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Experimental Studies on Structural Behaviour of Hybrid Fibre Reinforced Concrete

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Abstract: The present research work focus on the study of the structural behaviour of hybrid fibre reinforced concrete elements. The impact of fibre content on the structural characteristics of hybrid fibre reinforced specimens having different fibre-volume fractions will be investigated. The parameters of investigation include compressive strength, split tensile strength and flexural strength. The specimens are incorporated with 0.0 to 1% volume fraction of Steel and Polyester (Recron 3S) fibres in different proportions. The optimum percentage of hybrid fibre content is obtained. The structural behaviour of hybrid fibre reinforced concrete specimens at optimum fibre content will be compared with that of conventional concrete specimens.

1. Introduction

As a construction material, concrete is largely produced than all other materials. Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle fracture of the concrete. Addition of closely spaced and uniformly distributed fibres to concrete will act as crack arrester and substantially improve its static and dynamic properties of the concrete. This type of concrete is known as Fibre Reinforced Concrete. Fibres are usually used in concrete to control cracking due to both plastic shrinkage and drying shrinkage. They will reduce the permeability of concrete in considerable magnitude and by this reduce bleeding of water. Some types of fibres produce have greater impact against abrasion and shatter resistance in concrete. Venu Malagavelli et al [1] investigated the use of non-biodegradable waste (polyester fibers) in the concrete to improve the crack resistance and strength. In their study concrete 25Mpa incorporated with various fiber contents starting from 0 to 6% of with an increment of 0.5% for finding Compressive strength, split tensile strength and flexural strengths and concluded that strength parameters are increased as fibre content is increased upto certain extent. Nataraja et al [2] conducted a study on steel fibre reinforced concrete under compressive load, ranged from 30 to 50 N/mm^2 by using round crimpled fibres with three different volume fractions of 0.5 percent, 0.75 percent and 1.0 percent, the effect of fibre inclusion in concrete and its compressive strength variance was studied. And it was concluded that the addition of fibres increased the compressive strength. Wu Yao et al [3] examined the mechanical behaviour of hybrid fibre reinforced concrete with minimum fibre volume fraction. Three different combinations of hybrid composites such as polypropylene - carbon, carbon - steel and steel - polypropylene fibres were chosen and the mechanical strength properties of the concrete such as compressive strength, split tensile strength, modulus of rupture and flexural toughness were determined. Job Thomas and Ananth Ramasamy [4] performed some experimental investigations to find out mechanical properties of steel fibre reinforced concrete. Three different strengths such as normal strength (35 MPa), moderately high strength (65 Mpa) and high strength (85 Mpa) concrete mixes were selected for the study. A 30 mm long steel fibres with three different volume fractions as 0.5%, 1.0% and 1.5% were selected and uniformly distributed in the concrete mix. The mechanical strength properties such as compressive strength, split tensile strength, modulus of rupture and modulus of elasticity, poisson's ratio and strain corresponding to peak compressive stress were studied suggested that no significant improvement in compressive strength was obtained beyond 1.5% volume fraction of steel fibre content. Although much research exists on the structural applications of steel fibres in concrete, the potential of using hybrid steel and Recron 3S fibres is yet to gain wide acceptance. This experimental program is to gain a better understanding of the performance of these fibres in the structural elements.

2. Materials and methodology

In this research different types of material are used i.e. Ordinary Portland Cement 53 grade (OPC), natural river sand as fine aggregate, maximum stone size of 10mm is used as coarse aggregate, crimpled round Steel fibre, Recron 3S fibre and Ordinary portable water

2.1. Cement

Ultra Tech OPC 53 grade cement conforming to code IS: 12269-1987 (specific gravity of cement 3.1, initial setting time of 46 minutes and final setting time of 184 minutes) was used in this study.

2.2. Fine Aggregate

Fine aggregates are tested and conformed according to the IS: 383-1970 is used in the present research work. River sand was used as fine aggregate and it has a specific gravity of 2.63, fineness modulus of 2.86 and conforming to grading zone -2.

2.3. Coarse Aggregate

Coarse aggregates are tested and conformed according to the IS: 383-1970 is used in the present research work. The granite crushed angular shaped coarse aggregate was obtained from the local crushing plant. It has a specific gravity of 2.762; fineness modulus is 3.717 and bulk density of 1680 kg/m^3

2.4. Ordinary Portable and Water:

Portable water is used for making mortar. The pH value of water lies between 6 and 8 that indicate the water is free from organic matters.

2.5. Crimpled Round Steel Fibre

Steel fibre with crimped ends is made using high-quality stainless-steel wire. A kind of high-*performance steel fibre, with the characteristics of the high tensile strength, good toughness and* economical. The product is widely used in concrete strengthening. The dimensions of the fibre are

Length 25mm and dia 0.6 mm Conforming to ASTM A 820 Type I STANDARD was used in this study.

2.6. Recron 3S Fibre
Recron 3S is a polyester fibre having triangular cross section with available cut length of 6mm & 12mm. It is much cheaper fibre material than any other imported construction fibres.

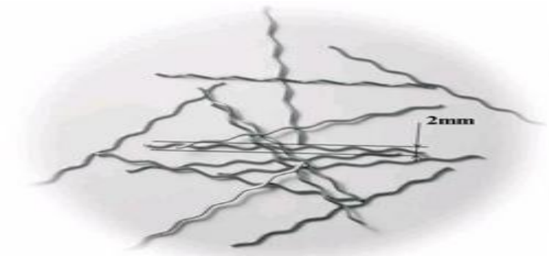

Figure 1: Crimped round steel Fibre

Figure. 2: Recron Fibre

3. Experimental Programme

3.1. Mix Design of Concrete
All the mixes prepared for experimental work are corresponds to M-20 grade. For the design of mix IS: 10262-2009 recommendations are adopted. Design mix proportions and quantities of M-20 grade are given in the following Table.1.

Table 1: Details of Design Mix, Test Data of Materials, Concrete Mix Proportions

Design Stipulation		
Characteristic compressive strength (28days)	=	20 N/mm^2
Maximum size of aggregate	=	10 mm
Degree of workability	=	0.9
Degree of quality control	=	Good
Type of exposure	=	Mild
Test Data of Materials		
Specific gravity of cement	=	3.15
Specific gravity of coarse aggregate	=	2. 81
Specific gravity of fine aggregate	=	2.65
Water absorption of coarse aggregate	=	0.5%
Water absorption of fine aggregate	=	1.0%
Free surface moisture for coarse aggregate	=	Nil
Free surface moisture for fine aggregate	=	2.0%
Concrete Mix-proportions		
Cement	=	412 kg/m^3
Water	=	206 litres
Fine aggregate	=	612.39 Kg/m^3
Coarse aggregate	=	1129.24 Kg/m^3
Water cement ratio	=	0.50

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3.2. Test specimen and testing procedures

For conducting compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm were casted. The moulds were prepared with 0%, 0.5%, 1%, Recron 3S, Crimped Steel and Hybrid fibres respectively. The samples were tested for their compressive strength at 7 and 28 days. Concrete cubes were tested on compression testing machine as per I.S. 516-1959. In each category three cubes were tested and their average value is reported. To determine the Split tensile strength, cylinder specimens of dimension 150 mm diameter and 300 mm length were casted. These specimens were tested under compression testing machine as per I.S. 5816:1999. For flexural strength test beam specimens of dimension 100x100x500 mm were casted. These flexural strength specimens were tested under four-point loading as per I.S. 516-1959, using universal testing machine (UTM).

Fig. 3: Compressive strength test

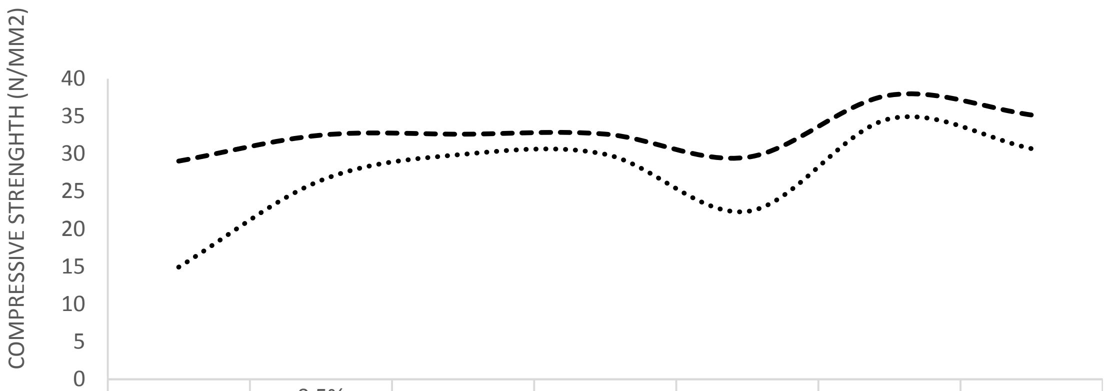
Fig. 4: Split tensile strength test

Fig. 5: Flexural strength test

4. Results and discussions

4.1. Compressive Strength in N/mm^2

From the fig.6 it is observed that the compressive strength, flexural strength of the 0.5% hybrid fibre reinforced concrete was found to be comparatively more than all the volume fractions. It was found that the 0.5% hybrid fibre reinforced concrete is 23% and 54% more than the conventional concrete. The compressive strength test values of the cube specimens at the age of 7 and 28 days are as shown in figure.6.

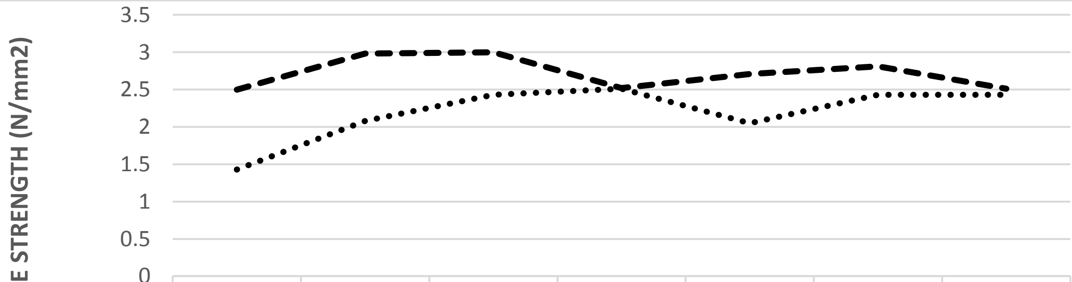


	CONVENTIONAL CONCRETE	0.5% RECRON 3S FIBER CONCRETE	1% RECRON 3S FIBER CONCRETE	0.5% STEEL FIBER CONCRETE	1% STEEL FIBER CONCRETE	0.5% HYBRID FIBER CONCRETE	1% HYBRID FIBER CONCRETE
7 DAYS	14.9	26.44	29.92	29.93	22.32	34.65	30.67
28 DAYS	29.02	32.47	32.6	32.61	29.53	37.78	35.15

Fig. 6: Compressive Strength values of different Concrete mixs

4.2. Test for Split Tensile Strength

The test cylinders were tested for their tensile strength values at the age of 7 and 28 days are as shown in figure.7.



	CONVENTIONAL CONCRETE	0.5% RECRON 3S FIBER CONCRETE	1% RECRON 3S FIBER CONCRETE	0.5% STEEL FIBER CONCRETE	1% STEEL FIBER CONCRETE	0.5% HYBRID FIBER CONCRETE	1% HYBRID FIBER CONCRETE
7 DAYS	1.43	2.08	2.43	2.51	2.05	2.43	2.43
28 DAYS	2.5	2.98	3.00	2.52	2.71	2.81	2.51

Fig. 7: Split Tensile Strength values of different Concrete mixs

From the above graph it is observed that the split tensile strength of the 0.5% and 1% Recron fibre reinforced concrete was found to be comparatively more than the 0.5% hybrid fibre reinforced concrete. But the split tensile strength of 0.5% hybrid fibre reinforced concrete is economical. It was found that the 0.5% hybrid fibre reinforced concrete is 14.7% more than the conventional concrete.

4.3. Test for Flexural strength

The specimens were tested for their flexural strength using UTM, the results were shown in fig.8

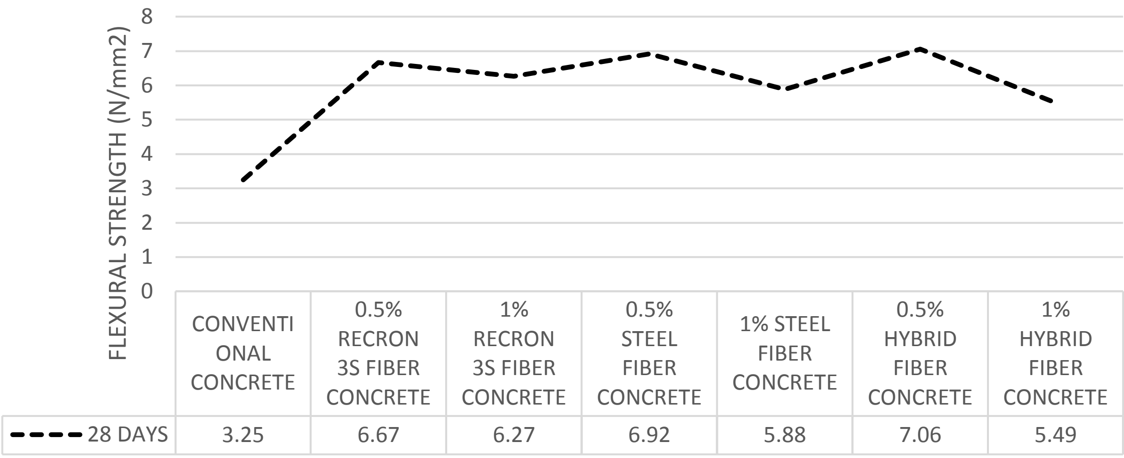


Fig. 8: Flexural strength values of different Concrete mixs

From the above fig. it is observed that the flexural strength of concrete is increasing considerably with the increase in fibre content compared to conventional concrete at 7 and 28 days. It is observed that at 0.5% of fibre dosage in the weight of cement, maximum strength is obtained and later strengths is reduced, although the fibre content is increased. This is evident from the figure.8 at 0.5% fibre content.

4.4. Load – Deflections curves for different Concrete mixes

The following figures 9 to 16 are the deflections curves for different concrete mixes/specimens. And it is clear that the young's modulus of the 0.5% hybrid fibre reinforced concrete was found to be comparatively more than all the volume fractions. It was found that the 0.5% hybrid fibre reinforced concrete is 12.5% more than the conventional concrete. Hence the optimum fibre content for hybrid fibre Reinforced concrete is taken as 0.5%.

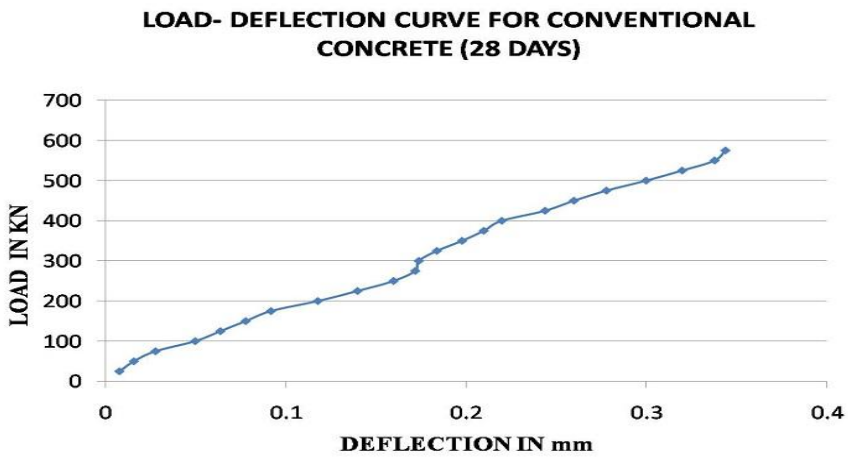


Fig. 9. Load - Deflection for Conventional Concrete

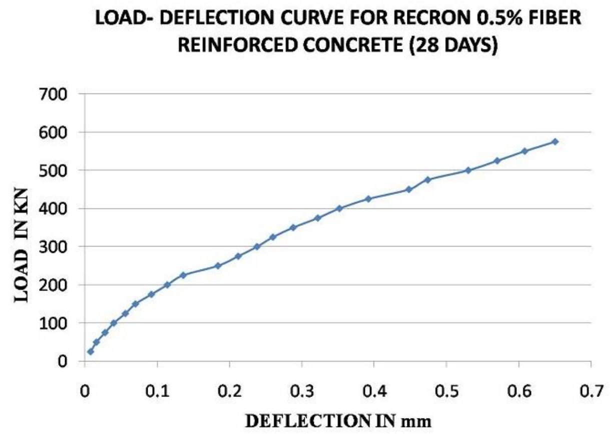


Fig. 10: Load-deflection curve for Recron 0.5% fiber reinforced concrete at 28 days

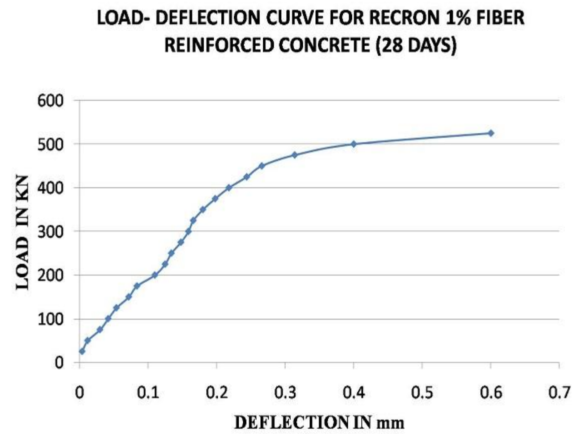


Fig. 11: Load-deflection curve for Recron 1.0% fiber reinforced concrete at 28 days

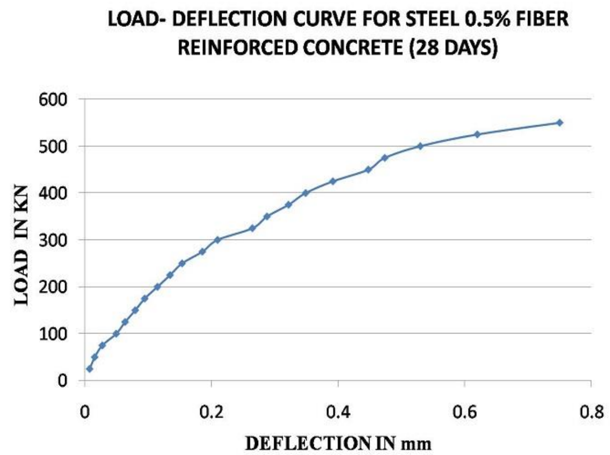


Fig. 12: Load-deflection curve for steel 0.5% fiber reinforced concrete at 28 days

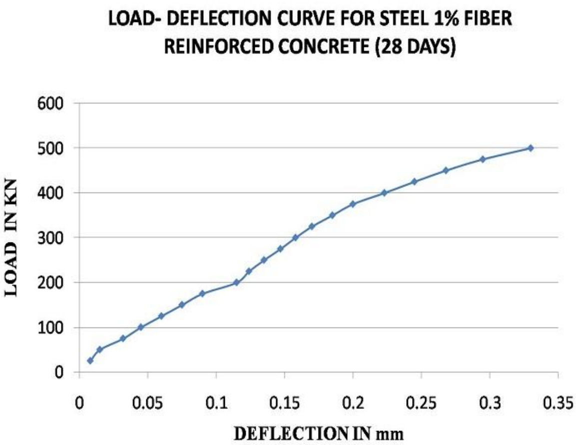


Fig. 13: : Load-deflection curve for steel 1.0% fiber reinforced concrete at 28 days

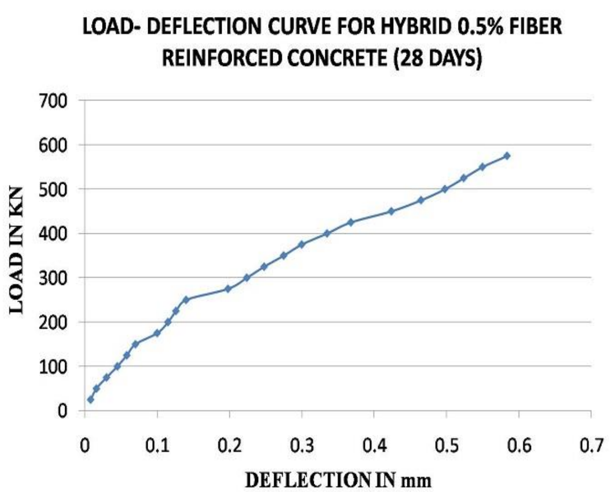


Fig. 14: Load-deflection curve for hybrid 0.5% fiber reinforced concrete at 28 days

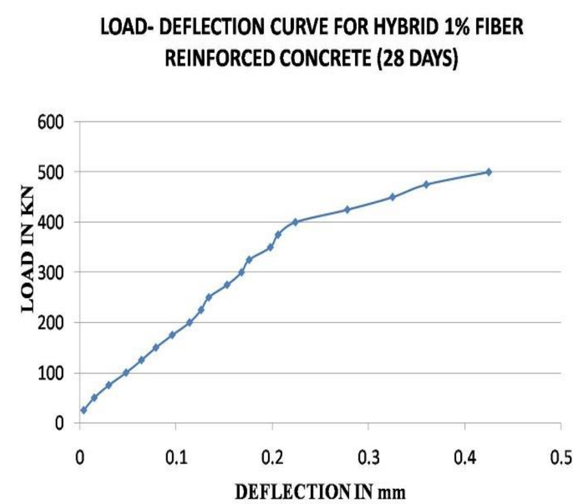


Fig. 15: Load-deflection curve for hybrid 1.0% fiber reinforced concrete at 28 days

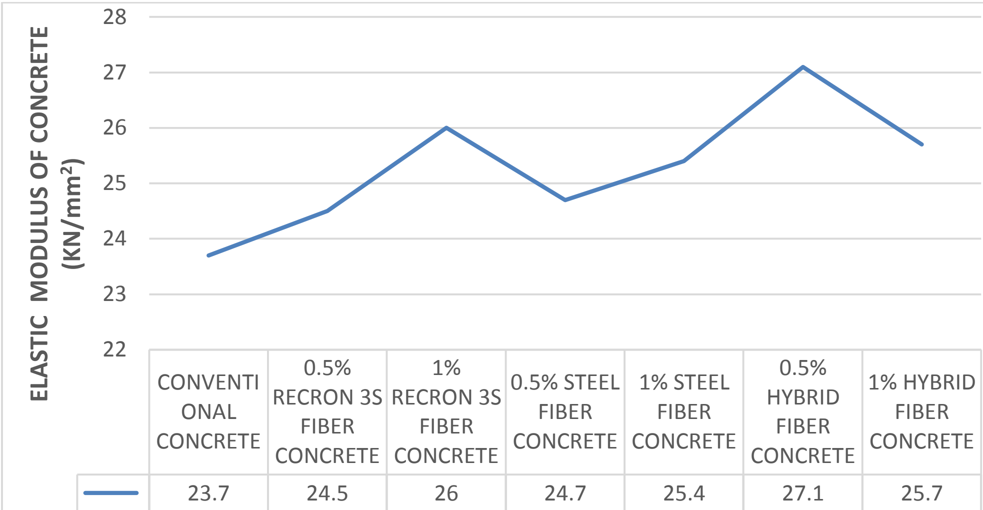


Fig. 16. Elastic Modulus of different Concrete Mixes

5. Conclusions

Since the mechanical properties like compressive strength, flexural strength and elastic modulus of 0.5% Hybrid Fibre Reinforced Concrete is more. The fibre volume fraction is optimized to 0.5% Hybrid Fibre Reinforced Concrete (HFRC). The structural behaviour of conventional beam is less when compared with that of 0.5% HFRC specimens. The 0.5% HFRC beam carries maximum load and shows reduction in deflection. Therefore, Hybrid fibre reinforced concrete yield better results when compared with convectional concrete and is optimum at certain percent replacement of fibres like crumbled round steel and Recron.

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