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Mechanical Properties of Hybrid Fibre Reinforced Concrete With Steel And Synthetic Fibre

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Abstract

The experimental study deals with Hybrid fibre reinforced concrete with the use of steel and synthetic fibres (Polypropylene and Recycled polyethylene terephthalate RPET). The M40 grade concrete used was designed by using IS10262-2009 code. The steel fibre and synthetic fibre were added at the volume fractions up to 0.5%. Test results showed that the fibres, when used in a hybrid form, could result in superior composite performance compared to their individual fibre-reinforced concretes. The results indicate that concrete containing a fibre combination of 0.38% steel fibres & 0.12% PET fibres can be adjudged as the most appropriate combination to be employed in HyFRC for compressive strength, splitting tensile strength and flexural strength.

Keywords : Hybrid fibre reinforced concrete, mechanical properties, polypropylene fibre, recycled polyethylene terephthalate fibre, volume fraction.

Introduction

There are many kinds of fibres, no matter metallic or polymeric, widely used in concrete engineering for their advantages [1]. In fact, no single fibre-reinforced concrete has the perfect mechanical properties. To improve properties of concrete like low tensile and low strain capacity, fibre reinforced concrete (FRC) has been developed which is defined as concrete containing dispersed randomly oriented fibres [3]. Mechanical properties such as compressive strength, splitting tensile strength and flexural strength were compared for concrete containing different combinations of steel, carbon, polyester and polypropylene fibres at a fibre volume fraction of 0.5% [4]. The test result shows that addition of steel fibres generally contributed towards the energy absorbing mechanism (bridging action) whereas, the non-metallic fibres resulted in delaying the formation of micro-cracks.

The hybrid combination of metallic and non-metallic fibres can offer potential advantages in improving concrete properties as well as reducing the overall cost of concrete production [5]. When fibre fractions are increased, it results in a denser and more uniform distribution of fibres throughout the concrete, which reduces shrinkage cracks and improves post-crack strength of concrete. In general, fibre-reinforced concrete or mortar shows excellent performance in tensile and crack resistance; as recycled PET fibres have excellent physical characteristics when used for concrete reinforcement, they are believed to improve the mechanical properties of the concrete [6–8]. The steel fibres have high elastic modulus and stiffness so they can improve compressive strength and toughness of concrete. On the other hand, the synthetic fibres have good ductility, fineness, and dispersion so they can restrain the plastic cracks .Therefore, proper mixture of these two complementary fibres can make better mechanical properties of concrete.

This study reports the experimental results of the strength properties of HyFRC cube, cylinder and prism namely, compressive strength, split tensile strength and flexural strength.

Materials and Experimental Methods

Materials Used

Pazzalona Portland cement was used for all mixes; fine aggregate used was river sand with specific gravity of 2.65 and conforming to grading zone III of IS 383-1970 specification. The coarse aggregate was crushed granite aggregate with specific gravity of 2.6 and passing through 20 mm sieve and retained on 12.5 mm was used for casting all specimens. To impart additional desire properties; a super plasticizer (conplast SP 430) was used. It is a chloride free admixture having specific gravity 1.2 to 1.25. The fibres used in the study were steel and synthetic; the properties of these fibres are listed in Table 1.and figure shows in Fig 1, 2 & 3

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Table1. Physical and mechanical properties of the various fibres

Property	Steel	PP	RPET
Length (mm)	50	38	38
Diameter (mm)	1	0.1	0.025
Aspect ratio (l/d)	50	380	1520
Specific gravity	7.8	0.9	1.35
Tensile strength	1700	450	970

Fig 1. RPET Fibre

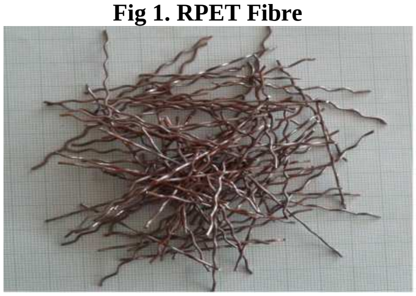

Fig 2. Steel Fibre

Fig 3.Polypropylene Fibre

Mixture Proportioning

Design mix were prepared to obtain target strength of 40 MPa at 28 days, along with a workability of 75–125 mm. In order to obtain the desired workability, only the super plasticizer dosage was varied. The detailed mixture proportions for the study are presented in Table 2, while the volume fractions of various fibres used in the mixtures are given in Table 3.

Table 2. Concrete mixture proportions

Cement kg/m^3	FA kg/m^3	CA kg/m^3	Water Lit/m^3	SP Lit/m^3
394.32	717.288	1152.58	157.728	3.943

Table 3. Dosage of different fibre combinations used in the study

Mix	Steel Fibre (%)	PP Fibre (%)	PET Fibre (%)	Fibre dosage (kg/m^3)		
				Steel	PP	RPET
SFRC	0.5	-	-	39	-	-
HyFRC 1&4	0.38	0.12	0.12	27.2	1.34	1.82
HyFRC 2&5	0.25	0.25	0.25	19.4	2.26	3.86
HyFRC 3&6	0.12	0.38	0.38	9.36	3.41	5.14
RPFRC	-	-	0.5	-		6.72
PPFRC	-	0.5	-	-	4.5	-

Mixing and casting details

Three different fibre were added to each of hybrid mixes at 0.5% by volume of concrete. In addition, super plasticizer was added to concrete mixes at 1% by weight of cement. The compressive strength was determined on 150x150x150 mm cubes at 28 days. The split tensile strength was determined on 150x300 mm cylinders at 28 days. In addition, flexural strength test were performed on 100x100x500 mm prismatic specimens at 28 days.

Test Results and Discussions

Compressive Strength

For compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm were casted for M40 grade of concrete. The moulds were filled with SF0.5%, RPET0.12% & ST0.38%, RPET0.25% & ST0.25%, RPET 0.38% & ST0.12%, PP0.12% & ST0.38%, PP0.25% & ST0.25%, PP 0.38%& ST0.12%, PP 0.5% and PET0.5% fibres. After 24 hours the specimens were demoulded and were transferred to curing tank where in they were allowed to cure for 28 days. These specimens were tested in compression testing machine. In each category, three cubes were tested and their average value is reported. The compressive strength results for HyFRC containing different combinations of steel and synthetic fibres are presented in Table 4 and Figure 4.

Split Tensile Strength

For tensile strength test, cylinder specimens of dimension 150 mm diameter and 300 mm length were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 28 days. These specimens were tested in compression testing machine. The split tensile strength results for HyFRC containing different combinations of steel and synthetic fibres are presented in Table 4 and Figure 5.

Flexural Strength

For flexural strength test, prism specimens of dimensions 500 x 100 x 100 mm were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 28 days. The flexural strength results for HyFRC containing different combinations of steel and synthetic fibres are presented in Table 4 and Figure 6.

Table 4. Test results for various fibre concretes at 28 days

S.No	Mix	Compressive Strength (Mpa)	Spli tensile strength(Mpa)	Flexural strength(Mpa)
1	SFRC	48.10	4.10	5.28
2	HyFRC 1	51.70	4.56	6.13
3	HyFRC 2	48.50	4.43	5.67
4	HyFRC 3	42.30	3.98	5.50
5	HyFRC 4	49.47	4.20	5.34
6	HyFRC 5	45.43	4.00	4.84
7	HyFRC 6	40.06	3.80	4.57
8	PPFRC	39.40	3.90	5.03
9	RPFRC	37.30	3.60	4.22

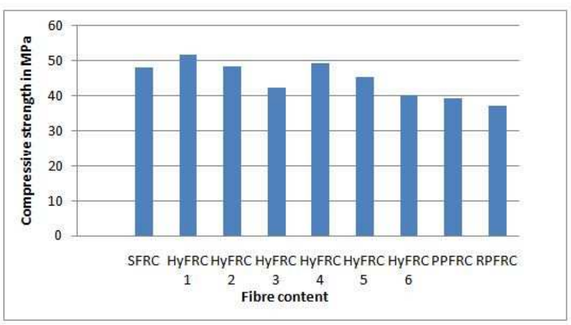

Fig 4. Compressive strength

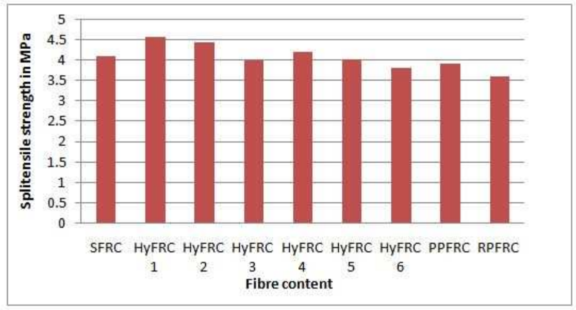

Fig 5. Split tensile strength

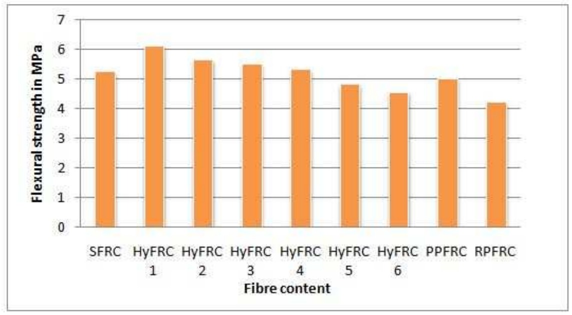

Fig 6. Flexural strength

Conclusion

The results of the compressive strength and split tensile strength test conducted on HyFRC containing different combinations of steel and synthetic fibres. However, an increase in the compressive strength of fibrous concrete is observed with the addition of steel fibres to the mix and maximum compressive strength is obtained for concrete containing 0.38% steel fibres+0.25% polypropylene fibres. In general, there is an increase in compressive strength varying from 7% to 18% on addition of fibres to concrete and the optimum fibre combination is 0.38% steel fibres + 0.12% polypropylene fibres for which the maximum increase in compressive strength of concrete is observed. Further, it can also be seen that the compressive strength and split tensile strength of concrete mix containing 0.38% steel fibres + 0.12% RPET fibres is higher than that of concrete mix containing 0.5% steel fibres.

It can be seen that in general, the flexural strength of concrete containing 0.5% RPET fibres is less than that of the PP concrete. The increase in flexural strength taken as average of three batches of fibrous concrete containing different combinations of steel and polypropylene fibres showing an increase of 13.8% for HyFRC with 0.38% steel fibres + 0.12% polypropylene fibres. Thus the optimum fibre combination for flexural strength is 0.38% steel fibres + 0.12% polypropylene fibres as obtained in this experimental study.

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