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Original Research Paper

Control of Environmental Pollution by Utilizing High and Low Volume of Fly Ash in Concrete

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ABSTRACT

Currently India produces around 120 million tones of fly ash per annum. The power requirements of the country have increased a lot due to industrial growth. India mainly depends on thermal power which contributes about 80% of the power produced resulting in accumulation of huge quantity of fly ash as residue. It is estimated that ash generation is likely to reach 170 million MT by 2010; only 32 % of the fly ash is utilised which needs an urgent attention. Effective utilizing of high and low volume of fly ash in concrete (HVFAC & LVFAC) has positive effects in an environmental friendly way, preserving resources and producing better concrete. This paper presents the experimental investigation carried on HVFA and LVFAC in concrete and the environmental benefits rendered by it.

INTRODUCTION

Fly ash is an inorganic, noncombustible by-product of coal-burning power plants. As coal is burnt at high temperatures, carbon is burnt off and most of the mineral impurities are carried away by the flue gas in the form of fly ash. Fly ash is a pozzolanic material possessing no cementitious value but which will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties. In the presence of moisture, alumino-silicates within the fly ash react with calcium ions to form calcium silicate hydrates. Today, there is a general trend to replace higher levels of Portland cement with fly ash in concrete. The increased pressure to use higher levels of fly ash in concrete stems from three main aspects. The first aspect is economics. In most markets fly ash is less expensive than Portland cement. Therefore, as the replacement level of fly ash increases, the cost to produce concrete decreases. The second aspect and arguably the most important one is the environment. Fly ash is an industrial by-product, much of which is deposited in landfills if not used in concrete. Also from an environmental perspective, the more fly ash being utilized in concrete, the less the demand for Portland cement; the less Portland cement production will lower CO_2 emissions. The third aspect influencing the use of higher replacement levels is the technical benefits of high volume fly ash concrete (HVFAC). HVFAC has improved performance over ordinary Portland cement concrete, especially in terms of durability when appropriately used (Basu 2006, Sivasundaram 2004). Although there are clearly economic and environmental benefits associated with the use of high levels of fly ash in concrete, there is relatively little information on the behaviour of such concrete and almost no guidance on its production or use. The aim of the investigation is to utilize effectively low volume and high volume fly ash in concrete and to reduce the pollution caused by fly ash.

Materials used: Ordinary Portland cement (OPC-53 grade) conforming to IS: 12269-1987 was used in the investigation. The required quantity was procured as single batch, stored in airtight bags and used for the experimental programme. Locally available river sand conforming to zone II of IS: 383(1970) was used as fine aggregate. The coarse aggregate was 20mm down graded crushed granite stone obtained from the local quarry. Potable water was used for the casting specimens and for curing purpose. Usually super plasticizers are added as 2-4% of cement mass or 5 to 15 its per m^3 of concrete. In this investigation, a sulphonated naphthalene polymer SUPAFLO super plasticizer, 2.5% by weight of cement, was added as admixture to enhance workability. Fly ash procured from Mettur Thermal Power Plant was used as partial replacement of cement.

Details of specimen: High strength and performance mix can be produced by reducing water-cement ratio lower than normal concrete. This is possible because of chemical admixtures. Mix proportioning of HVFAC is a more critical process than normal conventional concrete in view of high fines content and low w/b ratio. Jiang and Malhotra (2000) suggested a mix proportioning method based on combination of empirical results and absolute volume method. The mix proportion obtained was 1 : 1.4 : 2 and w/c 0.36.

Testing of specimen: Concrete cubes, 150 mm in size, were tested for compressive strength, 150 × 300 mm cylinders for splitting tensile strength, and 101.4 × 101.4 × 508 mm beams for flexural strength. A total of 234 specimens were cast for testing (90 cube specimens for compressive strength + 90 cylindrical specimens for split tensile strength + 54 beam specimens for flexural strength) (BIS 1959). Details of various mixes used are given in Table 1.

Experimental studies on HVFAC and LVFAC mixes: Compressive strength, tensile strength and flexural strength studies were conducted on various mixes (HVFAC & LVFAC, M60) to study the effect of presence of fly ash and its presence with admixture.

RESULTS AND DISCUSSION

Physical and chemical properties: Physical properties of cement fly ash are given in Table 2, and chemical properties in Table 3.

Compressive strength: The results of compressive strength at the age of 28 days are reported in Table 4 and the variation is shown in Fig. 1. It has been observed that compressive strength decreased with increased addition of fly ash content. With low quantity of fly ash, characteristic behaviour of fly ash mix is alike. The FA-10 of 10% replacement with fly ash showed strength characteristics greater than control reference mix FA-0 at the age of 90 days. Similarly, higher volume of fly ash content, FA-40, FA-50, FA-60 are showing alike characteristic features. From Fig. 2, it is clear that the age affect to a greater extent the strength of mix; with the increase in age the strength of mix also

Table 1: Mix proportions of the concrete.

Mix designation	FA-0	FA-10	FA-20	FA-30	FA40	FA-50	FA-60
Fly ash, %	0	10	20	30	40	50	60
w/c ratio	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Cement, kg/m^3	500	450	400	350	300	250	200
Fly ash, kg/m^3	0	50	100	150	200	250	300
Fine aggregate, kg/m^3	700	700	700	700	700	700	700
Coarse aggregate, kg/m^3	1000	1000	1000	1000	1000	1000	1000
Water, L/m^3	180	180	180	180	180	180	180
Super plasticizer, kg/m^3	8.5	8.5	8.5	8.5	8.5	8.5	8.5

Table 2: Properties of the constituent materials.

S. No.	Parameter	OPC used	Fly Ash	Fine Aggregate	Coarse Aggregate
1	Normal consistency	26 %	30%	-	-
2	Finess by sieving(% 45 micron)	80	78	-	-
3	Initial setting time	30	85	-	-
4	Final setting time	360	400	-	-
5	Specific gravity	3.15	2.12	2.51	2.64
6	Bulk density	-	-	1700	1600
7	Finess modulus	-	-	2.81	4.12
8	Water absorption	-	-	1.0%	0.5%

Table 3: Chemical composition of cement and fly ash.

S. No	SiO_2	Al_2O_3	Fe_2O_2	CaO	MgO	SiO_3
1. Cement	21.4	5.3	3.2	51.6	0.8	2.2
2. Fly ash	59.62	26.43	6.61	1.20	0.76	0.58

Table 4: Strength properties of concrete.

Parameters	FA-0	FA-10	FA-20	FA-30	FA-40	FA-50	FA-60
Cube compressive strength in MPa	61.12	60.68	56.23	54.53	48.4	40.12	38.45
Split tensile strength in MPa	4.75	4.25	4.22	3.81	3.15	3.12	3.07
Flexural strength in MPa	7.52	7.24	6.73	5.61	5.43	5.22	5.10

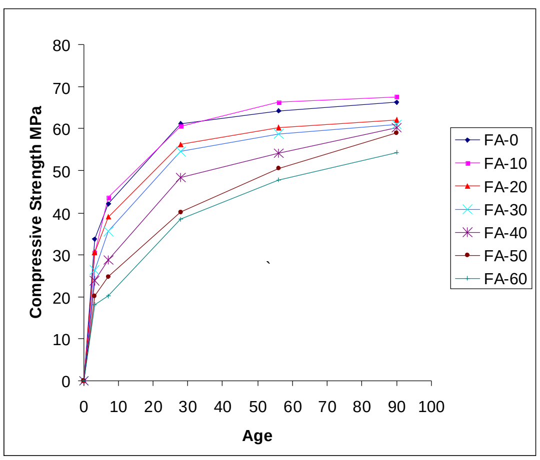

Fig. 1: Compressive strength variation with age for various quantity of fly ash.

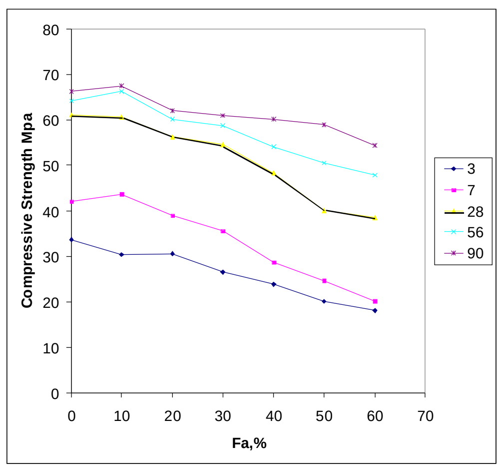

Fig. 2: Compressive strength variation with age for fly ash replacement.

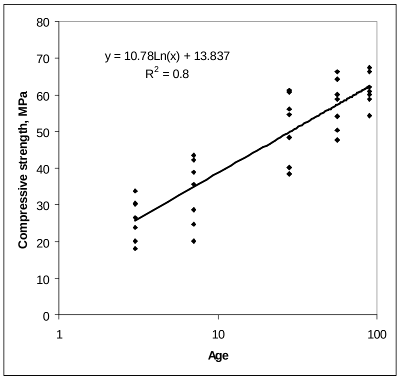

Fig. 3: Compressive strength variation with age.

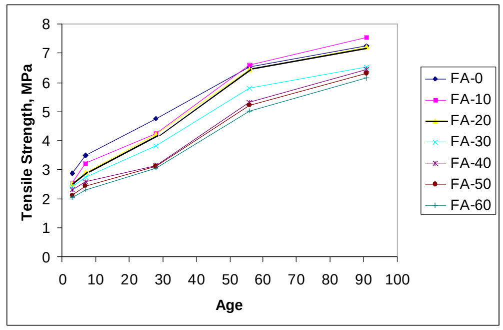

Fig. 4: Tensile strength variation with age for various quantity of fly ash.

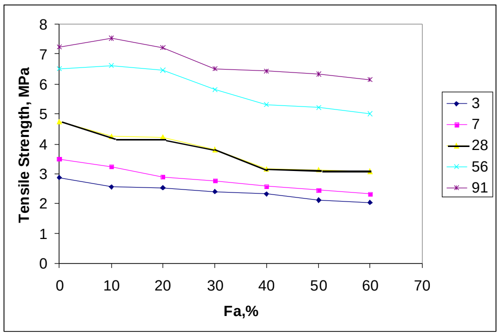

Fig. 5: Tensile strength variation with age for fly ash replacement.

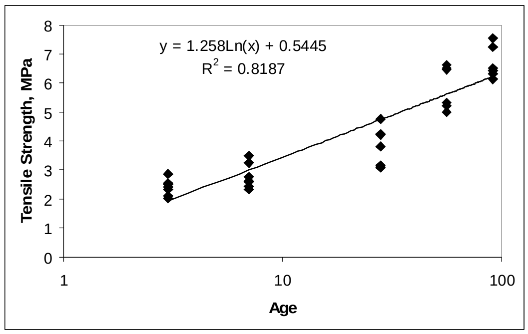

Fig. 6: Tensile strength variation with age.

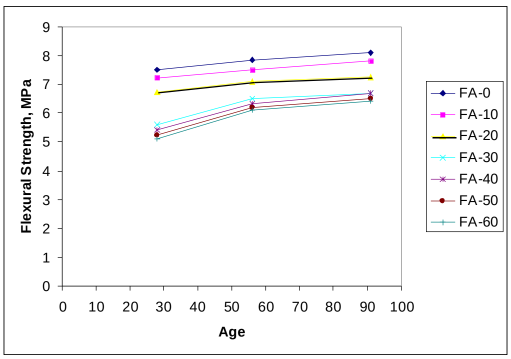

Fig. 7: Flexural strength variations with age for various quantity of fly ash.

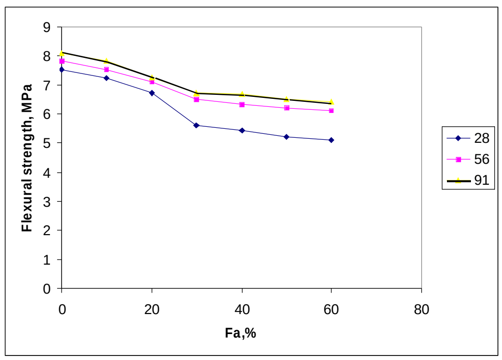

Fig. 8: Flexural strength variation with age for fly ash replacement.

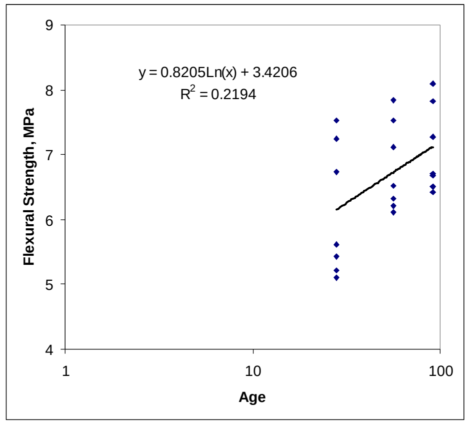

Fig. 9: Flexural strength variations with age.

increases. Up to the age of 28, 56 and 90 days, with fly ash replacements till 30% of cement show similar proportion achieving strength at their ages. Whereas, there is a vast variation in strength achievement in replacing cement by higher quantity of fly ash. The percentage decrease with reference to control mix is 6.23, 7.9, 9.1, 11.1, and 17.8 for the fly ash mixes FA-20, FA-30, FA-40, FA-50 and FA-60 respectively. The relationship between compressive strength and the age is given by the relation as shown in Fig. 3, which is:

Y = 10.78 Ln(X) + 13.837

Where, Y is compressive strength in MPa and X is age in days.

Split tensile strength: The results of tensile strength at the age of 28 days are reported in Table 4 and the variation is shown in Fig. 4. Low volume quantity of fly ash concrete shows distinct characteristics when compared with high volume of fly ash concrete as shown in Figs. 4, 5, 6. The percentage decrease with reference to control mix is 0.27, 10.1, 11.3, 12.82, and 15.31 for the fly ash mixes FA-10, FA-20, FA-30, FA-40, FA-50 and FA-60 respectively. The relationship between tensile strength and the age is given by the relation:

Y = 1.258 Ln(X) + 0.5445

Flexural strength: Flexural strength of concrete mixtures was determined at the ages of 7, 28 and 90 days. Results are given in Table 4, and shown in Figs. 7, 8, 9. Like compressive and splitting tensile strength results, flexural strength of concrete mixtures also increased with age. The percentage decrease with reference to control mix is 3.72, 10.51, 25.4, 27.8, 30.6 and 32.2 for the fly ash mixes FA-10, FA-20, FA-30, FA-40, FA-50 and FA-60 respectively. Increase in quantity of fly ash affects the flexural strength when compared to control mix, with the increase in age these deviations are reduced. The relationship between flexural strength and the age is given by the relation:

Y = 0.8205Ln(X) + 3.4206

Environmental aspects: Fly Ash is a chemically complex pollutant and, if not properly disposed, may cause serious environmental problems such as:

- Scattering of ash particles over land surface by precipitation results in degeneration of soil characteristics.

- Wet disposal of fly ash results in direct entrainment leading to leaching of heavy metals into groundwater.
- Particulate matter concentration in the atmosphere increases, causing increasing the incidents of pulmonary ailments.
- Visibility reduction around power stations when atmospheric moisture forms aerosols with the fine fly ash particles.
- Corrosion of metallic surfaces.
- Construction of large ash disposal areas results in land use issues such as resettlement, loss of agricultural production, grazing land and habitat as well as wastelands.
- Elevated RSPM ambient air concentration in the vicinity of under-maintained ash ponds.
- Slurry disposal systems put a strain on freshwater resources.

Considering the above points, fly ash can be effectively used judiciously according to the necessity and the application areas which act as effective tool in reduced CO_2 emissions, reduced energy consumption and reduced demand for primary resources.

CONCLUSION

The study has proved that the replacement of cement with six percentages of fly ash content reduced the compressive strength, splitting tensile strength, and flexural strength at the age of 28 days, but there was a continuous and significant improvement of strength properties beyond 28 days. The strength of concrete with low and high volume fly ash content, even at 28 days is sufficient enough for use in reinforced cement concrete construction. Judicious use of fly ash can effectively reduce pollution, energy consumption and saves the environment.

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