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Mechanical Properties of High Volume Fly Ash (HVFA) and Concrete Subjected to Evaluated 120^0C Temperature

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Abstract

The Aim of Paper is Fly ash is used as a mineral addition in concrete to improve its strength and durability characteristics At high temperatures, chemical transformation of the gel weakened the matrix bonding, which brought about a loss of strength of fly ash concrete. Fly ash can be used either as an admixture or as a partial replacement of cement or as a partial replacement of fine aggregates or total replacement of fine aggregate and as supplementary addition to achieve different properties of concrete. Pozzolanic concretes are used extensively throughout the world where oil, gas, nuclear and power industries are among the major users. Apart from the usual risk of fire, these concretes are exposed to high temperatures for considerable periods of time. Although concrete is generally believed to be an excellent fireproofing material, but there is extensive damage or even catastrophic failure at high temperatures. the compressive strength, split tensile strength and modulus elasticity of fly ash concrete at elevated temperature up to 120˚C with mix proportions of 1:1.45:2.2:1.103 with a water cement ratio of 0.5 by weight was determined. Cement was replaced with three percentages of fly ash. The percentages of replacements were 30, 40 and 50 % by weight of cement. Tests were performed for compressive strength, split tensile strength and modulus of elasticity. Compressive strength, split tensile strength and modulus of elasticity were performed at room temperature, 80˚C, 100˚C, and 120˚C for all types of fly ash concrete at different curing periods (28 and 56 days). Test results showed that the compressive strength, split tensile strength and modulus of elasticity of concrete having cement replacement up to 30% was comparable to the reference concrete without fly ash. Compressive strength, split tensile strength and modulus of elasticity of concrete mixtures with 30%, 40% and 50 % of fly ash as cement replacement was lower than the control mixture at all ages and that the strength of all mixtures continued to increase with the age. With the increase in temperature, compressive strength of concrete mixes with 30%, 40% and 50 % of fly ash as cement replacement decreases by 11.4%, 30.1%, 28.9%, and 27.5% at 120˚C when compared to room temperature.

Keywords: Component; Construction Materials, Fly ash, Pozzolanic concrete)

1. Introduction

Pozzolanic concretes are used extensively throughout the world where oil, gas, nuclear and power industries are among the major users. The applications of such concretes are increasing day by day due to their superior structural performance, environmental friendliness, and energy conserving implications. Although concrete is generally believed to be an excellent fireproofing material, but there is extensive damage or even catastrophic failure at high temperatures. These materials can also improve the durability of concrete and the rate of gain in strength and can also reduce the rate of liberation of heat, which is beneficial for mass concrete. There are changes in the properties of concretes, particularly in the range of 100–300 °C. Above 300°C, there is decrease in mechanical characteristics. The behavior of concrete subjected to high temperatures is a result of many factors; such as heating rate, peak temperatures, dehydration of C–S–H gel, phase transformations, and thermal incompatibility between aggregates and cement paste. On the other hand, quality control of concrete, by means of non-destructive methods, in structures subjected to fire or not so high temperature exposure conditions, is not particularly easy to be carried out. The correlation already exists usually refers to the hydration age of 28 .

Damage Mechanisms of Concrete under Fire The effects of high temperatures on high strength concrete (HSC) materials have also been studied since the past decade. Although there are significant differences between normal and high strength concretes in fire performance, their thermal damages (crack formation, explosive spelling, and degradation of mechanical/durability properties) are similar and mainly arise from (i) thermal mismatch, (ii) decomposition of hydrates, and (iii) pore pressure.

2. Experimental Method

The main objective of testing was to know the behaviour of concrete with replacement of cement with high volume fly ash at elevated temperature up to 120˚C.The main parameters studied were compressive strength, split tensile strength, modulus of elasticity. The materials used for casting concrete samples along with tested results.

2.1 Cement

Table 2.1: Properties of cement.

S. No.	Characteristics	Values obtained	Standard value
1	Normal consistency	34%	-
2	Initial setting time (minutes)	48 min.	Not less than 30
3	Final setting time (minutes)	240 min	Not greater than 600
4	Fineness (%)	3.5 %	<10
5	Specific gravity	3.07	-

2.2 Coarse aggregates

Locally available coarse aggregates having the maximum size of 10 mm and 20mm were used in the present work. The 10mm aggregates used were first sieved through 10mm sieve and then through 4.75 mm sieve and 0mm aggregates were firstly sieved through 20mm sieve. They were then washed to remove dust and dirt and were dried to surface dry condition. The aggregates were tested per Indian Standard.

Table 2.2: Properties of Coarse aggregates.

S. No.	Characteristics	Value
1	Type	Crushed
2	Maximum size	20 mm
3	Specific gravity (10 mm)	2.704
4	Specific gravity (20 mm)	2.825
5	Total water absorption (10 mm)	1.6432 %
6	Total water absorption (20 mm)	3.645 %
7	Moisture content (10 mm)	0.806 %
8	Moisture content (20 mm)	0.7049 %
9	Fineness modulus (10 mm)	6.46
10	Fineness modulus (20 mm)	7.68

2.3 Fine Aggregate

The sand used for the experimental programme was locally procured and conformed to rading zone III. The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and then was washed to remove the dust. The fine aggregates were tested per Indian Standard Specifications IS: 383-1970

Table 2.3: Properties of fine aggregates.

S. No.	Characteristics	Value
1	Type	Uncrushed (natural)
2	Specific gravity	2.68
3	Total water absorption	1.02 %
4	Moisture content	0.16 %
5	Net water absorption	0.86 %
6	Fineness modulus	2.507
7	Grading zone	III

2.4 Fly ash

Investigations were made on fly ash procured from Thermal Power Plant, Panipat, Haryana. It was tested for chemical and physical properties per ASTM C 311.The chemical and physical properties of the fly ash used in the investigation.

Table 2.4: Chemical Composition of Fly Ash.

S. N.	Particulars	Requirement ASTM C 618 (%)	Test Results (%)
1	$(SiO_2+Al_2O_3+Fe_2O_3)$, %	70.0 min	91.69
2	SiO_2, %	35.0 min	59.08
3	MgO	5.0 max	0.36
4	Sulphuric Anhydride, %	3.0 max	0.11
5	Total Alkali as Na_2O, %	1.5 max	0.62
6	Total Loss on Ignition, %	5.00 max	2.08

Table 2.5: Physical Properties of Fly Ash.

S. N.	Particulars	Requirement ASTM C 618	Test Results
1	Fineness Specific Surface (cm2/gm)	3200 min	3258
2	Residue on 45 micron (wet sieving)	34 max	30.17
3	Lime Reactivity (kg/cm2)	45 min	51.03
4	Compressive strength (kg/cm2), 28 days	Not less than 80% of strength of corresponding plain cement Mortar cubes	85.99
5	Dry shrinkage, %	0.15 max	0.04
6	Soundness expansion by auto clave, %	0.8 max	0.03

3. Results and Discussion

Temperature is one of the main factors that influence the strength. High temperature induces a loss of strength (both in compression and tension) and stiffness (Young's modulus). At high temperatures, chemical transformation of the gel weakened the matrix bonding, which brought about a loss of strength of fly ash concrete.

3.1 Compressive Strength

In this research, the values of compressive strength for different fly ash contents (0%, 30%, 40% and 50%) incorporating different temperature (40ºC, 80ºC ,100ºC, and 120ºC) at the end of different curing periods (28 days, 56 days) are given. The results have also been plotted .which shows the variation of compressive strength with cement replacements at different curing ages respectively and variation of compressive strength for different fly ash percent incorporating different degree of temperature. The compressive strength was calculated as the average of three cylinder tests. It is evident that compressive strength of concrete mixtures with 30%, 40% and 50 % of fly ash as cement replacement was lower than the control mixture (M-0) at all ages and that the strength of all mixtures continued to increase with the age. With the increase in temperature, compressive strength of concrete mixes with 30%, 40% and 50 % of fly ash as cement replacement decreased. compressive strength decreased with the increase fly ash at different temperature. Compressive strength also decreased with the increase in temperature.

Table 3.1: Compressive Strength (MPa) of Fly Ash Concrete.

Fly Ash Content, %	Temperature,ºC	Designation	Compressive Strength, MPa	
			28 DAYS	56 DAYS
0	N	M-0	23.0	29.4
0	80	M-1	22.9	27.0
0	100	M-2	19.3	26.5
0	120	M-3	17.6	26.0
30	N	M-4	16.2	25.2
30	80	M-5	13.3	20.5
30	100	M-6	12.1	19.7
30	120	M-7	10.8	17.6
40	N	M-8	15.4	20.4
40	80	M-9	14.3	17.9
40	100	M-10	12.9	17.8
40	120	M-11	12.8	14.5
50	N	M-12	10.8	13.3
50	80	M-13	10.5	12.2
50	100	M-14	8.9	11.3
50	120	M-15	8.4	9.6

3.2 Split tensile strength

It was found that split tensile strength of Class F fly ash concrete (using 30 %, 40 % and 50 % fly ash and a w/c of 0.5) at different temperature depended on the percentage of fly ash used and temperature. The variation of split tensile strength. the variation in splitting tensile strength with fly ash content and temperature was similar to that observed in case of compressive strength the variation of split tensile strength with replacements with Class F fly ash at various temperatures (40ºC, 80ºC, 100ºC, and 120ºC).shows that split tensile strength decreased with the increase fly ash at different temperature. It also decreased with the increase in temperature.

Table 3.2: Split tensile strength (Map) of Fly Ash Concrete.

Fly Ash Content, %	**Temperature,ºC**	**Designation**	**Split tensile strength,MPa**	
			28 DAYS	**56 DAYS**
0	N	M-0	2.8	3.0
0	80	M-1	2.0	2.8
0	100	M-2	1.9	2.5
0	120	M-3	1.6	2.4
30	N	M-4	1.7	2.7
30	80	M-5	1.4	2.3
30	100	M-6	1.3	2.2
30	120	M-7	1.2	2.0
40	N	M-8	1.4	2.1
40	80	M-9	1.1	1.6
40	100	M-10	1.0	1.5
40	120	M-11	0.7	1.3
50	N	M-12	0.7	1.4
50	80	M-13	0.6	1.1
50	100	M-14	0.5	0.9
50	120	M-15	0.3	.07

3.3 Modulus of elasticity

In this investigation, the modulus of elasticity, which is also called secant modulus, is taken as the slope of the chord from the origin to some arbitrary point on the stress-strain curve. The secant modulus calculated in this study is for 33% of the maximum stress. Modulus of elasticity of concrete mixtures was determined at the ages of 28 and 56 days. the variation of modulus of elasticity with replacements with Class F fly ash at various temperatures (40ºC, 80ºC, 100ºC, and 120ºC). Test results indicated that the use of large proportion of fly ash reduced the modulus of concrete compared to that of control mixture. It also decreased with the increase in temperature.

Table 3.3: Modulus of elasticity (GPa) of Fly Ash Concrete.

Fly Ash Content, %	Temperature,°C	Designation	Modulus of elasticity, GPa	
			28 DAYS	56 DAYS
0	N	M-0	17.6	26.2
0	80	M-1	15.1	21.3
0	100	M-2	14.7	17.8
0	120	M-3	11.6	16.4
30	N	M-4	10.9	19.4
30	80	M-5	9.6	16.3
30	100	M-6	9.5	16.2
30	120	M-7	9.9	15.8
40	N	M-8	7.7	15.8
40	80	M-9	6.9	15.4
40	100	M10	6.1	15.3
40	120	M-11	5.1	15.2
50	N	M-12	5.9	8.5
50	80	M-13	5.7	7.9
50	100	M-14	4.8	7.7
50	120	M-15	4.4	7.6

4. Conclusions

1. Compressive strength of concrete decreased with the increase in cement replacement with Class-F fly ash. However, at each replacement level of cement with fly ash, an increase in strength was observed with the increase in age.
2. With the variation of temperature compressive strength changed. With the rise in temperature from room temperature to 120˚C, compressive strength decreased
3. Splitting tensile strength and modulus of elasticity increased with increase in age at each replacement level of cement with fly ash up to 50% but they were decreased with increase in volume of fly ash.
4. Increase in temperature up to 120˚C decreased the splitting tensile strength and modulus of elasticity, this is due to the chemical transformation of the gel weakened the matrix bonding, which brought about a loss of strength of fly ash concrete at high temperatures.
5. The specimens failed after the formation of a number of longitudinal (vertical) cracks in the loading direction, and no shear type failures occurred.

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