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Utilization of Fly Ash in Concrete as Partial Replacement of Cement

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ABSTRACT: This paper presents the effect of addition of fly ash (0 to 40%) in concrete. Fly ash is a waste material having pozzolanic nature obtained from thermal power plant. Fly ash is added to the concrete in varying percentages, ranging from 0 to 40%. The compressive strength, flexural strength, splitting tensile strength and ultrasonic pulse velocity were measured. At all the replacement levels of fly ash in concrete the compressive strength is improved, when compared with nominal concrete (F0). A highest compressive strength is observed with F30 (30% fly ash) concrete. A similar trend of improvement in flexural strength and splitting tensile strength is observed, when compared with compressive strength. As per IS 13311(part 1): 1992 the UPV values obtained for fly ash concrete at 28 days of curing age denotes the excellent quality of concrete. The results support the use of fly ash as partial replacement of cement up to 30%.

KEYWORDS: Fly ash, compressive strength, splitting tensile strength, flexural strength, ultrasonic pulse velocity

I. INTRODUCTION

Fly ash is a waste material having pozzolanic nature obtained after the combustion of pulverized coal in electric power generating plants. It is collected from the exhaust gases by electrostatic precipitators. Fly ash particles are generally spherical in shape and diameter ranges from less than 1 μm – 150 μm . It is generally finer than Portland cement. The chemical composition of fly ash is determined by the types and relative amounts of fire-retardant material in the coal used. The main chemical components present in fly ash are Silicon dioxide (SiO_2), Aluminum oxide (Al_2O_3), Ferric oxide (Fe_2O_3), Calcium oxide (CaO). Fly ash is widely used in producing cement and concrete because of its fineness and pozzolanic nature and sometimes self-cementitious nature. As per ASTM C 618 (1993) fly ash is categorized into the following categories namely, class C which is produced from lignite of sub-bituminous coals, and class F produced from bituminous coals.

In total coal ash the percentage of fly ash present is 75 – 85% remaining ash is termed bottom ash or boiler slag. Due to mineralogical composition, the particle size of fly ash is finer and having amorphous character. Fly ash

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produced from various power plants is not equally pozzolanic and, it is not always suitable for use as mineral admixture in concrete. The major disadvantage of fly ash is its disposal in land fields creating environmental burden.

II. MATERIALS AND METHODS

Cement: Ordinary Portland cement 53 grade (OPC) is adopted throughout the experimental investigation. The properties of OPC are given in Table I.

Sand: Krishna river sand which is available locally is used in the experimental investigation. The specific gravity and fineness modulus of sand is 2.57 and 2.46 having zone II as per IS 383:2016^[1].

Coarse Aggregate: Crushed granite material passing through 20 mm sieve and retained on 10mm sieve. Its specific gravity and fineness modulus is 2.7 and 8.83.

Water: Potable tap water available from R.V.R & J.C College of Engineering was used for mixing and curing of concrete specimens.

Fly Ash: Fly ash, which is used for the present experimental study is collected from Narla Tata Rao Thermal Power Station near Vijayawada. The fly ash collected is shown in Fig. 1



Fig. 1 Fly ash collected from the power plant

Experimental tests

The mix proportion arrived for M25 grade concrete as per IS 10262: 2009^[2] is 1:1:2 with water to cement ratio of 0.4. OPC is replaced with fly ash by 0% (F0), 5% (F5), 15% (F15), 30% (F30), and 40% (F40) by weight. The compressive strength, flexural strength, and splitting tensile strength of concrete were measured at 7 days, 28 days, and 90 days. The UPV values of concrete are measured at 28 days of curing age. Table II, shows the standard references that are used for the experimental study.

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Table I: Physical properties of cement

S.no	Property	Value
1.	Specific Gravity	3.13
2.	Setting Time	
	Initial setting time	92 mins
	Final setting time	195 mins
3.	Compressive Strength	
	7 days	29.23 MPa
	28 days	41.62 MPa

Table II: code books used for tests

S.no	Property	Reference
1.	Mix (M25)	IS 10262: 2009 ^[2]
2.	Compressive Strength	IS 516: 1959 ^[3]
3.	Splitting Tensile Strength	IS 5816: 1999 ^[4]
4.	Flexural Strength	IS 516: 1959 ^[3]
5.	UPV	IS 13311(part 1): 1992 ^[5]

Experimental Procedures

Compressive strength test is conducted on concrete cubes of size 100 mm x 100 mm x 100 mm at the age of 7, 28 and 90 days. The cylindrical specimens prepared for testing are 150 mm in diameter and 300 mm depth. Fig. 2 shows a sample tested for splitting tensile strength. For flexural strength test, specimens prepared are 100 mm x 100 mm x 500 mm. For quality assessment of concrete UPV test was conducted on concrete cubes which are cured for 28 days. The UPV testing on concrete is conducted in accordance to IS 13311 (part-1):1992^[5]. The UPV testing equipment consists of two transducers. One is transmitter and the other is receiver with a capacity of 54 kHz. Table III shows the quality assessment of concrete in accordance with IS 13311 (Part 1): 1992. Fig. 3 shows the testing of concrete cube specimens using UPV equipment.

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Table III: Quality of concrete as a function of UPV values

S.no	Pulse velocity from probe	Designation of quality of concrete
1.	>4.5	Excellent
2.	4.5 – 3.5	Good
3.	3.5 – 3.0	Medium
4.	< 3.0	Doubtful



Fig. 2 Splitting tensile test sample



Fig. 3: UPV test Apparatus and concrete specimens

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III. RESULTS AND DISCUSSION

Compressive Strength

The compressive strength of F0, F5, F15, F30 and F40 at 7, 28 and 90 days are given in Table IV. At 7 days of curing age, the compressive strength of F5, F15, F30 and F40 are 108.96%, 138.91%, 153.27% and 134.22% that of F0. At 28 days of curing age, the compressive strength of F5, F15, F30 and F40 are 117.61%, 131.22%, 138.13% and 126.66% that of F0. At 90 days of curing age, the compressive strength of F5, F15, F30 and F40 are 112.33%, 124.24%, 129.69% and 121.39% that of F0. The performance of fly ash concrete in compression is shown in Fig. 4.

Table IV: compressive strengths for various percentages of Fly ash

Mix designation	Compressive strength (MPa)		
	At 7 days	At 28 days	At 90 days
F0	22.41	33.72	37.21
F5	24.42	39.66	41.8
F15	31.13	44.25	46.23
F30	34.35	46.58	48.26
F40	30.08	42.71	45.17

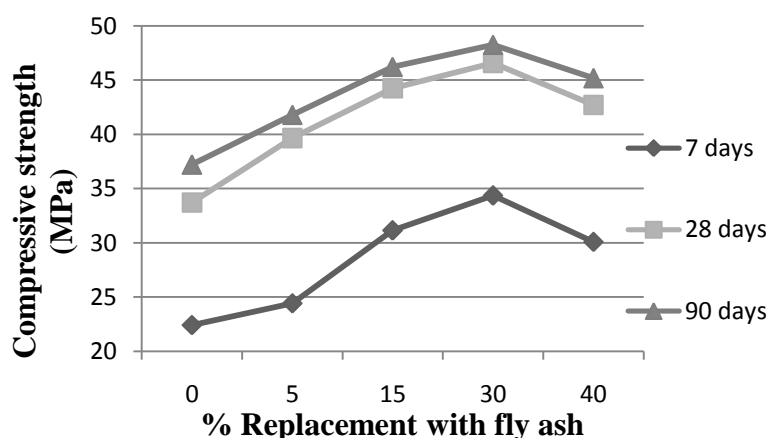


Fig. 4: Compressive strength (vs.) % of fly ash added

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Flexural strength:

Flexural strength of F0, F5, F15, F30 and F40 at 28 days and 90 days are given in Table V. At 28 days of curing age, the flexural strength of F5, F15, F30 and F40 are 105.94%, 112.62%, 114.60% and 112.37% that of F0. At 90 days of curing age, the flexural strength of F5, F15, F30 and F40 are 94.56%, 103.41%, 103.63% and 98.71% that of F0. The performance of fly ash concrete in flexural strength is shown in Fig. 5.

Table V: Flexural strength for various percentages of fly ash

Mix designation	Flexural strength (MPa)	
	At 28 days	At 90 days
F0	4.04	4.68
F5	4.28	4.43
F15	4.55	4.84
F30	4.63	4.85
F40	4.54	4.62

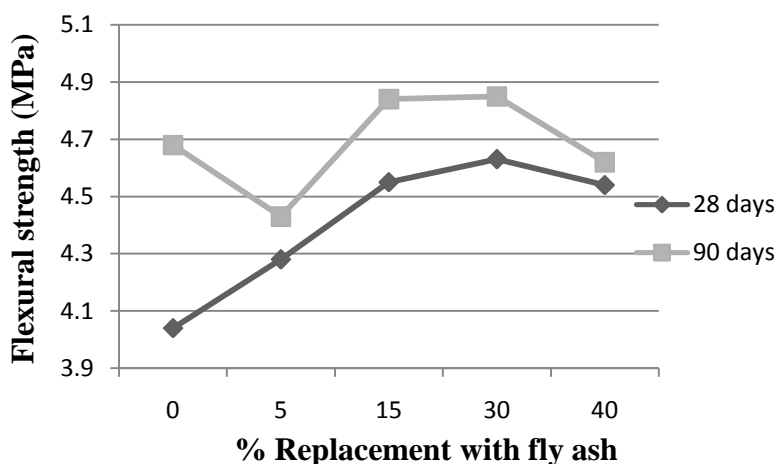


Fig. 5: Flexural strength (vs.) % of fly ash added

Splitting tensile strength

Splitting Tensile strength of F0, F5, F15, F30 and F40 at 28 days and 90 days are given in Table VI. At 28 days of curing age, the splitting tensile strength of F5, F15, F30 and F40 are 103.19%, 104.25%, 102.48% and 100.70% that of F0. At 90 days of curing age, the splitting tensile strength of F5, F15, F30 and F40 are 106.73%, 107.05%, 100.32% and 96.79% that of F0. The performance of fly ash concrete in splitting tensile strength is shown in Fig. 6.

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Table VI: Splitting tensile strength for various percentages of fly ash

Mix designation	Splitting tensile strength (MPa)	
	At 28 days	At 90 days
F0	2.82	3.12
F5	2.91	3.33
F15	2.94	3.34
F30	2.89	3.13
F40	2.84	3.02

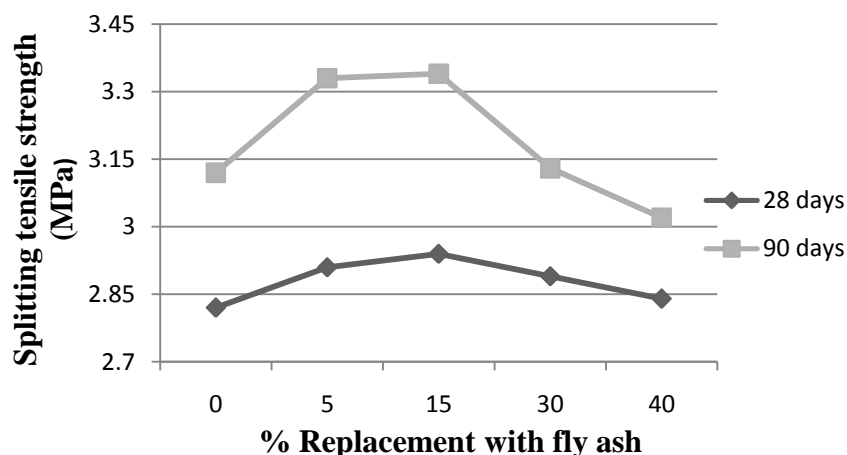


Fig. 6: Splitting tensile strength (vs.) % of fly ash added

Ultrasonic pulse velocity:

The UPV values obtained for fly ash concrete denotes excellent quality in accordance to IS 13311(Part 1): 1992^[5] are shown in Table VII. At 28 days of curing age, the UPV of F5, F15, F30 and F40 are 101.51%, 102.38%, 101.08% and 98.48% that of F0. The performance of fly ash concrete in UPV test is shown in Fig. 7.

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Table VII: UPV values at various percentages of fly ash in concrete

Mix Designation	Ultrasonic Pulse Velocity (Km/s)
	At 28 days
F0	4.61
F5	4.68
F15	4.72
F30	4.66
F40	4.54

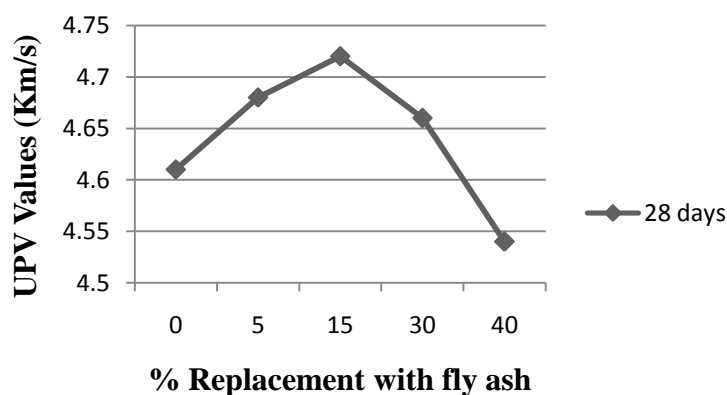


Fig. 7: UPV values (vs.) % fly ash added

IV. CONCLUSIONS

At all the replacement levels of fly ash in concrete the compressive strength is improved, when compared with nominal concrete (F0). A highest compressive strength is observed with F30 (30% fly ash) concrete. A similar trend of improvement in flexural strength and splitting tensile strength is observed, when compared with compressive strength. The use of pozzolanic material fly ash improved the strength properties of concrete. This could be due to the pozzolanic nature of fly ash and micro-filling property that leads to the dense packing of concrete. As per IS 13311(Part 1): 1992 the UPV values obtained for fly ash concrete at 28 days of curing age denotes the excellent quality of concrete. The results support the use of fly ash as partial replacement of cement up to 30%.

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