

Study on the Effect of Elevated Temperature with Intermittent Cooling on the Properties of Concrete

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Abstract: *The production of portland cement is not only costly and energy-intensive, but it also produces large amounts of carbon dioxide. With large quantities of fly ash available around the world at low costs, the use of flyash seems to offer the best short term solution to rising cement demands. Utilization of flyash will also solve the disposal problems. 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 intermediate 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 intermittent 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 plain concrete with replacement of cement by fly ash when it is subjected to elevated temperature with intermittent cooling. Therefore it is feasible to adopt fly ash as a partial replacement of cement when it is exposed to elevated temperature with intermittent cooling and can be effectively used for structural concrete*

Keywords: intermittent cooling, flyash replacement, elevated temperature, strength properties

1. Introduction

Human safety in the event of fire is one of the considerations in the design of residential, public and industrial buildings. Concrete has a good service record in this respect. Unlike wood and plastics, concrete is incombustible and does not emit toxic fumes on exposure to high temperature. Composition of concrete is important because both the cement paste and the aggregate consist of components that decompose on heating. The permeability of concrete, the size of the element, and the rate of temperature rise are important because they govern the development of internal pressures from the gaseous decomposition products.

Currently in India, it is estimated that the annual consumption of cement concrete is to the tune of 400 metric tones. This will obviously cause an equal demand on the materials like sand, aggregates and other materials required to produce huge quantity of cement concrete. This will naturally cause depletion of all the natural resources connected in producing cement concrete every year. Also the production of huge quantities of cement requires large amount of energy, cause emission of CO₂ and carry forward the allied problems. Therefore the researchers are concentrating on finding out the supplementary cementitious materials which can replace cement partially or fully. In this direction, fly ash, blast furnace slag, silica fume, metakaoline and rice husk ash have shown promising results to replace cement partially. Thus came into existence the blended cements [1].

Thus some of the industrial wastes are effectively utilized in the production of concrete. Fly ash is generally used as replacement of cement, as an admixture in concrete and in manufacture of cement. Enough studies have been carried out on partial replacement of cement by fly ash by earlier researchers. From the previous studies we have seen that an

increase in fly ash content results in higher strength for a given density, as fly ash is of pozzolonic nature [1].

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 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. 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 [2].

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 cementitious materials [3].

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 [4].

Lankard 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 [5]. 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 intermediate cooling.

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°C with intermittent cooling. 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 intermittent cooling is studied.

3. Materials and Methods

Ordinary Portland cement of 43 grade (IS 8112)[8] 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 [9]. Course aggregates used in experimentation were 20mm and down size and their specific gravity was found to be 3.1 [9]. 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 100mm x 100mm x 500mm, 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 later taken out and subjected to intermittent cooling. For every 15 min limited water was sprayed to the specimens and they were allowed to cool. This process was carried out for 1 hour. Later they were allowed to cool on their own.

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 intermittent 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°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°C the structure of cement paste is honeycomb structure and large cracks exist in cement paste which is separated from aggregate.

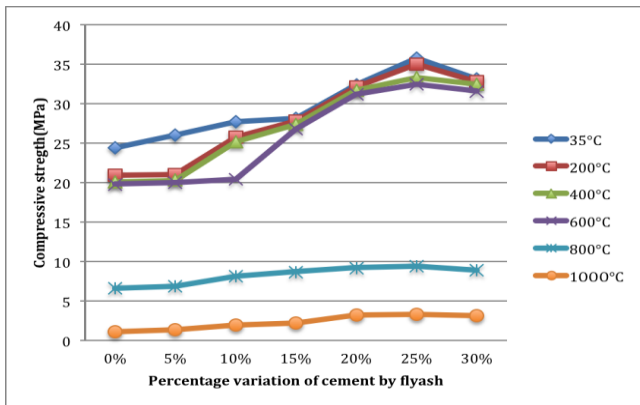


Figure 1: Variation of compressive strength for flyash concrete when subjected to different temperatures for 4 hrs and intermittent cooling

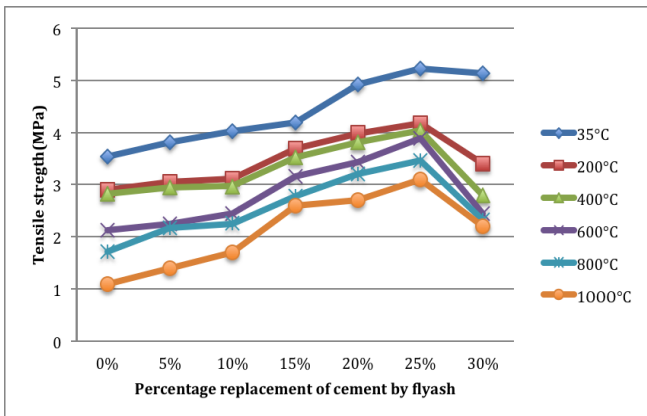


Figure 2: Variation of tensile strength for flyash concrete when subjected to different temperatures for 4 hrs and intermittent cooling

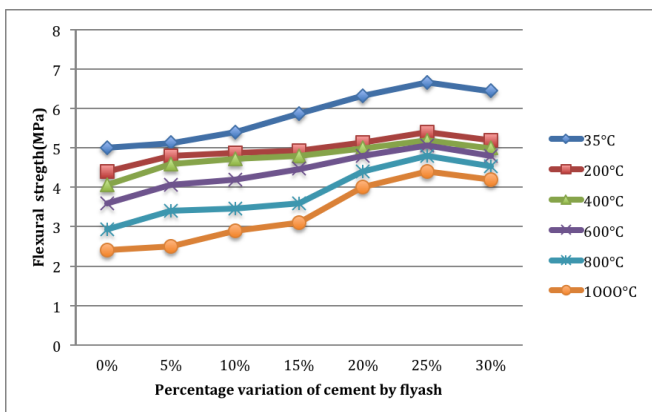


Figure 3: Variation of flexural strength for flyash concrete when subjected to different temperatures for 4 hrs and intermittent cooling

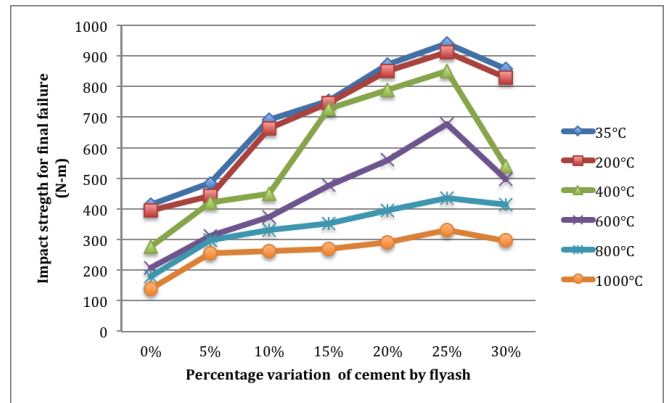


Figure 4: Variation of impact strength for flyash concrete when subjected to different temperatures for 4 hrs and intermittent cooling

5. Conclusions

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

- 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.
- 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 with intermittent cooling and thereafter decreased.
- Similarly when concrete is subjected to sustained elevated temperature of 400°C, 600°C, 800°C and 1000°C with intermittent cooling the strength parameters are maximum corresponding to 25% replacement of cement by fly ash.
- 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 intermittent cooling.

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Author Profile



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