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Experimental Study of fly ash based concrete

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ABSTRACT

A partial substitution of cement by an industrial waste, such as fly ash, ground granulated blast furnace slag (GGBFS), silica fume, metakaolin, rice husk ash etc. can improve the properties of concrete in the fresh and hardened state. The addition also enhances the durability and can provide means for the safe disposal of waste material, protecting the environment from pollution. The present work is aimed at studying characteristics of fly ash based high strength and standard concrete. Accordingly w/cm ratio is varied from 0.30 to 0.50 with an increment of 0.05. For each w/cm ratio, water content of 144.5 kg/m3, 161.5 kg/m3 and 174.25 kg/m3 is considered to achieve low, medium and high workability. The dose of superplasticiser is maintained constant for all the mixes. For each w/cm ratio and water content, the content of fly ash is 10%, 20% and 30% by weight of cementitious materials. There are 45 mixes cast in the laboratory. Test of each mix is determined as per IS 456 at the age of 7 and 28 days. The results revealed that with the replacement of cement by fly ash remarkably got high strength concrete of compressive strength 68 MPa at the age of 28 day that can be achieved with 30% fly ash.

Keywords: Compressive Strength, Fly ash, High Strength Concrete, Standard Concrete, Workability,

I.INTRODUCTION

1.1 General

Cement is the backbone for global infrastructural development. It was estimated that global production of cement is about 3400 million tons in 2011. Cement industries emit large quantity of carbon dioxide to the atmosphere. It is observed that 7% of the world's carbon dioxide emission is from cement industry. Because of the significant contribution to the environmental pollution and to the high consumption of natural resources like limestone etc., we cannot go on producing more and more cement. There is a need to economies the use of cement. One of the practical solutions in this regard is to replace cement with supplementary cementitious materials such as fly ash, ground granulated blast furnace slag (GGBFS), silica fume, metakaolin, rice husk ash etc. The use of fly ash as concrete admixture not only extends technical advantages to the properties of concrete but also contributes for controlling environmental pollution. In India about 112 million tons of fly ash is being

produced per year, with a utilization of about 38% only. The disposal of which has become a serious environmental problem. Research is therefore more focused on utilization of these materials to the maximum extent without compromising the required properties of concrete.

1.2 Fly ash:

A by-product of coal fired electric generating plants; it is used to partially replace Portland cement. The properties of fly ash depend on the type of coal burnt. In general, siliceous fly ash is pozzolanic, while calcareous fly ash has latent hydraulic properties. It is available in large quantities in the country as a waste product from a number of thermal power stations and industrial plants using pulverized coal or lignite as fuel for the boilers. The effective use of fly

ash as a pozzolana in the manufacture of cement and for part replacement of cement, as an admixture in cement mortar and concrete and in lime pozzolana mixture. In the recent time, the importance of fly ash in concrete has grown so much that it has almost become a common ingredient in concrete, particularly for making high strength and high performance concrete.

1.2.1 Advantages and Disadvantages of using fly ash

With these unique features and characteristics, the use of fly ash will have a number of performance benefits in concrete, both in the fresh and hardened state. The incorporation of fly ash minimizes the water demand, reduces the bleed channels and through pozzolanic activity increases the cementitious compounds, all of which increase the concrete density. Concrete changes from a liquid to a solid a few hours after pouring, but the curing process may take much longer. It continues to gain strength for weeks after its initial setting period. The addition of fly ash can increase the length of time concrete takes to reach its full strength.

II. EXPERIMENTAL PROGRAM

The experimental program consists of casting of concrete mixes with w/cm ratio of 0.30 to 0.50 with an increment of 0.05. For each w/cm ratio, water content is taken as 144.5 kg/m3, 161.5 kg/m3 and 174.25 kg/m3 to achieve concrete of low, medium and high workability. Dosage of superplasticiser is taken as 0.5 percent by weight of cementitious material, which is maintained constant throughout the work. Fly ash content is varied as 10%, 20% and 30% as partial replacement of cement, for each mix. In all 45 mixes were cast and tested for workability and compressive strength of concrete.

2.1 Materials

The cement used in this experimental work is “53 grade Ordinary Portland Cement”. Properties of cement are presented in Table 1. Processed Fly ash “Pozzocrete 100” is used as cementitious material. Properties of fly ash are presented in Table 2.

The natural sand from Godavari River is used as fine aggregate and crushed black trap basalt as coarse aggregate. A sulphonated naphthalene formaldehyde polymers based superplasticiser was used in addition to

normal tap water. Super plasticizer complies with the requirement of IS 9103-1999 [4]. Properties of the same presented in Table 3.

Table 1: Physical Properties of Cement

Sr. No.	Description of test	Results
1.	Fineness of cement	2.9%
2.	Specific gravity	3.15%
3.	Standard constancy of cement	30%
4.	Setting time	
	a) Initial setting time b) Final setting time	120 minutes 250 minutes

Table 2: Properties of Fly ash

Sr. No.	Properties	Details
1.	Color	Grayish white
2.	Specific density	2.3 metric ton per cubic meter
3.	Particle size	zero retention on 45 micron sieve Less than 0.25% retained on 25 micron sieve
4.	Setting Time	Increased 15 - 45 min
5.	Water Demand	Reduced, 8 -10%
6.	28 day Strength	Increased 15- 20%

Table 3: Properties of Superplasticiser

Sr. No.	Properties	Details
1.	Color	Dark brown
2.	Basis	Sulphonated Naphthalene Formaldehyde Polymers
3.	Density at 25^0C	1.270 ± 0.02 gm/cc
4.	pH value	Min 6
5.	Chloride content	0.2% Max

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2.2 Mix Proportions

Concrete mixes were designed in accordance with DOE method [5]. The quantity of ingredients per cubic meter of concrete is given in Table No. 4.

2.3 Casting and preparation of test specimens

The concrete was mixed in a laboratory pan mixer and tested for workability using the slump cone test. Concrete cubes of 150 x 150 x 150 mm were cast for compression test. The samples were demoulded at 24 hours after casting and then cured under water for 7 and 28 days of age.

III. RESULTS AND DISCUSSION

3.1 Workability

Slump test is conducted to measure workability of concrete according to IS 1199-1956 [6]. Water content of 144.5 kg/m^3, 161.5 kg/m^3 and 174.25 kg/m^3 is considered to achieve low, medium and high degree of workability. Superplasticiser dosage of 0.5 percent constant is used for each mix. The average value of design slump as per DOE Method without any mineral or chemical admixture for low, medium and high water content is shown in figure No. 1, 2 and 3.

Table 4: Concrete mix proportions

Mix Proportions by Weight							
Sr.No.	W/Cm ratio	Fly Ash %	Cement kg/m^3	Fly Ash kg/m^3	Water kg/m^3	FA kg/m^3	CA kg/m^3
1	0.30	10	433.5	48.16	144.5	655.58	1183.25
2		20	385.33	96.33		655.58	1183.25
3		30	337.16	144.5		655.58	1183.25
4		10	484.5	53.83	161.5	682.56	1067.60
5		20	430.66	107.66		682.56	1067.60
6		30	376.83	161.5		682.56	1067.60
7		10	522.75	58.08	174.25	756.86	925.05
8		20	464.67	116.16		756.86	925.05
9		30	406.58	174.25		756.86	925.05
10	0.35	10	371.57	41.28	144.5	709.52	1208.11
11		20	330.28	82.57		709.52	1208.11
12		30	289	123.85		709.52	1208.11
13		10	415.28	46.14	161.5	730.82	1096.24
14		20	369.14	92.28		730.82	1096.24
15		30	323	138.42		730.82	1096.24

16		10	448.07	49.78		811.85	953.04
17		20	398.28	99.57	174.25	811.85	953.04
18		30	348.5	149.35		811.85	953.04
19		10	325.12	36.12		748.31	1220.93
20		20	289	72.25	144.5	748.31	1220.93
21		30	252.87	108.37		748.31	1220.93
22		10	363.37	40.37		772.74	1112.00
23	0.40	20	323	80.75	161.5	772.74	1112.00
24		30	282.62	121.12		772.74	1112.00
25		10	392.06	43.56		858.74	968.37
26		20	348.5	87.12	174.25	858.74	968.37
27		30	304.93	130.68		858.74	968.37
28		10	289	32.11		783.66	1225.72
29		20	256.88	64.22	144.5	783.66	1225.72
30		30	224.77	96.33		783.66	1225.72
31		10	323	35.88		810.43	1119.17
32	0.45	20	287.11	71.77	161.5	810.43	1119.17
33		30	251.22	107.66		810.43	1119.17
34		10	348.5	38.72		900.25	975.27
35		20	309.77	77.44	174.25	900.25	975.27
36		30	271.05	116.16		900.25	975.27
37		10	260.1	28.9		816.6	1224.9
38		20	231.2	57.8	144.5	816.6	1224.9
39		30	202.3	86.7		816.6	1224.9
40		10	290.7	32.3		845.16	1120.33
41	0.50	20	258.4	64.6	161.5	845.16	1120.33
42		30	226.1	96.9		845.16	1120.33
43		10	313.65	34.85		937.98	976.26
44		20	278.8	69.7	174.25	937.98	976.26
45		30	243.95	104.55		937.98	976.26

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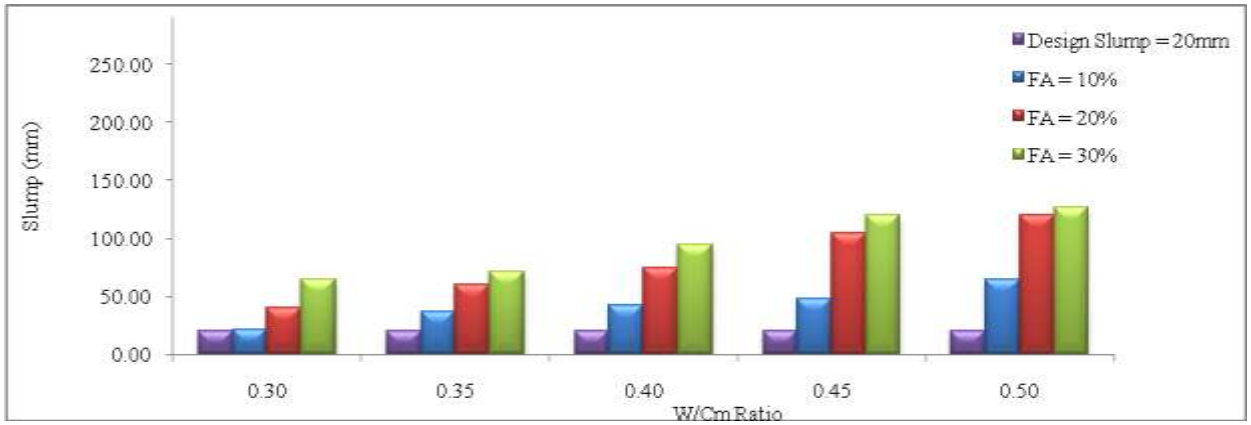

Fig. 1: Slump for Mixes of Water content 144.5 kg/m^3

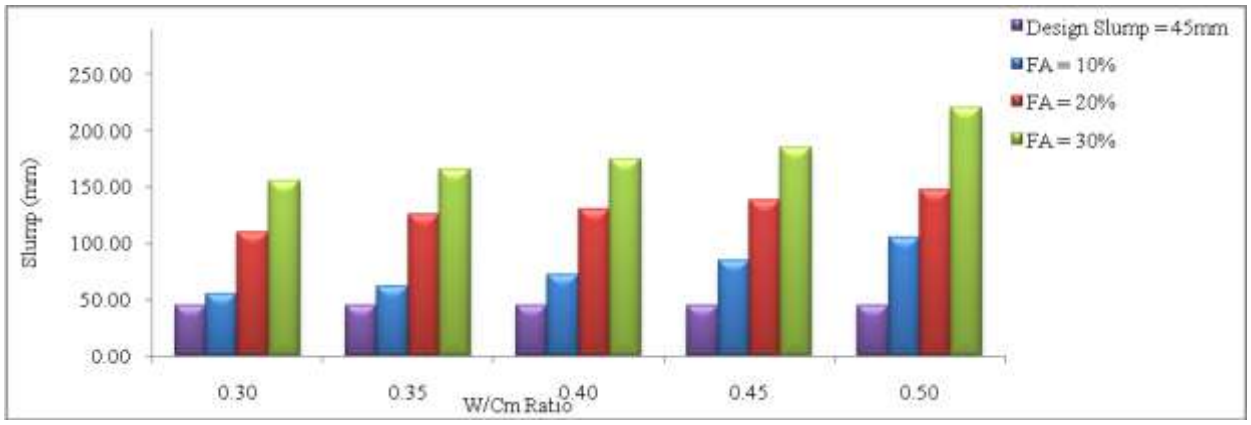

Fig. 2: Slump for Mixes of Water content 161.5 kg/m^3

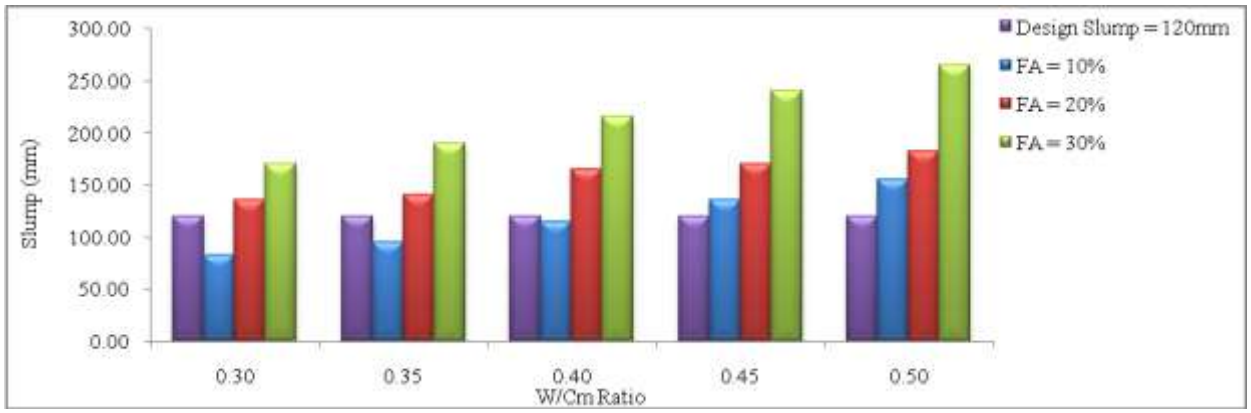

Fig. 3: Slump for Mixes of Water content 174.25 kg/m^3

It can be seen that for each w/cm ratio as the percentage of fly ash increases the workability goes on increasing. Similar trend can be observed for all the mixes with different water cementitious material ratio. The degree of workability of concrete with w/cm ratio of 0.30 to 0.40 changes from lower to medium when replacement is 10 and 20%, however for mixes with w/cm ratio of 0.45 and 0.50 it can be observed that the degree of workability

increased from low to medium and medium to high for the replacements of fly ash 20 and 30% if compared with the provisions of IS 456 [7].

3.2 Result of Compressive Strength

The compressive strength was evaluated by tests performed on cube specimens (150 x 150 x 150 mm) at the age of 28 days as per IS 516-1975 Standard [8]. Table No.6 shows the 28 days compressive strength for different water content.

Table 5: Compressive Strength Test Results

				Water content =144.5 kg/m^3	Water content =161.5 kg/m^3	Water content =174.25 kg/m^3
Sr. No.	W/Cm Ratio	Fly ash%	28 Day Strength as per E curve of IS 10262-1982	28 Day Compressive Strength	28 Day Compressive Strength	28 Day Compressive Strength
1	0.30	10%	54.33	58.96	53.04	53.33
2		20%		60.30	58.74	49.33
3		30%		68.44	62.22	45.48
4	0.35	10%	50.5	49.63	48.15	48.70
5		20%		50.96	49.63	44.60
6		30%		52.30	50.37	42.52
7	0.40	10%	43.5	47.41	47.85	45.93
8		20%		50.59	48.37	41.96
9		30%		51.41	49.11	40.78
10	0.45	10%	37	45.78	46.59	42.56
11		20%		42.22	44.30	39.20
12		30%		38.52	41.93	38.11
13	0.50	10%	31	40.59	38.81	33.89
14		20%		37.70	30.96	29.59
15		30%		34.67	29.48	27.70

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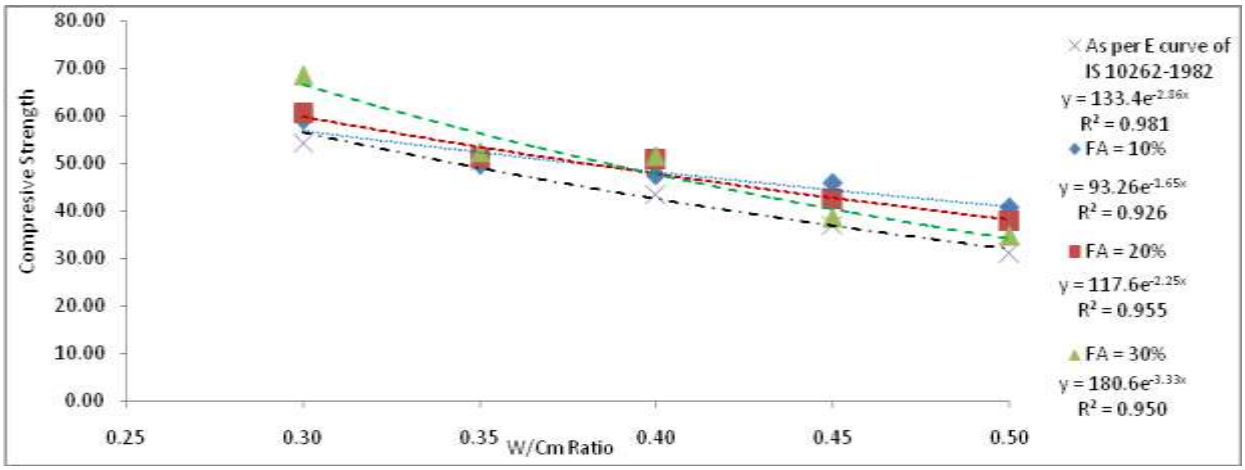

Fig. 5: Compressive strength at 28 Days for water content 144.5 kg/m^3

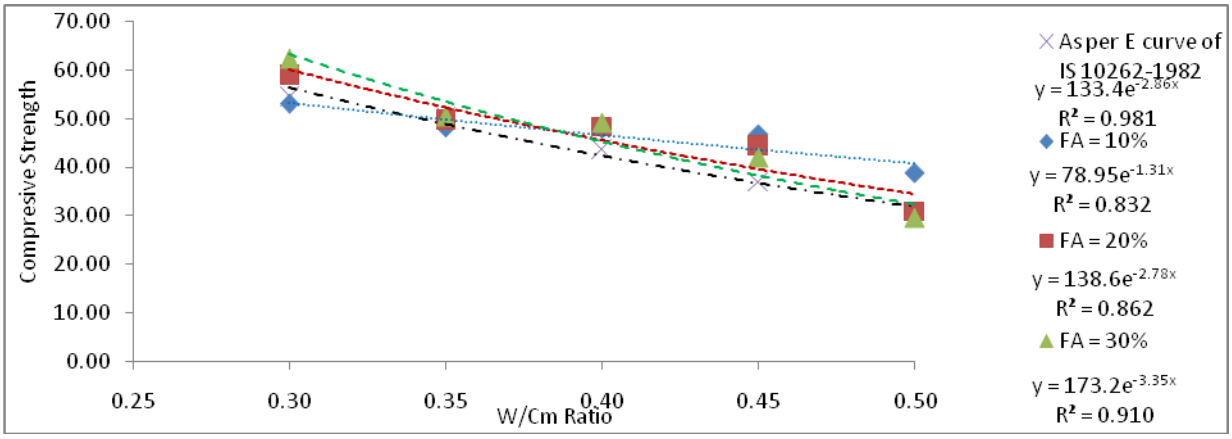

Fig. 6: Compressive strength at 28 Days for water content 161.5 kg/m^3

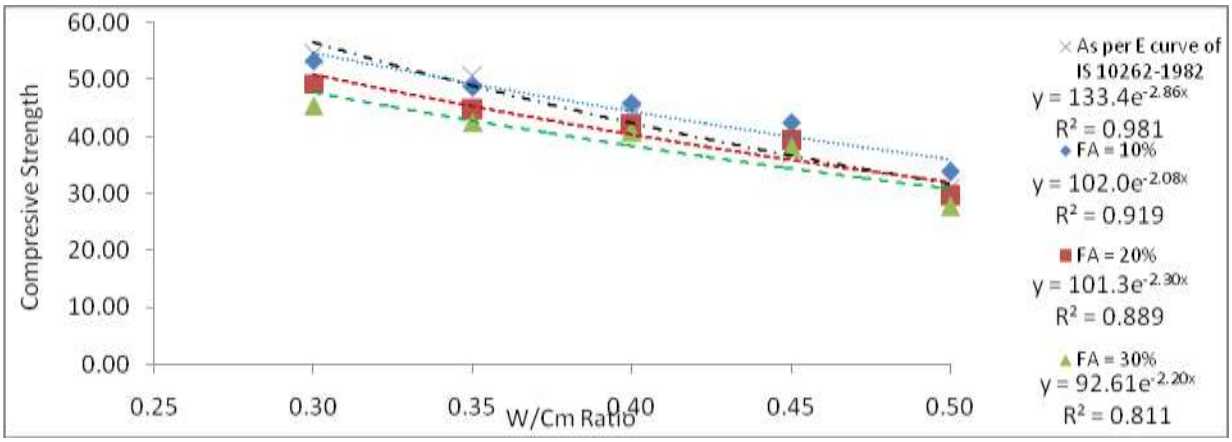

Fig. 7: Compressive strength at 28 Days for water content 174.25 kg/m^3

The compressive strength of the concrete mixes for different water content is shown in Fig. 5 to Fig 7. The results indicate that incorporation of fly ash in concrete increased strength at the age 28 for the water content of 144.5 and 161.5 kg/m^3, however for 174.25 kg/m^3 water content strength decreases as the percentage of fly ash increases.

For water content of 144.5 kg/m^3, 28 days compressive strength of all mixes with fly ash shows more strength than the expected value (as par E curve of IS 10262-1982 [3]). For w/cm ratio 0.30, 0.35 and 0.40, mixes with 30% fly ash shows more strength than the mix with 10 and 20% fly ash. However for w/cm ratio 0.45 and 0.50, strength is decreases with increasing the percentage of fly ash. Similar trend can be observed for all the mixes with water content of 161.5 kg/m3. For water content 174.25 kg/m^3 compressive strength is slightly less than expected value.

IV.CONCLUSIONS

Concrete were investigated to evaluate the effect of 10%, 20% and 30% fly ash content on some properties of concretes. The following conclusions are drawn from the test results:

1. Workability of concrete increases with the increase in the fly ash content.
2. High strength concrete with 28 day compressive strength of 68 MPa could be obtained with w/cm ratio of 0.30 and with 30% fly ash.
3. The compressive strength of concrete increased when the cement was replaced with processed fly ash at 7 days as well as 28 days when compared with strength-w/c ratio relationship as per 'E' curve of IS 10262-1982.
4. Addition of fly ash improves workability at a given w/cm ratio. It might be due to the fineness and spherical shape of fly ash particles.
5. Increasing amount of fly ash in the mix with w/cm less than 0.4, increases the compressive strength of concrete at 28 days, however for w/cm ratio 0.45 and 0.50 the strength goes on decreases.
6. High strength concrete of compressive strength 68 MPa at the age of 28 day can be achieved with 30% fly ash.

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