INVESTIGATION ON PERFORMANCE OF HYBRID FIBRE IN REINFORCED CONCRETE

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Abstract: Fibers are added to the concrete not only to increase tensile strength but also to control the crack and to change the behavior of cracked material by bridging across the cracks. Reinforcement of concrete with a single type of fiber may improve the desired properties to a limited level. If two or more types of fibers are rationally combined to produce a composite that derives benefits from each of the individual fibers. This paper is aimed at investigating the effect of hybrid fibres on the ductility of reinforced concrete beams. Three fibres namely hooked end steel fibre; recron fibre and coir fibre are used in this study with different aspect ratio. In addition comparisons are also made between solo fibre reinforced concrete, hybrid fibre reinforced concrete and controlled reinforced concrete. The parameters of investigation include compressive strength, flexural strength, ultimate load carrying capacity, stiffness, toughness index and ductility. A total of 7 beams and 42 cubes are casted to study the above parameters. The specimens incorporated 1% of fibre content. Compressive strength test result shows that the addition of fibres decrease the compressive strength. The experimental result shows that the ductility behavior of steel fibre reinforced beam and Hybrid fibre reinforced beam is high compared to controlled concrete.

Keywords: Hybrid, Steel fibre, Recron Fibre, Coir fibre, ductility

1. INTRODUCTION

Plain cement concrete possesses limited ductility and little resistance to cracking. Internal micro cracks present in the concrete eventually leads to brittle fracture of the concrete. The development of such micro cracks is the main cause of in elastic deformation in concrete. It has been recognized that the addition of small closely spaced and uniformly dispersed fibers to concrete would act as crack arrester and would substantially improve its static and dynamic properties. Several kinds of fibre such as steel, polypropylene, nylon, coir, jute, sisal, kenaf and carbon have been tried and these are available in a variety of shapes, sizes and thickness. These fibres are used either singly or jointly called as hybrid fibre. The main objective of inclusion of hybrid fibres in concrete is as follows

- To improve the rheology or plastic characteristics of the material in plastic state.
- To improve the tensile and flexural strength.
- To improve impact strength and toughness.
- To control crack and mode of failure by means of post cracking ductility.
- To improve durability.

2. LITERATURE REVIEW

There are many works with fiber reinforced concrete. It has been found that they are used as singly reinforced fibre and maximum of two. These include, the behaviour of concrete with nylon and steel fibre are studied by Nagarkar. **(Nagarkar 1987)**. A comprehensive review on the types of fibres and their influence on fresh and hardened concrete properties (**Ramakrishnan.V1987).** The effect of several variables of jute and coir fibres on the compressive and tensile strength of concrete has been investigated **(Rafiqul islam1987).** The flexural behavior of steel fiber reinforced concrete. The variables investigated were fiber type, length and volume fraction, and matrix composition are tabulated (**Balaguru 1992).** The influence of adding steel fibers to concrete mix with fiber reinforced plastics bars are studied **(Saleh alsyad 1998)**. Flexural behaviour of polypropylene fibre reinforced concrete I-beams-with and without stirrups-was evaluated **(Ahmed H. Ghallab 2005).** H. Wang investigates a nonferrous hybrid reinforcement system for concrete bridge decks by using continuous fiber-reinforced polymer (FRP) rebars and discrete randomly distributed polypropylene fibers **(H. Wang 2006)**. The influence of matrix strength, fibre content and diameter on the Compressive behaviour of steel fibre reinforced concrete is presented **(R. D. Neves 2006)**. The hybrid fibre concrete contains fibre mixtures of three different types of fibres are investigated by stahli **(P. Stahli 2007)**. High Performance Concrete (HPC) under compressive forces fails very brittle. On the opposite, concrete reinforced by steel fibres shows a very ductile behavior in tension. Some tests were performed to observe the influence of steel fibres on the post-peak behaviour of HPC under compressive forces (**Lars Kutzing 2007).** S.Eswari presents a study on the ductility performance of hybrid fibre reinforced concrete. **S.Eswari(2008).**

2.1 A critical appraisal of the existing methodology and need for the study.

The compressive, split tensile and flexural strength increased by addition of fibres. However workability of concrete is reduced. The results indicate that fiber content in the range of 30 to 50 kg/m^3 provides excellent ductility for normal strength concrete. Fiber length in the range of 30 to 60 mm. does not have a significant effect on toughness for hooked-end fibers.

The main variable in the studies were the type and volume fraction of steel fibre. Regarding Ductility the results reveal that the ductility of steel fibre – FRP is directly related to fibre content. The test result show that inclusion of 1% of hooked steel fibre can improve the ductility same as that of steel beams. The inclusion of polypropylene fibres into reinforced concrete beams reduced the crack propagation and steel tensile stress, and significantly improved the ductility of the reinforced concrete beams.

Based on literature review it is concluded that almost all FRC used today are of single type of fibre only. Clearly a given type of fibre can be effective only in a limited range of crack opening and deflection. The best composite properties can be obtained from the use of hybrid fibres which can enhance the flexural toughness and post peak strength of concrete by the synergistic interaction between two or three reinforcing bars. This hybrid fibre reinforced concrete can be used in self-compacting concrete, high performance concrete, high strength concrete (M40-M80) and ultra-high strength concrete (>M200).Hybrid fibre reinforced cement-based composites, especially having a high fracture toughness are potentially useful in slabs on grade, shotcrete and thin precast products like roofing sheets, tiles, curtain walls, cladding panels, I and L shaped beams, permanent forms, etc.

3. PROPOSED SYSTEM

An attempt has been made to study the ductility performance of hybrid fiber concrete with Steel-Recron-Coir fibre. The present investigation is intended to address the following major issues. The possibility of using hybrid fibre system for improved performance of reinforced concrete specimen is explored. Cube compressive strength of solo and hybrid fibre reinforced concrete specimens with controlled specimen is compared. Also a comparison on the enhancement in flexural capacity of solo and hybrid fibre reinforced concrete specimens with controlled reinforced concrete specimen. It's also compares the ductility of solo and hybrid fibre reinforced specimens with controlled reinforced concrete specimen

4. DESIGN METHODOLOGY

The mix proportion were designed as per I.S.10262-1982 by weight of 1:2.04:3.34:0.45(cement: fine aggregate: Coarse aggregate: water) was used throughout. The unit water content was kept constant for Plain concrete as well as Fibre reinforced concrete. For concrete, superplastizer (High range water reducing admixture- Conplast® SP430) 1% by weight of cement was used in appropriate dosage to maintain the workability of concrete mix. The experimental work consists of 7 beams and 42 cubes. All the beams were the same size of 100x150x1700 mm tested in a loading frame. Table 1 shows the details of the specimens used for testing. Materials, expect the fibres were first mixed in mixer machine, then water contain superplasticizer was added. After mixing uniformly, the fibres were added slowly to prevent bounding of the fibres and insure uniform distribution. The resulting mixture was then cast in to the moulds contain steel reinforcement with adequate top and bottom cover. The compaction is done using table vibrator. The specimens were allowed to set during the following 24 hours and then the moulds were stripped and the specimens were stored under curing tank.

Six Concrete specimens have cast in cube mould of 150x 150x 150 mm at the time of beam casting and compact using table vibrator for cube compressive strength at 7 and 28 days. Fig.1 shows the cast specimens and cubes.

Table 1: Specimen details

REFERENCE CODE	WF	STEEL	RECRON	COIR
CS1	0 %	0	0	0
CS2	1 %	100	0	0
CS3	1 %	0	100	0
CS4	1 %	0	0	100
CS5	1 %	50	50	0
CS6	1 %	50	0	50
CS7	1 %	33	33	33

Figure 1: cast specimens

5. EXPERIMENTAL INVESTIGATION

Three types of fibres, Metallic-hooked end steel fibre, Non-Metallic- Recron fibre, Natural-coir fibre were used in this investigation shown in fig1. The steel fibres used were Dramix steel fibres (RC80/60) which was supplied by Bekaert Fibre Technologies. The non-metallic Recron fibres were supplied by Reliance Industries limited. Commercially available coir fibre were collected in Nagerkovil, cleaned, entire foreign particles (dust,lump)removed and the fibres were tried to be separated. The coir of length 50mm and dia 0.5mm to 0.6mm were used. Physical Properties of fibres used in the Experimental work are shown in Table 2.

FIBRE PROPERTIES	STEEL FIBRE	RECRON FIBRE	COIR FIBRE
Length (mm)	60	24	50
Shape	Hooked at ends	Straight	Straight
Size/Diameter (mm)	0.75	0.37	0.5-0.6
Aspect ratio	80	65	85-100
Young's Modulus(Mpa)	$203x10^3$	-	(19-26) x 10^3
Tensile strength (Mpa)	1080	600	120-200

Table 2: Properties of Fiber

6. EXPERIMENTAL SET UP

All beams were tested under flexure in a loading frame of 500 KN for a simply supported condition. Two points loading was applied on beams at a distance of 500mm from each support by means of 250 KN capacity of hydraulic jack. The jack was operated manually. Three deflect meters were place under the beam. One was placed at the L/2 from support (centre of the beam) while the other was placed L/3 from support and last one was placed L/6 from the support to record deflection at these points. One deflect meter was placed at the end of the top of the beam. The deflections at a load increment of every 10 divisions in proving ring were recorded. To measure strain Mechanical strain gauge was placed at suitable interval. Crack patterns were recorded at every load increment. Figure: 3 shows the Flexure test set up for control beam, and all other fibre reinforced beams.

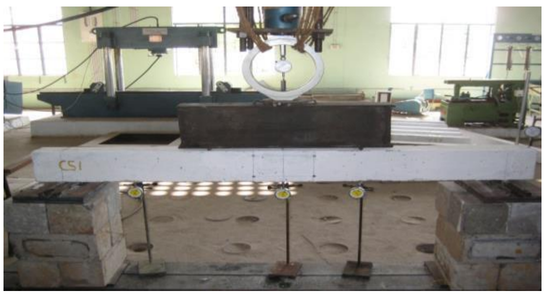


Figure 2: Flexure test set up

7. RESULT & DISCUSSION

7.1 CUBE COMPRESSIVE STRENGTH TEST

The variation of strength with respect to plain concrete strength for various solo and hybrid fibre concrete specimens are shown in fig.3.

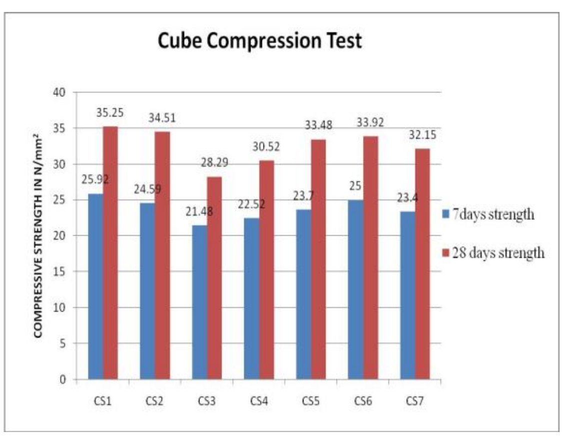
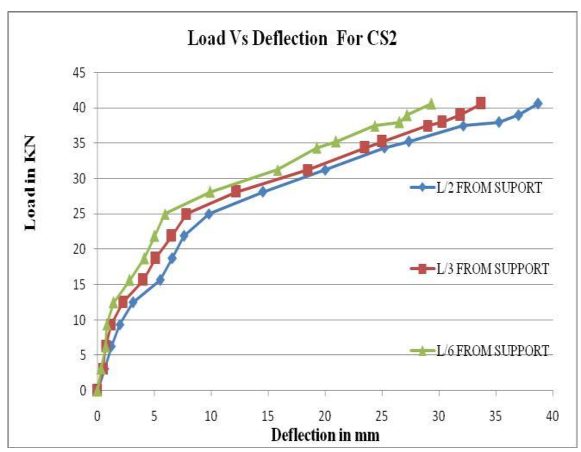


Figure 3: Cube compressive strength

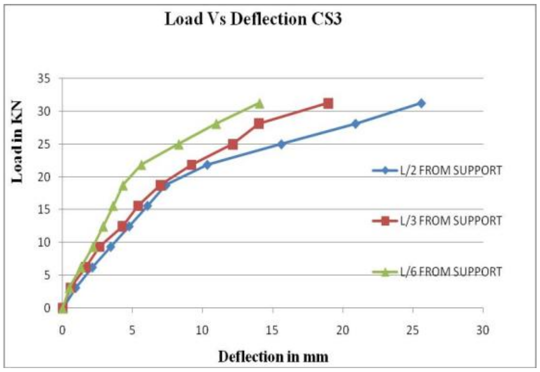
For both solo and Hybrid concrete the compressive strength for cubes is below plain concrete strength. Generally, by adding fibres the compressive strength of concrete is decreased. It is mainly depends upon percentage of fibres. Due to the high fibre content, the cube compressive strength decreased. In the case of specimen with coir fibres the average cube compressive strength is decreased. This is probably due to lower specific gravity of coir fibres. CS2 beam shows 2.09% lesser compressive strength than that of CS1. CS3 beam shows 19.74% lesser compressive strength than that of CS1. CS4 beam shows 13.41% lesser compressive strength than that of CS1 .CS5 beam shows 5% lesser compressive strength than that of CS1 .CS6 beam shows 3.77% lesser compressive strength than that of CS1. CS7 beam shows 8.79% lesser compressive strength than that of CS1.It is noticed that the plain concrete specimens exhibit severe spalling at failure whereas the steel fibre reinforced specimens exhibited very mild spalling. Other solo and hybrid concrete specimen spalling has been arrested appreciably.

7.2 FLEXURE STRENGTH TEST

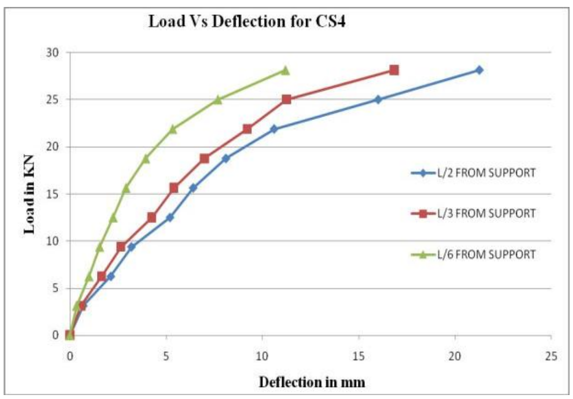
Load Vs Deflection plot has been drawn for all test specimens from the experimental data. The behavior of test specimens are compared from the below plots.



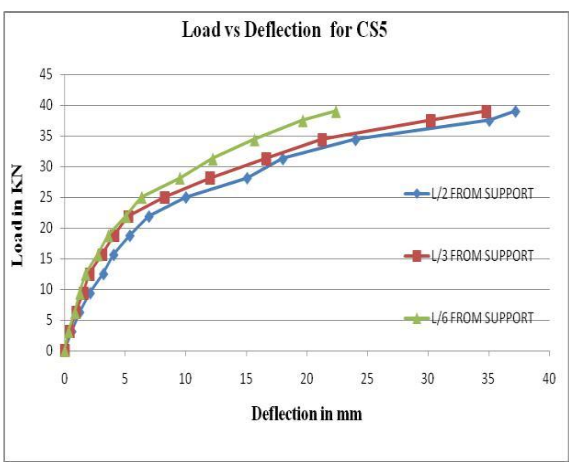
(a)



(b)



(c)



(d)

Figure 4: (a-d) Load vs Deflection for all beams

Control Beam (CS1) failed in bending zone. After the first crack load of 12 KN, The beam takes ultimate load of 35 KN.

Steel fibre Reinforced beam (CS2), the first crack load appears at 15.63 KN. The beam takes ultimate load of 41 KN. This is 17.14% higher than load carrying capacity of Control beam. The hooked end steel fibre proved its capacity as a crack arrester.

Recron Fibre Reinforced Beam (CS3), the first crack load appears at 9.38 KN, the reinforcement started yielding and less number of fine cracks has formed in the bending zone extended towards the point loads with the increment in loads. At ultimate load the failure of beam occurred. Large numbers of fine cracks were observed during failure. The beams take ultimate load of 31.25KN. The load carrying capacity of the beam is 10% lesser than that of controlled concrete.

The reinforcement provided by fibres can work at both a micro and macro level. At a micro level fibres arrest the development of micro cracks leading to higher flexural strength, whereas at a macro level fibres control crack opening, increasing the energy absorption capacity of the composite. On the other hand, Recron fibre addition causes some perturbation of the matrix, which can result in higher voidage. Voids can be seen as defects where micro cracking starts. In addition to fibre quantity, perturbation also depends on the ability of the matrix to accommodate fibres, which is an important property of the mortar fraction of the concrete. Therefore the influence of Recron fibres on the flexural strength may be seen as the balance between micro crack bridging and additional voids caused by fibre addition. It is observed ultimate load carrying capacity of Recron fibre beam is lesser than that of controlled concrete because of high fibre content.

7.3 DUCTILITY

Ductility can be defined as the “ability of material to undergo large deformations without rupture before failure”. The steel fibre reinforced beam shows higher ductility which is 58.38% higher than that of controlled concrete because of higher bond and anchorage. In hybrid fibre the beam with steel-Recron fibre shows higher ductility which is 47.59% higher than that of controlled concrete.

7.4 STIFFNESS:

It is observed from the above table the ultimate load stiffness for coir fibre reinforced beam (CS4) is higher which shows the beam is rigid and exhibit lesser deflection. The main contribution of coir fibre in concrete is it acts as a secondary reinforcement which control shrinkage cracks only and it did not contribute on ultimate load cracks. Hence the ductility of beam is reduced which allows higher stiffness

8. CONCLUSION

An extensive research was initiated to investigate the flexural behavior of hybrid fibre reinforcement system. From the flexural study covered in this paper, the following conclusions can be drawn. For both solo and Hybrid concrete the compressive strength for cubes is below plain concrete strength. It is noticed that the plain concrete specimens exhibit severe spalling at failure whereas the steel fibre reinforced specimens exhibited very mild spalling. Other solo and hybrid concrete specimen spalling has been arrested appreciably. Steel Fibre Reinforced Concrete (CS2) shows 17.14% increase in load carrying capacity when compared to controlled concrete (CS1) because of higher stiffness, bond and anchorage. Recron FibreReinforced Concrete (CS3) shows 19.62% decreases in load carrying capacity when compared to controlled concrete (CS1) because of high voids. Coir Fibre Reinforced Concrete (CS4) shows 10% decreases in load carrying capacity when compared to controlled concrete (CS1) because of high voids. The Ultimate load stiffness for coir fiber reinforced beam (CS4) is higher which shows the beam is rigid and exhibit lesser deflection.

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