Studies on Fly Ash Concrete Composites

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ABSTRACT

Using fly ash as a partial substitute for cement in concrete construction has become popular, mainly because of its availability and economicality in large volume construction. But, the resulting deficiency in performance of the concrete has been a cause of concern, and in this study, it is proposed to introduce polypropylene fibers adaptively to compensate for strength. An experimental program was carried out with fly ash, fiber content and layers as parameters. The fly ash content is varied from 0 % to 30% and the fiber content from 0 to 0.60%. It was found that the loss due to introduction of fly ash could be easily compensated through fibers. This study has been carried out to investigate the feasibility of use of polypropylene fibers and evaluate the effect of fiber length and fiber content in concrete to perform better structural properties. ANOVA statistical method was used to evaluate the effect of fiber and fly ash content in concrete to study the strength characteristics and modulus of elasticity.

KEYWORDS: Fly ash, Fiber, Concrete, Composite, Fiber content, Polypropylene Fiber.

INTRODUCTION

The preferable cover thickness of 15 mm is provided and the permeability of the concrete usually governs the corrosion of steel reinforcement in reinforced cement concrete structures. Generally, the specifications on the cover thickness are based upon the type of structural element and the environment to which it is exposed. Use of fibers in concrete ensures effective bridging of fibers across the inherent micro-flaws and improves the strength and behavior of the cement concrete. Steel Fiber Reinforced Concrete (SFRC) is being used in many engineering applications where the formation and propagation of cracks are to be controlled. But, the application of Steel Fiber Reinforced Concrete is limited due to the corrosion possibilities of the partially exposed fiber filaments on the surface. In such a situation, non-corrosive fiber seems to be appropriate. In this work, the behavior of the cement concrete reinforced with locally available polypropylene fiber, a typical non-corrosive and non-biodegradable fiber, has been studied

EXPERIMENTAL PROGRAM

In this experimental investigation, the structural properties of the polypropylene fiber reinforced concrete have been determined. The fiber concrete was prepared in various combinations of fiber length, of fiber content and of fly ash percentage parameters. Specimens were prepared to study structural properties such as compressive strength, tensile strength, modulus of elasticity and modulus of rupture.

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MATERIALS

The constituents of materials used for making the concrete were tested, and the results are furnished in Table 1. Tensile strength of polypropylene fiber reinforced concrete was also tested. The cement, fine aggregate, course aggregate and fly ash were tested prior to the experiments and checked for conformity with relevant Indian standards. Polypropylene fibers and fly ash were also tested to find their tensile strength and compressive strength. Figure 6 shows the view of polypropylene fibers.

Details of Specimens

A nominal mix proportion of 1:1.5:3 with suitable water/cement ratio was considered for this study. The exact quantity of materials for each mix was calculated. The parameters varied were fiber length, fiber content and fly ash percentage. The designations given for various mixes corresponding to fiber length, fiber content and fly ash percentage used for that particular mix are tabulated. Specimens were fabricated for various parameters to study their effect on the structural properties of concrete. Specimens fabricated for studying various structural properties are described in Table 3.

The number and size of the specimens cast in each batch of studying the basic structural properties are given in Table 3. Modulus of elasticity was computed from the load deformation characteristics of the cylinder specimens of the size 300 mm height and 150 mm diameter.

Testing Procedure

All the specimens were cast in oiled moulds compacted using needle vibrators and cured for the required period. These specimens were whitewashed before testing and tested under surface dry condition. Cubes and cylinders were tested using a compression testing machine. Prisms were tested using a universal loading frame.

RESULTS AND DISCUSSION

The structural properties studied in this work are compressive strength, tensile strength, modulus of elasticity and modulus of rupture. The test results of the fiber reinforced concrete have been compared with those of plain concrete.

Cube Compressive Strength

The cubes and cylinders were tested for 7 days, 14 days and 28 days. The test results are given in Table 4. The variation of cube compressive strength with respect to the fiber content, fiber length and fly ash percentage is given in Figures 1, 2 and 3.

The maximum compressive strength was obtained for a mix having a fiber length of 60 mm, 15% fly ash and a fiber content of 0.15% by weight, and the increase in strength over plain cement concrete was found to be about 22 %.

The 7-day compressive strength of the fly ash-based fiber concrete was found to be as high as 25.50 N/mm^2, which is about 35% more than for ordinary concrete. Similarly, 28-day compressive strength was found to be about 25.63 N/mm^2 and is 22% more than that of ordinary concrete. The increase in cube compressive strength for fly ash-based fiber concrete with respect to the age is generally less than that of ordinary concrete. This is because the bonding action of the fiber concrete is very effective even at 7days and this action is not getting improved after 28 days.

As the fiber content increases, the strength of the composite also increases. It is found that the loss due to introduction of fly ash could be easily compensated through the fibers. However, at the age of 28 days, the increase in pozzolonic activity of the fly ash was sufficient to contribute to the compressive strength. Thus, the efficiency of fly ash to act as cementitious material has increased substantially at the age of 28 days.

Cylinder Compressive Strength

The variation of cylinder compressive strength with respect to the fly ash percentage, fiber length and fiber content is given in Figures 1,2 and 3. The results of cylinder compressive strength are given in Table 4.

The maximum cylinder compressive strength is 22.5 N/mm^2, which is about 32% more than for ordinary concrete. It is observed that the variation of cylinder compressive strength is very much similar to the cube compressive strength. This shows that the fiber bonding action during the failure of the cylinder specimens is identical to that of the cube specimens and that fly ash-based fiber concrete specimens maintained their structural integrity at all stages of loading.

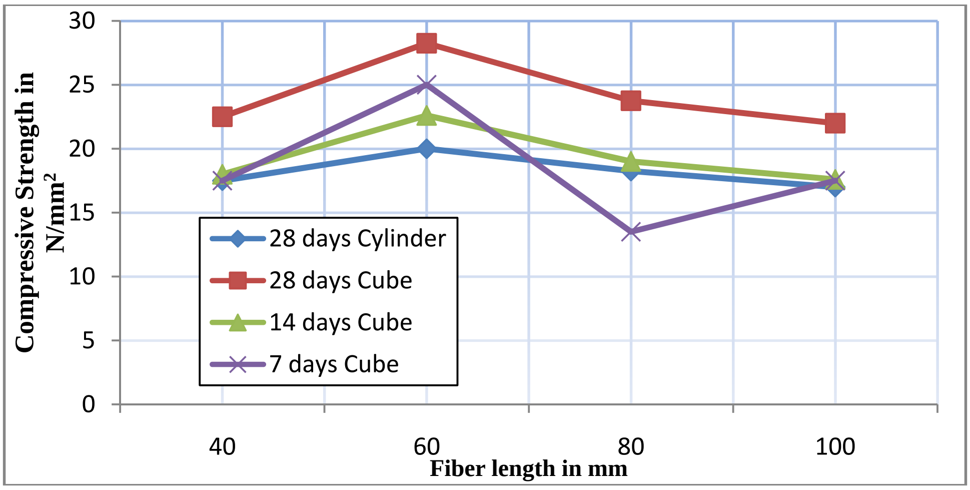

Figure (1): Effect of Fiber Length on Compressive Strength

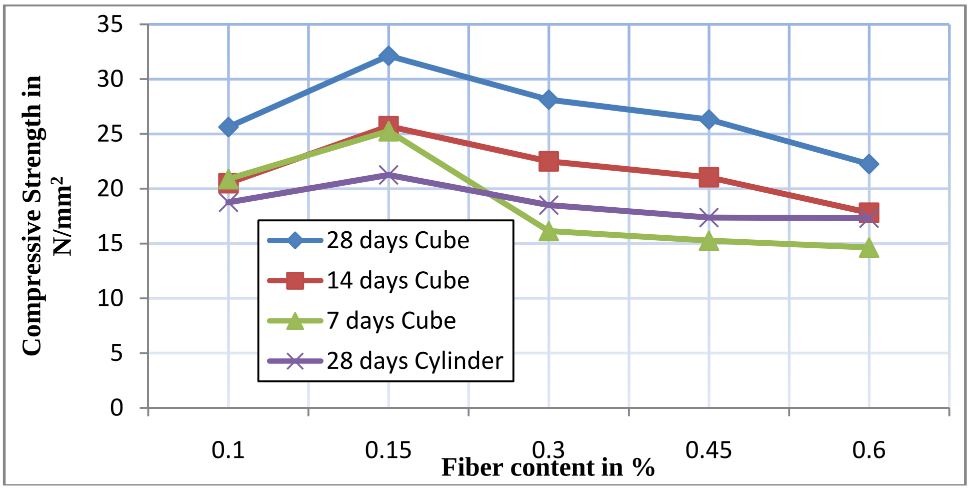

Figure (2): Effect of Fiber Content on Compressive Strength

Splitting Tensile Strength

In each mix, four standard cylinder specimens were tested to determine the splitting tensile strength. The results are given in Table 4. The variation of the splitting tensile strength with respect to fly ash percentage, fiber length and fiber content is given in Figures 4(c) and 5(c).

The maximum value of splitting tensile strength obtained is 4.5N/mm^2, which is about 44% more than for ordinary concrete. The maximum strength was obtained for a mix with a fiber length of 60 mm, a fiber content of 0.15% by weight and 15% fly ash replacement of cement. It is observed that because of fly ash percentage the split tensile strength may be increased.

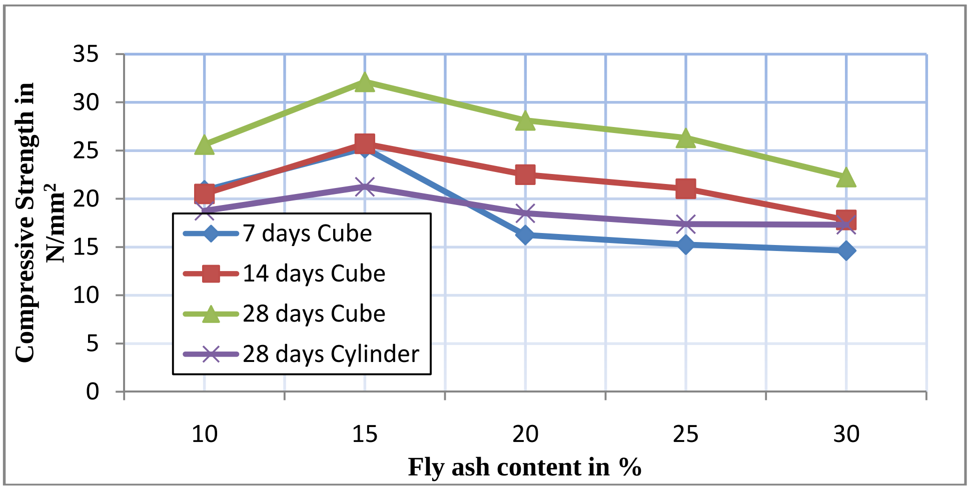

Figure (3): Effect of Fly Ash Content on Compressive Strength

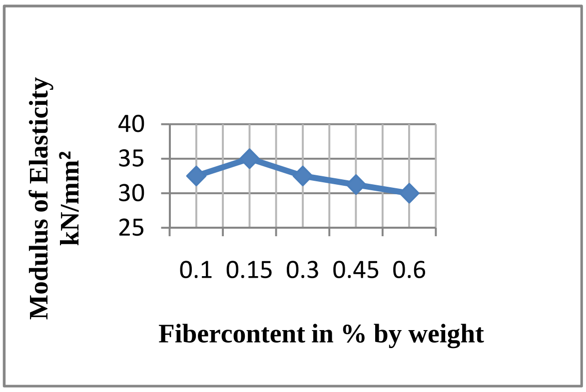

Figure (4a): Effect of Fiber Content on Modulus of Elasticity

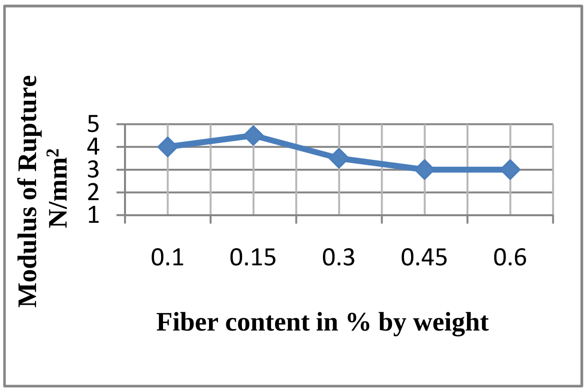

Figure (4b): Effect of Fiber Content on Modulus of Rupture

Table 1. Details of Constituent Materials

Materials	Description
Cement	43 grade Portland cement
Fly Ash and Percentage	Coal Ash (Neyveli Lignite), 10, 15, 20, 25, 30
Fine Aggregate	River sand falling on zone III having a fineness modulus of 2.5
Coarse Aggregate	20 mm nominal size aggregate, fineness modulus = 8.75
Polypropylene Fiber	Diameter = 1mm, Tensile strength of polypropylene fiber = 35 N/mm^2
Fiber Length	40,60,80,100 mm, ϕ = 1mm, Aspect ratio: (40), (60), (80), (100)
Steel Reinforcement	High Yield Strength Deformed (HYSD) bars of 6mmϕ and 8mmϕ
Grade of Concrete Water/Cement Ratio	M20 0.45

Table 2. Details of Fiber and Fly Ash Parameters Used in Batches

Description	Designation	FIBER PARAMETERS		Fly ash content in % by weight
		Fiber content in % by weight	Length of the fiber in mm	
Plain Concrete	S_0	--	--	--
Polypropylene Fiber Reinforced Concrete [PFRC]	S_{11}	0.10	40	0.10
	S_{12}	0.10	60	0.10
	S_{13}	0.10	80	0.10
	S_{14}	0.10	100	0.10
	S_{21}	0.15	40	0.15
	S_{21}	0.15	60	0.15
	S_{21}	0.15	80	0.15
	S_{21}	0.15	100	0.15
	S_{31}	0.30	40	0.20
	S_{31}	0.30	60	0.20
	S_{31}	0.30	80	0.20
	S_{31}	0.30	100	0.20
	S_{41}	0.45	40	0.25
	S_{42}	0.45	60	0.25
	S_{43}	0.45	80	0.25
	S_{44}	0.45	100	0.25
	S_{51}	0.60	40	0.30
	S_{52}	0.60	60	0.30
	S_{53}	0.60	80	0.30
	S_{54}	0.60	100	0.30

Table 3. Details of Specimens

Properties tested	Size in mm	Number of specimens
7-day cube compressive strength	150x150x150	4
14-day cube compressive strength	150x150x150	4
28-day cube compressive strength	150x150x150	4
Cylinder compressive strength	300x150ϕ	4
Split tensile strength	200x100ϕ	4
Modulus of rupture [prisms]	500x100x100	3

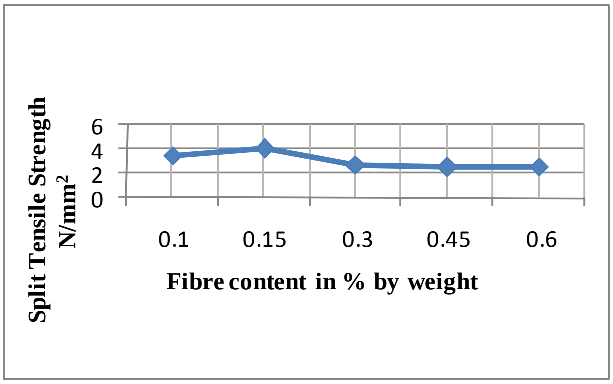

Figure (4c): Effect of Fiber Content on Split Tensile Strength

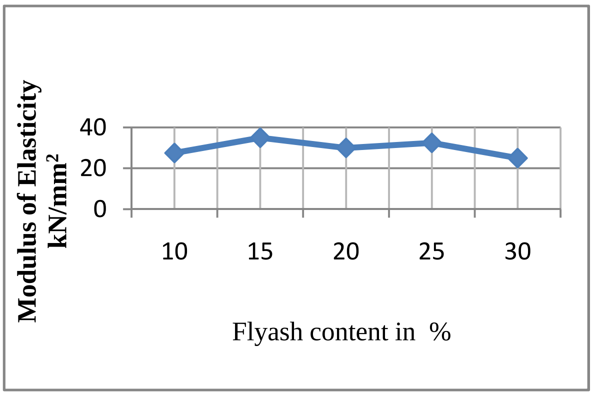

Figure (5a): Effect of Fly Ash Content on Modulus of Elasticity

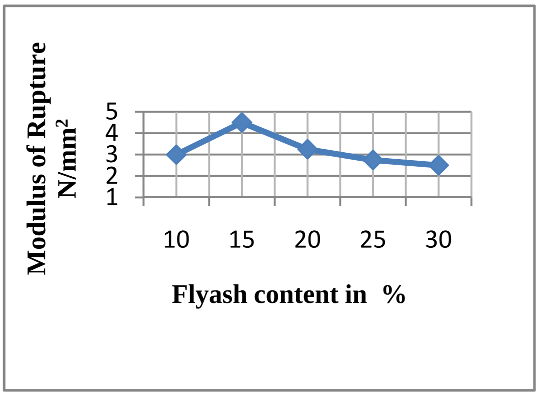

Figure (5b): Effect of Fiber Content on Modulus of Rupture

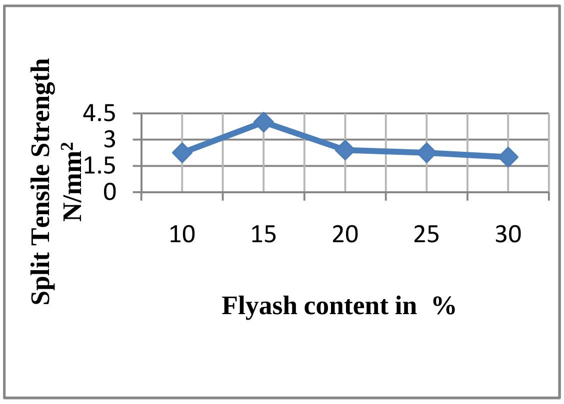

Figure (5c): Effect of Fiber Content on Split Tensile Strength

Table 4. Comparison of Structural Properties

Designation	% of fly ash by weight of cement	% of fiber by weight of concrete	Compressive strength in N/mm²				Split tensile strength in N/mm²	Modulus of rupture in N/mm²	Modulus of elasticity in N/mm²
			Cube [7days]	Cube [14 days]	Cube [28 days]	Cylinder [28 days]			
S11	10	0.10	20.75	20.25	25.75	18.00	3.50	4.00	3250
S12			20.50	19.60	25.50	19.00	3.25	3.75	2750
S13			21.25	20.75	25.25	19.50	3.00	4.25	2875
S14			21.25	18.45	26.00	18.50	2.75	4.50	2925
S21	15	0.15	21.50	25.75	25.75	21.25	4.00	4.50	3450
S22			25.25	25.50	25.50	22.50	4.50	4.25	3500
S23			25.50	26.25	25.25	20.00	3.75	4.75	3625
S24			25.25	24.25	26.00	21.25	3.50	4.00	3475
S31	20	0.30	16.25	22.50	28.25	18.75	2.75	3.75	3250
S32			16.50	21.75	28.50	18.00	2.40	3.50	3000
S33			16.00	21.50	27.75	18.75	1.75	3.00	2975
S34			15.75	22.25	28.00	18.50	2.50	3.25	2875
S41	25	0.45	15.00	21.40	26.25	17.50	2.50	2.75	3125
S42			15.75	20.75	26.00	17.25	2.25	3.00	3250
S43			15.50	21.25	26.50	17.00	2.75	2.50	3075
S44			14.75	21.00	26.50	17.75	1.75	2.75	2925
S51	30	0.6	14.75	17.80	22.75	17.50	2.00	2.75	3000
S52			14.00	17.50	22.50	17.00	2.25	3.00	2500
S53			14.75	17.40	21.75	17.50	1.75	3.25	2475
S54			15.00	17.40	22.00	17.25	1.75	3.00	2350

Modulus of Rupture

The maximum flexural strength obtained for polypropylene fiber reinforced concrete was 4.56 N/mm² for the 12th mix and that for plain cement concrete was 2.80 N/mm² .The corresponding strength improvement is 62%. It is observed during testing that ordinary concrete specimens failed without any warning, while the polypropylene fiber reinforced concrete specimens showed a ductile failure, giving ample warning. The flexural stress determined for both ordinary concrete and fiber reinforced concrete is given in Table 4 and graphically shown in Figures 4(b) and 5(b).

Table 5. Variance Ratio Values for Compressive Strength

Parameters	Actual variance ratio, F_{actual}				Critical variance ratio, $F_{critical}$
	7 days Cube	14 days Cube	28 days Cube	28 days Cylinder	
Fiber content	20.6	8.4	13.1	2.55	3.24
Fiber length	23.06	5.2	8.10	1.72	3.06
Fly ash content	20.5	8.4	13.1	2.55	2.87

Table 6. Variance Ratio Values for Split Tensile Strength, Modulus of Rupture and Modulus of Elasticity

Parameters	Actual variance ratio, F_{actual}			Critical variance ratio, $F_{critical}$
	Split tensile strength	Modulus of rupture (prisms)	Modulus of elasticity	
Fiber content	0.425	0.425	3.43	3.24
Fly ash content	0.650	0.61	15.625	3.24

Modulus of Elasticity

Modulus of elasticity was determined from the load deformation observation of the cylinder specimens. The variation of the modulus of elasticity value with respect to fly ash percentage, fiber length and fiber content is shown in Figures 4(a) and 5(a).The value of modulus of elasticity in compression of each mix is shown in Table 4.

The statistical (ANOVA) method was used to determine whether the effect of fiber length, fiber content and fly ash content was statistically significant. Here, F_{actual} and $F_{critical}$ were calculated and shown in Tables 5 and 6. F_{actual} is the ratio between the sample mean square and within the sample mean square. From statistical tables for known values of degrees of freedom and significance level, $F_{critical}$ is observed and compared with F_{actual}. Null hypothesis of no difference between two samples is accepted if F_{actual} is less than $F_{critical}$ and rejected if F_{actual} is greater than $F_{critical}$. Probability of error of 0.05 was used for ANOVA test. ANOVA test indicated the effect of fiber content. Tables 5 and 6 present the values of variance ratio for compressive and split tensile strengths, modulus of rupture and modulus of elasticity, of concrete mixes with varying fiber length, fiber content and fly ash content. As the F_{actual} values are greater than the $F_{critical}$ values for all cases, it can be concluded that the effect of fiber content on the above properties of concrete is significant.

CONCLUSIONS

Based on the results of the investigation reported in this paper, the following conclusions are made.

a. The fly ash-based polypropylene fiber reinforced concrete shows a better performance than ordinary concrete. A certain content of fine particles such as fly ash is necessary to evenly disperse the ultra fine polypropylene fibers.

b. The optimum content of polypropylene fibers was 0.15% under 15% fly ash concrete resulting in a better performance under compressive strength, split tensile strength, modulus of rupture and modulus of elasticity of concrete.

c. The different length of polypropylene fibers contributed to compressive strength. The addition of a small length of fiber had a more significant influence on the compressive strength than the addition of a large fiber length. Based on the test results, 60 mm length of fiber shows a better compressive strength than other lengths of fiber.

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