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Research Article

Investigations on the Effect of Sudden Cooling on the Properties of Fly Ash Concrete subjected to Sustained Elevated Temperatures

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Abstract

Utilization of industrial solid wastes in concrete would help environmental abatement, in solving solid waste disposal problems. Fly ash is the waste from the coal industries and poses serious problems of disposing. This present study focuses on the utilisation of Fly ash as a replacement to cement. In the present investigation the study of effect of elevated temperatures with sudden cooling on the properties of fly ash is dealt .The cement is replaced by flyash in proportions of 5% ,10%,15%,20%,25%,30% and concrete is exposed to elevated temperatures of 200°C, 400°C, 600°C , 800°C and 1000°C followed by sudden cooling. The various strength parameters studied are compressive strength, tensile strength, flexural strength and impact strength as per the relevant IS standards.. The experimental results indicate significant improvement in strength properties of plane concrete with replacement of cement by fly ash when it is subjected to elevated temperature with sudden cooling. Therefore it is feasible to adopt fly ash as a partial replacement of cement when it is exposed to elevated temperature with sudden cooling and can be effectively used for structural concrete.

Keywords: *Experimental investigation, Fly ash, replacement, strength, sustained elevated temperature, sudden cooling.*

1. Introduction

In designing the concrete structures subjected to high temperatures environments, for example cooling towers in power plants, pre-stressed concrete pressure vessels in nuclear industries and reinforced concrete skyscrapers, the information about fundamentals properties such as strength, stiffness, toughness, and brittleness under highly elevated temperature is very often required.

The fire resistance capacity of concrete is very complicated because not only is concrete a composite material with components having different thermal characteristics, it also has the properties that depend on moisture and porosity. The studies have shown that the high strength concrete has a poor resistance as compared to normal strength concrete. High strength concrete is more prone to explosives spalling due to their low permeability and high brittleness compared to normal strength concrete. During the heating up of the material in several chemical and physical reactions, bound moisture is detached out of the cement gel and vaporizes. The steam pressure produces stress, which the material is unable to resist. In this, stress is calculated to be about 8MPa for a temperature of 300 °C and about 17MPa for a temperature of 350 °C.

High temperature effect on concrete is one of the most important physical deterioration processes that affect the durability of the structure. This effect may decrease the expected service life of the structure due to permanent damage. It is possible to minimize the effect of high temperature by taking preventive measures such as choosing the right material and proper insulation methods.

The factors that influence the strength of cement based mortar and concrete under high temp can be divided into two groups' viz. material properties and environmental factors. The properties of aggregate, cement paste and aggregate cement paste bond and their thermal compatibility between each other greatly influence the resistance of the concrete. On the other hand the environmental factors such as heating rate, duration of exposure to maximum temp, cooling rate, loading condition and moisture regime affect the heat resistance of cementatious materials (Malhotra et.al.1956).

M.Potha Raju investigated the changes in flexural strength of fly ash concrete under elevated temperature of 100°C, 200°C and 250°C for 1 hour , 2 hour, and 3 hours duration. The results showed that the fly ash content upto 20% showed improved performance compared with the specimens without fly ash by retaining, a greater amount of its strength (M. Potha Raju *et al*, 2004).

(Lankard *et al*.,1971), investigated the changes in flexural strength of concrete containing gravel or limestone aggregate heated to temperatures upto 260°C. The results showed that the unsealed gravel and limestone concrete heat-treated at 79°C exhibited slight increase in flexural strength whereas concrete heat-treated at 121°C and 260°C exhibited loss of flexural strength.

However less attention has been paid by researchers to use fly ash as a replacement for cement and its behavior under sustained elevated temperature with sudden cooling.

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The main objective of this experimental study is to investigate the strength performance of concrete produced by replacing cement by fly ash in various percentages like 0%, 5% , 10% ,15% ,20% ,25% , 30% when subjected to sustained elevated temperature of 200°C, 400°C, 600°C , 800°C and 1000^{o}C. The various strength parameters studied are compressive strength, tensile strength, flexural strength and impact strength.

2. Research Significance

The rate of cooling plays an important role in the residual strength characteristics of concrete when the concrete is subjected to elevated temperatures. In real time situations, the concrete may be subjected to sudden cooling when fire-fighting engine start impinging the water on concrete structure which is on fire. Sometimes, the concrete may be subjected to gradual cooling as in case of chimneys etc. or even sometimes, the concrete may be subjected to intermittent cooling as in case of some fire fighting devices. In all such situations the concrete is subjected to different rates of cooling and this certainly affects the residual strength characteristics of concrete. Therefore the study of concrete subjected to different rates of cooling becomes an important parameter of study. In the present investigation concrete subjected to elevated temperatures and sudden cooling is studied.

3. Materials and Methods

Ordinary Portland cement of 43grade (IS 8112) with specific gravity 3.01 was used in making the concrete. The fine aggregate used was sand of zone I and its specific gravity was 2.57. Course aggregates used in experimentation were 20m and down size and their specific gravity was found to be 3.1. Class F Fly ash used in this experimentation was obtained from Raichur Thermal Power Plant Karnataka. The specific gravity of fly ash is found to be 2.1. To improve the workability Glenium B233 superplasticizer was used. The dosage of superplasticizer was varied from 0.1% to 0.25% by weight of cement. Mix proportion used for M25 concrete (control concrete) was 1:2.5:4.0 with w/c = 0.45 (IS 10262:2009)[11]. Slump test was carried out to assess the workability in fresh state. Specimens were casted by replacing cement in proportions of 5%,10%,15%,20%,25%,30%.Cubes of size 150x150x150mm, cylinders of size 150mm diameter and 300mm length, beams of size 100mmx100mmx500mm , cylinders of size 150mm diameter and 60mm length were casted. All the specimen were cured for 90 days. After 90 days of curing, the specimens were weighed accurately. The specimen were then transferred to oven and subjected to temperatures 200°C, 400°C, 600°C, 800°C and 1000°C for 4 hours. They were then immediately inserted in the tank of water after taking out of the oven and quenched in water for 15-20minutes and then taken out and allowed to cool. They were visually observed for change in colour and cracks. After cooling they were weighed again accurately for loss in weight. After this they were tested for their respective strengths. The cubes were tested for compressive strength, the beams were tested for flexural strength the cylinders of length 300mm were tested for split tensile strength and cylinders of length 60mm were tested for impact strength.

4. Results and Discussions

The variation in compressive strength, tensile strength, flexural strength and impact strength is represented in the form of graph as shown in Fig.1, 2, 3 and 4.

The following observations were made when the concrete is subjected to sustained elevated temperature with sudden cooling.

1. It is observed that the compressive strength of concrete when subjected to elevated temperature of 200°C for 4 hours, is higher at 25% replacement of cement by fly ash. After 25% replacement the compressive strength decreases. The percentage increase in the compressive strength at 25% replacement of cement by fly ash is about 66% as compared to reference mix (0% replacement)

2. It is observed that the tensile strength of concrete when subjected to elevated temperature of 200°C for 4 hours, is higher at 25% replacement of cement by fly ash. After 25% replacement the tensile strength decreases. The percentage increase in the tensile strength at 25% replacement of cement by fly ash is about 37% as compared to reference mix (0% replacement).

3. It is observed that the flexural strength of concrete when subjected to elevated temperature of 200°C for 4 hours, is higher at 25% replacement of cement by fly ash. After 25% replacement the flexural strength decreases. The percentage increase in the flexural strength at 25% replacement of cement by fly ash is about 22% as compared to reference mix (0% replacement).

4. It is observed that the impact strength of concrete when subjected to elevated temperature of 200°C for 4 hours is higher at 25% replacement of cement by fly ash. After 25% replacement the impact strength decreases. The percentage increase in the flexural strength at 25% replacement of cement by fly ash is about 80% as compared to reference mix (0% replacement).

5. Similar trend is observed when the concrete is subjected to elevated temperature of 400°C, 600°C, 800°C and 1000^{o}C. Again the strength parameters are maximum at 25% replacement of cement by fly ash.

At 200°C cement paste is compact and there is no spalling of concrete. At 400°C cement paste starts to become loose but is continuous and combined with aggregates. At 600°C the surface colour is French grey with slight red and cracks appear and cement aggregate interface is destroyed. At 800°C and 1000^{o}C the structure of cement paste is honeycomb structure and large cracks exist in cement paste which is separated from aggregate.

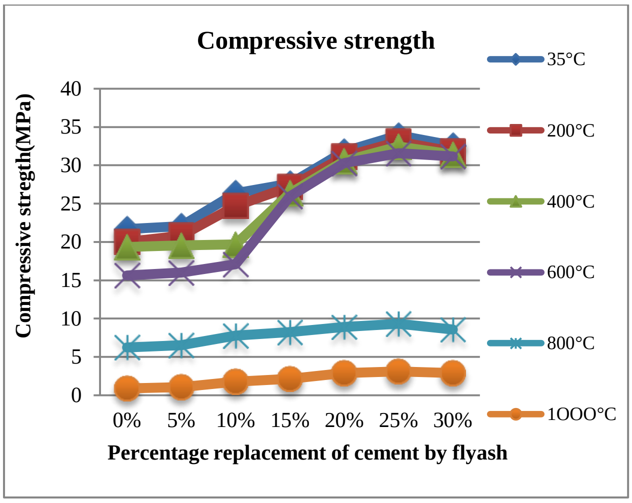

Fig.1 Variation of compressive strength for flyash concrete when subjected to different temperatures for 4 hrs and sudden cooling

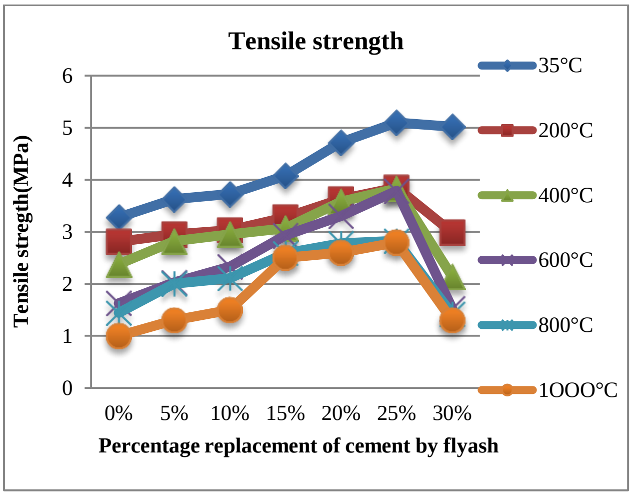

Fig.2 Variation of impact strength for flyash concrete when subjected to different temperatures for 4 hrs and sudden cooling

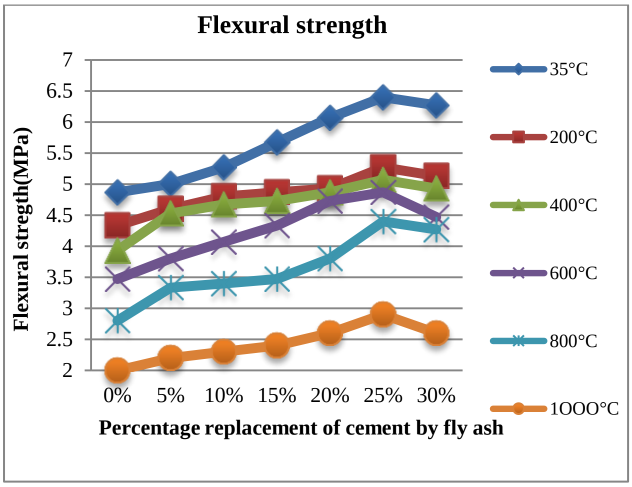

Fig.3 Variation of flexural strength for flyash concrete when subjected to different temperatures for 4 hrs and sudden cooling

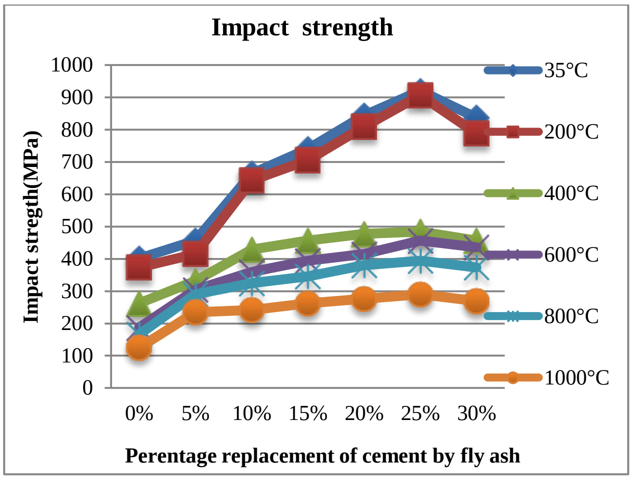

Fig.4 Variation of impact strength for flyash concrete when subjected to different temperatures for 4 hrs and sudden cooling

Conclusions

The following conclusions are derived from the results reported in the paper.

a. Results of investigation reveal that it is feasible to replace cement by fly ash to achieve strength, economy and to achieve problem of waste disposal.
b. The compressive strength, tensile strength, impact strength and flexural strength were found to increase with increase in the percentage replacement of cement by fly ash up to 25% at elevated temperature of 200°C and thereafter decrease.
c. Similarly when concrete is subjected to sustained elevated temperature of 400°C, 600°C, 800°C and 1000^{o}C the strength parameters are maximum corresponding to 25% replacement of cement by fly ash.
d. The results of this investigation suggest that the fly ash could be very conveniently used as a partial replacement of cement in structural concrete even at sustained elevated temperature with sudden cooling.

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