EFFECT ON MECHANICAL PROPERTIES OF CONCRETE USING FINE AGGREGATE AS PARTIAL REPLACEMENT WITH FLY ASH

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Abstract - *The use of flyash as a partial substitute in concrete mixtures is becoming more popular. Thermal power plants produce flyash, which is a waste product. The amount of fly ash generated by thermal power plants in India is estimated to be over 105 million tonnes per year, with a utilisation rate of less than 13%. The majority of fly ash generated is classified as Class F. The adoption of these materials would alleviate the current disposal issues that thermal power plants and industrial facilities confront. Some cement factories have begun to use fly ash in the production of 'Pozzolana Portland cement' in recent years, but overall utilisation remains low, and the majority of the fly ash is disposed of in landfills.*

Fly ash is widely utilised as a cement replacement, a concrete additive, and in the production of cement. Whereas concrete with fly ash as a partial replacement for cement has concerns with delayed early strength development, concrete with fly ash as a partial replacement for fine aggregate will not have this problem and will actually increase long-term strength. In this research, flyash is used as a sand replacement. The material proportions are 1:1.45:2.46:0.5 for this combination. Each category has different percentages of sand replacement material, such as 46 percent, 47 percent, 48 percent, 49 percent, 50 percent, 51 percent, 52 percent, 53 percent, 54 percent, and 55 percent, in increasing order. The workability of all mixes is maintained at the same level. For a seven-day and twenty-eight-day curing period, concrete mix strength characteristics such as compressive strength, flexural strength, and split tensile strength are evaluated, and the results are analysed.

Key Words: FlyAsh, Water cement ratio, compressive strength, Flexural strength, split tensile strength

1. INTRODUCTION

Because of the country's growing economy, population, and living standards, demand for cement and other main building materials is expanding. Cement output in the nation is predicted to be over 90 million tonnes per year, with a ten percent annual growth rate (1)

Because of its versatility, simplicity of manufacturing, and application, cement concrete has become the most used construction material (1). However, three factors of concrete use are becoming increasingly important. The first is the issue of long-term viability. The new code of practise for concrete IS 456-2000 emphasises the significance of durability. The second aspect is the economy in construction by improved design and cost reduction in cost of materials. The third aspect relates to energy conservation and environment protection. These three factors can be uniquely addressed by the use of fly ash in concrete.

In our nation, we now produce over 100 million tonnes of fly ash per year, of which only around 20% is used profitably. However, the use of fly ash in concrete production is minimal. Concrete's unique position as a structural material stems from its cost-effective resistance to fire, wind, water, and earthquakes. To keep up with the rising population, housing, transportation, and other facilities, demand is expected to rise in the future. Individual materials, on the other hand, may not always suit the intended function. Concrete is a composite material in the sense that it is made up of several different materials. Greater usage of pozzolonic materials like flyash and blast furnace slag was recommended as a way to reduce the cost of concrete. The use of these materials as the substitute material in concrete would reduce the disposal problems now faced by thermal power plants and industrial plants and at the same time achieving the required strength of concrete.

Flyash was employed as a partial substitute for sand in this research. The burning of powdered or pulverised bituminous coal or sub-bituminous coal produces flyash, which is a finely divided residue. It's widely accessible in the nation as a waste product from a number of thermal power plants and industrial operations that use pulverised coal or lignite as a boiler fuel. In recent years, the practical use of flyash as a partial replacement for sand as an additive in cement mortar and concrete has gained traction in the country. Greater use of flyash would not only save such construction materials, but will also help to solve the problem of disposal of this waste product. Recent researches have also revealed the need for suitable flyash collecting procedures in order to produce high-quality and consistent flyash, which are essential prerequisites for usage in building materials.

2. LITERATURE SURVEY

Although there have been a number of noteworthy results reported on the use of Class F fly ash in concrete, there is little literature on the use of Class F fly ash as a partial substitute for fine aggregates. Maslehuddinet conducted research to determine the compressive strength development and corrosion resistance of concrete mixes with fly ash as an additive (equal quantity of sand replacement). Fly ash additions of 0 percent, 20 percent, and 30 percent were used in concrete compositions with water–cement ratios of 0.35, 0.40, 0.45, and 0.50. They found that adding fly ash as an additive boosts the early age compressive strength and long-term corrosion-resisting qualities of concrete based on the test findings. The densification of the paste structure owing to pozzolonic action between the fly ash and the calcium hydroxide freed as a result of cement hydration was ascribed to the higher performance of these mixes compared to ordinary concrete mixes.

Ghafoori investigated a variety of roller compacted concretes (RCC) prepared in the lab with high-calcium dry bottom ash as a fine aggregate. Concrete examples with six different proportions (cement content of 188–337 kg/m3 and coarse aggregate content of 1042–1349 kg/m3) were manufactured in accordance with ASTM C 1170 Procedure A at their optimal moisture content. Compression, splitting stress, drying shrinkage, abrasion resistance, and quick freezing and thawing resistance were all evaluated on the samples. Based on the test results, they concluded that good strength, stiffness, drying shrinkage and resistance to wear, and repeated freezing and thawing cycles can be obtained with compacted concretes containing bottom ash.

Hwang investigated the rheology, compressive strength, and carbonation characteristics of fly ash and mortar after fine aggregate substitution. Rheological characteristics, compressive strength, and carbonation rate of mortars with water to Portland cement ratios of 0.3, 0.4, and 0.5, in which the fine aggregate was substituted with fly ash at 25% and 50% levels. The rheological constants rose with a larger degree of fly ash substitution, and the strength development and carbonation qualities improved when the water to Portland cement ratio was maintained.

Bakoshi substituted bottom ash for fine aggregate in the proportions of 10–40%. The compressive and tensile strength of bottom ash concrete typically rises with the replacement ratio of fine aggregate and curing age, according to test findings. Concrete made with bottom ash has a lower freezing–thawing resistance than standard concrete, but it has a greater abrasion resistance.

3. EXPERIMENTAL WORK

3.1 Outline

The experimental investigation consisted of designing fly ash concrete mixes following rational methods combined with efficiency factor considerations to obtain the optimum fly ash content for a requisite 28-day strength and workability.

3.2 Materials

Cement: Ordinary Portland cement of 53 grade confirming to IS 12269 was used in the investigation

Fine Aggregate: Natural sand was used. The specific gravity was found to be 2.65 and sieve analysis confirmed to zone II.

Coarse Aggregate: Crushed stone aggregate of maximum size 20mm was used Specific gravity was found to be 2.65

Flyash: Fly ash obtained from Nashik Thermal Power Station was used in the investigations. The chemical and physical properties are given in Table 2.

3.3 Design Parameters

The design parameters adopted are given in table 2. Control mixes are proportioned as per guidelines provided in IS 10262-1982.The proportions for control concrete are far each grade of concrete investigated are given in table 3, 4& 5

Table -1 Physical properties of Ordinary Portland cement

Physical test	Results obtained	IS: 8112-1989 specifications
Fineness (retained on 90-mm sieve) Fineness: specific surface Normal consistency	 8.5 285 30%	 10 max 225 min
Vicat time of setting (min) Initial Final	 120 215	 30 min min 600 min maxi
Compressive strength (MPa) 7 days 28 days Specific gravity	 13.729 21.28 3.15	 13.4 minimum 20.0 minimum

Table -2 Chemical composition of fly ash

Physical test	IS: 8112-1989 specifications
Silicon dioxide, SiO2	55.3
Aluminum oxide, Al2O3	25.7
Ferric oxide, Fe2O3	5.3
SiO2+Al2O3+Fe2O3	85.9
Calcium oxide, CaO	5.6
Magnesium oxide, MgO	2.1
Titanium oxide, TiO2	1.3
Potassium oxide, K2O	0.6
Sodium oxide, Na2O	0.4
Sulfur trioxide, SO3	1.4
LOI (100° C)	1.9
Moisture	0.3

Table -3 Physical properties of aggregates

Property	Fine aggregate	Coarse aggregate
Specific gravity	2.65	2.65
Fineness modulus	2.25	6.61
SSD absorption (%)	0.86	1.12
Void (%)	36.2	39.6
Unit weight (kg/m3)	1690	1615

4 CONCRETE MIX DESIGN BY INDIAN STANDARDS METHOD (GRADE M20)

DESIGN SPECIFICATIONS

a) Characteristic compressive strength required at the end of 28 days = 20 MPa

b) Maximum size of aggregates = 20 mm

c) Degree of workability = 0.85 cf

d) Degree of quality control = Fair

e) Type of exposure = Mild

TEST DATA FOR MATERIALS

a) Cement used – Ordinary Portland Cement satisfying requirements of IS: 269-1976

b) Specific Gravity of cement = 3.15

c) (i) Specific Gravity of coarse aggregates = 2.65

(ii) Specific Gravity of fine aggregates = 2.65

d) Water Absorption

(i) Coarse aggregates =0.5%

(ii) Fine aggregates =1.0%

e) Free Surface Moisture

(i) Coarse aggregates =0.5%

(ii) Fine aggregates = 5%

f) Sieve Analysis

(i) Coarse aggregates =2.5%

(ii) Fine aggregates =1.5%

Table -4 Sieve analysis of aggregates

Fine aggregates			Coarse aggregates		
Sieve size	% Passing	Requirement IS:383-1970	Sieve size	% Passing	Requirement IS:383-1970
4.75 mm	92.20	90-100	40 mm	100.00	100
2.36 mm	86.35	85-100	20 mm	95.00	95-100
1.18 mm	76.85	75-100	16 mm	86.00	85-90
600 mm	66.76	65-79	12.5 mm	76.00	75-80
300 mm	13.56	12-40	10 mm	27.85	25-55
150 mm	3.21	0-10	4.75 mm	06.00	0-10

5. FINAL MIX PROPORTION FOR 1 m^3

Table -6 Final mix proportion

Water	Cement	Fine aggregates	Coarse aggregates
215 liters	430 kg	654 kg	1056 kg
Mix Proportion			
0.5	1	1.46	2.8

FLY ASH CEMENT CONCRETE MIX

Table -7 Fly ash cement concrete mix

Type of mix	Water	Cement	Fine aggregates		Coarse aggregates
			Flyash	Sand	
	0.5	1	1.46		2.8
PLAIN	10.776	21.552	00.000	32.327	60.34
46 %	10.776	21.552	14.871	17.450	60.34
47 %	10.776	21.552			60.34
48 %	10.776	21.552	15.517	16.812	60.34
49 %	10.776	21.552	15.871	16.350	60.34
50 %	10.776	21.552	16.160	16.160	60.34
51 %	10.776	21.552	16.350	15.871	60.34
52 %	10.776	21.552	16.812	15.517	60.34
53 %	10.776	21.552			60.34
54 %	10.776	21.552	17.450	14.871	60.34
100 %	10.776	21.552	32.327	00.000	60.34

6. TEST PROGRAMME

Sand is quite expensive to get, and depending on its source, it may require further treatment, such as washing, to remove some unwanted compounds and organic debris that might weaken concrete. Fly ash, Laterite fines, and Granite fines have been identified as acceptable substitutes for sand in concrete after investigations on local raw materials. Fly ash is employed as a partial replacement material in concrete in this study. In this study, the strength of concrete with a mix percentage of 1: 1.45: 2.45:0.5 is compared to concrete with a mix proportion of 1: 1.45: 2.45:0.5.

1. 0% flyash as a partial replacement to sand. (Plain)

2. 46% flyash as a partial replacement to sand. (P 46)

3. 48% fly ash as a partial replacement to sand. (P 48)

4. 49% fly ash as a partial replacement to sand. (P 49)

5. 50% fly ash as a partial replacement to sand. (P 50)

6. 51% fly ash as a partial replacement to sand. (P 51)

7. 52% fly ash as a partial replacement to sand. (P 52)

8. 54% fly ash as a partial replacement to sand (P 54)

Compressive strength, flexural strength, split tensile strength, and modulus of elasticity of concrete were determined for 7 and 28 days as part of the complete programme. With increasing percentages, fly ash is being used to partially replace sand. i.e. 0%, 46%, 48%, 49%, 49%, 50%, 51%, 52%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 54%, 5 Concrete mix proportioning was done on an absolute weight basis. Proportioning is done on an absolute volume basis on the field.

Ordinary Portland Cement (5, 3) complying to IS: 4031-1968 was used to make normal concrete. Nashik Thermal Power Station acquired river sand free of organic matter and crushed stone aggregate of 20mm maximum size as per IS: 10262-1982(9) and flyash. In the laboratory, the concrete was prepared. The cement, fly ash, sand and coarse aggregate were first mixed in dry state to obtain uniform color.

The amount of water determined by a workability test (slump cone test) is then added to the dry mix to provide a homogenous mix with constant workability. The amount of water injected was calculated based on the results of a workability test performed in accordance with IS: 1199-1959(10), and the entire concrete was mixed in a wet condition. After mixing, the concrete was poured into cube, cylinder, and beam moulds and crushed using a vibrating table. 150mm cubes and 150 x 300mm cylinders were cased to determine compressive and split tensile strengths. The standard interior dimensions of the moulds were retained on the table vibrator, and the concrete was poured in three layers into the moulds by prodding with a tamping rod and vibrating with the table vibrator. The vibrator was turned on for one minute and kept at the same speed for all of the specimens. A 100 x 100 x 500mm beam and a 150 x 300mm cylinder were cast to determine flexural strength and modulus of elasticity.

For 7 and 28 days of curing, compressive strength, flexural strength, split tensile strength, and water permeability were determined. All of the foregoing tests were performed using a 300-tonne compression testing equipment in accordance with IS-516 - 1959. According to IS: 5816 - 1970, cylinders are tested by positioning the longitudinal axis of the cylinder horizontally (6).

After 24 hours, the moulds were removed. After identifying the specimens with some note, they were submerged in a clean water tank. The specimens were removed from the tank and left to dry under shade after curing for 7 and 28 days. The specimens were then evaluated for compressive, tensile, and flexural strength, as well as water permeability. Two cubes, two cylinders, and two beams were cast and tested for 7 and 28 days for each concrete mix category. A total of 45 samples were examined.

7. RESULTS

The experimental results are tabulated below

Table -8 Strength values of 1: 1.45: 2.45:0.5 concrete mix with different percentage replacement of sand (fine aggregate) with fly ash for 7 days curing period 20 mm machine crushed aggregate

Type of mix	w/c Ratio	% of sand replaced with fly ash	Compressive strength N/mm^2	Flexural strength N/mm^2	Split Tensile strength N/mm^2
PLAIN	0.50	0	13.729	2.042	1.713
46 P	0.50	46	13.149	2.05	1.051
47 P	0.50	47	21.218	3.053	2.224
48P	0.50	48	21.896	3.025	2.253
49P	0.50	49	22.05	3.124	2.312
50P	0.50	50	21.952	3.126	2.320
51P	0.50	51	22.983	3.213	2.306
52P	0.50	52	23.557	3.215	2.22
53P	0.50	53	23.31	3.152	2.231
54P	0.50	54	23.306	3.125	2.11
55P	0.50	55	23.204	3.126	2.16

Table -9 Strength values of 1: 1.45: 2.45:0.5 concrete mix with different percentage replacement of sand (fine aggregate) with fly ash for 28 days curing period 20 mm machine crushed aggregate

Type of mix	w/c Ratio	% of sand replaced with fly ash	Compressive strength N/mm^2	Flexural strength N/mm^2	Split Tensile strength N/mm^2
PLAIN	0.50	0	21.28	4.02	2.32
46 P	0.50	46	16.226	3.062	1.55
47 P	0.50	47	29.231	4.321	3.125
48 P	0.50	48	29.325	4.33	3.121
49 P	0.50	49	29.318	4.325	3.252
50 P	0.50	50	29.825	4.525	3.28
51 P	0.50	51	30.817	4.552	3.202
52 P	0.50	52	30.925	4.654	3.151
53 P	0.50	53	30.896	4.253	3.125
54 P	0.50	54	30.892	4.551	3.102
55 P	0.50	55	30.232	4.328	3.125

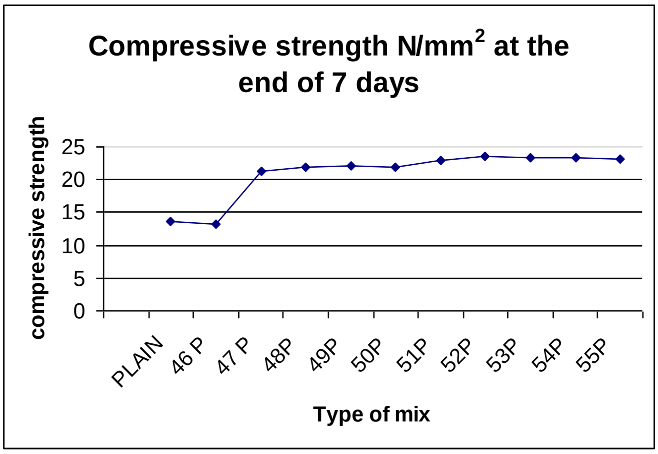

Chart -1: Compressive strength at 7 days

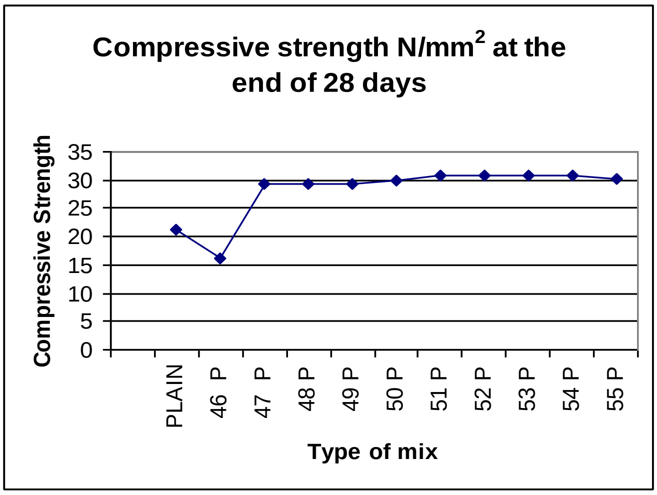

Chart -2: Compressive strength at 28 days

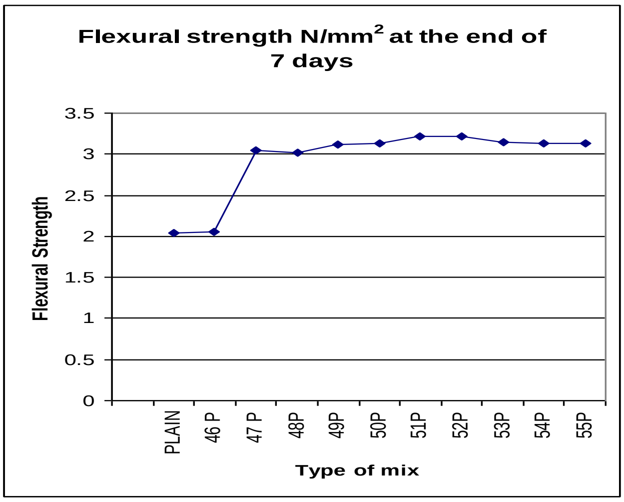

Chart -3: Flexural strength at 7 days

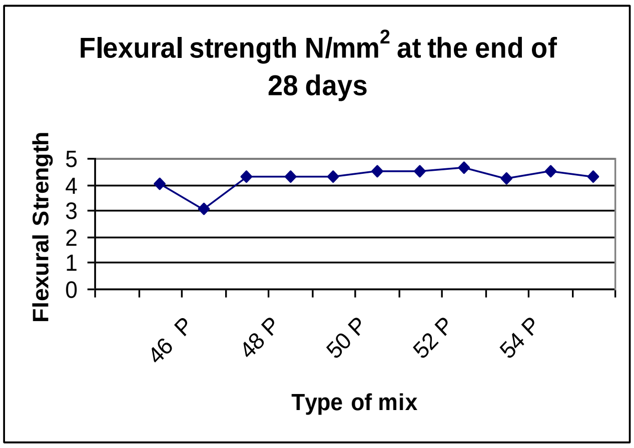

Chart -4: Flexural strength at 28 days

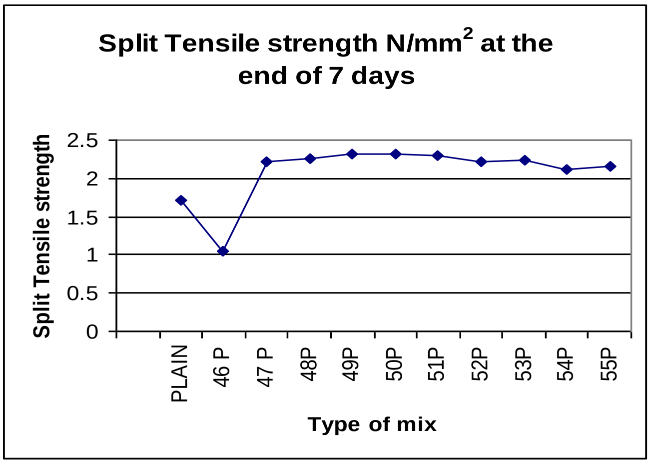

Chart -5: Split tensile strength at 7 days

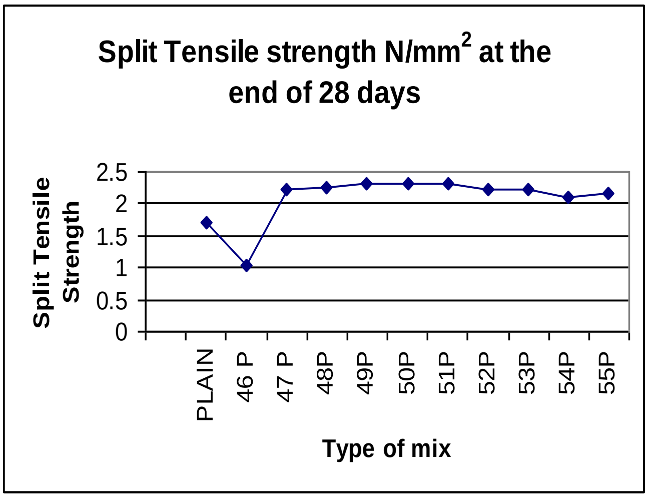

Chart -6: Split tensile strength at 28 days

The experimental results are tabulated as category wise as bellow. Graphs were also drawn for the experimental results.

8. DISCUSSIONS

The compressive strength, tensile strength, and flexural strength of concrete are all increased by 50% (50P) when sand is partially replaced by fly ash. Because of the improved packing and ball bearing effect caused by the spherical flyash particles, as well as interspatial forces that impact both the hydration and packing efficiency of concrete, the maximum strength is achieved. The strength of the fly ash is improved due to better deflocculation of cement agglomerates, which results in a higher rate of CaOH generation and promoted pozzolonic activity.

Because a significant amount of unreacted fly ash comprised of glassy spherical particles acts as tines to fill the spaces present in fine aggregate, the high modulus of elasticity is reached.

The strength is increased due to increased cohesiveness, total absence of bleeding and decreases in voids.

9. CONCLUSIONS

1. It has been discovered that when the amount of flyash grows, the compressive strength increases at first, but as the percentage climbs more, the compressive strength decreases. The compressive strength achieves its highest for both the 7 and 28 day curing periods when sand is partially replaced by flyash by 52 percent (52P). For 7 and 28 days of curing, the maximum compressive strength of flyash concrete (52P) is improved by 71.58 percent and 45.32 percent, respectively, when compared to plain concrete (P).

2. It has been noticed that when the amount of flyash grows, the tensile strength improves at first, but as the percentage climbs more, the tensile strength decreases.

   The tensile strength achieves its highest for both the 7 and 28 day curing periods when sand is partially replaced by flyash by 52 percent (52P). For 7 and 28 days of curing, the maximum tensile strength of flyash concrete (52P) is improved by 57.4% and 13.23%, respectively, as compared to plain concrete (P).

3. It has been shown that when the proportion of flyash grows, the flexural strength increases at first, but as the percentage climbs further, the flexural strength decreases. The flexural strength achieves its optimum for both the 7 and 28 day curing periods when sand is partially replaced by flyash by 52 percent (52P). For 7 and 28 days of curing, the maximum flexural strength of flyash concrete (52P) is improved by 34.61 percent and 35.81 percent, respectively, when compared to plain concrete (P).

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