International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 8 (2015) pp. 20371-20380

http://www.ripublication.com

RC Beam Added With Hybrid Fibres – Flexure

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Abstract

In this paper experimental result of flexural tests conducted on 28nos of beam specimens having dimensions 1 x 0.15 x 0.15m added with steel, palm, coir and sisal fibres in different hybrid combinations, has been discussed. It was found that the stiffness of fibres added has profound influence on the strength and ductility of a reinforced concrete flexural member. An appreciable increase in the value of ductility and flexural toughness compared to control specimen was observed for the beam specimen R8 having 0.5%steel fibre and 0.5% sisal fibre. The ductility factor for R8 specimen was found to be 1.4 times that of control specimen and its flexural toughness was found to be 8.04% more than that of the control specimen. The fibres of varied stiffness low and high was found to perform with synergy with one another where stiffer one contributes to increase in strength and other ductile fibre contributes to increase in toughness.

Keywords: Steel fiber, Palm fiber, Coir fiber, Sisal fiber, High strength concrete

Introduction

As the demand for construction materials such as cement, steel, sand and aggregates are increasing day by day and its use over decades has resulted in depletion of natural resources as well as caused environmental pollution to a greater extent, there is a need for alternative materials which could function as that of conventional one in all means. The use of fibres of both metallic and non-metallic nature in concrete has many advantages which include increase in flexural and fracture toughness to greater extent. Banthia etal [3] has expressed the advantage of using hybrid fibres having both low and high modulus where the stiffer one contributes to higher strength and other ductile one contributes to toughness and arrest the propagation of micro-cracks. Behzad Nematollahi [8] has found that addition of steel fibres of diameter 0.75mm and length 50mm in to concrete beams having characteristic compressive strength values 30Mpa and 50Mpa has resulted in increase of 13% and 25% in first crack load and 7% and 15% in ultimate load compared to control beams, at a fibre volume fraction of 1%.It was found that addition of steel fibres has more effect in concrete with higher compressive strength than concrete with lower compressive strength due to the fact that reduction in voids due to lower water cement ratio results in efficient bonding of steel fibres with surrounding matrix. Ramakrishna etal [6] has found that coir fibers retained good percentage of its original strength when subjected to alternate wetting and drying and continuous immersion in three medium such as water, saturated lime and sodium hydroxide .In the review of suitability of coir fibers in engineering applications, Majid Ali[5] has expressed that length and volume fraction of coir fibres contributes significant factor in changing the tensile strength and modulus of rupture of cement paste. He added that decrease in strength of concrete results when fibre content added goes beyond an optimum level. Eethar Thanon Dawood etal [7] has found that the hybrid combination of 1.75% steel fibre and 0.25% palm fibre yielded an increment in flexural strength to an extent of 43% to that of control mix. In this paper flexural behaviour of 28nos of reinforced concrete beams added with steel, coir, palm and sisal fibres in different combinations has been discussed based upon the experimental study conducted.

Materials and Experimental Methods

Materials and Mix Proportions

Ordinary Portland cement conforming to IS 12269-1987 has been used for making the concrete mixtures. Silica fume used for making high strength concrete. The fine aggregate used was river sand conforming to IS 383-1970, has specific gravity of 2.55 and fineness modulus of 2.925.The crushed granite having specific gravity of 2.68 is used as coarse aggregate. Enfiq super plast -400, a high range water reducing admixture was used to obtain desired workability. The fibres used in the study were corrugated steel, palm, coir and sisal fibres.The properties of fibres are listed in Table 1, Table 2, Table 3, Table 4 and Table 5. The amount of cement, silica fume, sand, coarse aggregate and water-binder ratio were kept constant. The amount of super plasticizer varied from 2.2% to 2.4% by weight of binder content to maintain appropriate slump. Control mix R was designed as per IS 10262-2009 to achieve a target compressive strength of 58MPa.The Total amount of hybrid fibres in all mixes were maintained at a volume fraction of 1%.The details of the mix proportions used are given in Table.5

Table 1: Characteristics of Steel Fibre

Fibre properties	Steel fibre
Average fibre length (mm)	50
Diameter (mm)	1
Aspect ratio	50
Tensile strength (MPa)	1100

Table 2: Characteristics of Palm fibre

Fibre properties	Palm fibre
Average fibre length (mm)	50
Average fibre width (µm)	21.13
Specific gravity	2.14
Tensile strength (MPa)	21.2

Table 3: Characteristics of Coir fibre

Fibre properties	Coir fibre
Average fibre length (mm)	50
Average fibre width (µm)	203
Density (g/cm^3)	1.25
Tensile strength (MPa)	304

Table 4: Characteristics of Sisal fibre

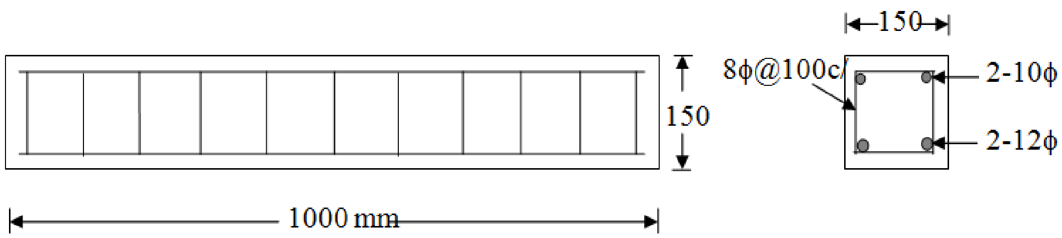
Fibre properties	Sisal fibre
Average fibre length (mm)	50
Moisture Content (%)	11
Density(kg/m^3)	1450
Tensile strength (MPa)	604

Table 5: Mix Proportions

Mix ID	Cement (Kg/m^3)	S.F (Kg/m^3)	Water (Kg/m^3)	S.P (%)	Sand (Kg/m^3)	Aggregate (Kg/m^3)	W/B	Steel Fibre (%)	Palm Fibre (%)	Coir Fibre (%)	Sisal Fibre (%)
C	405	45	145	2.0	612	1248	0.35	-	-	-	
C1	405	45	145	2.4	612	1248	0.35	1	-	-	
C2	405	45	145	2.4	612	1248	0.35	0.5	0.5		
C3	405	45	145	2.4	612	1248	0.35	0.5	-	0.5	
C4	405	45	145	2.4	612	1248	0.35	0.5	0.25	0.25	
C5	405	45	145	2.4	612	1248	0.35	0.25	0.5	0.25	
C6	405	45	145	2.4	612	1248	0.35	0.25	0.25	0.5	
C7	405	45	145	2.4	612	1248	0.35	-	0.5	0.5	
C8	405	45	145	2.4	612	1248	0.35	0.5			0.5
C9	405	45	145	2.4	612	1248	0.35	0.25	0.25	0.25	0.25
C10	405	45	145	2.4	612	1248	0.35				1.0
C11	405	45	145	2.4	612	1248	0.35	-	0.5		0.5
C12	405	45	145	2.4	612	1248	0.35	-	-	0.5	0.5
C13	405	45	145	2.4	612	1248	0.35	-	0.25	0.25	0.5

Reinforced Concrete Beam Details

Twenty Eight numbers of reinforced concrete beams of size 1000x150x150mm with two samples in each mix of fourteen beam specimens C to C13 were cast and compacted using vibrator.Control beam specimen was designated as C. The fibres at various combinations were added in the specimens C1 to C13. The casted specimens were then subjected to curing by complete immersion of beam specimen under water for a period of 28 days. The details and the dimensions of beam and reinforcement are shown in fig 1 and fig 2.



Test Set Up

Tests were carried out at room temperature and as per the Indian standards. Structural properties are ascertained by conducting middle third loading test. The testing arrangement is shown in Fig.3. Four point bending was applied on reinforced concrete beams having span of 0.9 m through hydraulic jack of capacity 100kN. The specimens were placed on a simply supported arrangement of 100 T Loading frame. The beams were suitably instrumented for measuring deflections at several locations including the midspan deflection with dial gauges and LVDTs. To avoid the excessive deformation at the support locations, additional dial gauges were placed at the top and bottom faces of ends. DEMEC (Demountable mechanical strain gauge) was used to measure the concrete strain readings at top as well as the bottom fibre on mid section of the beam. Load was applied through a hydraulic jack of capacity 100 kN. For every 2.5 kN loading interval, the corresponding mid span deflection as well as strain at mid section readings were taken. Simultaneously, the cracking behaviour on the faces for full length of the beam was also observed carefully. The first cracking was noted for all the beams and corresponding load, deflection and strain values are reported.

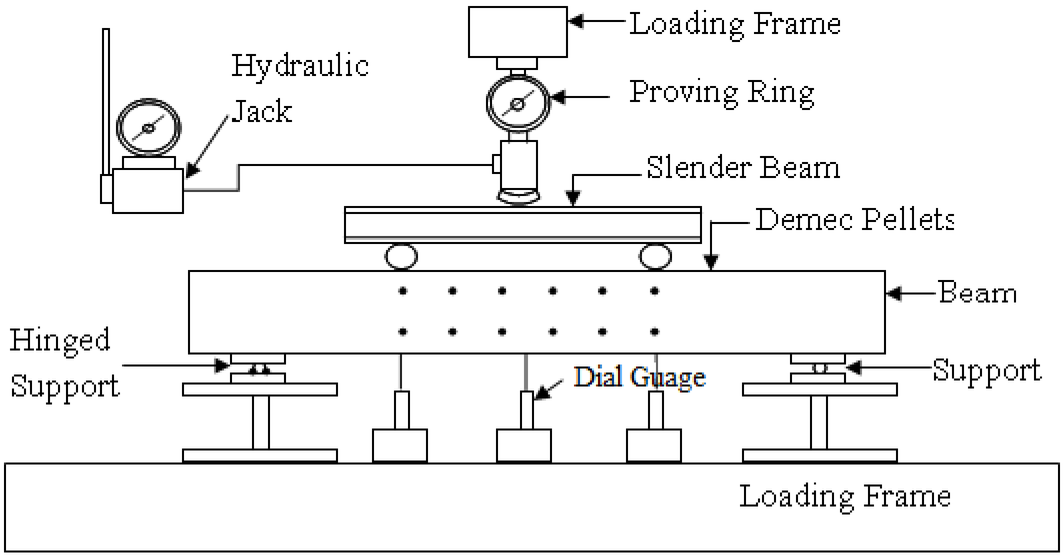


Figure 3: Loading Arrangement of Flexural Test

Results and Discussions

The results obtained from the experiments are furnished in Table.6.The graph showing Load versus deflection are shown in fig.4-fig.9.From the results it is evident that the hybrid combination of fibres performs well compared to the case of mono fibre addition.

First crack load

As stated by banthia etal [1], fibres having higher strength such as steel fibre contribute to strength and lower modulus fibres such as coir, palm and sisal contribute to increase in energy absorption capacity and prevents the propagation of micro cracks. During the experiment, it was observed that in the control specimen, first crack was observed at a load of 40kN and in all the beam specimens added with fibres the first crack load was found to increase appreciably.

Table 6: Results of The Flexural Test

Specimen No	Yielding Load (Py) Kn	Yielding Deflection Mm	Ultimate Load (Pu) Kn	Ultimate Deflecti on Mm	Ductility Factor	Flexural Toughness Kn. Mm
C	55	2.56	75	4.2	1.64	134.576
C1	65	3.04	85	5.06	1.66	138.99
C2	65	3.02	80	4.06	1.34	142.69
C3	60	3.48	80	4.68	1.34	121.45
C4	65	3.24	85	5.41	1.67	137.4
C5	60	3.32	75	6.24	1.88	117.278
C6	60	2.8	80	5.09	1.82	143.42
C7	65	3.02	85	4.26	1.41	144.986
C8	65	2.95	90	6.79	2.30	145.398
C9	65	3.72	95	6.51	1.75	124.703
C10	55	2.55	70	3.78	1.48	134.856
C11	55	3.68	75	5.53	1.50	122.466
C12	55	2.78	80	4.25	1.53	133.754
C13	55	2.42	90	5.09	2.10	144.162

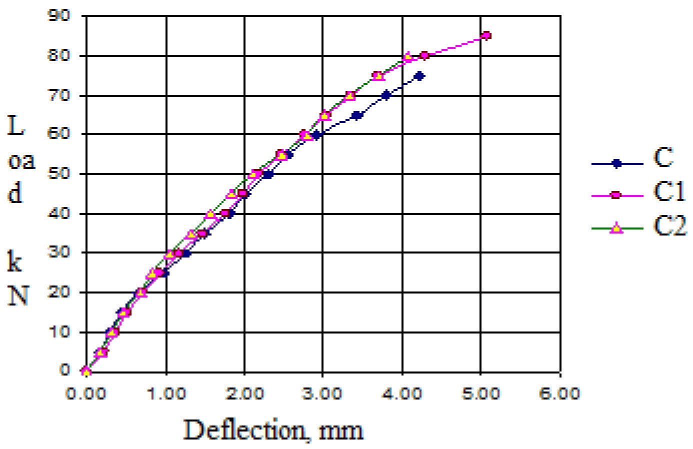


Figure 4: Load vs Deflection for C, C1 and C2

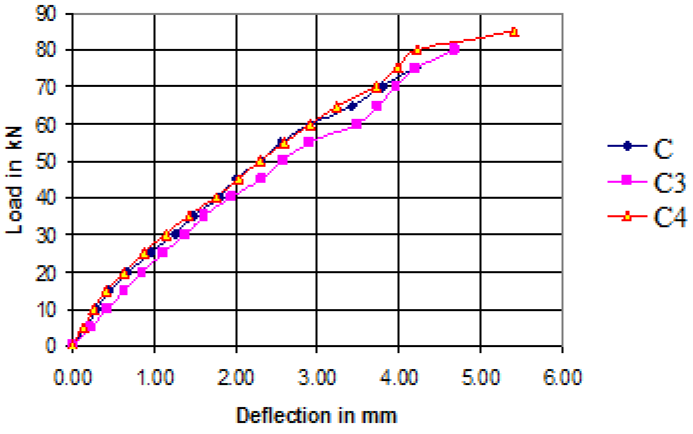


Figure 5: Load vs Deflection for C, C3 and C4

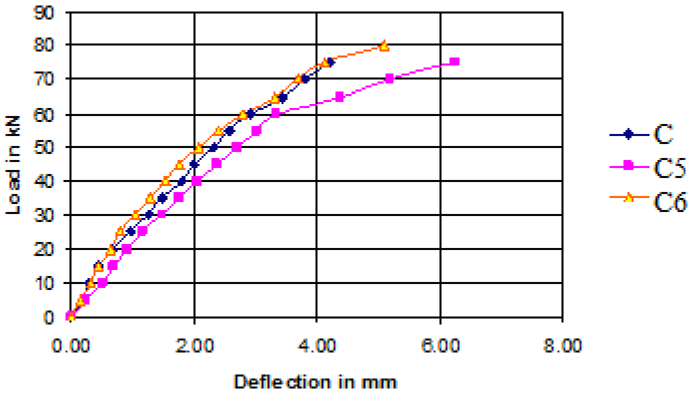


Figure 6: Load vs Deflection for C, C5 and C6

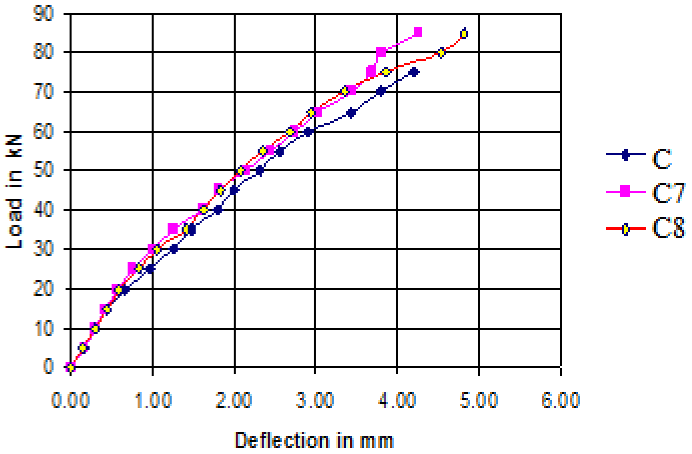


Figure 7: Load vs Deflection for C, C7 and C8

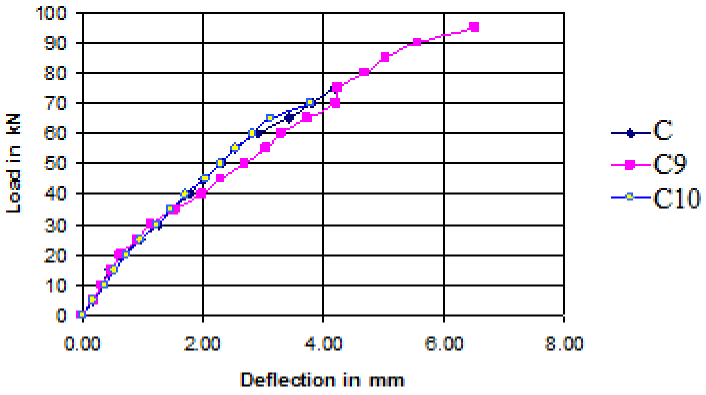


Figure 8: Load vs Deflection for C, C9 and C10

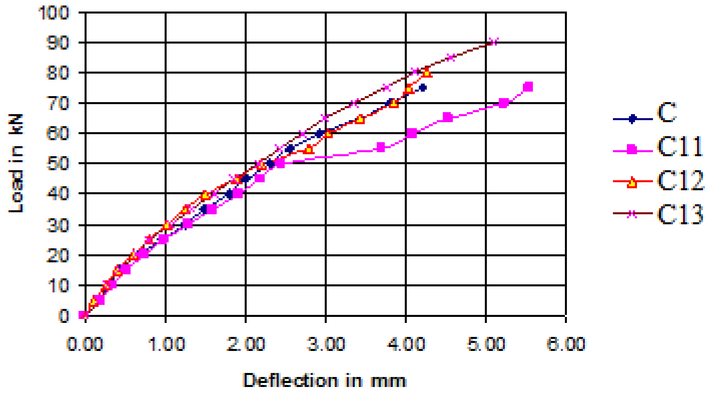


Figure 9: Load vs Deflection for C, C11, C12 and C13

Ultimate load

The results of ultimate load which beam specimen of different mixes C to C13 carried under flexure shows that the C9 having fibre combination as 0.25 Steel fibre+0.25 Palm fibre+0.25 Coir fibre +0.25 Sisal fibre carried 26.67% more load at ultimate stage when compared to control specimen. The values of ultimate load for the specimens such as C8 and C13 having fibre combination as 0.5 steel fibre+0.5 sisal fibre and 0.25 Palm fibre+0.25 Coir fibre +0.5 Sisal fibre were 20% more than that of control specimen. Similarly specimens such as C1, C4 and C7 having fibre combination as 1% Steel fibre, 0.5Steel fibre+0.25 Coir fibre +0.25 Palm fibre and 0.5 palm fibre+0.5 Coir fibre carried an ultimate load of 13.33% more than that of control specimen. Thus specimen C9 having hybrid combination of fibres of varied stiffness performs well compared to that of specimen having monofibre such as that of C1 and C10.

Ductility

Ductility can be defined as the "ability of material to undergo large deformations without rupture before failure". Ductility factor is the commonly used nondimensional term to compare the ductility of members based on the deflection. It is the ratio between the deflection experienced by the beam at ultimate stage to that of deflection at yield stage.

Ductility of beam specimens was found to be significantly influenced by the type of fibres used. The values of ductility factors for the beam specimen C8, C13, C5, C6 and C9, were found to be 1.40, 1.28, 1.14, 1.11 and 1.06 times greater than that of control specimen. Thus it is evident that beam specimen C8 having hybrid combination of 0.5% steel fibre + 0.5% sisal fibre showed an improved ductility compared to all other specimens. The presence of lower modulus fibre is found to have significant role in the improvement of ductility as in the case of C13, C5, C6 and C9.

Flexural Toughness

The energy absorption capacity of concrete is enhanced by the addition of fibres. It can also be defined as total amount of energy required to deflect the beam to a specified deflection. The flexural toughness is calculated as area under load-deflection curve for beam up to a specific point, in the present study up to 3.5mm deflection has been considered. It is inferred from the values of flexural toughness that beam specimens C8, C7, C13, C6 and C2 were found to have flexural toughness value 8.04%, 7.74%, 7.12%, 6.57% and 6.02%more than that of control specimen. Thus it is evident that flexural toughness is significantly influenced by fibres having lower stiffness.

Conclusion

From the above study it can be concluded that

1. The strength and ductility of reinforced concrete flexural member can be appreciably increased by adding fibres having both higher and lower stiffness at an optimum proportion.
2. The cracking load and flexural toughness has found to increase appreciably due to addition of hybrid fibres.
3. The beam specimen C8 having fibre combination as 0.5% steel fibre and 0.5% sisal fibre showed an improved flexural performance compared to control specimen.

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