Experimental Study on Strength and Durability Behaviour of Fly Ash Concrete

Minu Antony

Assistant Professor

Department of Civil Engineering, Saintgits College of Engineering, Pathamuttom, Kottayam, Kerala

***Abstract*— Fly ash is the fine powder produced as a product from the combustion of pulverized coal. When the pulverized coal is ignited in the combustion chamber, the carbon and volatile materials are burned off. However, some of the mineral impurities of clay, shale, feldspars, etc., are fused in suspension and carried out of the combustion chamber in the exhaust gases. As the exhaust gases cool, the fused materials solidify into spherical glassy particles called Fly Ash. 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. Therefore, the utilization of fly ash as an admixture in concrete instead of dumping it as a waste material can have great beneficial effects of lowering the water demand of concrete for similar workability, reduced bleeding and lowering evolution of heat. This paper deals with an experimental study on the properties of concrete containing fly ash. Both strength and durability tests were conducted on fly ash concrete. The cube compressive, split tensile and flexural tests of fly ash concrete were conducted in this study to determine the strength parameters. And Acid Resistance, Saturated Water Absorption and Porosity tests were conducted to determine the durability behaviour of fly ash concrete. The cement was replaced by10, 20, 30, 40 and 50 percentages of fly ash obtained from nearby thermal power station. Fly ash replacement up to 30 percent in concrete has shown good improvement in strength parameters.**

***IndexTerms*— Fly Ash Concrete (FAC)*)*, Strength Tests, Acid Resistance, Saturated Water Absorption, Porosity.**

1. INTRODUCTION

A. General

Fly ash is the fine powder produced as a product from the combustion of pulverized coal. 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. Therefore, the utilization of fly ash as an admixture in concrete instead of dumping it as a waste material can have great beneficial effects of lowering the water demand of concrete for similar workability, reduced bleeding and lowering evolution of heat.

The development and use of mineral admixture for cement replacement is growing in construction industry mainly due to the consideration of fast construction, cost savings, environmental protection, and low consumption of resources and utilizing the bye products that are available. Mineral admixture generally used is raw fly ash, rice husk ash, metakaoline, silica fume, geopolymers etc. Addition of such materials improves the concrete and mortar property. The fly ash is among the commonly used mineral admixtures which is available in large quantities in many developing countries. As per the estimation of Government of India, power plants are going to use 1800 million tons of coal that may result 600 million tons of fly ash by 2031-2032.

The small size and the essentially spherical form of low calcium fly ashes particles influences the rheological properties of cement pastes, causing a reduction in the water required or an increase in workability compared with that of an equivalent paste without fly ash. Fly ash differs from other pozzolona which usually increase the water requirement of concrete mixtures. A complete stress-strain curve is needed for the analysis and rational design of concrete structures. The structures built in severe environment need durable concrete because of huge amount of construction expenses and difficulty in concrete repairs.

The cement content of concrete is generally high which often leads to higher shrinkage and greater evaluation of heat of hydration besides increase in cost. A partial substitution of cement by an industrial waste, such as fly ash is not only economical but also improves the properties of fresh and hardened concrete and enhances the durability characteristics besides the safe disposal of otherwise waste material thereby protecting the environment from pollution.

.

II. EXPERIMENTAL PROGRAMME

A.Materials

1) Cement:

Strength development of concrete will depend on both cement characteristic and cement content. 53 grade Ordinary Portland Cement conforming to IS 12269 (Indian Standard Designation, IS 12269-1987) was used for the concrete mixtures. The different properties of the Cement tested in the laboratory are listed in Table 1.

Table 1: Properties of Cement

Type	Standard Consistency	Specific Gravity	Initial setting time in minutes	Final setting time in minutes
OPC	32.5%	3.15	30	320

2) Fly Ash:

Fly ash used in the experiments is taken from Ennore Thermal Plant, Chennai,Tamil Nadu. Physical properties are checked in laboratory and the chemical properties are reported here for ready reference as obtained from Thermal Plant. The physical and chemical properties of fly ash are given in Table 2.

Table 2: Physical and Chemical properties of Fly ash

Physical Properties		
Sl.No	Characteristics	Properties
	Colour	Grey
	Specific gravity	2.3
	Fineness, cm^2/gm	3200
Chemical Properties		
Sl.No	Characteristics	Properties
1	Silica(SiO_2)	45 to 89%
2	Alumina(Al_2O_3)	23 to 33%
3	Ferric Oxide ($Fe_2 O_3$)	0.4 to 0.6%
4	Titanium($Ti O_2$)	0.5 to 16 %
5	Calcium Oxide(CaO)	5 to 16%
6	Magnesia(MgO)	1.5 to 5%
7	Sulphuric Anhydride as SO_3	2.5%
8	Loss of ignition	1.0 to 2.0%

3) Aggregate:

Locally available river sand was used as Fine Aggregate. Sieve Analysis of the fine aggregate was carried out in the laboratory as per IS 383 and tested as per IS 2386 as shown in Table 3. Locally available crushed coarse aggregate was used. Sieve Analysis of the coarse aggregate was carried out in the laboratory as per IS 383 and tested as per IS2386 as shown in Table3.

Table 3: Physical properties of Fine and Coarse Aggregate

Sl No	Property	Value
Fine Aggregate		
1	Fineness	2
2	Specific Gravity	2.63
3	Density(kN/m^3)	16.9
Coarse Aggregate		
1	Fineness Modulus	7.8
2	Specific Gravity	2.78

4) Water:

According to IS 3025, water to be used for mixing and curing should be free from injurious or deleterious materials. Potable water is generally considered satisfactory. In the present investigation, tap water was used for both mixing and curing purposes.

5) Superplasticizer:

The chemical admixture used is superplasticizer. The superplasticizer used in the study was Conplast SP 430. It has a specific gravity of 1.20 to 1.22 according to the manufacturers and air entrainment of 1%. The dosage specified is 0.5 to 2 litres per 100kg.

B. Mix proportions

The mix proportion adopted was 1: 1.36: 2.77 with a water-cement ratio of 0.318. Table4 presents the control concrete mix proportions used in the testing programme.

Table 4: Mix proportion for M_{30} grade concrete

Cement (kg/m^3)	502.7
Sand(kg/m^3)	507.53
Coarse Aggregate(kg/m^3)	1228.25
Water(kg/m^3)	186

C. Specimen Detail

Specimen Details is as given in Table 5.

Table5: Specimen details

Sl.No.	Sample	Replacement Percentage of Cement by Fly Ash
1	FA0(Control Mix)	0%
2	FA1	10%
3	FA2	20%
4	FA3	30%
5	FA4	40%
6	FA5	50%

D. Test Methods

1. Strength Test

1.1) Compressive strength is determined as per IS 516-1959. Three cube samples of 150 mm are used for each mix to test the compressive strength.

1.2) The test for split tensile strength was carried out according to IS 5816- 1999 to obtain the splitting tensile strength using the average of three concrete cylinders (150 X 300 mm).

1.3) Determination of Flexural strength is as per IS 5816-1999. The specimens of 10 x 10 x 50 cm are used and two point loading is used to determine the modulus of rupture.

2. Durability Tests

2.1) Acid Resistance test- The acid resistance tests were carried out on 150 mm size cube specimens at the age of 28 days curing. The cube specimens were weighed and immersed in water diluted with one percent by weight of sulphuric acid for 45 days continuously. Then the specimens were taken out from the acid water and the surfaces of the cubes were cleaned. Next the weight and the compressive strengths of the specimens were found out and the average percentage of loss of weight and compressive strengths were calculated.

2.2) Saturated Water Absorption test -The saturated water absorption of concrete is a measure of the pore volume or porosity in hardened concrete which is occupied by water in saturated condition. It denotes the quantity of water which can be removed on drying a saturated specimen. The porosity obtained from absorption tests is designated as effective porosity. It is determined using the following formula:

$$\text{Effective porosity} = (\text{Volume of voids}/ \text{ bulk volume of specimen}) \times 100$$

The volume of voids is obtained from the volume of water absorbed by an oven dried specimen or the volume of water lost on oven drying water saturated specimen at 105°C to constant mass. The bulk volume of the specimen is given by the difference in mass of the specimen in air and it's mass under submerged condition in water.

$$\text{Effective porosity, } n = \{(W_s - W_d)/ (W_s - W_{sub})\} \times 100$$

Where

W_S - Weight of specimen at fully saturated condition

W_d- weight of oven dried specimen

W_{sub} = weight of specimen submerged in water.

2.3) Porosity test- The porosity is obtained from absorption tests is designated as effective porosity. It is determined using the following formula:

$$\text{Effective porosity} = (\text{Volume of voids}/ \text{ bulk volume of specimen}) \times 100$$

The volume of voids is obtained from the volume of water absorbed by an oven dried specimen or the volume of water lost on oven drying water saturated specimen at 105°C to constant mass. The bulk volume of the specimen is given by the difference in mass of the specimen in air and it's mass under submerged condition in water.

Effective porosity, $n = \{(W_s - W_d)/ (W_s - W_{sub})\} \times 100$

Where

W_s - Weight of specimen at fully saturated condition

W_d - weight of oven dried specimen

W_{sub} = weight of specimen submerged in water.
The test of porosity on 150 mm FAC cube specimens was carried out in accordance with the process described above

E. Results and Discussion

1.Results of Strength Tests

1.1). Cube Compressive Strength Test

The hardened properties were determined by casting standard specimens as per IS specifications. Compressive strength tests were carried out on 1000kN compression testing machine. The compressive strengths were determined on cube specimens of size 150 x 150 x 150 mm. The test results of the compressive strength for fly ash concrete are given in table.

Table6: Test Results of Cube Compressive Strength

S.No	Specimen Sample	Average Compressive Strength (N/mm^2)		
		7 DAYS	14 DAYS	28 DAYS
1	FA0	26.75	28.9	30.2
2	FA1	25	26.1	29
3	FA2	26.25	25.8	29.6
4	FA3	26.5	25.4	29.8
5	FA4	25.33	24	28.5
6	FA5	24	23.6	28

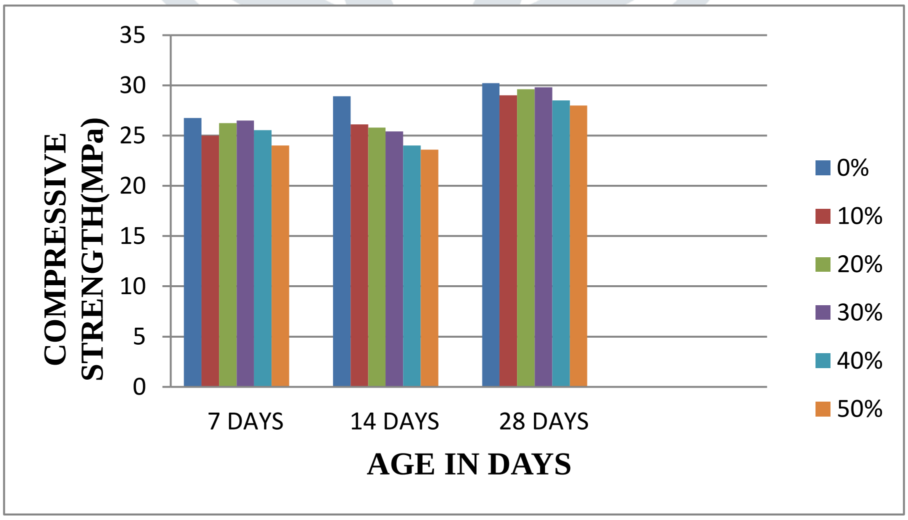

Fig1:Compressive Strength for Fly Ash Concrete (FAC)

1.2) Splitting Tensile Strength Test

Splitting tensile strength tests were conducted on 150mm diameter and 300mm high cylindrical specimens. The values obtained are tabulated in table 7.

Table7: Test Results for Splitting Tensile Strength of cylinders

S.NO	Sample Specimen	Average Split Tensile Strength 28 Days N/mm^2
1	FA0	3.01
2	FA1	2.88
3	FA2	2.95
4	FA3	2.98
5	FA4	2.64
6	FA5	2.43

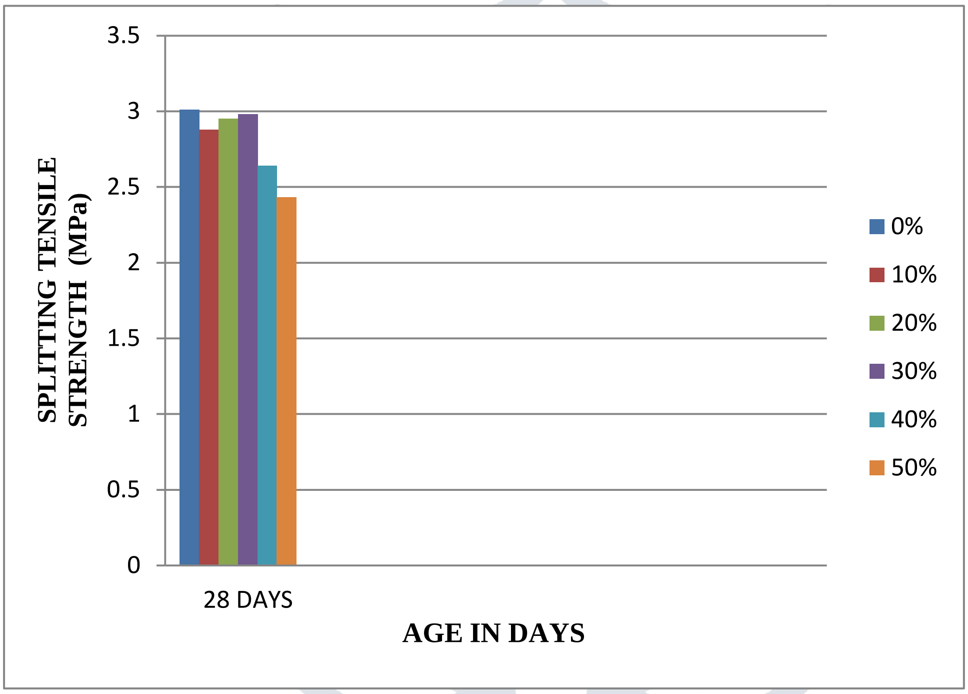

Fig 2: Splitting tensile strength for Fly Ash Concrete (FAC)

1.3) Flexural Strength Test

Flexural strength tests were conducted on prisms of size 150 x 150 x 500 mm. The values obtained are tabulated in table 8.

Table 8 Test Results of Flexural strength of prism

S.No	Sample Specimen	Average Flexural Stength 28 DAYS N/mm^2
1	FA0	3.23
2	FA1	3.31
3	FA2	3.42
4	FA3	3.38
5	FA4	2.89
6	FA5	2.46

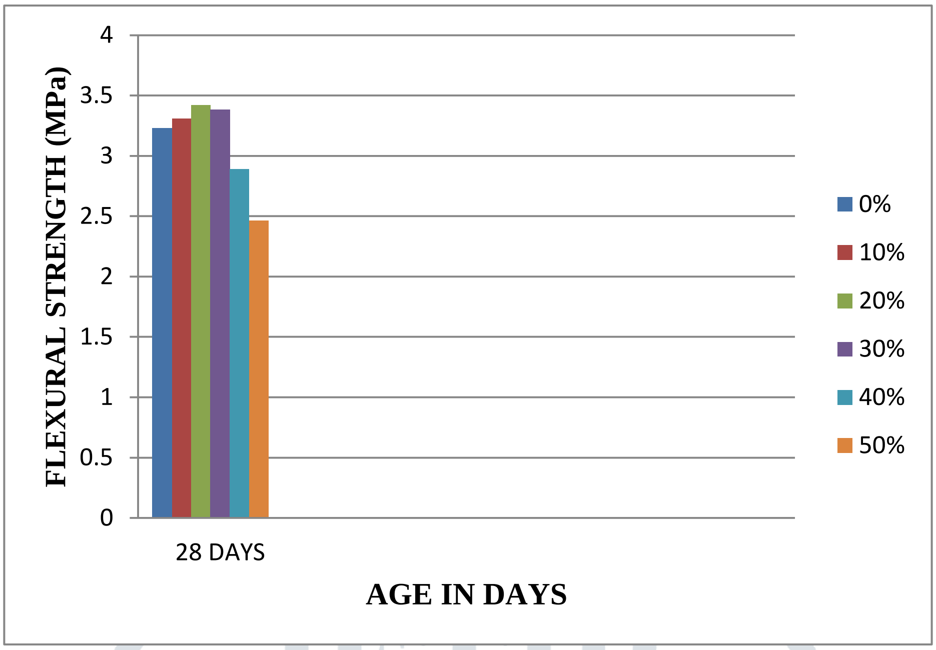

Fig3: Flexural Strength For Fly Ash Concrete(FAC)

2. Results of Durability Tests

2.1) Acid Resistance Test

The acid resistance tests were carried out on 150 mm size cube specimens. The weight and the compressive strengths of the specimens were found out and the average percentage of loss of weight and compressive strengths were calculated. The results obtained are tabulated in table 9.

Table 9:Test Results of Acid Resistance Test

Sample Specimen	28 day compressive strength (MPa)	After 45 days immersion of cubes in sulphuric acid solution		
		Percentage reduction in weight	Compressive strength (MPa)	Percentage reduction in compressive strength
FA0	30.2	0.42	27.26	9.72
FA1	29	0.47	25.72	11.3
FA2	29.6	0.51	26.02	12.1
FA3	29.8	0.56	25.73	13.66
FA4	28.5	0.59	23.96	15.92
FA5	28	0.63	23.1	17.45

2.2) Saturated Water Absorption Test

The Saturated Water Absorption tests were carried out on 150 mm size cube specimens. The results obtained are tabulated in table10.

Table 10: Test Results of Saturated Water Absorption Test

Sample Specimen	Saturated water absorption	Percentage increase in saturated water absorption
FA0	0.33	22.45
FA1	0.54	36.74
FA2	0.66	44.9
FA3	0.83	56.46
FA4	1.06	72.11
FA5	1.47	100

2.3) Porosity Test

The Saturated Water Absorption tests were carried out on 150 mm size cube specimens. The results obtained are tabulated in table 11.

Table 11: Test Results of Porosity Test

Sample Specimen	Effective Porosity	Percentage increase in Effective Porosity
FA0	2.26	45.12
FA1	2.45	48.9
FA2	3.02	60.28
FA3	4.32	86.23
FA4	4.71	94.01
FA5	5.01	100

III. CONCLUSIONS

Based on limited experimental investigation on the compressive, splitting tensile and flexural strength of concrete, the following observations are made regarding the resistance of Fly Ash Concrete

1) Fly ash replacement up to 30% in concrete has shown good improvement in flexural strength.
2) The 28 days flexural strength of OPC is 3.23MPa. The maximum flexural strength was obtained when cement was replaced 20% by Fly Ash ,i.e, 3.42MPa.
3) Cube Compressive Strength and Split Tensile Strength were found comparable to that of ordinary concrete for lower percentage replacements.
4) The 28 days compressive strength of OPC is 30.2 MPa. The maximum 28 days compressive strength of FA concrete among the five percentages is 29.8MPa. It is for 30% replacement of cement by Fly Ash.
5) The 28 days split tensile strength of OPC is 3.01MPa. The maximum 28 days split tensile strength of FA is 2.98MPa for 30% replacement.
6) The splitting tensile strength of 30% replacement by fly ash is found to be comparable to that of OPC.
7) The FA satisfies the zone II gradation for not only to partially replace the cement, but for making good concrete.
8) From the durability test results, it was observed that the percentage loss in weight of concrete cubes after 45 days immersion in 3% sulphuric acid increases as the percentage of Fly ash replacement increases.
9) From the results it is noted that the saturated water absorption and porosity of concrete mixes containing fly ash are higher compared to that of ordinary concrete.
10) The saturated water absorption and porosity is found to increase as the replacement percentage of cement by fly ash increases.
11) Fly Ash can be effectively replaced in place of cement up to 30% in conventional cement concrete productions.

REFERENCE

[1]. Arivalagan. S, "Flexural behaviour of Reinforced Fly ash concrete beams", International Journal of Structural and Civil Engineering, Volume 1, Issue 1, PP: 11-17.

[2]. Dakshina Murthy, Sudheer Reddy, " Moment-Curvature characteristics of Ordinary grade fly ash concrete beams", International Journal Of Civil And Structural Engineering,Volume 1, No 3, PP:497-508, 2010.

[3]. T.Koyama, Y.P. Sun, T. Fujinaga, H. Koyamada and F.Ogata," Mechanical properties of concrete beam made of a large amount of fine Fly ash", The 14th World Conference on Earthquake Engineering,October 12-17, 2008, Beijing, China.

[4]. Sunilaa George, Dr.R.Thenmozhi, "Behaviour of activated Fly ash concrete", International Journal of Engineering Science and Technology, Vol 3, No.10, PP:7633-7642, October 2011.

[5]. Rama Mohan Rao.P, Mohan.S, Sekar.S.K, " Shear resistance of high volume Fly ash Reinforced concrete beams without web reinforcement", International Journal of Civil and Structural Engineering, Volume 1, No 4,PP:986-993, 2011.

[6]. IS: 456 (2000) "Indian Standard Plain and Reinforced Concrete Code of Practice", Bureau of Indian standards, New Delhi.

[7]. IS: 516 (1959), "Methods of test for strength of concrete", Bureau of Indian standards, New Delhi

[8]. IS: 5816 (1999), " Splitting strength of concrete", Bureau of Indian standards, New Delhi

[9]. IS: 12269 (1987), "Specification for 53 grade ordinary Portland cement", Bureau of Indian standards, New Delhi

[10]. IS: 9103 (1999), "Concrete admixtures- specification", Bureau of Indian standards, New Delhi

[11]. IS: 10262 (2009), " Concrete mix proportioning- guidelines", Bureau of Indian standards, New Delhi