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Experimental Investigation on Partial Replacement of Cement by Fly ash

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Abstract: In India, according to the Ministry of coal 75% of total power generation takes place through thermal power plants, which use coal as the major fuel for electricity generation. This led to a huge amount of byproduct generation, fly ash being the major one. The fly ash is a combustion residue of coal, produced in the small dark flecks that rise with the flue gases that are captured by filters, electrostatic precipitators, and other air pollution control devices, the disposal of which creates a hazardous impact on the environment and human population. The dumping of fly ash in landfills leads to contamination of soil and underground water. Cement is the most consumed product after water, which can provide the right way for the disposal of fly ash since fly ash contains pozzolanic properties it can easily be mixed by weight with cement by doing so, the judicial use of fly ash can be achieved, and we can move toward greener and sustainable future. This paper shows the various properties related to strength partially by various studies conducted by different researchers and by experimentations conducted.

Keywords: Fly ash, Compressive Strength, flexural strength, Electrostatic Precipitators.

I. INTRODUCTION

Cement is one of the most important constituents of concrete. It acts as a binding agent in the concrete and imparts the required strength. The consumption of cement is increasing day by day and its demand will not decrease in the near future. Since many countries are now in their developing stage, the same with the power consumption major of which are derived from coal which leads to thousands of tonnes of fly ash generation which exhibits pozzolanic properties. A pozzolan is a siliceous and aluminous material that in finely divided form and in the presence of moisture chemically reacts with calcium hydroxide at ordinary temperatures to form compounds having cementitious properties. These cementitious properties are also exhibited by fly ash, which can replace cement in a certain proportion. In this study, cement is replaced by fly ash up to 40% by weight and compressive and flexural strength is determined, and the various studies are taken into consideration by different researchers.

Fly ashes are obtained from the thermal power plant by the burning of the anthracite and bituminous coal typically produces class F fly ash. Fly ash which has the pozzolanic in nature. Fly ash is composed of oxide of silicon, aluminum, and calcium. When we used it in the cement as admixture.[8] It will increase its strength and workability also fly ash is very hazardous for the environment. Fly ash will react with water and produces cementitious compounds.

Authors	Chemical Properties of fly ash as per literature					
	Sio_2	Al_2O_3	Fe_2O_3	CaO	MgO	LOI
Ismail [1].	59.00	21.00	3.70	6.90	1.40	4.62
Kushal & Partha [2].	65.81	22.17	3.23	2.45	0.35	0.81
Hasan et.al;[3].	59	29	6.50	1.8	1.44	1.20
Ullah and ahmad [4].	58	23.45	5.80	5.70	0.90	1.03
Kalyanshetti, & Thalange [5].	61.32	29.61	4.26	-	0.82	0.91

Table no. 1 Chemical properties of fly ash

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This property indicates the fineness of fly ash particles.as per ASTM, the fineness of particles is to be checked in both dry and wet sieving. Fineness is a measure of percentage retained on 45-micron sieve when sieving is done Specific gravity of fly ash usually ranges from a low value of 1.90 to a high value of 2.96. The shape of fly ash is usually spherical and size ranges between 10 to 100 microns. The spherical shape of fly ash improves the workability of concrete. It indicates the color in fly ash which mainly depends upon chemical and mineral components. The light color of fly ash is mainly due to lime content and the brown color of fly ash is due to presence of iron content.[6]

Authors	Physical Properties of fly ash as per literature			
	Specific gravity	Water absorption (%)	Fineness	Bulk density (kg/m³)
Ismail [1]	2.88	3.14	-	994
Ullah and ahmad [4]	2.51	-	-	-
Kalyanshetti, & Thalange [5]	2.253	-	-	-
Shwetha et.al; [6]	2.5	-	2.28%	-
Mallesh et.al; [7]	1.98	-	3.0%	-

Table no. 2 Physical Properties of fly ash

II. MATERIALS

1.1 Cement (OPC)
1.2 Coarse Aggregate
1.3 Fine Aggregate
1.4 Fly Ash

1.1 Cement (OPC): Cement is a finely grinded powdery substance which with the help of water is used to bind various other materials together. [1] The various other materials can be sand, aggregates, steel bar etc. which are commonly used in construction activities as shown in fig. no. 1. [3]

The chemical composition of cement mainly comprises of lime (CaO) [62-67%], silica (SiO2) [17-25%], alumina (Al2O3) [3-8%], Calcium Sulphate (CaSO4) [3-4%], iron oxide (Fe2O3) [3-4%], Magnesia (MgO) [1-3%], Sulphur (S) [1-3%], Alkalies (Na2O, K2O) [0.2-1%]. [5]

In the experimentation conducted Birla OPC 43 grade cement is used.

Fig. no. 1 Cement

1.2 Coarse Aggregate: Coarse Aggregates are irregular broken pieces of rock or stone which can be obtain naturally or man-made methods. Shown in fig no. 2. The coarse aggregates are used with cement to make concrete. [4] The size of coarse aggregates generally lies between 80mm – 4.75 mm. [12]

Fig. no. 2 Coarse Aggregate

1.3 Fine Aggregates: Fine Aggregates are granular material consists of any crushed stones or any natural sand particle obtained from mining process which have size less than 4.75 mm. [7] The fine aggregates are used with cement to produce mortar. Shown in fig. no. 3. [12]

Fig. no. 3 Fine Aggregates

Fly Ash: Fly ash is a combustion residue of coal, produced in small dark flecks that rises with the flue gases and is captured by filters, electrostatic precipitators, and other air pollution control devices.[4] Fly ash is finer than Portland cement and lime. [9] Fly ash consist of silt-sized particles which are generally spherical, typically ranging 10 – 100 micron. Fly ash generally consists of oxides of silicon, aluminum, iron, calcium and calcium. [11] Magnesium, potassium, sodium, titanium, and sulfur are also present but in very minimal quantities.[10]

III. METHODOLOGY

Design Mix: According to IS Code 10262:2019, M30 grade of concrete is prepared for casting the specimens for which the test has been performed. In the mix the cement is replaced by weight with fly ash. Five sample is created A, A1, A2, A3, and A4 in which the cement has been replaced by fly ash in 0%, 10 %, 20%, 30%, and 40% by weight respectively The water-cement ratio is taken 0.5 for the samples. Table 3 denote the exact quantities replaced.[6]

Fig. no. 4 Mix of Materials

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Workability test: For determination of workability Slump Test as shown in figure no 5 and 6 has been performed the apparatus used is according to the IS 7320:1974.The result of the test has been include in the table no. 4 [7]

Fig. no. 5 Slump Value measurement

Fig. no. 6 Measurement of slump value

Compressive strength: For determination of compressive strength the compressive test is conducted as per IS Code 516: Part 1: Sec 1: 2021.In which the standard 3 mould of 150 x 150 x150 mm in size is casted for each sample.as shown in fig. no. 7.[8] The compaction is done through table vibrator. After 24 hours the samples are demoulded and immersed in curing tank for curing at room temperature.[10] The sample are then test in compression testing machine having capacity of 200MT after 7, 14 and 27 days. The result of which is include in table no. 5 and also represent in graph 1. [12]

Fig. no. 7 Cube casting

Flexural strength: The flexural strength of concrete is an indirect method for measuring the tensile strength. The test procedure follows as per IS Code 516: Part 1: Sec 1: 2021.[8] In which the 3-bar mould of size 100 x 100 x 500mm is casted for each sample. The compaction is done through table vibrator. After 24 hours the samples are demoulded and immersed in curing tank at room temperature. The samples are then tested after 7, 14 and 28 days in the central point loading machine the load is applied at the rate of 180 kg/min. [8] The results of which has been included in table no. 6 and also represent in graph 2. [4]

VI. RESULTS

Sample	FA (kg/m^3)	CA (kg/m^3)	Cement (kg/m^3)	Fly ash (kg/m^3)
A	807	1152	383	-
A1	807	1152	344.7	38.3
A2	807	1152	306.4	76.6
A3	807	1152	268.1	114.9
A4	807	1152	229.8	153.2

Table 3: Mix Design Quantities

Sample	Value of Slump (in MM)		
A	73	75	75.5
A1	78	81.5	85
A2	92.5	89	91
A3	123	111	109.5
A4	140.5	142.5	139.5

Table 4: Slump Value Test

Sample	Compressive Strength(N/MM^2)		
	7 days	14 days	28 days
A	23.2	32.5	36.2
A1	21.3	30.7	34.5
A2	20.5	28.4	32.3
A3	18.8	26.2	29.6
A4	17.5	23.4	26.7

Table 5: Compressive Strength Result

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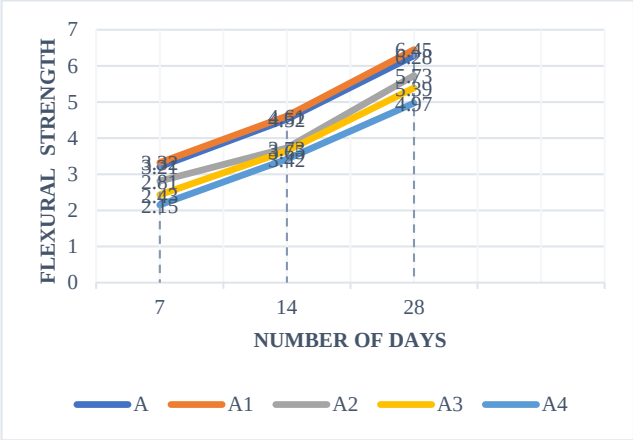
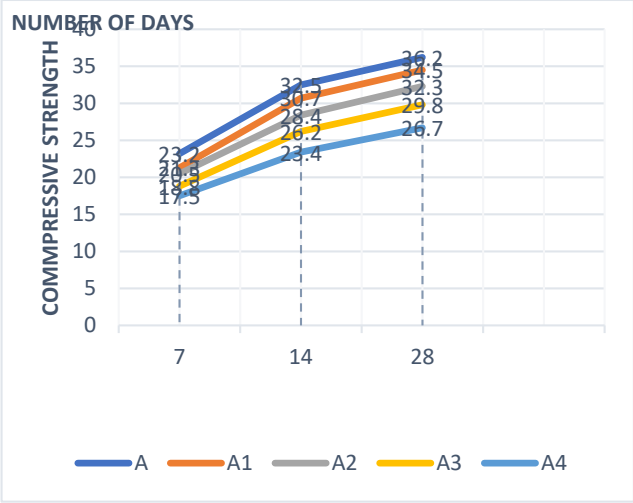


Graph 1: Compressive Strength in N/mm2 at various age (Days)

Sample	Flexural Strength (N/MM²)		
	7 days	14 days	28 days
A	3.21	4.52	6.28
A1	3.32	4.61	6.45
A2	2.81	3.73	5.73
A3	2.43	3.65	5.39
A4	2.15	3.42	4.97

Table 6: Flexural Strength Result



Graph 2: Flexural Strength in N/mm2 at various age (Days)

V. CONCLUSION

In this experimental investigation concerning the compressive & flexural strength of concrete, the following conclusions are drawn:

When the replacement of cement by fly ash is lower than 20% there is no significant change in the workability. The workability remains more or less the same but when the percentage of replacement exceeds by 20% the workability increase drastically making concrete highly workable, pumpable and suitable for heavily reinforced structures.

Up to 30% replacement of cement by fly ash the compressive strength of the concrete remains in the bearable zone but as the percentage of fly ash increases beyond 30% the compressive strength decreases but decrease in the strength is not sharp instead the decrease is gradual when the replacement of fly ash is up to 40% as the percentage of fly ash increases further the compressive strength decreases significantly.

The variation in the flexural strength in the early stages with different percentage of replacement is not significant but as the age of the concrete increases the variation in flexural strength increases.

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