	67
		50	50		59
		30	70		46

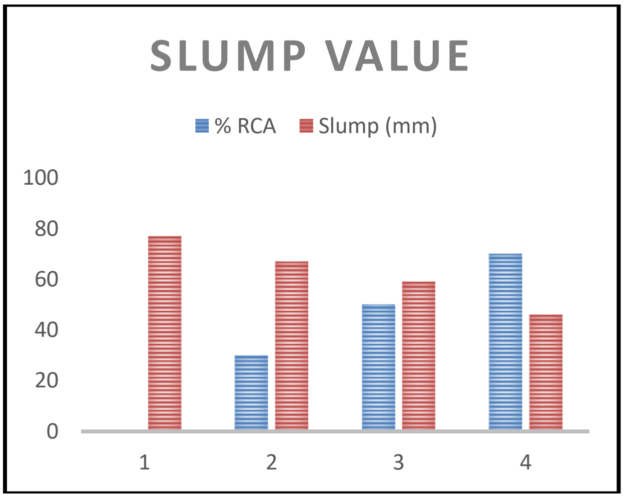

Fig. Slump for different %age replacement of RCA

COMPRESSIVE STRENGTH TEST:

MIX	7days compressivestrength(N/mm^2)	28days compressivestrength(N/mm^2)
M1 (100% NCA + 0% RCA)	16.25	29.30
M2 (30% NCA + 70% RCA)	14.64	26.20
M3 (50% NCA +50% RCA)	15.21	27.31
M4 (70% NCA +30% RCA)	14.67	23.00

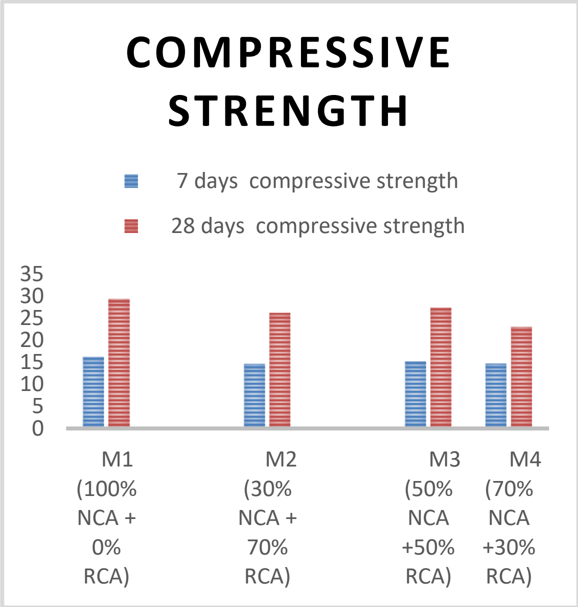

Figure : Compressive strength for 7 days and 28 days

SPLIT TENSILE STRENGTH TEST:

MIX	7 days (N/mm^2)	28 days (N/mm^2)
M1 (100% NCA + 0% RCA)	2.65	3.68
M2 (30% NCA + 70% RCA)	2.12	3.83
M3 (50% NCA +50% RCA)	1.98	3.62
M4 (70% NCA +30% RCA)	1.93	3.54

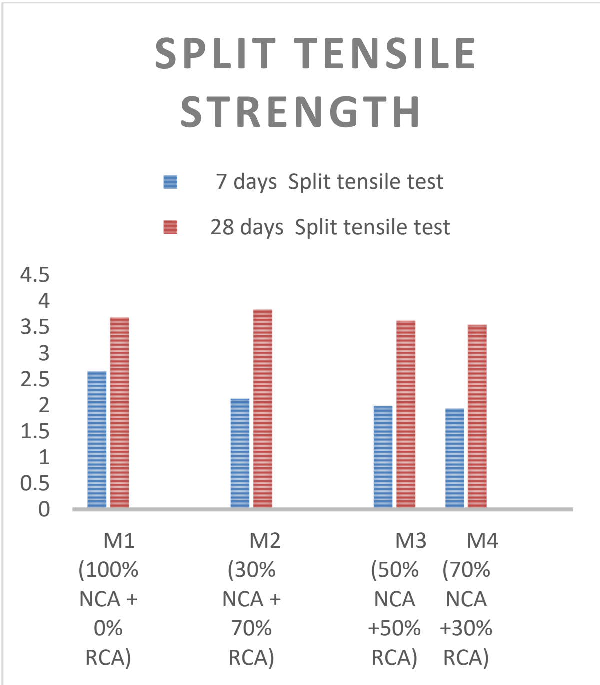

Figure : split tensile strength for 7 days and 28 days

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Flexure strength test:

MIX	7 days flexural strength (N/mm^2)	28 days Flexural strength (N/mm^2)
M1 (100% NCA + 0% RCA)	2.43	4.05
M2 (30% NCA + 70% RCA)	2.23	3.73
M3 (50% NCA +50% RCA)	2.10	3.50
M4 (70% NCA +30% RCA)	1.84	3.07

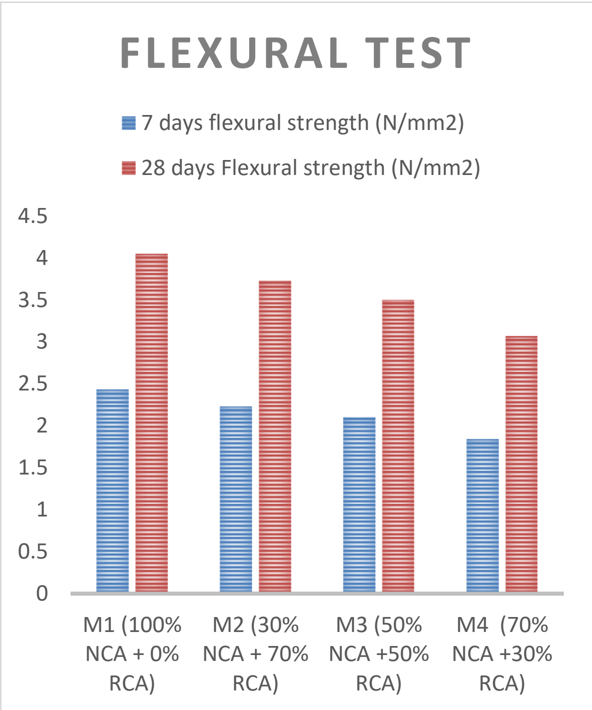


Figure : Flexural strength test for 7 days and 28 days

SPLIT TENSILE STRENGTH TEST:

S no.	MIX	SPLIT TENSILE STRENGTH AT 7 DAYS (N/mm^2)	SPLIT TENSILE STRENGTH AT 28 DAYS (N/mm^2)
1	M1(0%PCM)	1.98	3.62
2	M2(10%PCM)	1.87	3.41
3	M3(20%PCM)	1.61	3.24
4	M4(30%PCM)	1.52	2.99

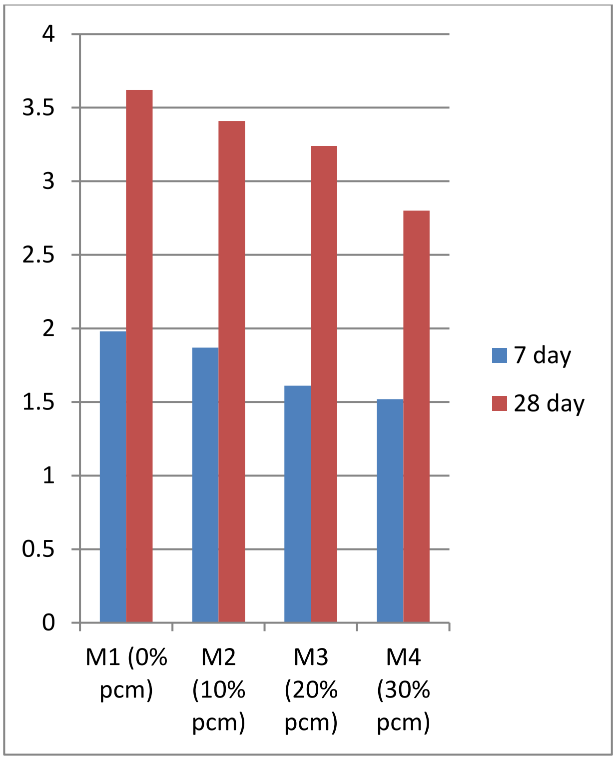


Figure : split tensile strength for 7 days and 28 days

Flexure strength test:

S no.	MIX	FLEXURE STRENGTH AT 7 DAYS (N/mm^2)	FLEXURE STRENGTH AT 28 DAYS (N/mm^2)
1	M1(0%PCM)	2.10	4.05
2	M2(10%PCM)	1.97	3.91
3	M3(20%PCM)	1.75	3.61
4	M4(30%PCM)	1.32	3.21

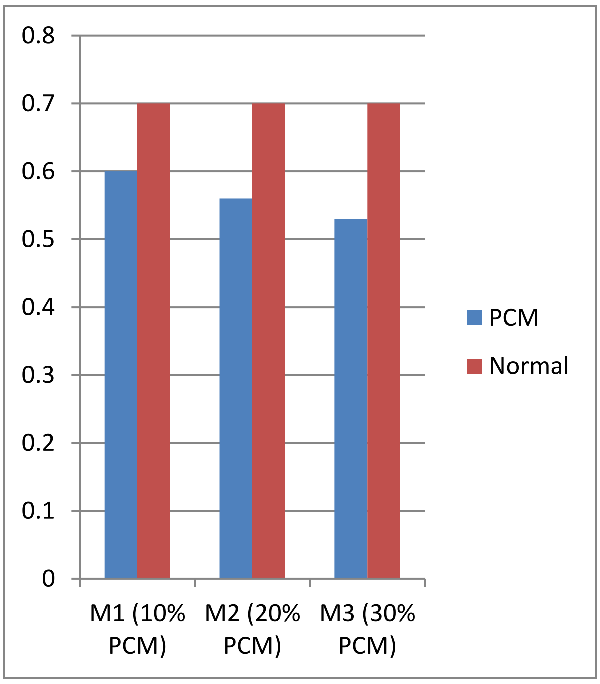
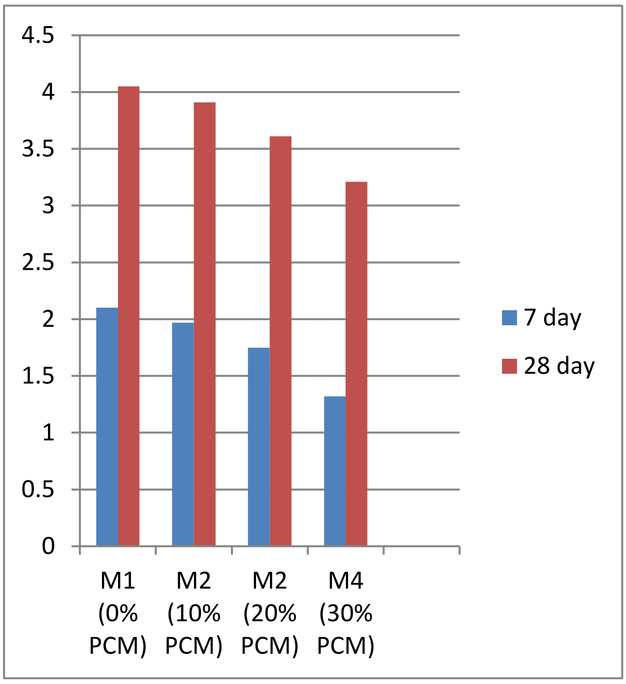


Figure : Flexural strength test for 7 days and 28 days

Thermal conductivity test for PCM integrated concrete

S.No	MIX	Thermal Conductivity (W/mK)
1	M1(0% PCM)	0.7
2	M2(10%PCM))	0.6
3	M3(20%PCM)	0.56
4	M4(30% PCM)	0.53



Bar chart for Thermal Conductivity

CONCLUSIONS & RECOMMENDATIONS

Based on the experimental works from this research work, the following conclusions are drawn:

1. The water content used in all mixes is 0.45. The proportion of Cement: Sand: Gravel is (1:1.61:2.74).
2. Water absorption of RCA and PCM is higher than natural Concrete.
3. Water required producing the same workability increases with the increase in the percentage of demolished waste.
4. Due to lack of treatment process adequate strength is not achieved but by applying more advanced and sophisticated treatment process the strength can be improved.
5. Using Recycled fine aggregates in concrete can prove to be better however in less quantity and can be recommended for lower grade applications.
6. RAC can achieve high compressive strength and Split tensile strength.
7. Slump is very low in case of 100% RCA, it can be increased by using SSD RCA. The physical and Mechanical properties of Recycled Concrete aggregates are important factors governing the strength characteristics of the concrete. And the properties of Recycled Concrete Aggregates are governed by the parent source.
8. The value of Recycled Aggregate with 0% that is normal concrete was the highest score for compressive strength. When Recycled Aggregate was added to the mixture, the value of compressive strength, decreased. It can be concluded that the value of compressive strength decreases when more recycled Aggregate is used.
9. Partial replacement can be successfully adopted with recycled coarse aggregate. The partial replacement does not affect much strength, and can be used for construction purpose. This would prevent the dumping and wasting the demolished concrete waste.
10. Flexural Strength of Recycled Aggregate Concrete is lower than that of virgin concrete.
11. Many researchers shown by their study that flexural strength of Recycled Aggregate Concrete can be increased by using fibers or admixtures.
12. Porosity increases with increase of PCM in cement.
13. Thermal conductivity of pure cement (0% PCM integration) was found to be 0.7 W/mK.f 10% of PCM s integrated n cement, thermal conductivity dropped to 0.6 W/mK. With 20% of PCM integration, thermal conductivity continued decreasing till 0.56 W/mK. For 30% PCM, the value s 0.53 W/mK.
14. Phase Change Materials (PCMs) integration in building materials reduces the need for air conditioning use n summer and brings comfort and well-being throughout the seasons.

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