Experimental Investigation on Flexural Performance of Hybrid Fibre Reinforced Concrete

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Abstract - *This paper presents a study on the flexural performance of hybrid fibre reinforced concrete. The influence of fibre content on the strength and ductility performance of hybrid fibre reinforced concrete specimens having different proportions of steel (S) and polyester (P) fibres was investigated. The parameters of investigation included modulus of rupture, ultimate load, service load, ultimate and service load deflection, crack width, energy ductility and deflection ductility. 100 x 100 x 500 mm prisms were tested to study the above parameters. The specimens incorporated 1.0% fibre volume fraction of steel and polyester fibres in different proportions. The strength and ductility performance of hybrid fibre reinforced concrete specimens was compared with that of plain concrete. The test results show that a proportion of S60P40 hybrid fibres improve the performances appreciably.*

Key Words: *Ductility, Fibres, Hybrid fibre reinforced concrete, Strength.*

1. INTRODUCTION

Concrete is considered a brittle material with low tensile strain capacity and poor fracture toughness. Concrete can be modified to perform in a more ductile form by the addition of randomly distributed discrete fibres in the concrete matrix[1-4]. Fibre reinforced concrete specimens' do not fail immediately after the initiation of the first crack. After the first crack, the load transferred from the concrete matrix to the fibres. For an optimal response, different type of fibres may be suitably combined to produce hybrid fibre reinforced concrete (HFRC)[5]. The use of optimized combinations of two or more types of fibres in the same concrete mixture can produce a composite with better engineering properties than that of individual fibres. This includes combining fibres with different shapes, dimensions, tensile strength and young's modulus to concrete matrices[6].

This research work focuses on the steel-polyester hybrid fibre reinforced system. In this system, steel fibre, which is stronger and stiffer, improves the first crack strength and ultimate strength, while the polyester fibre, which is more flexible and ductile, leads to improved toughness and strain capacity in the post - cracking zone[7-8]. Information available on the strength and ductility performance of hybrid fibre reinforced concrete is still limited. Hence an attempt has been made to study the strength and ductility performance of hybrid fibre reinforced concrete.

2. EXPERIMENTAL PROGRAM

2.1 Specimen Details

100 x100 x 500 mm prisms were tested in a loading frame. The test program was designed to study the strength and ductility performance of concrete specimens with and without fibres. Table 1 shows the details of the specimens used for testing.

Table -1: Specimen Details

Sl. No.	Specimen ID	Volume Fraction (%)	Steel Fibre	Polyester Fibre
1	S0 P0	0	0	0
2	S100 P0	1.0	100	0
3	S80 P20	1.0	80	20
4	S60 P40	1.0	60	40
5	S50 P50	1.0	50	50
6	S0 P100	1.0	0	100

Note: S0 P0 –Plain Concrete

Material Properties

Cement concrete having cube compressive strength of 26.80 MPa was used for casting the specimens. Properties of fibres used in the experimental work are shown in Table 2. For concrete with fibres, superplastizer (High range water reducing admixture-Conplast® SP337) was used in appropriate dosage to main the workability of concrete mix.

Table -2: Properties of Fibres

Sl. No.	Fibre Properties	Fibre Details	
	Material	Steel fibre	Polyester fibre
1	Shape	Hooked end	Straight
2	Cross section	Round	Substantial
3	Diameter (mm)	0.5 mm	0.036 mm
5	Specific gravity	7.90	1.36
6	Density (Kg/m^3)	7900	$(1.3 – 1.4) \times 10^{-3}$
7	Young's Modulus (GPa)	2.1×10^5	17250

A reinforced concrete specimen S0 P0 was used as plain concrete. S100 P0, S80 P20, S60 P40 S50 P50 and S0 P100 were cast with a total fibre volume fraction of 1.0%. The proportion of and S (Steel) and P (Polyester) being 100-0, 80-20, 60-40, 50-50 and 0-100 for all the specimens.

Testing of Specimens

All the specimens were tested under four point-bending in a loading frame. Deflection measurements were made using dial gauges of 0.01 mm accuracy. The crack widths were measured using a crack detection microscope with a least count of 0.02 mm. The above measurements were taken at different load levels until failure.

RESULTS AND DISCUSSION

The test results are presented in Tables 3 & 4. The ductility indices of test beams are presented in Table 5. Each value presented is the average of three specimens. It is clear from Table 3 that the increase in flexural strength was found to be 45% when compared to the plain concrete. The flexural strength for beams with and without fibres is shown in Fig. 1. The test results show that the increase in ultimate load was found to be 45% with 60-40 steel-polyolefin hybrid fibre content when compared to that of plain concrete. The ultimate and service loads for beams with and without fibres are shown in Figs 2 - 3. From the test results furnished in Tables 3 & 4, it can be observed that the hybrid fibre reinforced concrete specimens exhibit increase in deflection with increase of fibre content both at service and ultimate loads when compared to the plain concrete. The increase in ultimate and service load deflection was found to be 86.36% and 65.85% respectively when compared to the plain concrete.

It is evident from Table 4 that the hybrid fibre reinforced concrete specimens exhibit more number of cracks with lesser widths when compared to the plain concrete. The percentage reduction was of the order of 61.3% when compared to the plain concrete. Table 4 indicates that the hybrid fibre reinforced concrete specimens exhibit enhanced ductility than that of plain concrete. It was noticed that for specimens with fibres the failure was not sudden. The randomly oriented fibres crossing the cracked section resisted the propagation of cracks and separation of the section. This caused an increase in the load carrying capacity beyond the first cracking[9-11]. The increase in energy and deflection ductility was found to be 67% and 58% respectively when compared to that of plain concrete. The enhancements in energy and deflection ductility for specimens with and without fibres are shown in Figs. 4 – 5. The crack pattern and failure modes are presented in Figs. 6-7.

Table -3: Test Results of Specimens in Flexure

Specimen ID	Flexural strength (MPa)	Ultimate Load (kN)	Service Load (kN)
S0 P0	4.65	11.62	7.75
S100 P0	5.63	14.10	9.40
S80 P20	5.89	14.73	9.82
S60 P40	6.72	16.80	11.20
S50 P50	5.56	13.90	9.27
S0 P100	4.90	12.25	8.17

Table -4: Deflection and Crack width of Specimens

Specimen ID	Ultimate Deflection (mm)	Service Load Deflection (mm)	Average Crack Width (mm)
S0 P0	0.44	0.41	0.50
S100 P0	0.59	0.48	0.44
S80 P20	0.72	0.57	0.40
S60 P40	0.82	0.68	0.31
S50 P50	0.80	0.64	0.32
S0 P100	0.76	0.60	0.36

Table -5: Ductility Indices of Test Specimens

Sl. No.	Specimen Designation	Energy Ductility	Deflection Ductility
1	S0 P0	1.00	1.00
2	S100 P0	1.20	1.16
3	S80 P20	1.40	1.31
4	S60 P40	1.67	1.58
5	S50 P50	1.98	1.82
6	S0 P100	1.59	1.45

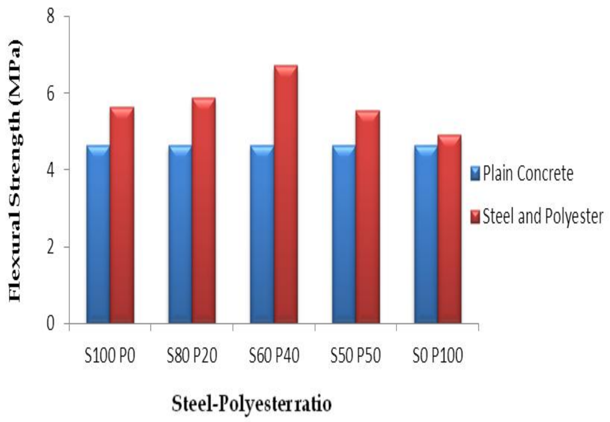

Fig. 1 Flexural Strength for Specimens with and without Fibres

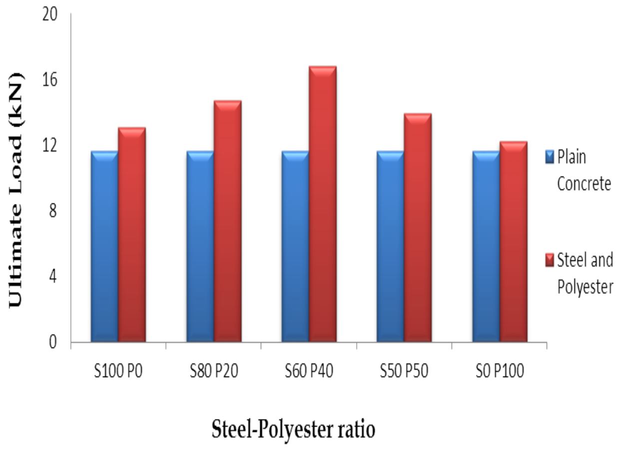

Fig. 2 Ultimate Load for Specimens with and without Fibres

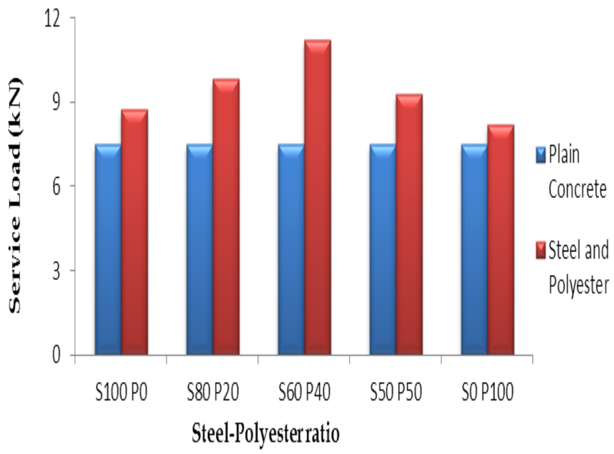

Fig. 3 Service Load for Specimens with and without Fibres

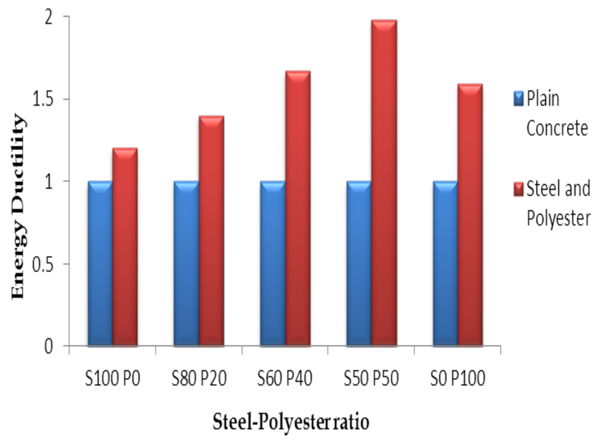

Fig. 4 Energy Ductility for Specimens with and without Fibres

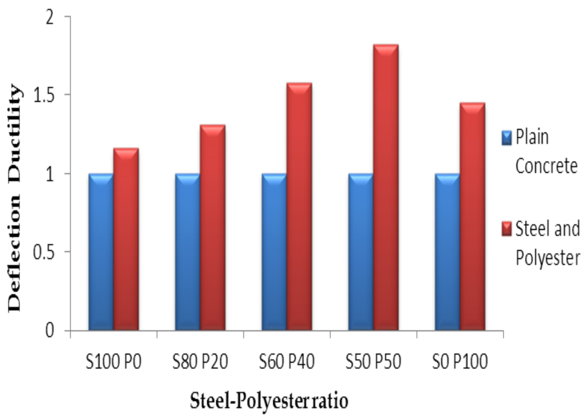

Fig. 5 Deflection Ductility for Specimens with and without Fibres

Fig. 6 Crack pattern and failiure mode of beam without fibre

Fig. 7 Crack pattern and failure mode of beams with fibre

CONCLUSSIONS

1. A hybrid proportion of 60–40 Steel-Polyester combine significantly improves the overall performance of reinforced concrete specimens.
2. The hybrid fibre reinforced concrete specimens' exhibit enhanced strength in flexure. The values of flexural strength were increased up to 45% compared to their plain counterparts.
3. The hybrid fibre reinforced concrete specimens exhibit increase in deflection to the tune of 86.36% in comparison with plain concrete.
4. The hybrid fibre reinforced concrete specimens exhibit reduced crack width at all load levels, the maximum reduction in crack width was found to be 61.30% compared to that of plain concrete.
5. The hybrid fibre reinforcement appreciably enhances the ductility of concrete specimens. The increase in ductility was found to be 67% and 58% in terms of energy and deflection respectively.

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BIOGRAPHIES

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