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Experimental Investigations on Mechanical Properties of High Volume Fly Ash Concrete with Polypropylene Fibres

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Abstract—*High volume fly ash concrete is a tailor made solution to effectively use produced fly ash. Compressive strength of High Volume Fly Ash Concrete (HVFAC) is found to be maximum when 50% of cement was replaced by fly ash. The replacement of Cement with Flyash in HVFAC was made at different percentages (50%, 60% 70% and 80%). With further addition of Polypropylene fiber at volume fraction ranging from1% to 1.5%, gain in the compressive strength of concrete is from 8.1% to 19.11. Flexural strength of HVFAC is also increased from 7.08% to 13.56% by addition of Polypropylene fiber. To study its properties SEM and XRD test were also performed.*

Keywords*: High Volume Fly Ash Concrete (HVFAC).Compressive strength, Polypropylene Fibers, Scanning Electron Microscope and X-ray diffraction.*

1. 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.

Available resources indicate that presently codes (IS 1489) do not allow cement companies to replace more than 25% of cement with fly ash. The lower percentage replacements of cement by fly ash are attributed to lower 3, 7 and 28 days strength. For sustainability it is high time to shift from fast construction, which generally reduces the effective life of construction to a structure with HVFAC concrete requiring long curing period. The slower strength gain of HVFA concrete will increase the durability and life of structure.

According to the American Concrete Institute (ACI) Committee 116R, fly ash is defined as 'the finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gasses from the combustion zone to the particle removal system' (ACI Committee 232 2004).

Presently all the efforts of Indian construction industry are focused on early removal of shuttering and fastest possible completion of construction work. Industry is more focused on 3 hour strength for early removal of formwork. This is leading to high heat of hydration cracks and lower durability of structures. (IS 456, 2000) recommends at least 10 days of curing where mineral admixtures are used. However for sustainability focus must be shifted to long term strength and durability over short term gain. Hence at least 28 days of curing should be made mandatory for high volume fly ash concrete.

Fly ash that results from burning sub-bituminous coals is referred as ASTM Class C fly ash or high-calcium fly ash, as it typically contains more than 20 percent of CaO. On the other hand, fly ash from the bituminous and anthracite coals is referred as ASTM Class F fly ash or low-calcium fly ash. It consists of mainly an aluminosilicate glass, and has less than 10 percent of CaO. The colour of fly ash can be tan to dark grey, depending upon the chemical and mineral constituents (Malhotra and Ramezanianpour 1994; ACAA 2003; Rangan & Wallah 2006; Rangan & Hardjito 2005). Aside from the chemical composition, the other characteristics of fly ash that generally considered are loss on ignition (LOI), fineness and uniformity coal itself. Finer gradation generally results in a more reactive ash and contains less carbon.

The utilization of fly ash, especially in concrete production, has significant environmental benefits, viz, improved concrete durability, reduced use of energy, diminished greenhouse gas production, reduced amount of fly ash that must be disposed in landfills, and saving of the other natural resources and materials (ACAA 2003).

2. RESEARCH SIGNIFICANCE

Considering the above mentioned significance of HVFAC in construction, the following investigations were carried out with following objectives:

I. To study the effect of different percentage of fly ash and polypropylene fibre on mechanical properties of HVFAC.
II. To monitor strength of HVFAC using NDT methods through Rebound Hammer Test & Ultrasonic Pulse Velocity Test (UPVT).
III. To perform microstructure studies of HVFAC.

3. EXPERIMENTAL PROGRAM

In this study cement was replaced with Flyash at 50%, 60% and 70%. Table 1 shows the mix proportion for 50 % replacement of cement with Flash. The Bureau of Indian standards, recommended a set of procedure for mix design of concrete. The mix design procedure are covered in IS 10262-82. As per the revision of IS 456-2000 few modification are made in mix design and a new guideline 10262-2009 is followed along with DOE method, further in which slump value is taken in to consideration.

Table 1: Mix Proportion

Water	Cement	Flyash	CA	Fine Aggregate
160 kg/m3	192.76 kg/m3	192.78 kg/m3	1194.78 kg/m3	701 kg/m3

3.1 Materials and Methods of Testing

HVFAC can be manufactured by adopting the conventional techniques used in the manufacture of OPC concrete. In the laboratory, the fly ash and the aggregates were first mixed together dry in a pan mixer for about three minutes. The aggregates were prepared in saturated-surface-dry (SSD) condition. The liquid was mixed with the super plasticizer and the extra water, if any. The liquid component of the mixture was then added to the dry materials and the mixing continued usually for another four minutes. The concrete cube specimens were cast using the given HVFAC mix. The standard cube moulds of size 100x100x100 mm for compressive test and beam molds of size 100x100x500 mm for flexural strength test were filled with concrete in three layers. The concrete was compacted carefully using table vibrator.

4. TESTS AND RESULTS

4.1 Compressive Strength Test

Concrete cubes incorporated with HVFA and PPF are tested for compressive strength with varying percentage of fly ash and PPF.

4.1.1 Compressive Strength of HVFAC

Table 2 represents the average compressive strength of cubes incorporated with HVFAC and as well as a combination of FA.Compressive strength were determined for M-25 concrete cube at 3, 7, 14, 28, 56 days curing period on the basis of which following results has been obtained. Compression testing machine (CTM) is used to perform the test.

Table 2: Compressive Strength of HVFAC Concrete at different curing periods (N/mm^2)

S. NO.	HVFAC (%)	3 Days	7 Days	14 Days	28 Days	56 Days	90 Days
1	Control	14.15	18.46	25.35	29.85	30.96	32.25
2	50	11.14	13.15	16.50	20.56	31.11	33.05
3	60	8.37	9.88	12.40	17.74	22.73	25.33
4	70	4.37	5.45	7.63	9.29	14.45	16.47

On the basis of results obtained following graph is drawn for different curing period for HVFAC concrete, which signifies a clear view of optimum strength of concrete.

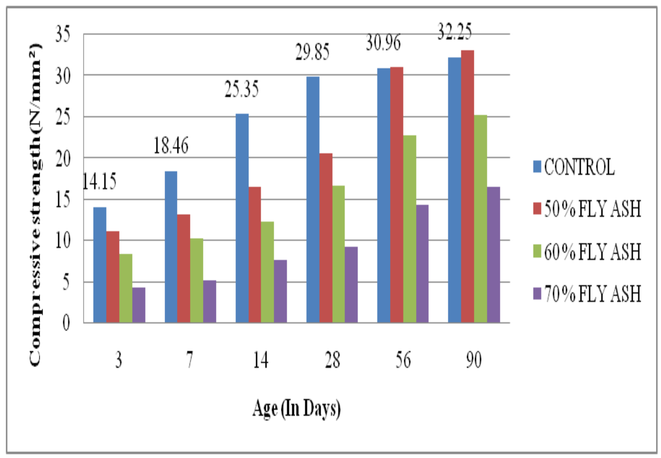

Fig. 1: Compressive strength of HVFAC concrete at different curing periods

4.1.2 Compressive Strength of HVFAC with PPF

On the basis of following results it is observed that maximum compressive strength is obtained at 50% replacement of cement with FA. Further to improve the properties of concrete a few amount of PPF is incorporated in HVFAC which signifies the change in development of strength on concrete. Table 4.2 shows the value obtained by compressive strength, which are as given below.

Table 3: Compressive strength of HVFAC incorporated with Polypropylene Fibre(PPF)

Description	Compressive Strength(N/mm²)	
	7 Days	28 Days
Control	18.46	29.85
50% FA concrete	13.15	20.56

50% FA+1.25% PPF	16.34	22.37
50% FA+1.50% PPF	17.63	25.42
50% FA+1.75% PPF	17.24	24.96

On the basis of above results, following graph is drawn for different curing period for HVFAC Polypropylene fibers.

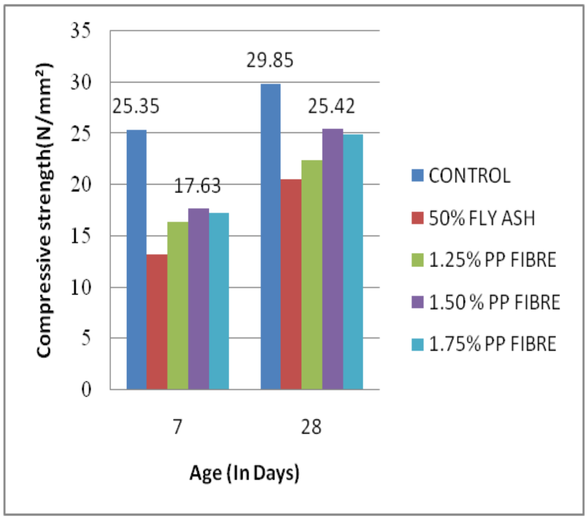

Fig. 2: Compressive strength of HVFAC with polypropylene fibers

The results obtained above shows that PPF has no significant effect on compressive strength of concrete.

4.2 Flexural Strength Test

The determination of flexural strength is essential to estimate the load at which the concrete members may crack. Flexural strength shows the resistance against bending. The flexural strength test is carried out at 7 days and 28 days which signify the optimum % of the HVFA and PPF at which the maximum value of flexural strength is obtained. Beam specimens were tested in Universal testing machine for flexural strength. Following results were obtained.

Table 4:Flexural strength of HVFA concrete incorporated with PPF

Description	Flexural strength (N/mm²)	
	7 Days	28 Days
Control	2.05	2.52
50% FA Concrete	1.83	2.23
50% FA+1.25% PPF	1.92	2.40
50% FA+1.50% PPF	2.14	2.58
50% FA+1.75% PPF	2.03	2.51

From the result above it is found that 50% FA with addition of 1.50% PPF gives maximum value of flexural strength at 7 and 28 days.

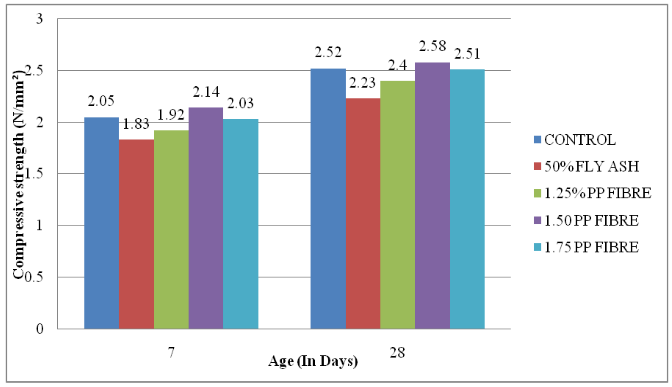

Fig. 3: Flexural strength of HVFA concrete incorporated with PPF at different curing periods

From the result above it is found that 50% FA with addition of 1.50% PPF gives maximum value of flexural strength at 7 and 28 days.

4.3 Rebound Hammer Test

20 readings (rebound values) are obtained for each cube, at different locations on the surface of the specimen. Table 5 shows average rebound value calculated for different percentage of fly ash. Value obtained by rebound hammer test is correlated with compressive strength of concrete.

Table 5: Rebound value of different percentage of FA in HVFAC

Fly Ash %	Mean Rebound Value			
	7 Days	14 Days	28 Days	56 Days
45	19.73	21.44	25.82	36.56
50	14.97	17.83	21.11	32.33
55	14.37	15.34	18.23	26.53

From the result above it is found that 45% replacement of cement with fly ash gives maximum rebound value but 50% fly ash replacement will be used for further study since HVFAC starts with minimum 50% replacement of cement with fly ash. Following are the graphical representation of rebound hammer test.

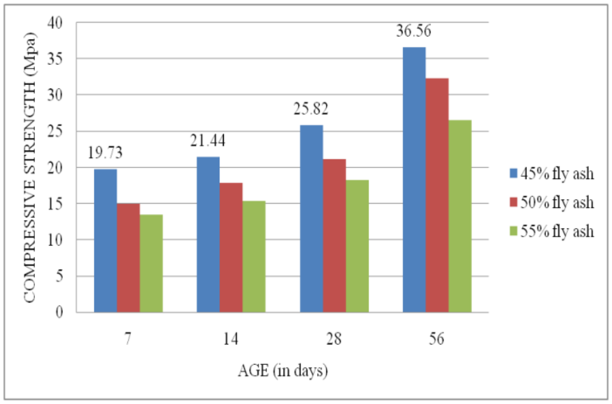

Fig. 4: Rebound Hammer Value of HVFAC incorporated with PP fibre

4.4 Ultrasonic Pulse Velocity Test

The test for ultrasonic pulse velocity of concretes is carried out in accordance with ASTM C 597 (2004). An operational stage of the ultrasonic pulse velocity test is shown in Table 6. The test is conducted at the age of 28 days. Triplicate 100D×200H mm cylinders were tested. The specimens are air-dried at room temperature (23±2 ^{0}C) for 24 hours prior to testing. The drying process helped to obtain good coupling between transducers and specimen. The average path length of the specimens is determined by taking the measurement at four quaternary longitudinal locations. The ultrasonic pulse velocity is determined from measured transit time and path length and averaged based on the results of three specimens.

Transit time is obtained both for different combination of HVFA-PPF concrete as well as for control concrete.

Table 4.5: USPV Test Results

Description	Length of sample(mm)	Travel time (micro-second	Velocity (m/sec)	Quality of concrete
Control	100	20.70	4830	Excellent
50% FA concrete	100	27.24	3670	Good
50% FA+1.25% PPF	100	25.77	3880	Good
50% FA+1.50% PPF	100	21.50	4650	Excellent
50% FA+1.75% PPF	100	22.12	4520	Good

On the basis of the result obtained it can be concluded that maximum velocity obtained with 50% FA+1.5% PPF. It is more cleared from following graph. So properties wise we can interpret that 50% FA+1.5% PPF gives optimum strength.

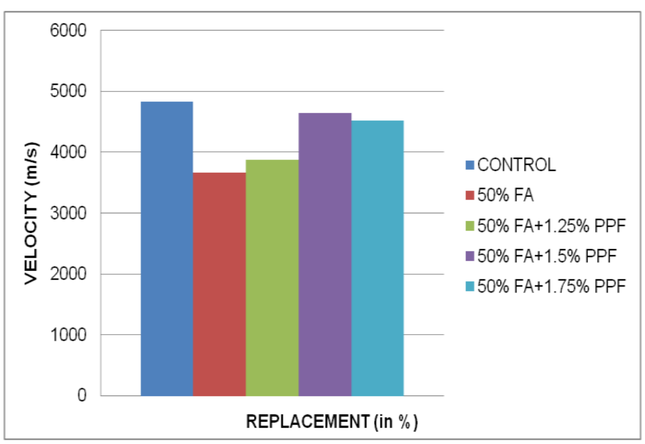

Fig. 5: USPV of HVFA concrete incorporated with PP Fibre

4.5 Micro-Structural Analysis

This analysis is performed to observe the change in internal structure of concrete at different curing periods. Microstructure analysis is performed by SEM (Scanning electron microscope). This instrument works on the basis of electron beam which pass through the concrete and shows the images of concrete at different magnification. The test is carried out on control, 50% FA and 50% FA+1.5% PPF. This analysis shows the cohesion and adhesion among the particles and also shows a pictorial view of pore structure of concrete.

4.5.1 Comparative Changes in Microstructure of Control, FA and FA+PPF Based Concrete

Comparative images of Control, 50% FA and 50% FA+1.5% PPF microstructure images are shown below to show the internal structure or surface morphology of concrete.

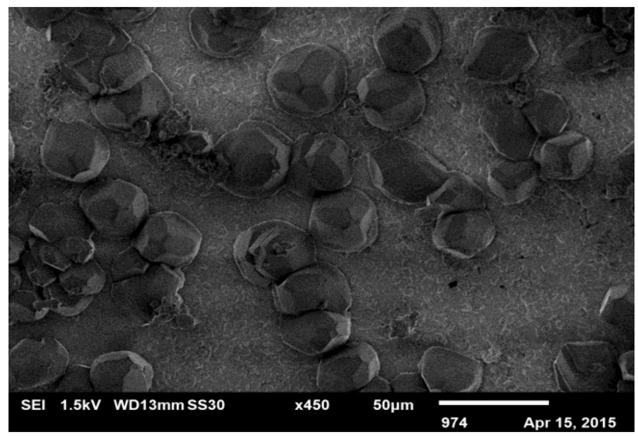

Fig. 6: Microstructure of Control

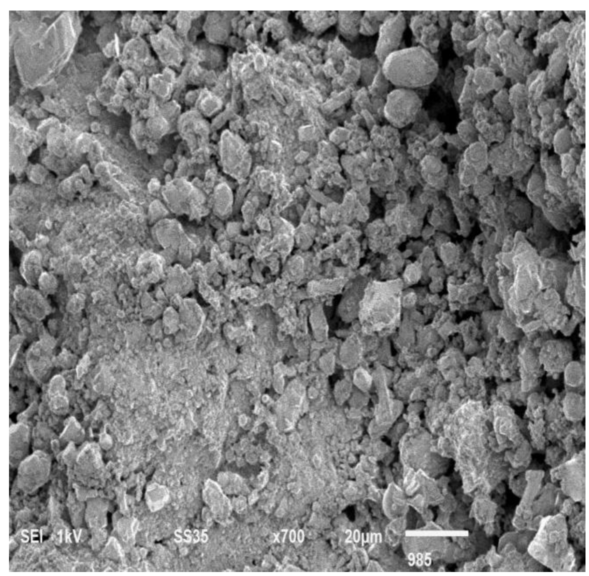

Fig. 7: Microstructure of HVFAC with 50% FA

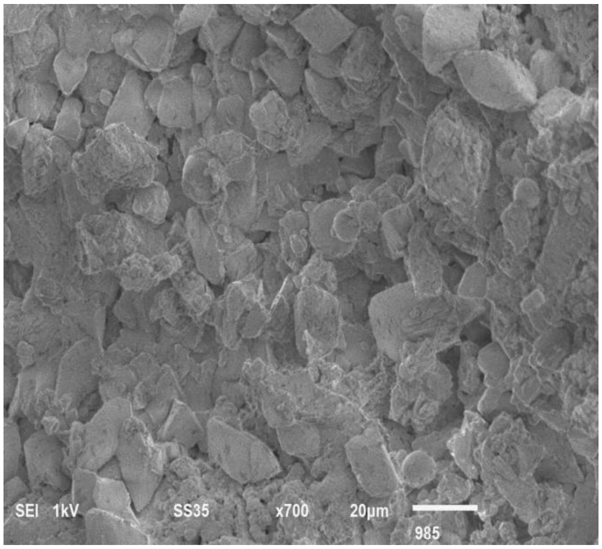

Fig. 8: Microstructure of HVFAC with 50% FA+1.5% PPF

On the basis of the above microstructure analysis it was interpreted that in control images that the pore spaces is more but in concrete with 50% FA, the pore spaces get filled with fly ash particle and in concrete with 50% FA+1.5% PPF, the pore spaces get even more compact as compared to previous samples.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

Use of waist and By-products as cement replacement not only makes the concrete economic but also solve the problem of dumping the waist product which is a major problem when the waist product is like fly ash because there is lots of tons of coals burn daily and lots of ash produce from this coal, dumping of this ash in such a large scale is a big problem. By using fly ash in concrete this problem can be solved very easily.

Based on study following conclusions are drawn:-

1) Use of fly ash in concrete solves the problem of disposal of this material.
2) Compressive strength of HVFAC found maximum when 50% cement is replaced by fly ash.
3) Compressive strength of concrete increases gradually by addition of Polypropylene fiber from 8.1% to 19.11%. There is increase in compressive strength as compared with normal plain concrete (without fibers).
4) Flexural test of concrete gradually increases by addition of Polypropylene fiber from 7.08% to 13.56%. There is increase in Flexural strength as compared with normal plain concrete (without fibers).
5) Microstructure analysis of HVFAC with PP fibre shows that the pore spaces are filled with PP fibre which reduces the porosity of concrete.
6) USPVT shows the excellent quality of concrete when 50% of cement is replaced by fly ash and 1.5% of PP fibre added in HVFAC.

5.2 RECOMENDATIONS

On the basis of experimental experience it is recommended that HVFAC required more time to get strength as compared to control concrete. Hence it is required to increase the curing period of HVFAC.

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