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A Study on Flexural Behaviour of RCC Beams Containing High Volume Fly Ash

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Abstract: *Fly ash is a waste product generated by coal burning power plants. The disposal of fly ash is one of the major issues as dumping of fly ash as a waste material may cause severe environmental problems. Fortunately the discovery made several years back that fly ash can be used as a partial replacement for cement in concrete. This paper deals with an experimental study on the mechanical properties of concrete and the flexural behaviour of Reinforced Cement Concrete (RCC) Beams containing high volume fly ash. In this experiments M_{20} grade of concrete (1:2.3:3.3) is used with w/c ratio 0.556 for various compositions of fly ash replacement to cement (0%, 30%, 50%, and 70%). The test specimens are cast, cured for 28 days and tested under standard conditions. The Comparison of flexural response of beams are made with ordinary portland cement concrete (OPCC) and high volume fly ash concrete (HVFAC) for various compositions of fly ash replacement to cement at the same percentage of reinforcement. After testing it is observed that up to 50% fly ash replacement, the compressive and flexural strength of concrete decreases slightly, but from 50 to 70% the strengths are abruptly fallen and there is no much variation in deflection and it is under serviceability limits as per IS456-2000 up to 70% replacement of cement.*

Key Words: *Flexural behaviour, high volume fly ash concrete (HVFAC), RCC Beams, ordinary Portland cement concrete (OPCC), flexural strength.*

I. Introduction

Concrete is one of the widely used common construction material. Every year, concrete consumes 12.6 billion tonne of natural raw materials. This huge rate of consumption of the natural raw material creates several ecological problems. In India around 320 million tonne of cement is produced every year. On the other hand, safe disposal of huge amounts of fly ash produced (more than 115 million tonne / year) by Indian coal fired thermal power plants is a cause of national concern. The acceptance of fly ash in Indian construction industry is gaining popularity but at very slow rate due to various reasons. In construction industry, it is mostly used in the form of Portland pozzolana cement. The current fly ash utilization rate is about 30%. The concept of high-volume fly ash concrete in Indian construction industry is yet to get acceptance. The Indian construction industry is yet to open its doors for the acceptance of this eco-friendly concrete containing 50% to 70% of fly ash of total cementitious material. The present study on high volume fly ash concrete, which involves replacement of 30%, 50% and 70% of Portland cement by fly ash on mass basis. It seems to be more than 50% replacement of ordinary Portland cement with fly ash may be suitable for the Indian construction industry due to abundant availability of it at very cheap cost and the favorable climatic conditions; hence this technology may become the best solution for high value, high rate utilization of fly ash.

II. Materials

2.1 Ordinary Portland Cement

In the experimental investigations, 53-grade of ordinary Portland cement of Ultra-tech Brand is used. The cement thus procured was tested for physical properties in accordance with the IS: 4031-1968 and found to be conforming various specifications of IS 12269-1987.

2.2 Fine Aggregate

In the present investigation, fine aggregate used is obtained from local sources. The sand is made free from clay matter, silt, and organic impurities and sieved on 4.75mm IS sieve. The physical properties of fine aggregate like specific gravity, bulk density, gradation and fineness modulus are tested in accordance with IS: 2386 and the results are shown in table 1 and 2. Grain size distribution of sand shows it is close to Zone II of IS 383-1970.

2.3 Coarse Aggregate

The crushed angular aggregate of 20mm maximum size obtained from the local crushing plants is used as coarse aggregate in the present study. The physical properties of coarse aggregate such as specific gravity, bulk density, gradation, flakiness, elongation index and sieve analysis are tested in accordance with IS: 2386-1963. The results of coarse aggregate are shown in the table 3 and table 4. The presence of elongated and flaky particles is 20% and 16.47% of the weight of the coarse aggregate. This shows that the coarse aggregate used in the concrete mixes is considered desirable as the indices are within 10-25%.

2.4 Fly Ash

In the present study of work, the Class F-fly ash is used, which is obtained from Vijayawada thermal power station in Andhra Pradesh. The specific surface area of fly ash is found to be 4750 cm^2/gm by Blain's Permeability Apparatus. The typical composition of fly ash and chemical requirements are shown in table 5 and table 6 respectively.

2.4 Water

Water free from chemicals, oils and other forms of impurities has been used for mixing of concrete as per IS: 456:2000.

III. Experimental Investigation

3.1 General

The present investigation is aimed to study the properties like compressive, flexural strength and flexural behavior of RCC beams made with same percentage of reinforcement for the different composition of fly ash replacement to cement for M_{20} grade of concrete (*1:2.3:3.3* with water cement ratio of 0.556). The test specimens were cast for various compositions of Fly Ash replacement to cement (0%, 30%, 50%, and 70%). The test specimens are cast, cured for 28 days and tested under Standard conditions on 28^{th} day. For each composition, set of 3-beams of size 100mm*100mm*500mm without reinforcement for testing flexural strength and set of 3-beams of size 1.8m in length and 225 x 225 mm in cross section with reinforcement for each composition to study the flexural behavior of RCC beams. The various combinations used in this experiment are given in table 7. The results are tabulated and the required comparative study is done.

3.2 Reinforcement Details

All the Twelve Reinforced cement concrete beams made up of 4 nos. of 12mm dia. bars, 2 nos. at top and 2 nos. at bottom with secondary reinforcement as 6mm at 150mm c/c as shown in fig 1. The beams are cured for 28 days and tested on 28^{th} day.

3.3 Mixing of Concrete

3.3.1 Ordinary Concrete

In the present study the machine mixing process was employed. In the process of mixing the materials are weighed exactly with their proportions and thoroughly mixed in their dry condition before water is added. The prepared mix was then immediately used for casting cubes and RCC beams.

3.3.2 Blended Cement Concrete

The fly ash and cement are thoroughly mixed in exact proportion for each batch and then the mixture was poured in to rotating drum which consists of aggregates in dry condition. The prepared mix was then immediately used for casting cubes and RCC beams. For the various percentage of fly ash, the detailed weight of cement and fly ash used in this study are shown in table 8.

IV. Test Results

4.1 Compressive Strength

Compressive strength of the cubes is given in table 9. From the table it is observed that the Compressive strength is not changing invariably from 0% to 50% of Fly ash, but from 50% to 70% of Fly ash it is fallen abruptly.

4.2 Flexural Strength

Flexural strength of the beams is given in table 10. From the table it is observed that the Flexural strength is not changing invariably from 0% to 50% of Fly ash, but from 50% to 70% of Fly ash it is fallen abruptly.

4.3 Flexural Behavior of RCC Beams

The Flexural behavior of RCC beams can be studied from the fig 2. From this figure it is observed that the deflection is not changing invariably from 0% to 70% of Fly ash.

According to IS 456-2000 clause 23.2, the deflection should not normally exceed span/350 or 20 mm whichever is less.
The effective span of the beam = 1500mm
Permissible deflection = l/350=1500/350
4.29 mm or 20 mm whichever is less
From the fig 2, it is observed that the deflection is still less than 2mm when the cement being replaced by fly ash even up to 70%, so the test specimens are safe against the deflection.

Table 1: Physical Properties of Fine Aggregate

S.No	Properties		Test Results
1	Specific Gravity		2.63
2	Bulk Density	Loose	1597 Kg/m3
		Compacted	1725 Kg/m3

Table 2: Sieve Analysis on Fine Aggregate
Quantity of fine aggregate for sieve analysis = 1000gms

S.No	IS Sieve No	Weight Retained (gm)	Percentage Weight Retained	Cumulative Percentage Weight retained	Percentage Weight passed
1	40mm	0	0	0	100
2	20mm	0	0	0	100
3	10mm	0	0	0	100
4	4.75mm	3.5	0.35	0.35	99.65
5	2.36mm	15	1.5	1.85	98.15
6	1.18mm	96	9.6	11.45	88.55
7	600µ	430	43	54.45	45.55
8	300µ	420.5	42.05	96.5	3.5
9	150µ	35	3.5	100	0
Total				264.6	

Fineness modulus of fine aggregate = Cumulative percentage retained/100
= 264.6/100 = 2.65

Table 3: Physical Properties of Coarse Aggregate

S.No	Properties		Test Results
1	Specific Gravity		2.63
2	Bulk Density Kg/m3	Loose	1597 Kg/m3
		Compacted	1725 Kg/m3
3	Elongation Index (%)		20
4	Flakiness Index (%)		16.47

Table 4: Sieve Analysis on Coarse Aggregate
Quantity of fine aggregate for sieve analysis = 5000gms

S.No	IS Sieve No	Weight Retained (gm)	Percentage Weight Retained	Cumulative Percentage Weight retained	Percentage Weight passed
1	40mm	0	0	0	100
2	20mm	400	8	8	92
3	10mm	3715	74.3	82.3	25.70
4	4.75mm	885	17.7	100	82.30
5	2.36mm	0	0	100	100
6	1.18mm	0	0	100	100
7	600µ	0	0	100	100
8	300µ	0	0	100	100
9	150µ	0	0	100	100
Total				717.32	

Fineness modulus of fine aggregate = Cumulative percentage retained/100
= 717.32/100 = 7.17

Table 5: Typical Oxide Composition of Fly Ash

S.NO.	Constituent	Percentage
1	CaO(Lime)	0.7-3.6
2	SiO_2(Silica)	49-67
3	Al_2O_3(Alumina)	16-28
4	Fe_2O_3(iron oxide)	4-10
5	MgO(magnesia)	0.3-2.6
6	SO_3(Sulphur trioxide)	0.1-1.9
7	Surface area m^2/kg	230-600

Table 6: Chemical Requirement of fly ash (IS: 3812-part 1 2003)

S.NO.	Characteristics (Percent by mass)	Minimum Requirement in %	Composition of VTPS fly ash in %
1	$SiO_2 + Al_2O_3 + Fe_2O_3$	70	86.75
2	SiO_2	35	54
3	Reactive Silica	20	25
4	MgO	5	7
5	SO_3(Sulphur trioxide)	3	6
6	Available alkali as sodium oxide (Na_2O)	1.5	2.16
7	Loss of ignition	5	7.23

Table 7: Various Combinations Used

S.No.	% of Cement	%Fly Ash
1	100	0
2	70	30
3	50	50
4	30	70

Table 8: Quantities of Cement and Fly Ash per Cubic Meter of Concrete (M20)

S.No.	% of Fly Ash in Cement	Quantity of Cement(kg)	Quantity of Fly Ash(kg)
1	0	320	0
2	30	224	96
3	50	160	160
4	70	96	224

Table 9: Test Results of Compressive strength

S.No.	% of Fly Ash	% of Cement	Compressive strength (N/mm2)
1	0	100	37.02
2	30	70	33.27
3	50	50	30.36
4	70	30	10.24

Table 10: Test Results of Flexural strength

S.No.	% of Fly Ash	% of Cement	Flexural strength (N/mm^2)
1	0	100	3.35
2	30	70	2.99
3	50	50	2.73
4	70	30	0.92

Fig 1: Reinforcement Details of Beams

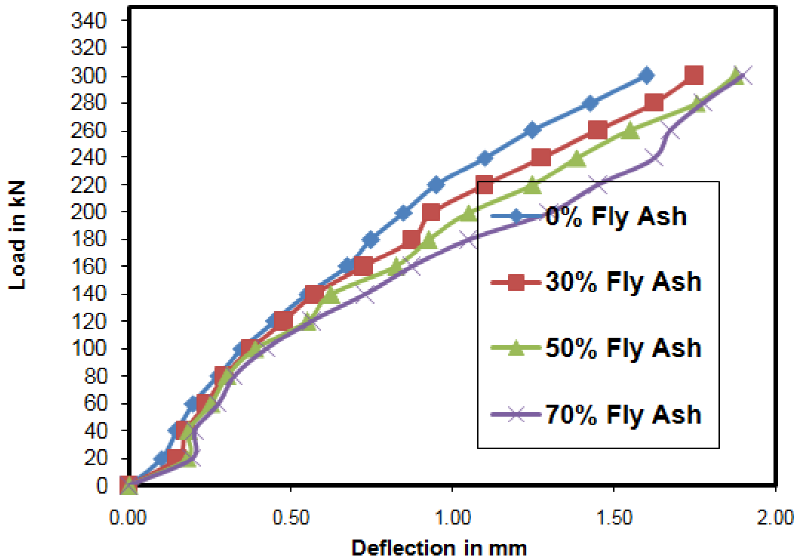

Fig 2: Figure shows Load verses Deflection for different % of Fly Ash replacement to Cement in RCC Beams

Fig. 3: Experimental set-up for the test specimen

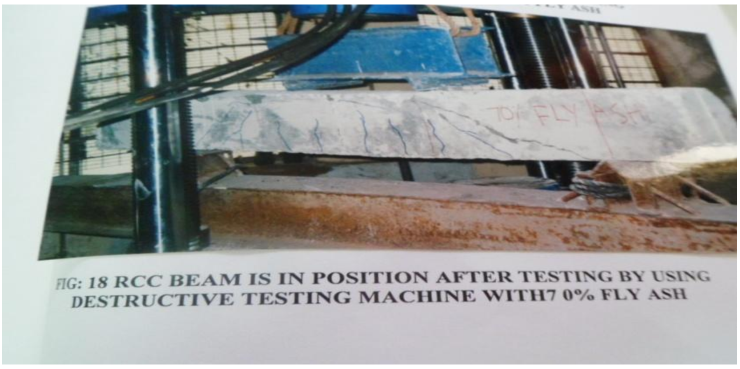

Fig. 4: Failure Pattern of the beams with 70% Fly Ash

V. Conclusions

1. It can be concluded that even though a slight decrease in compressive strength when the cement being replaced up to 50% with fly ash, which is still more than the target mean strength so that a concrete can be used for various structural applications in the construction industry.
2. It is observed that the RCC beams underwent deflection, but the deflection is under serviceable limits as per IS 456-2000 even though the replacement of fly ash is about 70% to cement.
3. It is observed that the strengths have suddenly fallen from 50% to 70% replacement of cement with fly ash, for more economical purpose the concrete may be used for non-structural works by replacing cement with fly ash up to 70%, so that about 34% saving in cost per cubic meter of concrete
4. The deflections under the service loads for the RCC beams with 50% fly ash are same as that of the controlled beams at 28 days testing.

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