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Experimental Study on Strength Properties of High Volume Flyash Concrete with Polypropylene Fibre

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Abstract : High volume flyash concrete is a concrete in which atleast 50% of cement is replaced by flyash[7]. This study focuses on the influence of high volume flyash replacement for cement with the constant amount of polypropylene fibre content. Flyash is replaced in various replacement levels of 0, 40, 50, 55 and 60% by the weight of cement in concrete. Slump, compressive and split tensile strength of concrete mixes were evaluated. The test results indicate that the addition of high volume of flyash improves the slump and strength properties of concrete. Flyash replacement of 55% by the weight of cement is considered as the optimum replacement level.
Keywords : cement; fly ash; polypropylene fibres; slump; compressive strength; split tensile strength.

1.0 Introduction

Cement is the most widely used composite material in concrete structures[1].Cement manufacture causes environmental issues at all stages of the process like depletion of natural resources, production of greenhouse gases and energy consumption. Cement causes 7% of total greenhouse gas emission in the world. Production of one ton cement is generates the one ton CO_2.emissions[8]. The unit cost, environmental impacts are to be reduced by using of supplementary cementitious materials like fly ash, silica fume, metakaolin and slag. Fly ash is the common replacement material in concrete by replacing of Portland cement.

Fly ash is the by-product of coal combustion material. Generally Fly Ashhas been considered as a waste material in the past and disposal of which has posed numerous ecological and environmental problems. However, recent researches fly ash had high pozzolanic activity which is attributed by $SiO_2$and Al_2O_3[5,7].In addition of fly ash in concrete gain strength and gives various other application in construction over the last 20 years, without affectingthe mechanical and durability properties of concrete[6]. Several laboratory and filed investigation have reported that the partial replacement of cement by Fly ash give good mechanical and durability properties. Fly ash improves the workability of concrete depending the shape of the particle.

The use of high volume fly ash concrete is introduced by Malhotra in 1986[3] (HVFA concrete). It is defined as at least 50% of the binder material consists of class F fly ash. The HVFA concrete is beneficial for the low cost and high workability of the concrete, also has to been improving the strength and durability of the concrete. More over fly ash containing the slow pozzolanic properties to decrease the early age strength of concrete, but longer period the strength will be increased.

Polypropylene fibres are added to concrete to improve the tensile and flexural strength of concrete. Also the addition of fibres reduces the brittleness of concrete by the action of fibre bridging. The fibres also improve the durability behaviour of the concrete.

This paper investigates the fresh, hardened properties of HVFA concrete with the addition of polypropylene fibres.

2.0 Materials

2.1. Cement

Ordinary Portland cement(OPC) of 53 grade conforming to IS 12269-1987[12] was used. The specific gravity of cement used was 3.16.

2.2 Fly Ash

Class F fly ash obtained from Eklahare Thermal Power Station,Nashik conforming to IS 3812 – 2003[9] (part I) was used. The fly ash used for the study belongs to class F flyash. The chemical properties in comparison with cement are shown in table 1. The specific gravity of flyash used was found to be 2.30.

Table.1. Chemical composition of cement and fly ash

Chemical Composition (Wt %)	Cement	Fly ash
SiO_2	21.0	55.47
Al_2O_3	5.4	26.89
Fe_2O_3	3.3	4.34
CaO	65.6	1.30
MgO	1.1	0.58
SO_3	2.7	0.90
K_2O	-	0.67
TiO_2	-	1.30
Na_2O	-	0.98
LOI	1.2	1.10

2.3 Aggregates

Crushed stone aggregates of 20 mm size obtained locally conforming to IS 383-1970 was used as coarse aggregates. The properties of coarse aggregate and fine aggregateusedare shown in table 2. Locally available river sand passing through IS 4.75 mm sieve conforming to zone II of IS 383-1970 [9](part 3) was used.

Table.2. Properties of Aggregate

S.no	Particulars	Fine Aggregate		Coarse Aggregate	
1.	Specific gravity	2.56		2.79	
2	Bulk density	Loose	Rodded	Loose	Rodded
		1.640	1.728	1.414	1.420

2.4 Fibres

Polypropylene fibres of monofilament type of 12 mm length were used in this study to enhance the mechanical properties of concrete.

2.5 Admixtures

Commercially available polycarboxylate ether based superplasticizer(SP) conforming to IS 9103- 1999 was used to reduce the water-cement ratio.

2.6 Mix Proportion and Preparation of Specimens

Six mixes were totally made. A reference mix was designed without fly ash replacement in accordance with IS 10262-2009[11] to attain a target strength of 48.25 N/mm^2 at 28 days of curing. Four mixes were made with fly ash replacements in 40, 50, 55 and 60% of cement. Polypropylene fibres were added at 0.2% to all five mixes. The water-cement ratio was kept as 0.33 and super-plasticizer was added to all mixes at 0.8% of cementitious material. Table.3 shows the mix proportion of all mixes. Concrete mixtures were mixed using drum mixer and placed in required moulds. The concrete specimens were demolded after 24 hours and placed in curing tank for curing.

Table.3. Mix Proportions

Mix Designation	Cement		Fly Ash		FA	CA	W/C	Water	Super plasticizer		Fibre	
	%	kg	%	kg	kg	kg		kg	%	kg	%	kg
M1	100	448	0	0	732	1125	0.33	148	0.8	2.24	0	0
M2	100	448	0	0	732	1125	0.33	148	0.8	2.24	0.2	1.8
M3	60	268.8	40	179.2	732	1125	0.33	148	0.8	2.24	0.2	1.8
M4	50	224	50	224	732	1125	0.33	148	0.8	2.24	0.2	1.8
M5	45	201.6	55	246.4	732	1125	0.33	148	0.8	2.24	0.2	1.8
M6	40	179.2	60	268.8	732	1125	0.33	148	0.8	2.24	0.2	1.8

3.0 Experimental Program

3.1. Slump Test

Slump test is the most commonly used fresh concrete test to determine the workability of concrete. All mixes were tested for the slump value to determine the workability of concrete in the fresh state in accordance with IS 1199-1959.

3.2. Compressive Strength

Compressive strength of all mixes were determined in accordance with IS 516-1959. Cubes of size 150mm × 150mm×150mm were used for the determination of compressive strength. Average of three specimens tested in each mix is considered as the compressive strength of the concrete.

3.3 Split Tensile Strength

Split tensile strength of all mixes were determined using concrete cylinders specimens of diameter 150mm and height 300mm in accordance with IS 5816 -1999. Average of three specimens tested in each mix is considered as the split tensile strength of concrete.

4.0 Results and Discussion

4.1 Slump Test

Table. 4 shows the slump test values of all mixes and fig.1 shows the variation of slump for different fly ash replacements. From the table.4 and fig.2 it can be noted that the addition of flyash increases the slump of concrete. The addition of fibre reduced the slump of concrete however the slump value of concrete increases with the increase in fly ash content. The increase in slump value is due to the spherical particles of flyash, which ease the workabiltity of concrete. The spherical nature of flyash decreases the friction between the particles which reduces the water required for the slump, which inturn increases the slump of concrete.

Table.4 Slump test

Mix	Slump Values (mm)
M1	107
M2	98
M3	115
M4	134
M5	152
M6	174

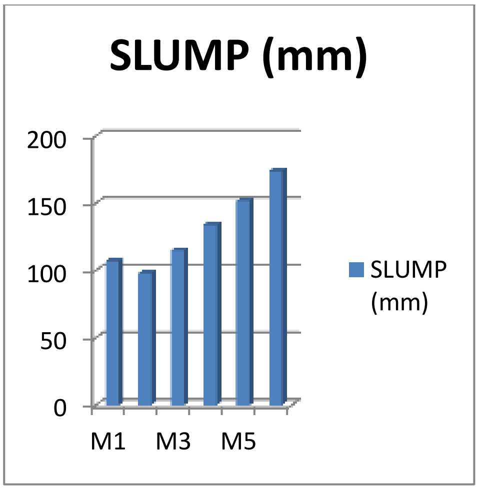

Fig.1. Slump test values variation with fly ash replacement

4.2 Compressive Strength

Table.5 shows the compressive strength of all mixes and fig.2 shows the variation of compressive strength at different ages for all mixes. From table.5 and fig.2 it can be seen that the early age strength of flyash concrete mixes were lower than that of the reference mixture. The strength of all fly ash concrete mixes increases with age of the concrete. At the age of 28 days the compressive strength increased with the increase in fly ash content upto 50% and beyond that the compressive strength starts decrease, but the compressive strength of the mix with 55% fly ash replacement is higher than the reference mix and the mix with 60% flyash replacement showed lower strength than the reference mix. The decrease in compressive of the mix beyond 50% of flyash replacement is due to the higher flyash content and its slower pozzolanic reaction. At the age of 56 days all mixes with fly ash replacement showed greater improvement in strength. The early age of strength of flyash mixes is lower due to the slower pozzolanic reaction of the flyash at early ages. At later ages, the fly ash starts reacting with the calcium hydroxide liberated from the hydration of cement and results in the formation of secondary C-S-H gel. The formation of the secondary C-S-H gel increases the strength of concrete at later ages. From fig.2 it is evident that the compressive strength of high volume flyash concrete is increases with the increase in the age of concrete.Addition of polypropylene fibres in concrete to increase the compressive strength of the concrete.

Table.5 Compressive strength

Mix	Compressive Strength In N/mm²		
	7 Days	28 Days	56 Days
M1	35.56	48.89	53.25
M2	36.15	51.0	54.55
M3	30.52	56.03	64.15
M4	29.63	58.27	66.83
M5	27.11	55.97	62.83
M6	25.92	49.19	57.81

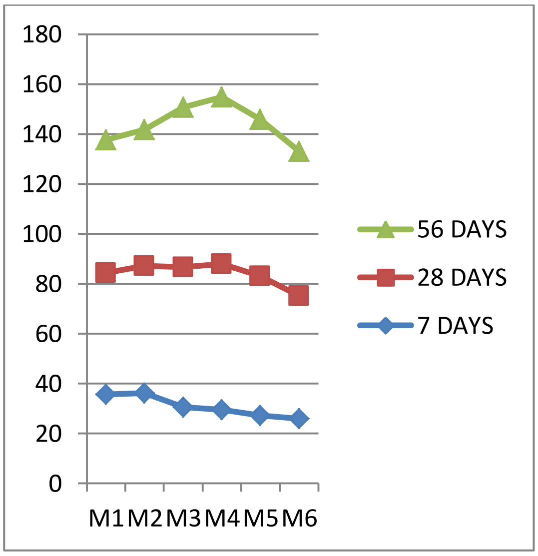

Fig.2. Compressive strength variation with fly ash replacement

4.3 Split Tensile Strength

Table.6 shows the split tensile of all mixes and fig.3 shows the variation of split tensile strength at 28 and 56 days with different flyash levels. From table.6 and fig.3 it can be noted that the split tensile strength the age of 28 days increase with the increase in flyash content upto 50% replacement level and thereby decreases. However the mix with 55% flyash replacement shows the split tensile strength higher than that of the reference mix. Split tensile strength is similar to that of compressive strength; it also increases with the age of the concrete. At the age of 56 days the split tensile strength of all flyash mixes were found to be greater than the reference mix. The increase in strength at later ages is due to the pozzolanic contribution of the flyash.

Table.6 Split Tensile Strength

Mix	Split Tensile Strength In N/mm²	
	28 Days	56 Days
M1	3.54	3.90
M2	3.77	3.99
M3	3.96	4.32
M4	4.01	4.41
M5	3.73	4.03
M6	3.35	3.85

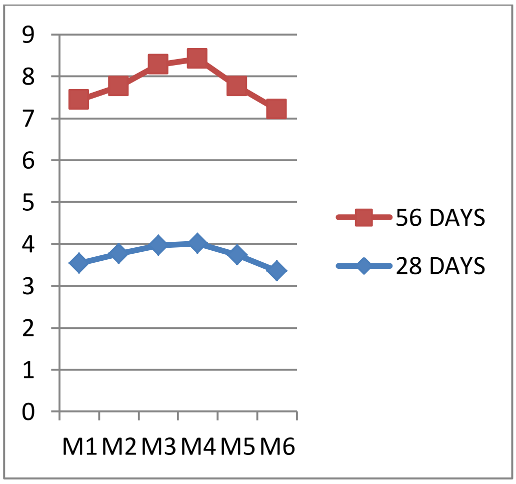

Fig.3. Split Tensile strength variation with fly ash replacement

5.0 Conclusion

From the experimental results, the following conclusions can be drawn:

1. High volume of flyash in concrete affects the slump and strength properties of concrete.
2. Addition of fibre reduced the slump of concrete and improved the strength of concrete.
3. The slump values of concrete increases with the increase in flyash, flyash thereby acts as a water reducer in concrete.
4. The compressive of high volume flyash concrete at early ages were found to be lower than the reference mix.
5. The compressive strength and split tensile strength increases with the addition of flyashupto 50%. The mixes with flyash replacements upto 55% showed higher compressive and split tensile strength than the reference at the age of 28 days.
6. The strength of high volume flyash concrete increases with the age of the concrete.
7. From the test results flyash replacement level of 55% by weight of cement is considered as the optimum replacement level.

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