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Strength and Behaviour of High Volume Fly Ash Concrete

Mini Soman[1] Sobha.K[2]

Associate Professor, College of Engineering, Trivandrum, Kerala, India.

Asst. Engineer, University of Kerala, India.

Abstract: Fly ash is a waste product generated by coal burning power plants. It has been generally used for land filling. However in places where regulations preventing atmospheric pollution do not exist, it is billowed into the atmosphere. Fortunately the discovery made several years back that fly ash can be used as a partial replacement for cement in concrete.

The present study aims at developing a concrete by replacement of Ordinary Portland Cement (OPC) with 50% Fly Ash by mass. The fresh and hardened properties of High Volume Fly Ash Concrete (HVFAC) with 50% replacement of cement and Ordinary Portland Cement Concrete (OPCC) are studied. The study discloses that high volume of Fly Ash in concrete reduces the water demand and improves the workability. Study also reveals that the OPCC and HVFAC exhibits similar hardened properties. Comparison of flexural response of beams made with OPCC and HVFAC with different percentage of reinforcement are also studied. It is observed that HVFAC beams have shown notable improvement in the deflection , cracking behaviour and load carrying capacity**.**

Keywords: Ordinary Portland Cement; High Volume Fly Ash Concrete; Flexural response.

I. INTRODUCTION

FLY ASH generated by the burning of coal in coal fired power plants was considered till a few years back as mere waste material. This was considered as a material of very low value, useful only for land fill. But its usefulness as pozzolonic additive to cement is an important discovery. Continuous research studies by various engineering research laboratories revealed its varied usefulness as an additive for enhancing the various qualities of concrete including its workability, strength and durability if handled and cared properly. Partial replacement of cement with fly ash in concrete save much of the energy required for production of OPC and also facilitates the economical disposal of millions of tons of fly ash.

At present most of the fly ash blended cements commercially produced in India has 18 to 25% fly ash by weight and addition of fly ash to this extent has a beneficial effect on the workability and economy of concrete. It has been found that in order to improve the other qualities of concrete like resistance of sulfate attack and thermal cracking, larger percentage of fly ash is to be used in concrete. Fly ash content greater than 35% can be considered as high volume replacement or high blending. The seven storey structure of 10780m^2 office space in Canada was constructed with HVFAC having compressive strength 30-50N/mm^2 [4].

II. RELATED WORK

Previous studies reveals that the addition of fly ash in concrete resulted in great benefits such as reduction in heat of hydration, minimization of potential alkali aggregate reaction, significant reduction of steel corrosion, improvement in durability of concrete, reduction in cost etc. [1, 9, 11, 12, 13, 14, 15, 16]. In addition, it improves the environment by contributing towards reduction of greenhouse gases [2]. The objective of this investigation is to study the effect of high volume of fly ash in the fresh and hardened properties of concrete and to study the flexural response of HVFAC beams in comparison with OPCC beams.

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III. PRELIMINARY INVESTIGATION

The preliminary experimental investigation consists of test on constituent materials, development of fly ash mixed concrete and determination of fresh and hardened properties of HVFAC and OPCC.

A. *Test on constituent materials*

Cement: Cement used in all mixes is OPC (53 grade), which conforms to IS specification [3]. Laboratory tests are conducted on cement to determine its standard consistency, initial setting time, final setting time and compressive strength. The standard consistency of the cement used is 31%.

Fine Aggregate: Commercially available M-Sand passing through 4.75mm IS sieve and conforming to zone II of IS 383-1970 is used. All physical properties as per IS recommendation [4] are determined. Specific gravity and fineness modulus of M-Sand used are 2.45 and 2.53 respectively.

Coarse Aggregate: 20mm downgraded aggregate is used for the study. The properties of coarse aggregate conformed to the IS specification [4, 5]. Specific gravity of the coarse aggregate used is 2.78.

Water: Potable water is generally considered as being acceptable. Hence clean drinking water available in the college water supply system is used for casting as well as curing of the test specimens.

Super plasticizer (SP): Sulphonated Naphthalene Formaldehyde Super plasticizer is used for the study. The dosage used is 0.40% of powder content.

Reinforcement: HYSD bars of 12mm, 8mm and 6mm diameters and ultimate strength 785.56N/mm^2,630N/mm^2 and 610.64N/mm^2 respectively are used for the study. The moduli of elasticity of bars are 2x10^{5}N/mm^2 and the percentage elongations of the bars are in the range of 25-30%.

Fly ash: The fly ash collected from HI- TECH Fly Ash (India) Private Limited, Tuticorin is used for the study. IS 456:2000 specifies that ‘Fly ash conforming to Grade I of IS 3812 [6] may be used as part replacement of mixing Portland Cement, provided uniform blending with cement is ensured’. The chemical and physical properties of fly ash provided by the supplier are given in Table I and Table II.

Table I. Chemical Properties of Fly ash

Sl. No	Constituents	Percentage
1.	$SiO_2+Al_2O_3+Fe_2O_3$	94.25
2.	Sulphur trioxide as SO_3	0.71
3.	Sodium oxide as Na_2O	0.26
4.	Loss On Ignition	0.38
5.	Silica as SiO_2	59.90
6.	Alumina as Al_2O_3	30.81
7.	Iron as Fe_2O_3	3.83
8.	Reactive SiO_2	30.01
9.	Calcium oxide as CaO	1.94
10.	Free CaO	Nil
11.	Reactive CaO	1.44
12	Chloride as Cl	0.009
13	Magnesium oxide as MgO	0.36
14	Manganese dioxide as MnO_2 (mg/Kg)	12.38
15	Potassium oxide as $K_2OP_2O_5$(mg/Kg)	0.031

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Table II. Physical Properties of Fly ash

Sl. No	Physical parameters	Values
1.	Fineness residue retained on 325 mesh sieve (%)	9.02
2.	Moisture content (%)	0.080
3.	Comparative compressive strength at 28 days with OPC (%)	91.90
4.	Initial setting time (OPC/Pfa) (minutes)	150/170
5.	Soundness by Le Chateliers expansion (mm)	0.70
6.	Particle density (kg/cum)	2150

B. *Mix proportioning*

M_{40} mix is designed based on the guidelines given by IS 10262-2009 [7]. Several trial mixes are made with 20%, 30%, 40%, 50% and 60% replacement of cement with fly ash and it is observed that a maximum of 50% cement could be replaced with fly ash with out affecting fresh and hardened properties.

Hence HVFAC with 50% replacement is selected for further study. The mix designations and the material requirements are shown below in the Table III.

Table III. Mix Designations and Material Requirements

Designation	F0	F50
% replacement of cement by fly ash (kg/m^3)	0	50
Cement (kg/m^3)	400	200
Fly ash (kg/m^3)	-	200
Water (ltr)	160	140
Fine Aggregate (kg/m^3)	692	662
Coarse aggregate (kg/m^3)	1241	1115
Super plasticizer (kg/m^3)	1.60	1.60

Studies conducted on fresh properties of OPCC and HVFAC are given in Table IV. From the results, it can be seen that HVFAC is more workable than OPCC.

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Table IV. Properties of Fresh Concrete

Sl. No.	Properties	F0	F50
1.	Slump(mm)	30	50
2.	Compaction factor	0.84	0.90

Cube compressive testing is done on 3rd, 7th, 28th, 56th and 90th day. Splitting tensile strength, Young's Modulus and flexural strength of concrete mixtures are determined at the age of 28 days. The hardened properties are tabulated in Table V and the graphical variation of cube compressive strength of F0 and F50 is shown in Fig.1.

Table V. Properties of Hardened Concrete

Sl. No.	Properties (N/mm^2)	Age of testing (days)	F0	F50
1.	Compressive strength	3	22.22	17.77
		7	31.11	25.92
		28	48.29	47.11
		56	49.11	50.22
		90	50.22	51.11
2	Young's Modulus	28	36900	35500
3	Flexural strength	28	5.65	5.65
4	Split tensile strength	28	4	4.50

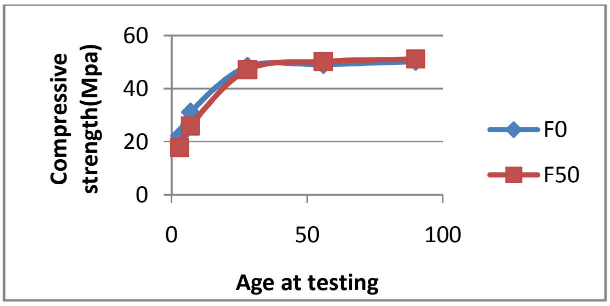

Fig. 1.Variation of compressive strength with age.

The results show that the early strength of fly ash mixed concrete is less compared to control mix but at 28 days the strength of fly ash mixed concrete is similar to that of control mix. The results at 56 and 90 days indicates that there is continuous and significant improvement in strength after 28 days.

Splitting tensile strength increased with the increase in fly ash content. This could be attributed to the pozzolanic action due to fly ash. Test results for flexure and modulus of elasticity indicate that addition of fly ash does not affect much on the results compared to control mix.

IV. EXPERIMENTAL PROGRAMME

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The test programme is designed to study the flexural response of reinforced HVFAC beam and to compare its behaviour with that of similar conventional reinforced concrete beams. Beams of size 100mmx150mm and 1200mm long are cast with different reinforcement percentages. The reinforcement details of the beams are shown in Fig.2. The reinforcements are provided as balanced and under reinforced section based on the provisions of IS code [8]. For each type, 3 beams are cast.The details of beams cast are given in Table VI.

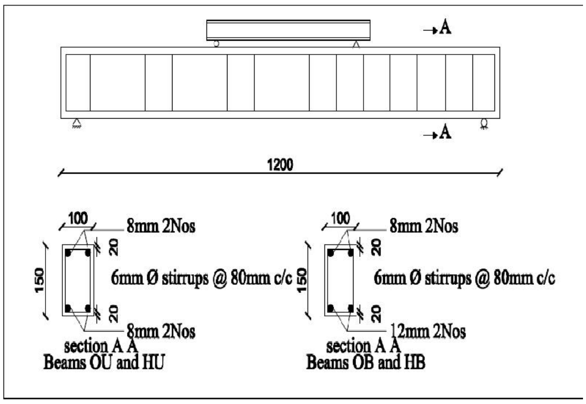

Fig. 2. Details of the reinforcement for beam

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Table VI. Details of the RC Beam Specimens

Beam designation	Type of Concrete	Section	Reinforcement at Bottom	Reinforcement at Top
OU	OPCC	Under reinforced	2 Nos, 8mm	2 Nos, 8mm
OB	OPCC	Balanced	2 Nos, 12 mm	2 Nos, 8mm
FU	HVFAC	Under reinforced	2 Nos, 8mm	2 Nos, 8mm
FB	HVFAC	Balanced	2 Nos, 12 mm	2 Nos, 8mm

Moulds for casting beams are made of waterproof plywood. Concrete is mixed in a concrete mixer in the laboratory. The beams are vibrated with a mechanical vibrator. The formwork of beams are demoulded after 24 hours after casting and cured by ponding. After 28 days, the beams are white washed for easy detection of cracks.

A. *Test Set Up*

The specimens are tested in a compression under two point loading with a clear span of 1m as shown in Fig.3.

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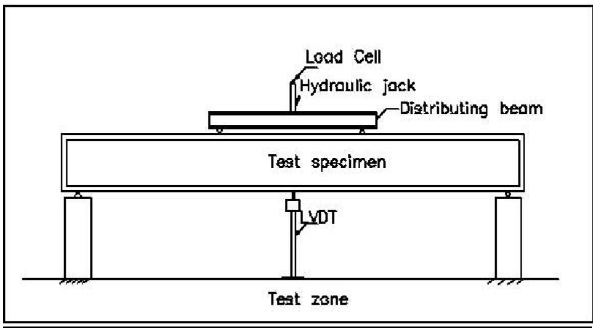

Fig. 3. Test Set Up

The load is applied by hydraulic jack and measured using 50 T Load Cell. A LVDT is used to measure the mid span deflection which is connected through a data acquisition system. The crack widths are measured with the help of a crack detection microscope of least count 0.02mm.

The following observations are made.

1. First crack load
2. Mid span deflection at each load increment.
3. Ultimate load
4. Crack Pattern

B. *Results and discussions*

First crack load is noted as the load at which a crack is observed visually. This agrees with the point at which load deflection graph deviates from linearity, as shown in Fig.4 and Fig.5.

Table VII. First crack load and ultimate load

Beam no.	First crack Load (KN)		Gain factor	Ultimate Load (KN)		Gain factor
	Load	Average		Load	Average	
Under reinforced beams						
OU1	10	11.67	1	45	45	1
OU2	15			45		
OU3	10			45		
FU1	25	23.33	1.99	60	56.66	1.26
FU2	20			50		
FU3	25			60		
Balanced beams						
OB1	15	18.33	1	60	61.66	1
OB2	20			65		
OB3	20			60		
FB1	40	33.33	1.82	87	82.33	1.33
FB2	30			80		
FB3	30			80		

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Load-deflection plots of balanced beams and under reinforced beams at mid span are shown in Fig. 4 and Fig. 5 respectively.

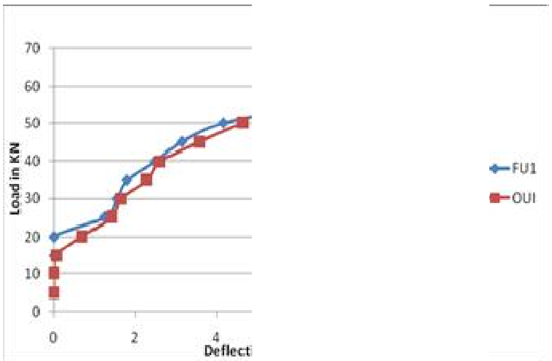

Fig. 4. Load Deflection Curves of Under Reinforced HVFACand OPCC Beams in Flexure at Mid Span

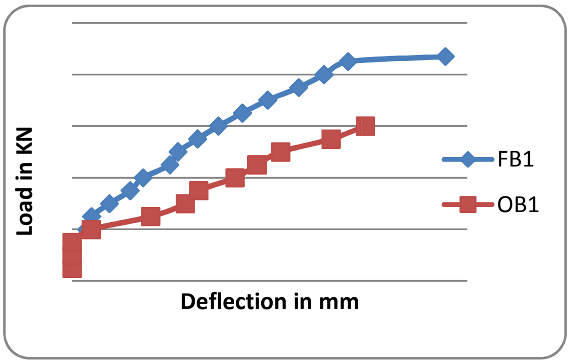

Fig. 5. Load Deflection Curves of Balanced HVFAC and OPCC Beams in Flexure at Mid Span

The load deflection curves in Fig.1 and Fig.2 shows that the mid span deflection of HVFAC beams are less when compared to OPCC beams at all load levels. The total cracks developed, maximum and minimum spacing between cracks and maximum crack width are also determined and tabulated in Table VIII.

Table VIII. Crack details

Description	FU1	FB1	OU1	OB1
Total cracks developed	15	23	21	32
Maximum spacing between cracks (mm)	95	100	95	110
Minimum spacing between cracks(mm)	65	55	45	35
Max Crack Width at failure(mm)	1	1	2	2

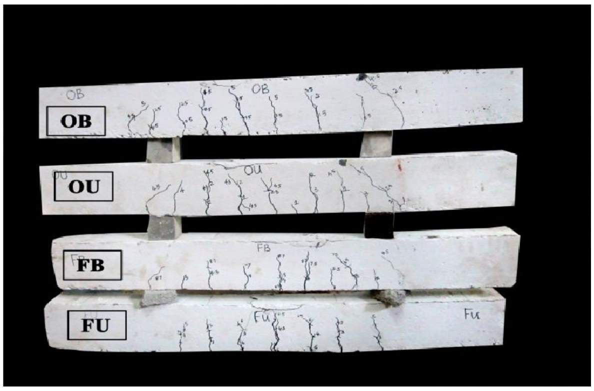

Fig 6. Crack pattern of beams after testing.

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The strength and cracking behaviour reveals that HVFAC beams exhibit more strength and less cracking compared to OPCC beams. From the load deflection plots it can be observed that the deflection of HVFAC beam is less than OPCC beams at all load levels. The area under load deflection plot which is a measure of energy absorption capacity is also higher for HVFAC beams.

V. COST COMPARISON

The cost of cement per cubic meter concrete is taken in to consideration. From the mixture proportion of OPCC and HVFAC used in this investigation, it is evident that in one cubic meter of concrete, the control mix uses 400 kg of cement, while HVFAC uses only 200kg of cement.

The material cost for fly ash is negligible since it is an industrial waste and the conveyance charge is taken as Rs.1.00/kg. For a developing country like India the savings in cost will be great step for the infrastructural development. The costs are estimated based on the actual purchase rate and the cost comparison is given in Table IX.

Table IX. Cost comparison

Ingredients	F0 Qty /m^3 (Kg)	F50 Qty /m^3 (Kg)	Cost /m^3 (Rs.)	Material cost of F0/m^3 (Rs.)	Material cost of F50/m^3 (Rs.)
Cement	400	200	6.40	2560	1280
Fly Ash	-	200	1.00	-	200
Fine aggregate	692	662	1.50	1038	993
Coarse aggregate	1241	1115	1.30	1613.30	1449.50
Super plasticizer	1.60	1.60	100	160	160
Total				5371.30	4082.50

From the Table IX it is clear that site mixed OPC with 50% fly ash concrete is 24% cheaper than OPCC. Hence, the fly ash which otherwise creates an environmental nuisance can be used in a productive way contributing to sustainable development.

VI. CONCLUSION

Based on the investigation conducted following conclusions can be arrived at.

1. Addition of fly ash improves the workability of concrete.
2. Addition of 50% fly ash reduces 7 day strength by about 20% when compared to control mix. But it acquires strength almost equal to that of control mix at 28 days and attained higher strength thereafter.
3. All hardened properties are similar for OPCC and HVFAC at 28 days.
4. The first crack load and ultimate load are more for HVFAC beams with different reinforcement compared to OPCC beams.
5. The load deflection curve shows that the mid span deflection of HVFAC beams are less when compared to OPCC beams at all load levels.
6. Cracking behaviour studies indicate that HVFAC beams are more crack free compared to OPCC beams
7. Cost comparison reveals that site mixed OPC with 50% fly ash concrete is 24% cheaper than OPC concrete.
8. From the studies it is found that the fly ash can be considered as resource material and can be used in a productive way contributing to sustainable development.

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REFERENCES

[1] AnilBanchhor and S. Krishnan, “Evaluating the effectiveness of fly ash incorporation as PPC vis-à-vis separated addition to the site-mixed OPC Concrete”. The Indian concrete Journal, April 2006, pp. 17-26.
[2] Deepak Juneja, “High Volume Flyash Concrete for the Reduction of Greenhouse Gases”. – CE &CR Feb 2009, pp. 34-43.
[3] IS 12269-1987. Specification for 53 grade Ordinary Portland Cement, Indian Standard Code on Properties of Cement.
[4] IS 383-1970, Specification for Coarse and Fine Aggregates from Natural Sources for Concrete. (Second Revision).
[5] IS 2386 Part III-1963, Mehods of Test for Aggregates Part 3 – Specific gravity, Density, Voids, Absorption and Bulking.
[6] IS 3812-2003, Pulverised Fuel Ash- Specification- Part I For use as pozzolana in cement, cement mortar and concrete.
[7] IS 10262 : 2009 Concrete Mix Proportioning – Guidelines (First revision)
[8] IS 456-2000, Plain and Reinforced Concrete- Code of Practice (Third revision)
[9] Jain.L.K. “Fly ash in cement and concrete, what expert say”, - The Indian concrete Journal, April 2003, pp. 989-995.
[10] KodeVenkata Ramesh and D. SreeRamachandra Murthy, “Flexural response of RC beams made of high volume fly ash concrete”. The Indian Concrete Journal, April 2005, pp 47-53.
[11] Mukesh Kumar, Umesh. K.Kakkar, N.P.Singh, Sanjay Singh and N.B.Singh, “ Concrete properties in the presence of fly ash, super plasticise and crystalline water proofing compound”. The Indian concrete Journal, December 2011, pp. 54-58.
[12] Mullick.A.K, “Use of fly ash in structural concrete: Part I –Why?”- The Indian concrete Journal, May 2005, pp. 13-22.
[13] Mullick.A.K, “Use of fly ash in structural concrete: Part II –How much?”- The Indian concrete Journal, June 2005, Vol79, No.6, pp. 10-14.
[14] Prabhakar.J, P.DevadasManoharan and M. Neelamegam, “Effect of fly ash on durability and performance of concrete”, November 2011, pp. 9-15.
[15] Prabir C. Basu, Director, Civil and Engg. Division, Atomic Energy Regulatory Board Mumbai, “Fly ash based concrete”. – CE &CR Feb 2009, pp. 78-87.
[16] RafatSiddique, “Performance characteristics of high volume class F fly ash concrete” Cement and Concrete Research 34 (2004), pp.487-493