International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 10, Issue 11 (November 2014), PP.23-27

An Experimental Investigation on Effect of Elevated Temperatures on M35 grade Concrete

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Abstract:- In the event of sudden fire break out, the concrete elements such as columns, beams etc. are subjected to extreme temperatures. The assessment of their performance after fire becomes necessary to decide upon its fitness and required repair measures. Hence, it is important to understand the changes in the concrete properties due to its exposure to extreme temperatures. It is important to know the effect of elevated temperature on the properties of concrete. In this project thesis work experimental investigation is carried out to study the effects of elevated temperatures on the compressive strength of normal concrete and on concrete by partial replacement of cement with various percentages of fly ash. In the present study a concrete mix M35 and is taken. In the normal concrete, cement is replaced with (0, 5, 10, 15, 20 and 25%) fly ash.The compressive strength of concrete with various percentages of fly ash (0%to 25%) are subjected to temperatures (400 to 600^0C), for different time periods (30 and 60min) which were tested for 28 days and 56 days of curing. The samples are cured in water and later exposed to various temperatures with various time periods. After heating the samples in electrical furnace to the desired temperatures .They are allowed to cool to the room temperatures and tested under compression. The average of the readings obtained is recorded and presented in various tables. This study shows that the compressive strength of fly ash (0%to 10%) concrete is more than the normal concrete at room temperatures and elevated temperatures and also compared to compressive strength of fly ash (15%to 25%) concrete.

Keywords:- Cube Compressive Strength, Fly Ash, Elevated temperatures

I. INTRODUCTION

Concrete though not a refractory material, is incombustible and has good fire resistant properties. Fire resistance of concrete structure is determined by three main factors - the capacity of concrete itself to withstand heat and the subsequent action of water without losing strength unduly, without cracking or spalling, the conductivity of the concrete to heat and coefficient of thermal expansion of concrete.

The effect of increase in temperature on the strength of concrete is not much up to a temperature of about 250^0 C but above 300^0 C definite loss of strength takes place. Hydrated hardened concrete contains a considerable proportion of free calcium hydroxide which loses its water above 400^0 C leaving calcium oxide. If this calcium oxide gets wetted or is exposed to moist air, rehydrates to calcium hydroxide accompanied by an expansion in volume. This expansion disrupts the concrete..

So, it is important to know the effects of elevated temperatures on the compressive strength of concrete. Presented in the following sections is an experimental study on the effects of elevated temperatures on the structural M35 grade concrete.

The present study was carried out on Fly Ash .Fly Ash is procured from Vijayawada Thermal Power Station(VTPS), Vijayawada. The cement has been replaced by fly ash accordingly in the range of 0%, 5%, 10%, 15%, 20% & 25% by weight of cement for mix. Concrete mixtures were produced, tested and compared in terms of compressive strengths with the Conventional concrete. These tests were carried out to evaluate the compressive strength properties for the test results of 28, 56 days compressive strengths which were exposed to elevated temperatures of 400^0C, 500^0 C &600^0 C for a time duration of 30 minutes and 60 minutes respectively for 28 & 56 days respectively.

II. LITERATURE REVIEW

H. G. Mundle [1] have studied the Variation In Strength Of Concrete Subjected To High Temperature. In their study they have taken the elevated temperature range from 0^0 - 200^0 C. Their test results showed that the compressive strengths The compressive strength was found to increase after 72 hours of exposure to an elevated temperature up to 150 ^{0} C after that the compressive strength of concrete decreases with increasing temperature. The peak value in the ratio of the compressive strength at high temperature is observed around 150 ^{0} C. This

peak value obtained due to the evaporation of free water inside the concrete. The compressive strength was found to increase after 24 hours of exposure to an elevated temperature up to 200 ^{0} C after that compressive strength of concrete will be decreases with increasing temperature after the peak point.

Balakrishnaiah et al., [2] study of mechanical properties of concrete at elevated temperatures. In their study they studied the effect of elevated temperature on mechanical properties and microstructure of silica flour concrete was investigated and studied using ordinary Portland cement (OPC) and silica flour (SF) in percentages varying from 0,5 to 20% with water/binder ratio of 0.5. After 28 days of curing, the specimens were exposed to 100^{o}C to 800^{o}C.

M.V. Krishna Rao et al., [3] investigated the effect of sustained elevated temperature on the properties of ordinary concretes of M40 grade, containing different types of cements and cured by two different methods. The specimens were heated to150 ^{0}C, 300 ^{0}C and 450 ^{0}C for 1 hour duration in a muffle furnace. They were tested for compressive strength after air cooling to the room temperature. The variables considered in the study include type of cementing material, temperature and method of curing. The comp. strength of concrete and weight of concrete decreased with increasing temperature.

Belkacem Toumi et al., (2010) [4] have studied the Influence of High Temperatures on Surface Cracking of Concrete Studied by Image Scanning Technique. They have studied the identification and quantification of surface cracking of concrete heated to different temperatures ranging from 105 to 1250ºC. In addition to the quantification of the residual compressive strengths of concrete after high temperature exposure, both initial surface absorption and total porosity were measured. The crack density was determined using a flat bed scanner and then images were treated using paint shop pro program. The total porosity was obtained using ASTM boiling. The mechanical properties of concrete were largely affected by temperatures beyond 500°C and were very feeble when temperatures exceeded 1000°C. The surface cracks' density, initial surface absorption and total porosity by boiling methods gave a rapid indication on concrete durability.

III. EXPERIMENTAL INVESTIGATION

3.1Materials

a) Cement

In the experimental investigations ordinary Portland cement (OPC) of 53 grade is used. The cements procured were tested for physical properties in accordance with IS: 4031-1988 and IS: 8112-1989.

b) Fine Aggregate

Fine aggregate (river sand) obtained from local market was used in this study.

c) Coarse Aggregate

The properties of coarse aggregate like size of aggregate, shape, grading, surface texture etc play an important role in workability and strength of concrete. These properties were determined as per IS: 2386-1963.

d) Water

Potable water confirming to IS: 456-2000 was used in the investigations for both mixing and curing.

e) Fly Ash

The present study was carried out on Fly Ash .Fly Ash is procured from Vijayawada Thermal Power Station(VTPS), Vijayawada. The grade of Fly Ash used was Class F.

3.2 Experimental Programme

In this experimental work the concrete specimens were casted. The specimens considered in this study consisted of 100 mm x 100 mm x 100 mm cubes. The mix design of concrete was done according to Indian standard guidelines for target mean strength 43 N/mm^{2} and the water cement ratios is 0.4.Based upon the quantities of ingredient of the mixes, the quantities of fly ash for 0, 5, 10, 15, 20 and 25% replacement by weight of the cement. The water/cement ratio is same to investigate the effects of replacing cement with fly ash when other parameters are almost kept same. The compressive strength of concrete with various percentages of fly ash (0%to 25%) are subjected to temperatures (400 to 600^{0}C), for different time periods (30 and 60min). The samples are cured in water and later exposed to various temperatures with various time periods. After heating the samples in electrical furnace to the desired temperatures .They are allowed to cool to the room temperatures and tested under compression. The average of the readings obtained is recorded and presented in various tables. This study shows that the compressive strength of fly ash (0%to 10%) concrete is more than the normal concrete

at room temperatures and elevated temperatures and also compared to compressive strength of fly ash (15%to 25%) concrete

IV. RESULTS AND DISCUSSIONS

4.1 Compressive strength of cubes when exposed to 400 ^{0} C at 28 days

The following tabular form presents the compressive strengths of various proportions of M35 grade concrete mix with various replacement levels of fly ash when exposed to 400 ^{0} C at 28 days

Table 1: Compressive strength of cubes when exposed to 400 ^{0} C,500 ^{0} C, 600^0 C at 28 days for 30 minutes duration

SAMPLE DESIGNATION	% OF FA	UNHEATED	400 ^{0} C	500 ^{0} C	600^0 C
M-0	0	43.55	42.66	41.33	40.00
M-5	5	44.00	43.11	41.77	40.44
M-10	10	44.44	43.55	42.66	41.77
M-15	15	43.11	42.66	41.33	40.44
M-20	20	41.33	41.77	40.44	39.55
M-25	25	40.44	40.44	40.00	38.66

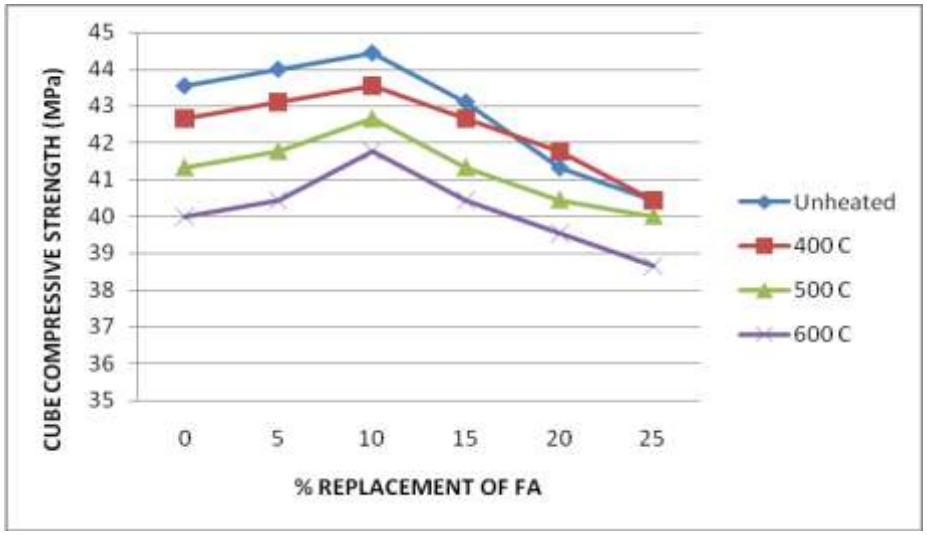

Fig.1 Graph showing variations in compressive strengths at 28 days duration exposed to 400 ^{0}, 500 ^{0} & 600 ^{0} C for 30 mintues duration

Table:2 Compressive strength of cubes when exposed to 400 ^{0} C,500 ^{0} C, 600^0 C at 28 days for 60 minutes duration

SAMPLE DESIGNATION	% OF FA	UNHEATED	400 ^{0} C	500 ^{0} C	600^0 C
M-0	0	43.55	41.77	40.44	39.55
M-5	5	44.00	42.22	40.88	39.11
M-10	10	44.44	43.11	42.22	40.88
M-15	15	43.11	42.22	40.88	40.00
M-20	20	41.33	40.88	40.00	39.11
M-25	25	40.44	41.33	39.55	37.77

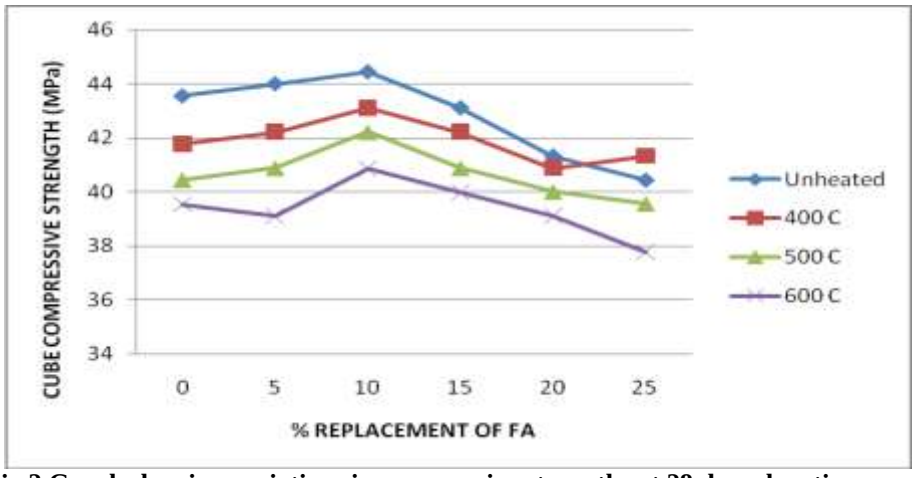

Fig.2 Graph showing variations in compressive strengths at 28 days duration exposed to 400 ^{0}, 500 ^{0} & 600 ^{0} C for 60 mintues duration

Table: 3 Compressive strength of cubes when exposed to 400 ^{0} C,500 ^{0} C, 600^0 C at 56 days for 30 minutes duration

SAMPLE DESIGNATION	% OF FA	UNHEATED	400 ^{0} C	500 ^{0} C	600^0 C
M-0	0	45.33	44.44	41.77	39.55
M-5	5	46.22	44.00	43.11	41.88
M-10	10	47.11	44.88	44.00	43.11
M-15	15	44.88	44.00	42.22	41.77
M-20	20	43.00	43.11	41.77	40.88
M-25	25	42.22	41.77	41.33	40.00

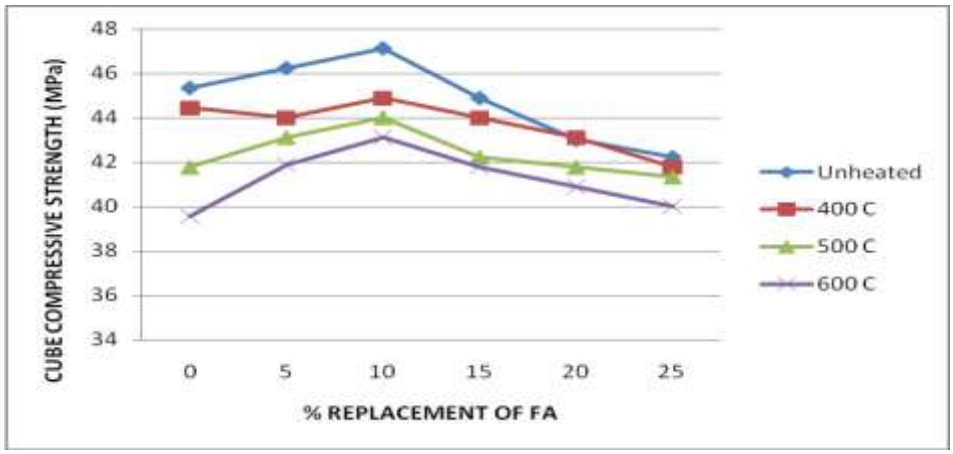

Fig.3 Graph showing variations in compressive strengths at 400 ^{0} C, 500 ^{0} C, 600 ^{0} C at 56 days duration for 30 minutes

Table:4 Compressive strength of cubes when exposed to 400 ^{0} C,500 ^{0} C, 600^0 C at 56 days for 60 minutes duration

SAMPLE DESIGNATION	% OF FA	UNHEATED	400 ^{0} C	500 ^{0} C	600^0 C
M-0	0	45.33	42.66	42.00	41.33
M-5	5	46.22	43.55	41.33	40.44
M-10	10	47.11	45.33	43.55	42.22
M-15	15	44.88	43.11	42.66	41.00
M-20	20	43.00	42.22	41.00	40.44
M-25	25	42.22	42.00	40.88	39.11

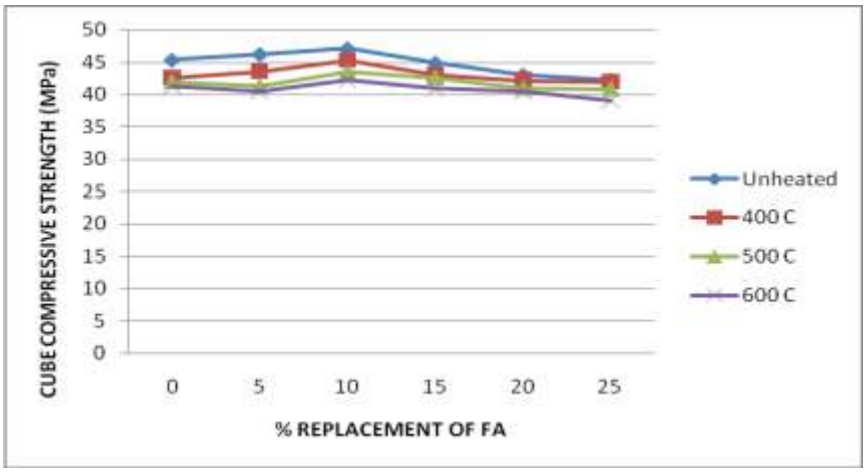

Fig.4 Graph showing variations in compressive strengths at 400 ^{0} C, 500 ^{0} C, 600 ^{0} C at 56 days Duration for 60 minutes

V. CONCLUSIONS

1. The reduction in compressive strength of concrete was significantly larger for samples exposed to temperature greater than 400^0 C at any time interval.
2. The result for the reduction in compressive strengths is due to lost water of crystallisation resulting in a reduction of $Ca(OH)_2$ content and the formation of micro cracks due to exposure to heat.
3. The compressive strengths of concrete were found to decrease when they are exposed to temperatures between 400^0 C - 600^0 C with or without the replacement of mineral admixtures at both 30 minutes and 60 minutes duration at 28 & 56 days.
4. Results indicated the losses in relative strength due to high-temperature exposure and the presence of 10% fly ash as a cement replacement seemed to have no significant effect.
5. By using 10% of fly ash as a partial replacement with cement the compressive strength is increased compared to target mean strength.

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