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RESEARCH ARTICLE

Effect of Fly Ash on Flexural Strength of Portland Pozzolona Cement Concrete

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Abstract

In India, thermal power is the largest source of power and about ¾th part of electricity consumed in India is generated by thermal power plants. Approximately 75 thermal power plants are present in India and these plants produce a large amount of fly ash. Fly ash is very harmful for environment and living organisms. The disposal of fly ash is a big problem. Fly ash may be utilized in various civil engineering applications such as concrete making, cement manufacture and embankment etc. This study presents the result of an experimental investigation carried out to evaluate the flexural strength of concrete made using Portland Pozzolona cement (PPC) and its part replacement fly ash. The PPC replacement level was varied (10, 20, 30, 40, 50 and 60% by weight of cement) and M-25 referral mix at 0.48 water cement ratio was used. The beam specimens (100 mm x 100 mm x 500 mm) were cast and tested for determination of flexural strength of concrete at different replacement levels. It was observed that up to 30% replacement level, the flexural strength increased marginally at 56 d.

Keywords: Fly ash, flexural strength, portland pozzolona cement, concrete, replacement level.

Introduction

Fly ash is residue resulting from combustion of pulverized coal/lignite in thermal power plant, collected through electrostatic precipitants or bag house filters. Fly ash is a fine (85% of its mass passing through a 45 micron screen), siliceous and/or aluminous glassy powdered material having micron-sized earth elements and pozzolanic in nature. Fly ash consists of inorganic materials mainly silica and alumina with some quantum of organic material in the form of unburnt carbon. In India, presently around 150 million ton fly ash is produced annually which is likely to increase continuously due to growing number of thermal power plants. Disposal of fly ash is a great challenge for environmentalists and engineers working for the sustainable developments. The ill effects of fly ash on environment have been discussed by various researches during the last few decades and it has been concluded that the possibility be explored for the consumption of fly ash in different sectors. However, the utilization level of fly ash has to increase due to strict environmental regulations and growing awareness for the same among the people. Major portion of fly ash is currently being utilized by the cement companies in making Portland Pozzolona Cement. The other field where fly ash can be used are, fly ash bricks, tiles, paving blocks, embankments, soil stabilization etc. Siddique (2002) reported that significant improvement in the strength properties of plain concrete by the inclusion of fly ash as partial replacement (10, 20, 30, 40 and 50%) of fine aggregate (sand) can be effectively used in structural concrete. Compressive strength, splitting tensile strength, flexural strength and modulus of elasticity of fine aggregate (sand) replaced fly ash concrete specimens were higher than the plain concrete (control mix) specimens at all the ages (7, 14, 28, 56, 91 and 365 d). The strength differential between the fly ash concrete specimens and plain concrete specimens became more distinct after 28 d. The maximum flexural strength has been found to occur with 50% fly ash content at all ages. Agarwal and Sharma (2009) reported that with the addition of powdered SNF (sulfonated naphthalene-formaldehyde condensate), it is possible to increase the fly ash content up to 35% in ordinary port land cement (OPC). The addition of fly Ash has no negative effect on the compressive strength of cement up to 35%. It is found that more fly ash can be utilized with OPC. This will help saving limestone used in the manufacture of clinker and hence, environmental pollution caused due to CO_2 in the clinker production can be reduced. Islam and Islam (2010) reported that strength of mortar increases with fly ash up to an optimum value, beyond which, strength values start decreasing with further addition of fly ash. Among the six fly ash mortars, the optimum amount of cement replacement in mortar is about 40%, which provides 14% higher compressive strength and 8% higher tensile strength as compared to OPC mortar. Ndihokubwayo (2013) reported that by using 30, 40 and 50% of fly ash in cementitious materials as its part replacement, the compressive strength of high performance fly ash concrete at 28 d was 30.9, 29.7 and 26.2 MPa respectively.

Table 1. Properties of cement (Method of test refers to IS: 4032:1985).

Properties	As per IS:1489-1991 Part-1	Experimental
Normal consistency %	-	31.5%
Initial setting time	(Not less than 30 min)	165 min
Final setting time	(Not more than 600 min)	215 min
Soundness of Cement (Le chatelier expansion)	(Not more than 10 mm)	0.75 mm
Fineness of Cement (%age retained on 90 micron IS sieve)	10%	3.77%
Specific gravity of cement	3.15	2.67
Compressive strength		
3 d	16.0 N/mm^2 (min)	23.0
7 d	22 N/mm^2 (min)	33.0
28 d	33 N/mm^2	43.2
Declared % of fly ash	15.0-35.0 (min-max)	26.0

The flexural strength of concrete was 5.1, 4.0 and 3.9 MPa respectively. The study also concluded that rate of gain in strength of fly ash mortar specimens is observed to be lower than the corresponding OPC mortar. Venkatakrishanaiah and Mohankumar (2013) reported that fly ash utilization is a global thinking as its addition to cement concrete supplements for durable concrete. But, most of the fly ash utilized and recommended for use in conventional structural concrete including geopolymer concrete is the low calcium fly ash. The high calcium fly ash being more cementitious and pozzolanic is used only in non-structural applications. The excess calcium, if consumed by pozzolanic material may be expected to result in a better concrete. Rajdev *et al*. (2013) reported that the ratio of 7 d to 28 d strength is higher in PFA blended OPC concrete-mix than the PPC concrete-mix. Target mean strength is highest in OPC + 20% PFA Mix. The most economical concrete-mix design was obtained is with OPC + 25% PFA. Harison *et al*. (2013) reported that 20% replacement PPC by fly ash strength increased marginally (1.9-3.2%) at 28 and 56 d respectively. It was also observed that up to 30% replacement of PPC by fly ash, strength is almost equal to referral concrete after 56 d. PPC gained strength after the 56 d curing because of slow hydration process. Nevertheless, large fraction of fly ash is still unused and needs the attention of researches to explore the possibility of its utilization. Many works have been carried out so for, replacing OPC by fly ash in concrete making. However, to the best knowledge of the authors no substantial work has been done on utilization of fly ash in PPC concrete. In this study, the part replacement of binder PPC with fly ash has been investigated.

Materials and methods

The materials used in present investigation were tested as per the procedures laid down in Indian Standards.

Cement: The binder used in this work was Portland Pozzolona Cement (Birla Gold Brand) and was obtained from the single batch. The cement test results are presented in Table 1.

Aggregate: The Yamuna river sand was used as a fine aggregate. The coarse aggregate (20 and 10 mm) was obtained from local market. The Aggregate test results are presented in Table 2.

Table 2. Properties of aggregate.

Type of aggregate	Specific gravity	Fineness modulus
Fine aggregate	2.2	2.84
Coarse aggregate of size 10 mm	2.66	6.428
Coarse aggregate of size 20 mm	2.66	6.006

Table 3. Physical properties of PPC and fly ash.

Properties	PPC	Fly ash
Specific gravity	2.67	2.30
Mean grain size (µm)	21.5	20
Specific area (cm^2/g)	3770	2680
Colour	Grey	Grey to black
Chemical composition (%)	PPC	Fly ash
Silicon dioxide (SiO_2) + Aluminium oxide (Al_2O_3) + Iron oxide (Fe_2O_3)	-	95.5
Silicon dioxide (SiO_2)	-	60.5
Sulphur trioxide (SO_3)	2.12 (3% max)	0.2
Reactive Silica (SiO_2)	-	33.4
Chlorides (Cl)	0.011(0.1% max)	0.01
Magnesium oxide (MgO)	2.5 (6% max)	0.6
Loss on ignition	1.74 (5% max)	1.1
Sodium oxide (Na_2O)	-	0.1
Insoluble residue	24.28	-

Fly ash: It was obtained from the NTPC, Unchahar Raibareli and UP. The physical and chemical properties of fly ash along with PPC are given in Table 3.

Mixture proportion: For the concrete mix of grade M25, the total weight of cementitious materials used was 380 kg/m^3 which satisfy the minimum requirement of 300 kg/m^3 in order to avoid the balling affect. The control mix proportion was 1:2.08:3.86 w/c ratio of 0.48. To compute the compressive strength of control (referral) PPC concrete, 9 cube specimens of dimension (100 mm X 100 mm X 100 mm) were cast and tested in the laboratory at the end of 7, 28 and 56 d of moist curing. Average compressive strength at the end of 7, 28 and 56 d recorded as 23, 35 and 39 MPa.

Preparation and casting of test specimens: To evaluate the effect of replacement of PPC by fly ash on flexural strength of cement concrete, 63 beams of dimension (100 mm X 100 mm X 500 mm) were cast in the laboratory.

The binder was replaced by fly ash at 10, 20, 30, 40, 50 and 60% (by weight). The specimens were cast in two layers and were compacted using an internal vibrator. They were demolded after 24 h and were transferred to a water tank until required for testing. Beams made with different percentages of fly ash were tested at the end of 7, 28 and 56 d of moist curing.

Cost analysis: The cost of control (referral) and different concrete mixes prepared using fly ash a part replacement of binder PPC was calculated.

Results and discussion

Flexural strength of referral concrete as well as fly ash concrete at 7, 28 and 56 d are given in Table 4. For the first 7 d and then again for 28 d, no improvement has been noticed in any of the specimens. It is evident that beyond 28 d, the strength is increased with the addition of fly ash. The variation of flexural strength with different percentage of fly ash is shown in Fig. 1. The figure shows that the flexural strength of control (referral) PPC concrete is 3.18, 5.7 and 6.0 at 7, 28 and 56 d respectively. At 10, 20 and 30% replacement of PPC (binder) by fly ash, it is observed that the flexural strength of beam specimen is increased by 5, 10 and 2.5% respectively at the end 56 d. The cost of control (referral) and different concrete mixes prepared using fly ash as a part replacement of binder PPC is included in Table 5. By adopting a 30% replacement level, the cost of concrete may be reduced significantly about 15.9%.

Table 4. Flexural strength of fly ash concrete (W/C = 0.48).

Beam designation	Fly ash (%)	Flexural strength (MPa)		
		7 d	28 d	56 d
B1	0	3.18	5.70	6.00
B2	10	3.12	5.40	6.30
B3	20	3.00	5.25	6.60
B4	30	2.25	5.10	6.15
B5	40	2.13	4.50	4.80
B6	50	2.10	3.30	3.90
B7	60	1.9	2.70	3.00

Fig. 1. Flexural strength of fly ash concrete (line chart) (W/C = 0.48).

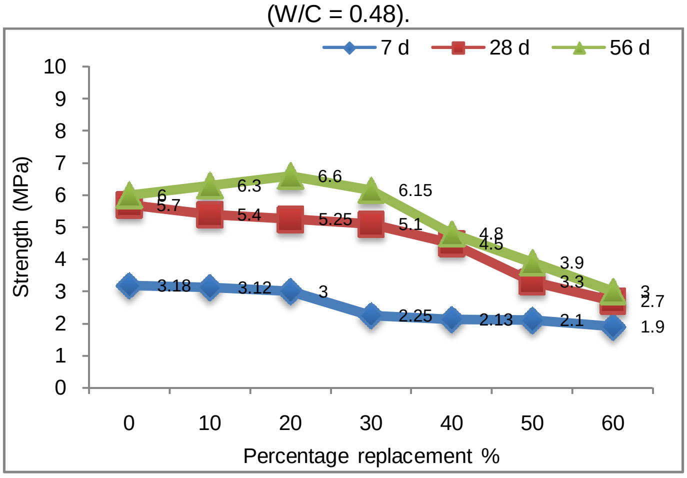

Table 5. The cost of control (referral) and different concrete mixes.

Percentage replacement by weight	Cost of concrete mix (Rs./m^3)	Percentage decrease in cost
0%	4205.00	-
10%	3982.50	5.29%
20%	3758.10	10.62%
30%	3535.00	15.93%

Conclusion

From the above study, the following conclusions are drawn:

1. PPC concrete is potential for further use of fly ash.
2. The flexural strength of fly ash concrete, with PPC as binder, increase positively up to a replacement level of 30%.
3. By adopting a 30% replacement level, the cost of concrete may be reduced significantly about 15.9%.

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