International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 7, July - 2013

Flexural Behaviour Of Solo And Hybrid Fibre Concrete-A Comparative Study

Mr C. Chandra Sekar , Dr. N. V. Ramamoorthy
[1]**Asst.Professor, INFANT JESUS COLLEGE OF ENGINEERING &TECHNOLOGY, THOOTHUKUDI**
2Professor & Head, INFANT JESUS COLLEGE OF ENGINEERING &TECHNOLOGY

ABSTRACT

Fibres 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 fibre may improve the desired properties to a limited level. On the other hand hybrid fibres with two or more that are rationally combined may produce better benefits. 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; Polyster 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, 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.

KEY WORDS: Hybrid, Steel Fibre, Polyster Recron Fibre, Coir Fibre, Ductility

1.0 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 forms of fibre such as steel, polypropylene, nylon, coir, jute, sisal, kenaf and carbon have been tried and these are available in 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 tensile and flexural strength.
- To improve durability of structural member.
- To control crack and mode of failure by means of post cracking ductility.
- To improve the impact strength and toughness.
- To improve the rheology or plastic characteristics of the material in plastic state.

2.0 LITERATURE REVIEW

There are many works with Fibre Reinforced Concrete (FRC). 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 are studied by Ramakrishnan (**Ramakrishnan.V1987).** The effect of several variables of jute and coir fibres on the compressive and tensile strength of concrete has been investigated by Rafiqul Islam **(Rafiqul islam1987).** Balaguru investigated the flexural behavior of steel fiber reinforced concrete with fiber type, length and volume fraction, and matrix composition (**Balaguru 1992).** The influence of adding steel fibers to concrete mix with fiber reinforced plastics bars are studied by Saleh **(Saleh Alsyad 1998)**. Flexural behaviour of polypropylene fibre reinforced concrete I-beams- with and without stirrups was evaluated by Ahmed **(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 by Neves **(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 strength Concrete (HSC) under compressive forces fails very brittle. On the opposite, concrete reinforced by steel fibres shows a very ductile behavior in tension & Compression also. Some tests were performed to observe the influence of steel fibres on the post-peak behaviour of HSC under compressive forces by Larz kutzing(**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.

Based on literature review, most of the works on 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 steel reinforcement. 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.

Though the compressive, split tensile and flexural strength increased by addition of fibres, the workability gets reduced. Literature indicates 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. Most of the works takes the main variable as type and volume fraction of steel fibre. Regarding Ductility the literaure reveals that the ductility of steel fibre – FRP is directly related to fibre content. Saleh Alsyad test result show that inclusion of 1% of hooked steel fibre can improve the ductility same as that of steel beams **(Saleh Alsyad 1998)**. 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.

Keeping the above, there is an urgent need for improvement of ductile property of FRC using Hybrid fibres.

3.0 STUDY OBJECTIVE

An attempt has been made to study the ductility performance of hybrid fibre concrete with Steel- Polyster Recron-Coir fibre .The present investigation is intended to address the following major issues.

1. To explore the possibility of using hybrid fibre system for improved performance of reinforced concrete.
2. To compare the cube compressive strength of solo and hybrid fibre reinforced concrete specimens with controlled specimen
3. To compare the enhancement in flexural capacity of solo and hybrid fibre reinforced concrete specimens with controlled reinforced concrete specimen.
4. To compare the ductility of solo and hybrid fibre reinforced specimens with controlled reinforced concrete specimen

4.0 EXPERIMENTAL INVESTIGATION

Three types of fibres, Metallic-hooked end Steel fibre, Non-Metallic-Polyster Recron fibre, Natural-Coir fibre were used in this investigation. The steel fibres used were Dramix steel fibres (RC80/60) which was supplied by Bekaert Fibre Technologies. The non-metallic Polyster Recron fibres were supplied by Reliance Industries limited. Commercially available coir fibres were collected in Nagerkovil, it is cleaned and entire foreign particles (dust, lump) removed and the fibres are separated. Physical Properties of fibres used in the Experimental work are shown in Table 1.

FIBRE PROPERTIES	STEEL FIBRE	POLYSTER 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: 1Properties of Fibre

ISSN: 2278-0181
Vol. 2 Issue 7, July - 2013

5.0 DESIGN MIX

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). The unit water content was kept constant for Plain 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 2 shows the details of the specimens used for testing. Materials, except 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 detail of reinforcement is shown in Fig. 1.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.

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

Six Concrete specimens have been cast in cube mould of 150x 150 x 150 mm. At the time of beam casting, table vibrator is used. Fig.2 shows the cast specimens and cubes.

Table.2 Specimen details

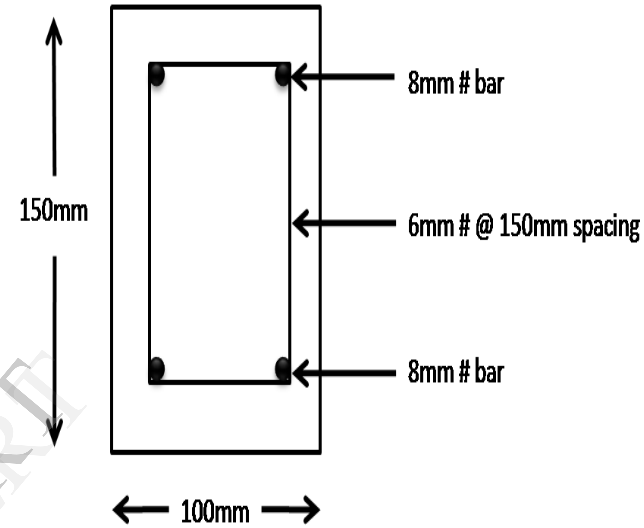


Fig: 1 Reinforment details

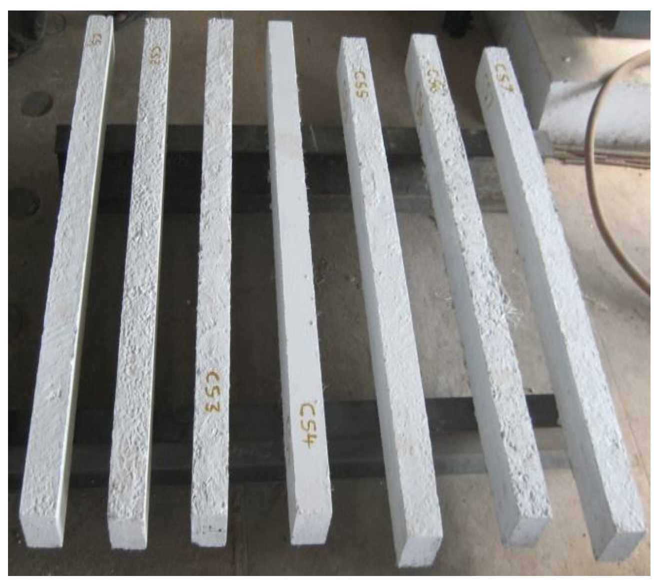


Fig: 2 cast specimens

6.0 EXPERIMENTAL SET UP

All beams were tested under flexure in a loading frame of 500 KN for a simply supported condition. Two point loading was applied on beams at a distance of 500mm from each support by means of 250 KN capacity of hydraulic jack. Three deflectometers 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 deflectometer 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 guage 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

Fig.3 Flexure test set up

7.0TEST RESULT & DISCUSSION

7.1CUBE 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.4.

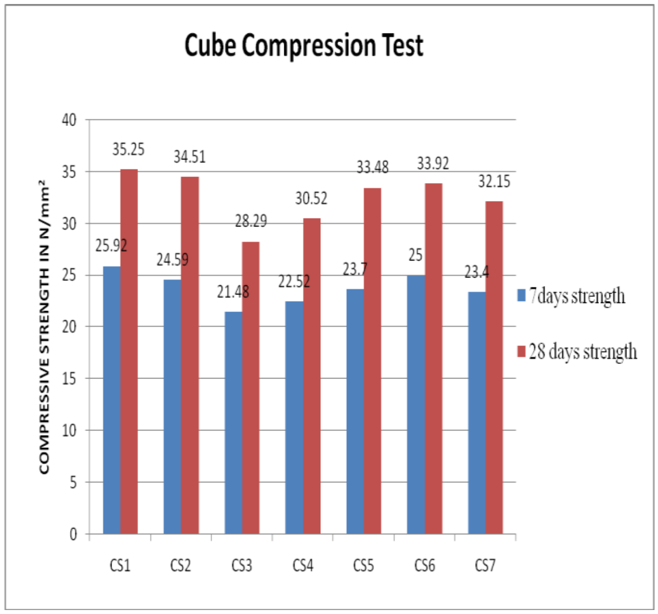


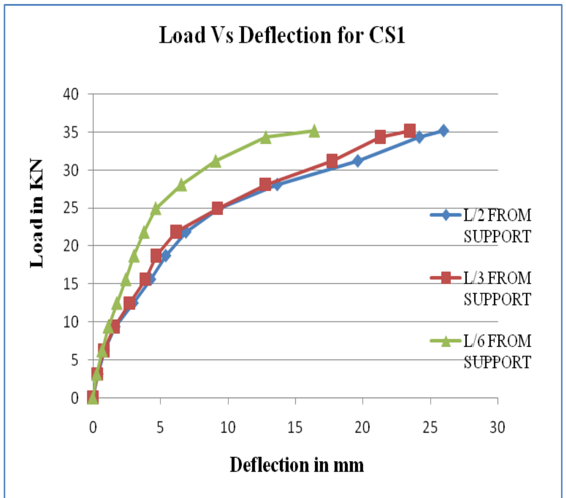
Fig: 4 cube compressive strength

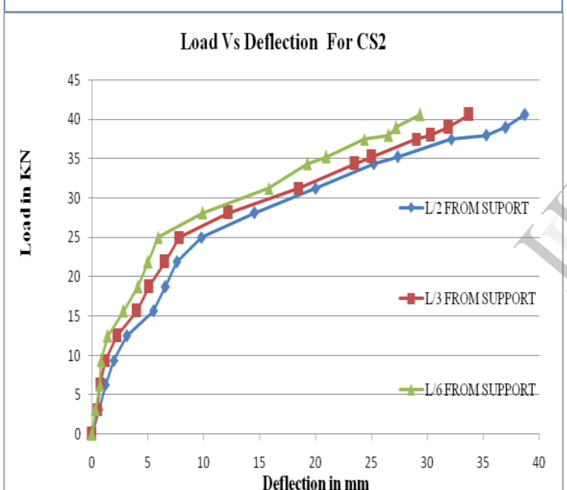
For both solo and Hybrid concrete the compressive strength for cubes is below plain concrete strength. Generally, by adding fibres the compressive strength of concrete is decreases. It mainly depends upon percentage of fibres. Due to the high fibre content, the cube compressive strength decreased. In the case of specimen with coir fibres the average cube compressive strength decreased. This is probably due to lower specific gravity of coir fibres. Different cube give less strength starting from the range of 2.09% to19.74 % .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 was arrested appreciably.

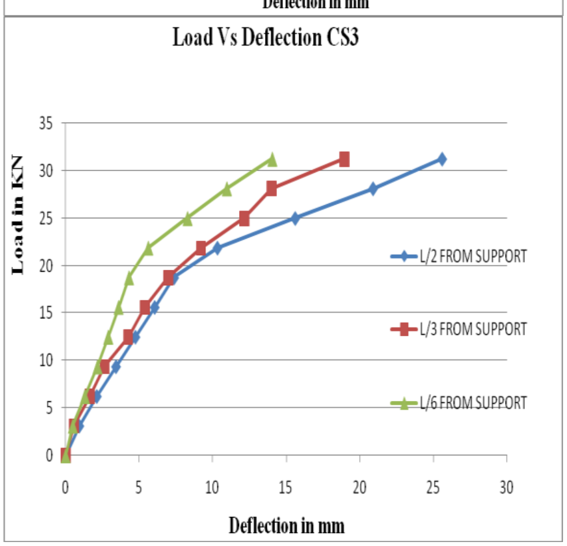
ISSN: 2278-0181
Vol. 2 Issue 7, July - 2013

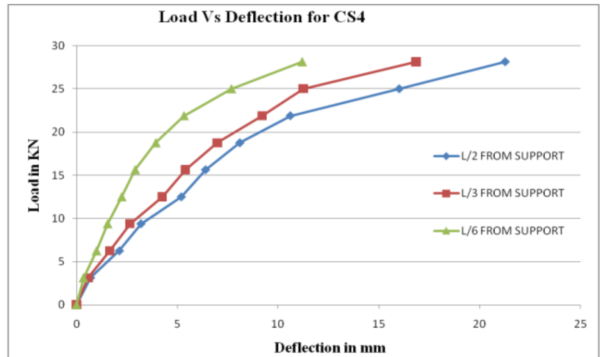
7.2 FLEXURE STRENGTH TEST

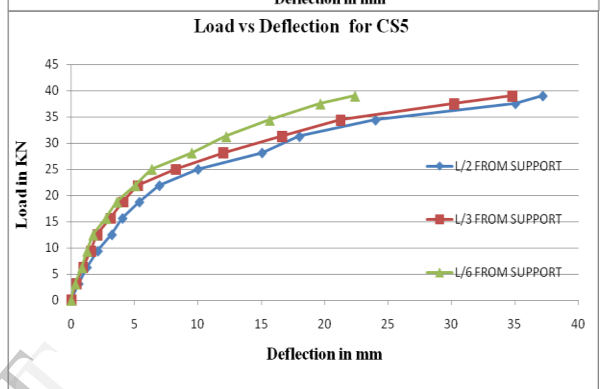
Load Vs Deflection plot has been drawn for all test specimens from the experimental data. The behavior of test specimens are compared from the below plots.

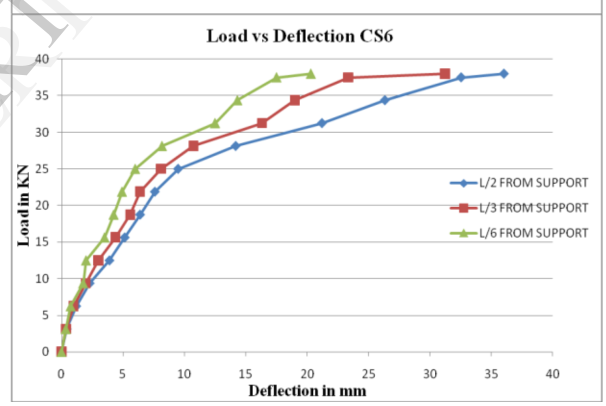












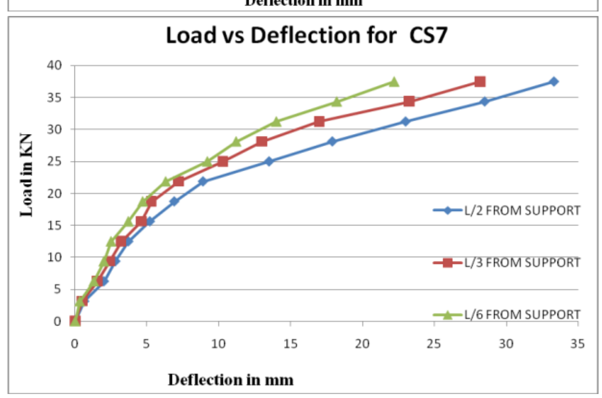


Fig: 5 Load vs Deflection for all beam

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

Steel fibre Reinforced beam (CS2), the first crack load appears at 15.63 KN. The ultimate load was 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.

With the addition of hooked end steel fibers, the mechanism of crack formation is slightly changed because of higher stiffness, bond and anchorage. Some tensile loads can be transferred across the cracks by the bridging of fibers. Thereby, the stress in the concrete comes from not only the bond stress but the bridging of fibers as well. With the contribution from the fibers, less bond stress is needed to reach the same cracking stress. Consequently, the spacing of crack is smaller in the Steel FRC beams than in the plain concrete beams. At the high level of load, due to loss of bond between the fibers and concrete, fibers are pulled out and the contribution from the bridging of fibers is diminished.

Polyster 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. The ultimate load was 31.25KN. Large numbers of fine cracks were observed during failure. 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, Polyster Recron fibre addition causes some perturbation of the matrix, which can result in higher voids. 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 Polyster 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 Polyster Recron fibre beam is lesser than that of controlled concrete because of high fibre content.

Coir Fibre Reinforced Beam (CS4), 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. The ultimate load was 28.13 KN. Large numbers of fine cracks were observed during failure. The load carrying capacity is 19.62% lesser than that of controlled concrete. The coir fibre reinforced beam shows more or less similar behavior to that of Polyster Recron fibre reinforced beam.

Steel – Polyster Recron Fibre Reinforced Beam (CS5), the first crack load appears at 12.5 KN, The ultimate load was 39 KN. The load carrying capacity is 11.43% higher than that of controlled concrete. The main objective of Hybridization is two or more types of fibres are rationally combined to produce a composite that derives benefits from each of the individual fibres. In this case hooked end steel fibre and Recron fibre are combined. The hooked end steel fibre proved its capacity as a crack arrester. The cracks are prevented from propagating until the composite ultimate stress is reached. The mode of failure was simultaneous yielding of fibres and matrix. It is seems obvious that the deformed end of these fibres contribute significantly to the increase in bond between fibre and matrix. The significance of good bond can be seen from the load-deflection curve. This curve indicates a ductile behavior and large energy absorption.

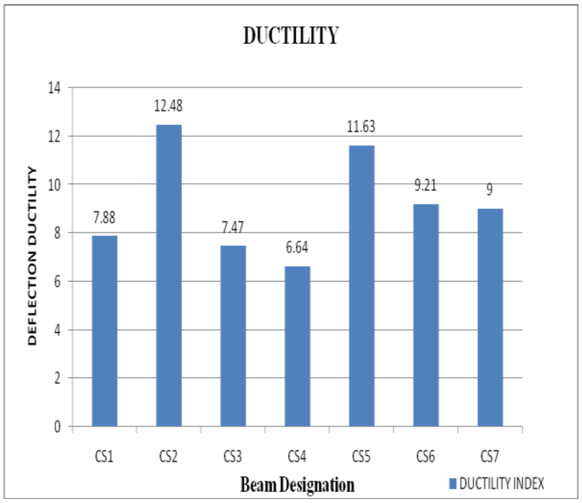
The ability of the Polyster Recron fibre to control micro cracking growth depends mainly on the number of fibres, deformability and bond to the matrix. A higher number of fibres in the matrix lead to a higher probability of a micro crack being intercepted by a fibre. Therefore the influence of Polyster Recron fibres on the flexural strength may be seen as the balance between micro crack bridging and additional voids caused by fibre addition. Because of optimum fibre content of 0.5%, Voids problem is avoided and the load carrying capacity is increased than that of control beam. Lesser number of fine cracks was observed due to the presence of Polyster Recron fibre

Steel -Coir Fibre Reinforced Beam (CS6), the first crack load appears at 12.5 KN, beam occurred. The ultimate load was 38 KN. The load carrying capacity is 8.57% higher than that of controlled concrete. It shows more or less similar behavior to that of CS5 beam.

Steel – Polyster Recron - Coir Fibre Reinforced Beam (CS7), after the first crack load of 12.5 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 ultimate load was 37.5 KN. The load carrying capacity is 7.14% higher than that of controlled concrete. The main objective of hybridization is two or more types of fibres are rationally combined to produce a composite that derives benefits from each of the individual fibres. In this case hooked end steel fibre, Polyster recron and coir fibre are combined. As already discussed the effect of three fibre contribute and increase the flexural strength of concrete

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- Polyster Recron fibre shows higher ductility which is 47.59% higher than that of controlled concrete. Steel- Polyster Recron-Coir fibre hybrid shows higher ductility which is 14.21 % higher than that of controlled concrete. This shows the significance of steel fibre plays an important role in ductility behavior of beam.



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

Beam Designation	Ultimate load (kN) x	Mid span deflection at Ultimate load (mm) Y	Stiffness X/Y KN/mm	% decrease from control beam
CS1	35.00	26.00	1.34	-
CS2	41.00	38.70	1.05	21.64
CS3	31.25	25.62	1.21	9.70
CS4	28.13	21.25	1.32	1.49
CS5	39.00	37.20	1.04	22.38
CS6	38.00	36.00	1.05	21.64
CS7	37.50	33.32	1.12	16.42

CONCLUSION

An extensive research was initiated to investigate the flexural behaviour of hybrid fibre reinforcement system. From the flexural study covered in this paper, the following conclusions can be drawn.

1. 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.
2. Steel Fibre Reinforced Concrete (CS2) shows 17.14% increased in load carrying capacity when compared to controlled concrete (CS1) because of higher stiffness, bond and anchorage.
3. Polyster Recron Fibre Reinforced Concrete (CS3) shows 19.62% decreases in load carrying capacity when compared to controlled concrete (CS1) because of high voids.
4. Coir Fibre Reinforced Concrete (CS4) shows 10% decreases in load carrying capacity when compared to controlled concrete (CS1) because of high voids.
5. Steel – Polyster Recron Fibre Reinforced Concrete (CS5) shows 11.43% increase in load carrying capacity when compared to controlled concrete (CS1) because it obtains benefits from both fibres.
6. Steel –Coir Fibre Reinforced Concrete (CS5) shows 8.57% increase in load carrying capacity when compared to

controlled concrete (CS1) because it obtains benefits from both fibres.

7. Steel –Polyster Recron- Coir Fibre Reinforced Concrete (CS5) shows 7.14% increase in load carrying capacity when compared to controlled concrete (CS1) because it obtains benefits from hybrid fibres.

8. With the addition of fibre, the crack widths are smaller at service load

9. The steel fibre reinforced beam shows higher ductility which is 58.38% higher than that of controlled concrete because of higher bond and anchorage.

10. The ultimate load stiffness for coir fibre reinforced beam (CS4) is higher which shows the beam is rigid and exhibit lesser deflection.

REFERENCES:

1) Ahmed H. Ghallab.," Flexural behaviour of Polypropylene Fibres Reinforced Concrete beams", HFBRC journal, 2005.

2) Balaguru, P. N., Narahari, R., and Patel, M." Flexural Toughness of Steel Fiber Reinforced Concrete", ACI Materials Journal, Vol. 89, No. 6Nov-Dec 1992, pp. 541-54.

3) Eswari.S. Ragunath .P.N., and Suguna.K.," Ductility Performance of Hybrid Fibre Concrete", American journal of applied sciences, Proceedings, 2008,pp.1257 – 1262.

4) Lars Kutzing.," Influence Of Fibres on the Improving of Ductility of High Performance Concrete (HPC)", Universitat Leipzig 2007.

5) Nagarkar.P.K.,Tambe.S.K.,andPazar e.D.G.,"Study of Fibre Reinforced Concrete", International symposium on Fibre Reinforced Concrete, Proceedings, vol.1,Dec16-19,1987,pp.2.131-2.142.

6) Neves.R.D., and Fernandes de almeida .J. C. O.," Compressive behaviour of Steel Fibre Reinforced Concrete", American Concrete Institute International Syposium,2006.

7) Ramakrishnan.V.,"Materials and Properties of Fibre Reinforced Concrete",International symposium on Fibre Reinforced Concrete, Proceedings, vol.1,Dec16-19,1987,pp.2.3-2.21.

8) Rafiqul Islam.M., and Khorshed Alam.A.K.M.,"Study of Fibre Reinforced Concrete with Natural Fibres", International symposium on Fibre Reinforced Concrete, Proceedings, vol.1, Dec16-19, 1987, pp.2.131-2.142.

9) Saleh H. Alsayed and Abdulrahman M. Alhozaimy.," Ductility of Concrete Beams Reinforced with FRP Bars and Steel Fibres", Journal of Composite Materials 1998.

10) Stahli.P.,and Van Mier. J. G.M.," Three- Fibre- Type hybrid Fibre Concrete", Institute of building materials, Proceedings, 2007.

11) Wang.H and Belarbi.A." Flexural Behavior of Fiber-Reinforced-Concrete Beams Reinforced with FRP Rebars", RILEM symposium france 2006, pp.379-386.