EXPERIMENTAL STUDY ON EFFECT OF FLY ASH ON COMPRESSIVE STRENGTH OF CONCRETE

[1]Bhawani Singh Bhati, [2]Kapil Gandhi, [3]Puneet Hiranandani, [4]Dr. S.S. Sankhla
[1]Junior Engineer, [2]Consultant Engineer/Director, [3]Lecturer, [4]Associate Professor
[1]Urban Improvement Trust, Barmer, Rajasthan, India
[2]K.G. Infrabuild, Jodhpur, Rajasthan, India
[3]Department of Civil Engineering, Government Polytechnic College, Jodhpur, Rajasthan, India
[4]Department of Structural Engineering, M.B.M. Engineering College, J.N.V. University, Jodhpur, Rajasthan, India

Abstract*—Energy generation is increasing day by day due to rapid industrialization. Energy generation through thermal power plants is very typical now days. Fly ash (FA) from these thermal plants is available in large quantities in fine and coarse form. Fine fly ash is used in construction industry in some amount and coarse fly ash is subsequently disposed over land in slurry forms. In India around 160 MT fly is produced and only 40% of that is being utilized in different sectors. Balance fly ash is being disposed over land. Currently around 65000 acres of land is occupied by fly ash. This experiment research study is aimed to investigate the physical, chemical and mechanical properties of fly ash cement concrete for improve the compressive strength of concrete and road construction. From research, it has been observed that the use of 30% of fly ash and 70% of cement possess a superior performance. Moreover, in construction, the use of fly ash would result in the reduction of the cost of materials and the reduction of greenhouse gas emission. Experimental investigation was carried on fly ash concrete to know the effect of fly ash characteristic performance of the concrete. In the investigation, cubical specimens of size 150x 150 x 150 mm were cast for compressive strength test at the ages of 28 days curing with different fly ash % replacement (0%,3%,6%,9%,12%) for mix M-25. Results of the laboratory investigation conclude that the performance of concrete made up of fly ash is superior to achieve the required strengths at higher ages and improved performance characteristics were observed from strength and durability studies. Judicious selection of materials, appropriate mixing methods, proper curing, and appropriate dosage of superplasticizer will enable the production of high performing high volume fly ash concrete.

***Index Terms*— Concrete, Cubes, Fly ash, Compression test**

I. INTRODUCTION

Construction Industry is a fast growing sector to meet the current trends of industralisations and infrastructure development and concrete forms a non-detachable module of construction. The principal binder in concrete is Portland cement, the production of which is a major contributor to greenhouse gas emissions that are implicated in global warming and climate change. Fly ash is an industrial by-product, generated from combustion of coal in the thermal power plants and its disposal is a major problem faced by all the nations across the globe. fly ash concrete will be the solution for the above mentioned problems and its adoption will enable the construction industry to become more sustainable in the resource depleting environment. Hence it requires a detailed investigation.

The total production of fly ash in the world is estimated currently to be 600 million tons. Over 75% of power generation plants in India are coal based, 230-250 MT coal is being used every year which results in the generation of 110 MT of fly ash every year. The estimated amount is about 170 million MT by the year 2010. Presently 30% of ash is being used in fillings, embankments, construction activities, fly ash hollow block and tiles. Presently majority of the coal ash generated is being handled in wet form and disposed off in ash ponds which are harmful for the environment and moreover ash remains unused for gainful applications. Fly ash has a vast potential for use in fly ash concrete especially due its physico-chemical properties.

Detailed studies on the properties of Indian fly ash mix concrete with available local ingredients to use the full potential of this concrete is needed. Experimental investigation was carried on fly ash concrete to know the effect of fly ash characteristic performance of the concrete. Based on the detailed experimental investigation conducted on the various structural elements, it is concluded that high volume fly ash concrete achieves the required strengths at higher ages and improved performance characteristics were observed from strength and durability studies. Judicious selection of materials, appropriate mixing methods, proper curing, and appropriate dosage of superplasticizer will enable the production of high performing high volume fly ash concrete.

II. LITERATURE REVIEW

Rafat Siddique (2003) performed experimental investigation to study the effects of replacement of cement (by mass) with three percentages of fly ash (35 %, 45 % and 55 %) and the effects of addition of natural san fibers on the slump, vebe time, compressive strength, splitting tensile strength, flexural strength and impact strength of fly ash concrete. The test results indicated that the replacement of cement with fly ash increased the workability (slump and vebe time), decreased compressive strength, splitting tensile strength and flexural strength and had no significant effect on the impact strength of plain (control) concrete. Addition of san fibers reduced the workability, did not significantly affect the compressive strength, increased the splitting tensile strength and flexural strength and tremendously and enhanced the impact strength of fly ash concrete as the percentage of fibers increased.

Bouzoubaa et al (2001) examined the mechanical properties and durability of concrete made with a high-volume fly ash (HVFA) blended cement using a coarse fly ash that does not meet the fineness requirement of ASTM C 618. The results were compared with those of the HVFA concrete in which ungrounded fly ash had been added at the concrete mixer. The results showed that except for the resistance of the concrete to the deicing salt scaling, the mechanical properties and the durability of concrete made with this blended cement were superior to the concrete in which the ungrounded fly ash and the cement had been added separately in the mixer. Therefore, the production of HVFA blended cements offers an effective way for the utilization of coarse fly ashes that do not otherwise meet the fineness requirements of ASTM C 618.

The strength of roller-compacted concrete with high volume fly ash (HFRCC) is examined by Cheng Cao et al (2000). From the experimental results it was concluded that

(1) The strength at early ages of HFRCC is poor, while the fly ash effect is low or negative.

(2) The strength of HFRCC increases rapidly following its curing age; meanwhile, the fly ash effect gradually improves and is more beneficial to raising flexural strength.

(3) With increasing proportion of fly ash, its effect on HFRCC at long curing age becomes more remarkable.

Sivasundaram et al (1990) monitored the strength development of high volume fly ash concrete over a period of 3 years, and it reached a maximum compressive strength of 70 MPa at 1/2 years. The modulus of elasticity of this concrete at 2 years was 47 GPa. Following its excellent performance in the laboratory investigations, this concrete was utilized in a field application.

III. Materials Used For Present Experimental Study

Cement

The characteristics of cement on water demand are more noticeable in fly ash concrete. Some of the important factors which play vital role in the selection of cement are compressive strength at various ages, fineness, heat of hydration, alkali content, tricalcium aluminate (C3A) content, tricalcium silicate (C3S) content, dicalcium silicate (C2S) content etc. It is also necessary to ensure compatibility of the chemical admixtures with cement. Ordinary Portland Cement, 43 Grade conforming to IS: 8112-1989. The results of the tests on cement sample are listed in Table 1.

Table 1 Test results for Ultratech 43 OPC

S.No.	Tests	Results
1	Normal consistency	29%
2	Initial Setting Time	85 Minutes
3	Final Setting Time	195 Minutes
4	Specific Gravity	3.10
5	7 days compressive strength of cement	41.2 N/mm^2

Coarse Aggregate

Aggregates are important constituents of concrete. They form integral structure to the concrete, reduce shrinkage, and affect economy. Aggregates occupy 70 to 80 percent of volume of the concrete. Properties such as crushing strength, durability, modulus of elasticity, maximum size, gradation, shape and surface texture characteristics, percentage of deleterious materials as well as flakiness and elongation indices need special consideration while selecting the coarse aggregate for fly ash mix. The aggregate should be sound, free from deleterious materials, and must have crushing strength at least 1.5 times that of concrete. Locally available (Kakani) Coarse aggregate were tested as per the procedure given in IS 383-1970 and the results are given below in table 2.

Table 2 Sieve Analysis Test results for Coarse aggregate

No.	Sieve Size	% passing	According to IS 383-1970 % passing for 20 mm single size Aggregate
1.	40 mm	100	100
2.	20 mm	89.68	85-100
3.	10 mm	0.7	0-20
4.	4.75 mm	0.04	0-5

The above result confirms coarse aggregate of 20-mm single size aggregate and specific gravity 2.65 and voids content 45%.

Fine Aggregate

Fine aggregate used for fly ash concrete showing high performance characteristics should be properly graded to give minimum void ratio and be free from deleterious materials like clay, silt content, and chloride contamination etc. Fly ash concrete contains large quantity of fine cementitious materials. Hence, the grading of fine aggregate is relatively different from that of conventional cement concrete. Properties such as void ratio, gradation, specific gravity, fineness modulus, free moisture content, specific surface, bulk density, etc. have to be assessed to design a dense fly ash mix with optimum cement content and reduced mixing water. Locally available river sand were tested as per the procedure given in IS 383-1970 and the results are given below in table 3.

Table: 3 Sieve Analysis Test results for fine aggregate (sand)

No.	Sieve Size	% passing	from table IS 383-1970 for Zone II% Passing
1.	4.75 mm	96.4	90-100
2.	2.36 mm	91.2	75-100
3.	1.18 mm	73.5	55-90
4.	600 micron	52.4	35-59
5.	300 micron	30.7	8-30
6.	150 micron	9.8	0-10
7.	Pan	0.0	-

Above sieve analysis conforms to fine aggregate of zone II and specific gravity 2.42 and voids content 26%.

Fly Ash

Fly ash is an inorganic, non-combustile by-product of coal-burning power plants. As coal is burnt at high temperature, carbon is burnt off and most of the mineral impurities are carried away by the flue gas in the form of ash. Fly ash is a pozzolanic material which possesses no cementitious value but which will, in finely divided form and in the presence of moisture, alumino-silicates within the fly ash react with calcium ions to form calcium silicate hydrate. In today's construction industry there is a general trend to replace higher levels of Portland cement with fly ash in concrete is due to the three main aspects i.e. economic, environment and technical benefits. Fly ash sample is collected from Suratgarh Thermal Power Plant.

Water

Potable water was used for concreting and curing for the entire investigation.

Plasticizer

Plasticizer are used in this study is BASF.

IV. Concrete Mix Design

Design Mix M-25

As per IS 10262 and SP (23)-1982 and IS 456-2000

Target mean strength of concrete

For a tolerance factor of 1.65 as specified in IS 456-2000 and the standard deviation 5.0 N/mm2 (as given in table 1, IS-10262), target mean strength of concrete:

F_{tms} = 25+5*1.65

F_{tms} = 33.25 N/mm^2

Selection of W/C ratio

Selected W/C ratio for the desired target mean strength = 0.45

Selection of water and sand content

Water per cubic meter = 170 kg/m^3

Sand as percentage of total aggregate by absolute volume = 0.35 or 35%

Cement required = 170/0.45= 380kg/m^3

Determination of coarse and fine aggregates

Volume of concrete- 1m^3

Volume of cement- 0.121m^3

Volume of water- 0.170 m^3

Volume of plasticizer- 0.0025m^3

Volume of all in aggregate- 0.7065 m^3

Mass of fine aggregate- 598 Kg/m^3

Mass of coarse aggregate- 1220 Kg/m^3

0.75% Admixture (Plastisizer) by weight of cement (for coarse aggregate mix proportion as 60% for 20 mm size aggregate and 40% for 10 mm size aggregate)

V. Test Program And Procedure

Compressive Strength Test for Brick Prisms

Experimental investigations carried out on the test specimens to study the basic strength properties and strength related properties of fly ash concrete. Basic strength test conducted for compressive strength on cubical specimens.

Cube Compressive Strength

Compressive strength is a qualitative measure of the properties of hardened concrete. For compression test, concrete cubes of 150 x 150 x 150 mm were used. All the cubes were tested in saturated condition, after wiping out the surface moisture. For each mix combination, three cubes were tested at the age of 28 days of curing using compression testing machine of 2000 kN capacity. Thirty specimens were cast for the cube compression strength test.

The tests were carried out at a uniform stress of 140 kg/cm2/minute after the specimen has been centered in the testing machine as shown in Fig. 1.

Loading was continued till the dial gauge needle reversed its direction of motion. The reversal in the direction of motion of the needle indicates that the specimen has failed. The dial gauge reading at that instant was noted which indicates the ultimate load. The ultimate load divided by the cross sectional area (150x150) of the specimen is equal to the ultimate cube compressive strength.

Figure 1 Test set up for compressive strength on cube fly ash concrete specimen

For mix M-25 after 28 days of curing cube specimens are taken out and after surface dried condition compressive strength test results are given in tables 4 to 8 with fly ash replacement as cement 0%,3%,6%,9% and 12% respectively.

Table 4 28 Day compressive strength of M-25 with 0 % fly ash replacement

S. no.	Weight (Kg)	Crushing Load	Compressive strength (N/mm^2)
1	8.778	760	33.78
2	8.955	780	34.67
3	8.94	800	35.56
Average =			34.67

Table 5 28 Day compressive strength of M-25 with 3 % fly ash replacement

S. no.	Weight (Kg)	Crushing Load	Compressive strength (N/mm^2)
1	8.965	780	34.67
2	8.876	800	35.56
3	8.963	805	35.78
Average =			35.34

Table 6 28 Day compressive strength of M-25 with 6 % fly ash replacement

S. no.	Weight (Kg)	Crushing Load	Compressive strength (N/mm^2)
1	9.006	825	36.67
2	8.773	800	35.56
3	9.009	830	36.89
Average =			36.38

Table 7 28 Day compressive strength of M-25 with 9 % fly ash replacement

S. no.	Weight (Kg)	Crushing Load	Compressive strength (N/mm^2)
1	8.883	880	39.12
2	9.02	860	38.23
3	8.88	870	38.67
Average =			38.68

Table 8 28 Day compressive strength of M-25 with 12 % fly ash replacement

S. no.	Weight (Kg)	Crushing Load	Compressive strength (N/mm^2)
1	9.08	825	36.67
2	8.802	830	36.89
3	8.768	840	37.34
Average =			36.97

Average of Compressive Strength of cubes of M-25 are with different fly ash ratio is given in table 8. And graph is plotted between average compressive strength and fly ash percentage replacement.

Table 8 Compression of compressive strength of concrete (cube specimens)(M-25 grade mix)

S. No.	Mix	Average Compressive Strength(N/mm^2)
1	FA 0%	34.67
2	FA 3%	35.34
3	FA 6 %	36.38
4	FA 9%	38.68
5	FA 12%	36.97

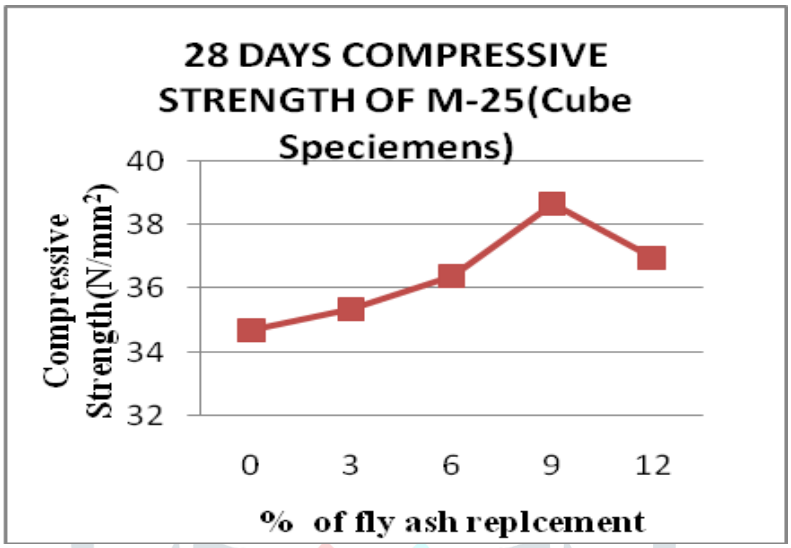

Figure 2 Average 28 days compressive strength of M-25(cube specimens)

Above results show that compressive Strength at 28 Days increases with increase in Fly ash content up to 9 % of fly ash replacement and after 9 % fly ash replacemnt Compressive Strength of concrete decreases. Hence Compressive Strength of concrete can increase by adequate use of fly ash.

VI. Conclusions

In this investigation we have used Fly ash mix concrete with available local ingredients to utilize the full potential of this concrete is needed. Experimental investigation was carried on fly ash concrete to know the effect of fly ash characteristics performance of the concrete. In this investigation, fifteen specimens (15) cubical specimens were cast for compressive strength test. This sample is having three samples from Each Mix of M-25 (with fly ash % as 0, 3, 6, 9, 12). Conclusions are presented on the basis of results show that for mix M-25 compressive Strength of cube specimens at 28 Days increases with increase in fly ash content up to about 9 % of fly ash replacement and after that fly ash replacement Compressive Strength of concrete decreases. So we have stopped the further increment of mix design. Further study can be done by addition of more amount of fly ash and admixture and mix design of concrete cube.

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