

EFFECT OF THERMAL PROPERTIES ON FLY ASH BASED CONCRETE

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Abstract - The dumping of factory waste is one of the major concerns and challenge to the society, as the products are hazardous as well as proper method is to be followed for the dumping of waste. Reusing the waste product from the factory is one of the best solutions for dumping problems. In this paper, the waste product reused is fly ash, which we obtain during the burning of coal in sugar industries, the fly ash is sieved to obtain grain sizes, (0 to 300 μ m and 300 to 600 μ m) are reinforced with the concrete and molded into a concrete slab with 20, 25, 30% fraction of fly ash. Experiments are conducted to determine the thermal properties such as thermal conductivity, coefficient of thermal expansion, specific heat and thermal diffusivity of the concrete slab. There is a decrease in thermal conductivity, increase in specific heat capacity and decrease in thermal expansion. The results obtained are compared with the normal concrete slab.

Key Words: Fly ash, Specific heat, Temperature, Composite, Concrete, Thermal conductivity, Thermal Diffusivity, Specific heat, Coefficient of Thermal Expansion.

1. INTRODUCTION

Concrete is the most widely used man made construction material. It is obtained by Mixing cement, water and aggregate in adequate proportion. The hardening is induced by Chemical action between water and cement, it continues for a long time and consequently the Concrete grows stronger with age. The strength, durability and other characteristics of Concrete depend upon the properties of its gradients, the proportions of mix, the method of Compaction and Curing. [1]

Many of the experiments which are conducted on fly ash based concrete is mainly on the mechanical properties of the mixture concrete, very less research has been conducted on its thermal properties.

Thermal properties are very important factors of the fly ash based concrete, because in real scenarios the concrete structures undergo many physical and chemical changes due to the temperature effects. These temperature effects cause the thermal failure of the concrete and crack formation in the structure takes place. When there is a fire hazard the ordinary concrete structures fails to withstand the high temperature and the structure collapses due to the overheating.

The work presented in this paper reports an investigation on the behavior of concrete produced from partial replacement of cement with Fly Ash. Fly ash being a

waste product has pozzolanic property and can be used to replace cement.

In this work fly ash, a waste product which is formed after burning the coal in thermal power plant, is taken as reinforcement material for cement. Fly ash is obtained from Grasim Industries Ltd. Kumarpattanam, Karnataka. Using fly ash in concrete mixtures will reduce the dumping problem and is ecofriendly.

Attempts are made to study the effect of thermal properties on different composition of Fly ash and grain sizes of fly ash. Some of the earlier investigations showed that the mechanical properties are enhanced with increase in fly ash percentage. With mechanical property, thermal properties are also varying. In order to explore an interesting, useful engineering material and to check whether the Fly ash is able to withstand the change in temperature effects, with increase in percentage of Fly ash this study is carried out [2].

1.1 Thermal Properties

To conduct this experiment following thermal properties are considered.

- **Thermal conductivity** - defined as the ability of material to conduct heat.
- **Specific heat** - termed as Heat carrying capacity per unit mass.
- **Coefficient of thermal expansion** - defined as the ratio of change in length to product of temperature change and original length.
- **Thermal diffusivity of the material** - defined as the thermal conductivity divided by density and specific heat capacity at constant pressure [3].

2. SPECIMEN PREPARATION

2.1 Mixing Procedure

The dry cement and aggregates were mixed for two minutes in mixer in laboratory. The mixing continued for further few minutes while about 80% of the water was added. The mixing was continued for another few minutes and the fly ash were fed continuously to the concrete for a period of 2-3 min while stirring. Finally, the remaining water was added and the mixing was continued for an additional two minutes. This ensured a complete distribution of fly ash throughout the concrete mix.

2.2 Compaction

The mold with half-filled fresh concrete was vibrated vertically on the vibrate table while casting for about 30 seconds. The mold is then completely filled with fresh concrete and vibrated further for about 60 seconds. This method of compaction was to align the aggregates normal to the direction of vibration.

2.3 Curing

After compaction, the specimen is stripped from the mold after casting for 24 hours and submerged in water. The specimens are removed from the water after 28 days for testing.

2.4 Mold

PVC pipes were cut and formed into various sizes that served as molds for the test samples. The three sets of pattern (thermal conductivity, thermal expansion, specific heat) are produced. Glass sheets were used at the bottom and served as mold control volume, the surfaces were rubbed with lubricating oil to ensure easy removal of the composite.

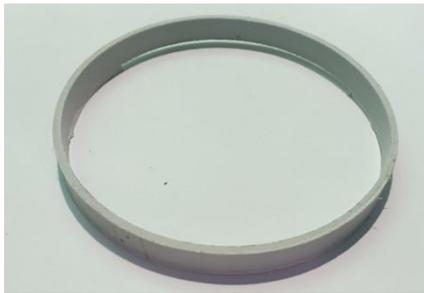


Figure -1: Mold used for specimen preparation

2.5 Dimensions of Specimens.

Seven specimens were casted according to the sizes, one pure cement specimen and 3 set of specimens were molded for the experiments conducted namely S1, S2, S3, S4, S5, S6 and S7. Table-1 shows the specimen with the grain size and fly ash percentage.

- **Thermal conductivity**

Figure-2 shows the Thermal Conductivity specimen

Diameter of the specimen = 100 mm

Thickness of the specimen = 8 mm

- **Specific heat**

Figure-3 shows the Specific heat specimen

Diameter of the specimen = 50 mm

Thickness of the specimen = 10 mm

- **Co-efficient of Thermal Expansion**

Figure-4 shows the Specific heat specimen

Diameter of the specimen = 15 mm

Thickness of the specimen = 50 mm



Figure -2: Thermal Conductivity specimen



Figure -3: Specific heat specimen



Figure - 4: Coefficient of thermal expansion specimen

Table -1: Specimen with different grain size

Specimen	Grain size in μm	Fly ash %
S1	-	0
S2	1-300	20
S3	300-600	
S4	1-300	25
S5	300-600	
S6	1-300	30
S7	300-600	

3. EXPERIMENTAL SETUP

3.1 Thermal conductivity

Setup for the measurement of Thermal Conductivity is shown in the figure below, it consists of voltmeter (0-250 V), ammeter (0-2A), dimmer stat (4A load), thermocouples (0-250°C), temperature indicator (up to 1000°C), heater, insulated container etc. Electric flow diagram is also shown below.

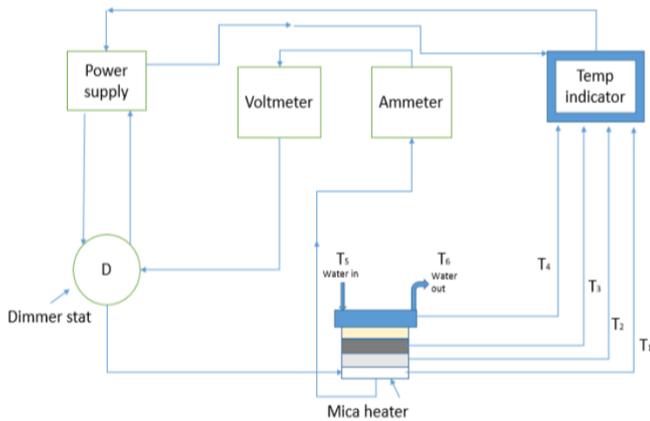


Figure -5: Electrical Flow diagram of the experimental setup.



Figure -6: Test setup for the determination of specific heat capacity

The specimen is heated with the help of mica heater by supplying heat with dimmer stat, up to a temperature of 250°C and the constant flow of water is maintained. Thermocouples are placed at different places in the set up to check the temperatures at the inlet at outlet of the specimen.

After some time, the temperatures come to steady state, at this condition the temperatures are taken down and the thermal conductivity is measured.

3.2 Specific heat

The specimen is heated to the required temperature using the Hot air Blow oven (Figure-6). Once the specimen reaches the desired temperature it is dipped inside the insulated container which contains water at room temperature. The heat transfer will takes place from Specimen to surrounding water. After some time interval both concrete temperature and water temperature becomes equal. That temperature is used as the final temperature of water as well as specimen. The calculation will give us the specific heat for that specimen.

3.3 Coefficient of thermal expansion

For coefficient of thermal expansion by using digital Vernier caliper, the initial specimen length is measured, and then the specimen is kept inside the Oven (figure-7) for heating to get desired temperature. After the specimen attains the desired temperature the length of specimen is measured, this data used to find the Co efficient of thermal expansion.

3.4 Thermal diffusivity

In heat transfer analysis, Thermal diffusivity of the material is defined as the thermal conductivity divided by density and specific heat capacity at constant pressure.



Figure -7: Test setup for the determination of Coefficient of thermal expansion capacity

It measures the capability of a material to transfer thermal energy relative to its capacity to withheld thermal energy. It has the SI unit of m²/s. Thermal diffusivity is usually denoted by “α” or “D”. The formula used to calculate thermal diffusivity is,

$$\alpha = \frac{k}{\rho C_p}$$

Where, ‘K’ is thermal conductivity, W/m-K

‘ρ’ is density, kg/m³

‘C_p’ is specific heat capacity, J/kg-K

By using above formula, the required thermal diffusivity for all the different fly ash epoxy composite can be calculated [4].

4. RESULTS AND DISCUSSION

4.1 Thermal conductivity

From Chart-1, the Thermal conductivity of pure concrete is around 1.38 W/m-K. This is in the range 1.2-1.4 W/m-K of the Pure Cement Concrete [5]. The greater are the porosity and pore size, the smaller is the thermal conductivity. That is because if the porosity and pore size increased, the pores in concrete would be filled with more air, and the thermal conductivity of the gas is much smaller than the solid, compared to pure cement concrete, fly ash concrete has lower thermal conductivity, Also we can observe that the specimen having the grain size of ‘1-300µm’ has more thermal conductivity than that of ‘300-

600 μ m' which is due to the porosity and pore size increase in fly ash concrete due to grain size.

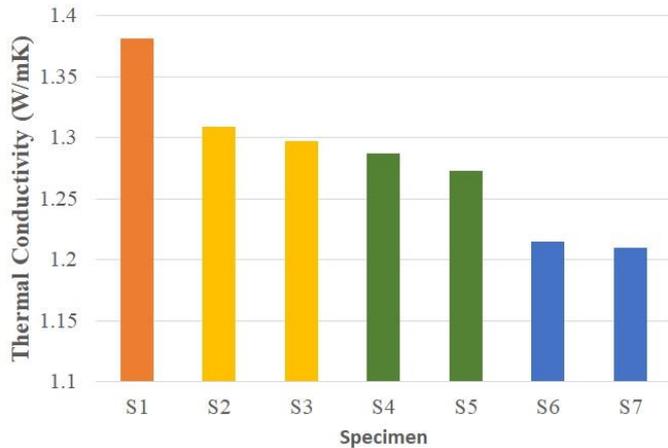


Chart -1: Thermal conductivity for different composition of fly ash

4.2 Specific Heat Capacity

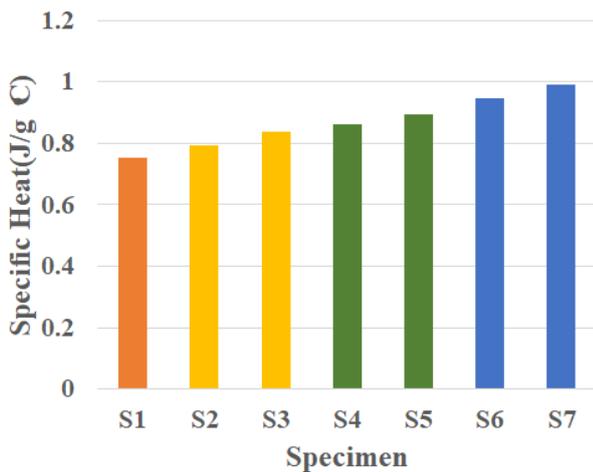


Chart -2: Specific heat capacity for different composition of fly ash

From Chart-2, specific heat capacity is found as 0.753 J/g \cdot $^{\circ}$ C. This is in the range of pure Cement Concrete 0.72 – 0.84 J/g \cdot $^{\circ}$ C [6]. From the above figure it can be observed that specific heat carrying capacity of composite is gradually increasing with increase in fly ash percentage. It is mainly because the fly ash particle exhibits higher specific heat capacity. The variation of specific heat with respect to fly ash grain size is higher for small sized particles. It is because fine powdered particles exhibit lower thermal expansion, as a result of this specific heat carrying capacity increases.

4.3 Coefficient of Thermal Expansion

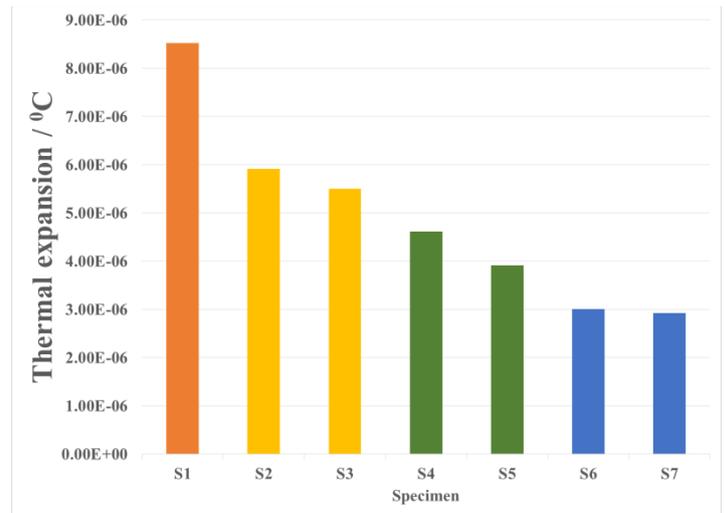


Chart -3: Coefficient of Thermal Expansion for different composition of fly ash

Chart-3 depicts variation of thermal expansion of composite material. The pure cement specimen has the maximum expansion while the expansion goes on decreasing with the increase in percentage of the fly ash. Also we can see that there is little less expansion for the higher grain size, this shows that there is a greater bond of the cement and fly ash when the grain is little coarse [7].

4.4 Thermal Diffusivity

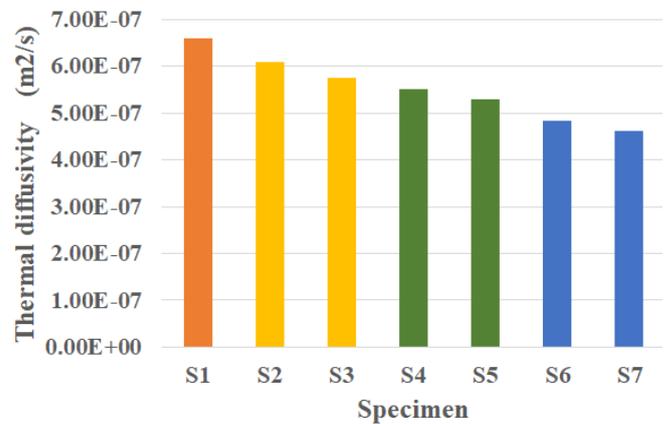


Chart -4: Thermal Diffusivity for different composition of fly ash

The thermal diffusivity is directly dependent on specific heat and thermal conductivity, Chart-4 shows that the thermal diffusivity decreases with increase in the fly ash percentage this is because of the porosity and pore size of the fly ash. Also we can see that the diffusivity of the higher grain size is lesser than that of the smaller grain size because of the fine powder [8].

4.0 CONCLUSION

This experimental investigation of thermal properties of fly ash based concrete composite have led to the following conclusions

1. It is observed that the incorporation of fly ash particles results in decrease in the thermal conductivity compared to that of pure Cement. A maximum decrease of about 8% in thermal conductivity of concrete is observed with increase of fly ash in the cement proportion in concrete composite there by improves its thermal insulation capability. This decrease in the thermal conductivity is widely accepted in the Industrial applications.
2. The specific heat capacity of composite with fly ash particles exhibit higher specific heat carrying capacity than concrete without fly ash. For pure cement concrete it is around 0.753J/g°C and for concrete with higher weight fraction fly ash composite it is observed as 0.989J/g°C. Higher fly ash content in concrete composite higher will be the heat carrying capacity of the composite.
3. Thermal diffusivity of composite with different weight fractions of fly ash is calculated. In this work thermal diffusivity of pure concrete is $6.597 \times 10^{-7} \text{m}^2/\text{s}$. Thermal diffusivity is decreased with addition of fly ash, thus its ability to store the thermal energy will be increases with increase in the fly ash percentage.
4. It is observed that the thermal expansion is greatly influenced with the addition of fly ash particles. Coefficient of thermal expansion of pure concrete is 8.844×10^{-6} at temperature range of around (100-500)°C and for composite with 30% fly ash, thermal expansion is $2.581 \times 10^{-6}/^\circ\text{C}$. In practice it shows that with increasing the fly ash percentage in concrete reduces the Thermal expansion.
5. From above comparison we can say that the concrete with fly ash more than 20 % is suitable for construction considering the thermal properties.

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