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Strength Evaluation and High Temperature Performance Assessment of Fly Ash Based Cementecious Material

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ABSTRACT

Concrete is the most common construction material in the world because it combines very good mechanical and durability properties, workability and relative low cost. However, cement production emits greenhouse gases, mainly CO2, being responsible for about 5% of global anthropogenic CO2 emissions in the world. The use of pozzolans as cement replacement is a problem that would have local solutions since transport is one of the main cost components for cementitious materials. The application of fly ash in concrete production brings positive effects of the environment; hence it reduces the problems associated to their disposal. Several benefits will be attained regarding green house gas emissions resulting from the use of mineral admixtures as cement additive, since their use allows reducing cement production. Regarding their use as cement additive, mineral admixtures affect the performances of paste, mortar and concrete owing to both physical and chemical effects. Therefore it is possible to use fly ash as cement additive and replacement material to improve quality and reduce cost of pozzolonic construction material The cement has been replaced by fly ash accordingly in the range of 0%, 5%, 10%, 15%, 20% & 25% by weight of cement for mix.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 4000C, 5000 C &6000C for time duration of 30 minutes and 60 minutes respectively.

Keywords: *Concrete, Construction, fly ash, Compressive strength*

I. INTRODUCTION

Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in civil construction industry. But, production of cement involves emission of large amount of carbon dioxide gas into the atmosphere which results to global warming. So it is advisable to search for another material or partly replace it by other material that should lead to lowest environmental impact.

The effect of increase in temperature on the strength of concrete is not much up to a temperature of about 2500 C but above 3000 C definite loss of strength takes place. Hydrated hardened concrete contains a considerable proportion of free calcium hydroxide which loses its water above 4000 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.

The influence of elevated temperatures on mechanical properties of concrete is of very much important for fire resistance studies and also for understanding the behavior of containment vessels, chimneys, nuclear reactor pressure vessels during service and ultimate conditions structures like storage tanks for crude oil, hot water, coal gasification, liquefaction vessels used in petrochemical industries, foundation for blast furnace and coke industries, furnace walls industrial chimney, air craft runway etc., will be subjected to elevated temperatures. So that the variation of compressive strength, performance are some of the important parameters to be investigated when concrete structures are subjected to temperatures. 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 grade concrete.

A. Necessity and Objectives Of The Work

Concrete is the most common construction material in the world because it combines very good mechanical and durability properties, workability and relative low cost. However, cement production emits greenhouse gases, mainly CO_2, being responsible for about 5% of global anthropogenic CO_2 emissions in the world. Fly ash is an important by-product of the thermal power plants and most of it is burned to produce steam and electricity in the plant. The fly ash is the result from the coal combustion and mainly consists of high amount of silica and unburned carbon. Its utilization as an adsorbent as well as mineral admixture in cement and concrete has been examined.

B. Scope of the Work

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^{0}C, 500^0 C & 600^0 C for time duration of 30 minutes and 60 minutes respectively.

II. LITERATURE REVIEW

M.V. Krishna Rao et al., (2011) 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.

K. Srinivasa Rao et al., (2004) “A Study On Variation of Compressive Strength of High Strength Concrete At Elevated Temperatures”. In their study, the effect of elevated temperatures (up to 950°C) on compressive strength of HSC of M60 grade using fly ash based Pozzolona Portland Cement. High strength concrete cube specimens were exposed to different temperatures of 50°C to 950°C in intervals of 50°C for different durations of 1,2 and 3 hours. After exposing the specimens to elevated temperatures, they were tested for their compressive strength in hot state. Then effect of elevated temperatures on compressive strength of HSC was assessed.

P.C.Taylor (1987) presently a professor at Wuhan University of Technology has said that mineral admixtures affect the physical and mechanical properties of High Strength Structural Light weight Concrete. Addition of Fly Ash enhances the compressive strength and splitting tensile strength of HSSLC when FA was more than 20% in cementitious materials, its 28 days compressive strength and splitting tensile strengths are less than those of the concrete without FA.

III. EXPERIMENTAL INVESTIGATION

A. Materials Used

Cement

Ordinary Portland Cement (OPC) is the basic Portland Cement and is best suited for use in general concrete construction. It is of tree types 33 grade, 43 grades, 53 grade. One of the important benefits is the faster rate of development of strength. Ordinary Portland Cement (OPC) available in the market conforming to IS 12269-1987 was used for casting the specimens.

The cement used was 53 Grade.

PROPERTIES OF CEMENT

Property Test Result

Normal consistency- 33%
Initial setting time- 80 minutes
Final setting time -180 minutes
Specific Gravity -3.15
Soundness (Le-chatlier Exp.) -1.30mm
Compressive strength of Cement (28days)-53 Mpa
Specific surfacearea-320m^2/Kg

B. *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.

Chemical Composition of Fly Ash

SiO2 % by mass - 66.80
Al2o3 by mass- 24.5
Fe2o3 by mass- 4.00
Cao by mass- 1.50
Mgo by mass -0.45
Na2o by mass- 0.4
K2o by mass- 0.22

Physical properties of Fly ash

Specific gravity- 2.67
Fineness cm^2/gm – 4069

C. Aggregate:

Properties Of Fine Aggregate

Specific Gravity- 2.60
Bulk density (Kg/m^3) - 1543(loose state)
-1750 (dry rodded)
Fineness Modulus 2.74
Zone- 2

Properties Of Coarse Aggregate

Bulk density (kg/m^3)
1468 [loose state]
1611 [dry rodded]
Specific Gravity (G) - 2.74
Fineness Modulus - 7.17

D. Water:

Clean portable water is used for mixing concrete. Water used for mixing and curing should be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete and steel.

E. Mixing

Initially the coarse aggregates and fine aggregates are weighed. Later required quantities of cement and fly ash are mixed dry to a uniform colour. As per the mix design water is measured. All the ingredients are added to the concrete mixture and mixed for the time period to achieve a homogeneous mix of uniform colour. Before casting the specimens, workability of mixes is found by compaction factor test.

IV. TESTS CONDUCTED ON FRESH CONCRETE

A. Workability

The workability was measured by using the compaction factor and slump cone apparatus as per IS 1197 for various percentage ratios of fly ash concrete.

B. Casting

The cast iron moulds are used for casting. They are securely tightened to correct dimensions before casting. Care is taken that there is no gaps left from where there is no possibility of leakage out of slurry. Clean and oiled moulds for each category are then placed on the vibrating table respectively and filled in three layers. Vibrations are stopped as soon as the cement slurry appeared on the top surface of the mould. Excess concrete was removed with trowel and top surface is finished level and smooth as per IS 516-1959.

C. Curing of the specimens:

The specimens are allowed to remain in the steel moulds undisturbed at room temperature for the first 24 hours after that these are de moulded carefully so that no edges are broken and are placed in the curing tank for curing and then cured for required period as per IS: 516-1959.

D. Heating and Cooling Regimes

At the age of 28 & 56 days, specimens are heated in an electrical furnace up to 400^{0}C, 500^{0}C, and 600^{0}C. After reaching the required temperature specimens are subjected to the steady temperature for 30 and 60 minutes. Now the specimens are taken out from furnace and are allowed to cool naturally to room temperature.

E. Compression Testing Machine

The compression testing machine (Microprocessor based) used for testing the cube specimens is of standard make. Concrete specimens cubes are used to determine the compressive strength of fly ash concrete as per IS 516-1959.

F. Concrete Mix Design

In the present investigation mix proportioning is done using BIS method for, M35 grade concrete. The resulting mixes are modified after conducting trials at laboratory by duly following the Indian standards guidelines to achieved following mix proportion by weight.

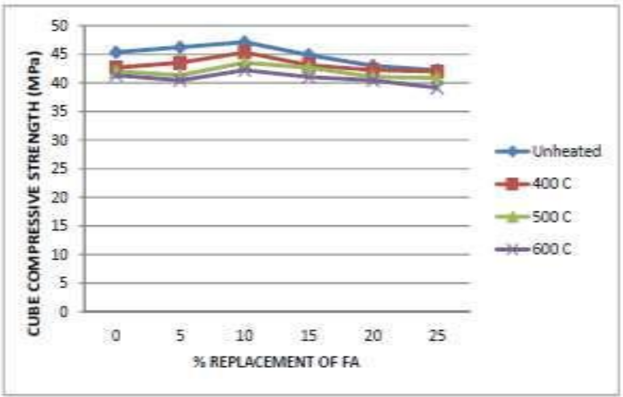
Cement	Fine aggregate	Coarse aggregate	w/c ratio
450	523.68	1229.86	187.78
1	1.16	2.73	0.41

G. Test Results

Compressive strength of cubes when exposed to 400⁰C,500⁰C,600⁰C at 28 days for 30 minutes duration

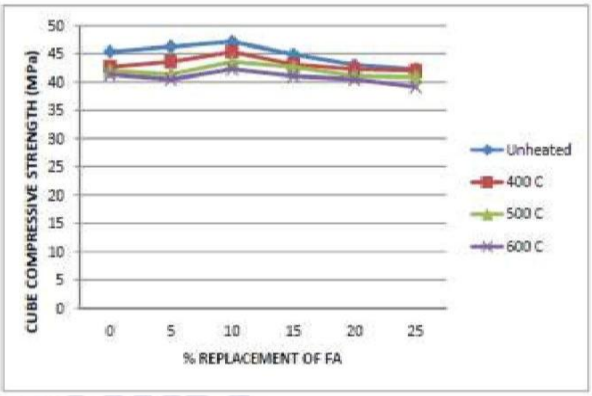
Sample Designation	% of FA	Unheated	400 ⁰C	500 ⁰C	600⁰ C
M-0	0	43.55	42.66	41.33	40.00
M-5	5	44.00	43.11	41.77	40.44
M-10	10	44.44	43.55	42.66	41.77
M-15	15	43.11	42.66	41.33	40.44
M-20	20	41.33	41.77	40.44	39.55
M-25	25	40.44	40.44	40.00	38.66

Variations in compressive strengths at 28 days duration exposed to 400⁰, 500⁰ & 600⁰C for 30 minutes duration



Compressive strength of cubes when exposed to 400⁰C, 500⁰C, 600⁰ C at 28days for 60 minutes duration

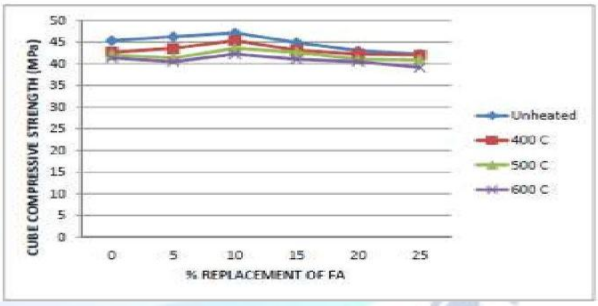
Sample Designation	% of FA	Unheated	400 ⁰C	500 ⁰C	600⁰ C
M-0	0	43.55	41.77	40.44	39.55
M-5	5	44.00	42.22	40.88	39.11
M-10	10	44.44	43.11	42.22	40.88
M-15	15	43.11	42.22	40.88	40.00
M-20	20	41.33	40.88	40.00	39.11
M-25	25	40.44	41.33	39.55	37.77



Variations in compressive strengths at 28 days duration exposed to 400⁰, 500⁰ & 600⁰ C for 60 minutes duration.

Compressive strength of cubes when exposed to 400⁰ C,500⁰ C, 600⁰ C at 56 days for 30 minutes duration.

Sample Designation	% of FA	Unheated	400 ⁰C	500 ⁰C	600⁰ 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

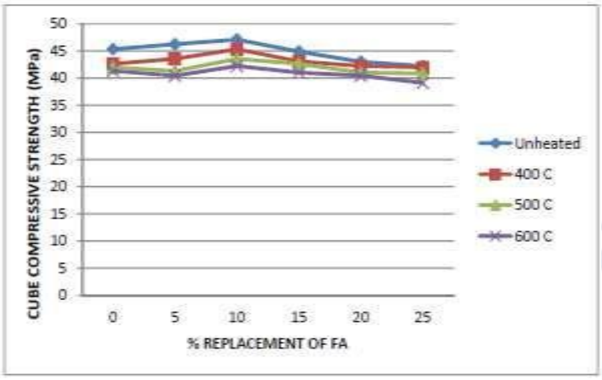


Variations in compressive strengths at 400 ⁰ C, 500 ⁰ C, 600 ⁰ C at 56 days duration for 30 minutes

Compressive strength of cubes when exposed to 400 ⁰ C,500 ⁰ C, 600⁰ C at 56 days for 60 minutes duration.

Sample Designation	% of FA	Unheated	400 ⁰C	500 ⁰C	600⁰ 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

Variations in compressive strengths at 400⁰C, 500⁰C, 600⁰C at 56 days duration for 60 minutes.



V. CONCLUSIONS

The reduction in compressive strength of concrete was significantly larger for samples exposed to temperature greater than 400^0 C at any time interval.

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.\

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.

The longer the duration of heating before testing, the larger is the loss in strength. 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.

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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