

EXPERIMENTAL INVESTIGATION OF MIXED FIBER REINFORCED CONCRETE DEEP BEAM IN SHEAR

Mr. Kumbhar A. N.¹, Assistant Prof. Kadam S. S.²

¹ PG Student, SKN Sinhgad College of Engineering, Korti, Pandharpur, Maharashtra, India.

Email: kumbhar.akshayn@gmail.com (PH-7507550019)

² Assistant Professor Of Civil Engineering Department, SKN Sinhgad College of Engineering, Korti, Pandharpur, Maharashtra, India.

Email: asganesk@rediffmail.com

Abstract—Shear strength reinforced concrete deep beams is complex phenomenon because we can't get the value of shear strength directly like compressive strength. The main aim of this paper is to study the effect of addition of mixed (Crimped steel – Polypropylene) fibers on shear strength reinforced concrete deep beams without any shear reinforcement. Results of an experimental investigation on the behavior and ultimate shear strength of 27 reinforced concrete deep beams are summarized. In this the main variables are percentage of mixed (Crimped steel – Polypropylene) fibers (0%, 1.5% & 2.5%) and clear span to depth ratios (1.87, 1.76 & 1.66) by keeping compressive strength (35 Mpa) and do tensile reinforcement make constant. All the beam specimens are tested under two point loading test set-up up to failure and record the first crack load, failure load and central deflection. The obtained test results are compared with the equations proposed by different codes and author's in past years to find which equation gives accurate results. From the experiments present that the mixed (crimped steel – Polypropylene) fibers have great influence on the shear strength of longitudinal reinforcement concrete deep beams. It also observes that shear strength increased with increase in fiber volumes (%) and decreasing a clear span to depth ratio (l/D).

Keywords— Shears strength, mixed (Crimped steel-Polypropylene) fibers, Deep Beam, Diagonal tension, Concrete, compressive strength, Cracks clear span to depth ratio, tensile reinforcement etc.

INTRODUCTION

Deep beams are structural elements or members are generally used in heavily loaded and important structure like high rise building, pile caps, load bearing wall, irrigation project and plate elements in folded plates. The load transformation of deep beam is different than slender beam. In slender beam load will transfer by the bending action and in deep beam load is transfer by shearing action by making and forming a diagonal cracks. So which beam is a deep beam that question arises in our mind. As per the Indian standard code method the deep beam is a beam having a ratio of clear span to depth is less than 2 for simply supported beam & 2.5 for continuous beam.

Flexural or shear failure are the two main failures occurs in reinforced concrete beams. Shear strength of concrete beam is a complex phenomenon that is still not very well understood. When bending stresses is more than shear stresses than flexural failure occurs mostly in long span beam (slender beam) and deep beam fails in shear below the ultimate flexural capacity of beam. Simple beam theory is does not include the effect of shear and the effect of stresses on planes parallel to neutral axis due to this it cannot applicable to deep beam. A effect of these is that the plane section do not remain plane and perpendicular to the neutral plane after deformation. The nature of the resulting non-linear bending stress distribution and location of neutral axis depends on the span to depth ratio and on the types and position of loading and supports. The shear action in the deep (web) beam is permanent. A large amount of load is carried to support by compressive thrust joining the loading point and support reaction. The failure modes of deep beams could be diagonal failure and bearing failure.

Concrete is mainly used construction material all over the world in view of its compressive strength, high mouldability, structural stability and economic considerations. Also it is very weak in tensile and shear strength and very strong in compression. We can directly calculate the compression strength of concrete but there is no direct way to find out the tensile and shear strength of concrete. Due to non-homogeneous, heterogeneous and non-linearity in its material response concrete does not possible to apply a shearing

action i.e. direct shearing force in a plane. Due to these various debates and controversies takes place from the beginning of 20th century. The flexural and shear failure are very sudden and unexpected and sometimes violent and catastrophic. Therefore whole knowledge of different modes of shear failures and mechanism involved is necessary to prevent them.

Now as we know concrete is brittle material and to decrease brittleness of concrete and increase ductility increase the mechanical properties of concrete. Therefore to enhance mechanical property of concrete fibers are used in concrete. This type of concrete we called as Fiber reinforced concrete (FRC). Generally in actual practice most type FRC use only one type of fibers i.e. steel fibers. But now a days for achieve more accurate results the researcher combine the two different fibers and add in concrete. This type of concrete we call as mixed fiber reinforced concrete. Generally rapid fracture and unstable propagation is occurred due to the conversion of micron crack in to the micro crack by increasing an joining the cracks to each other when external load is applied on them. Therefore for good results we combine steel fibers and polypropylene fibers. Steel fibers can be used to boost the shear capacity and replace the web (shear) reinforcement in conventional RCC deep beam and polypropylene fibers used to control the micro cracks present in to the concrete.

The effect of mixed fibers on concrete depends on the types of fibers, aspect ratio (length to diameter ratio) and orientation of fibers in concrete. The strength of beam with normal amount of longitudinal reinforcement is usually governed by shear not by flexure. The shear strength of mixed fiber reinforced concrete deep beam depends on different parameters such as types of fibers, aspect ratio of fibers, percentage of longitudinal reinforcement, a/d ratio or l/d ratio, and amount of fibers. The addition of small mixed fibers into the concrete mix helps to improve the post cracking tensile strength of concrete. Therefore the main objective of this work is to study the main effect of addition of different percentage of mixed (Crimped steel – polypropylene) fibers with varying clear span to depth ratio (l/d).

RESEARCH SIGNIFICANCE

Generally we know that the concrete is a brittle material due to its low tensile strength and shear strength. To overcome this problem and increase the ductility of concrete the fibers (mixed) is add into the concrete mixture to increase the shearing and tensile strength of concrete members. The steel fibers are used for replacement of the shear reinforcement and increase the tensile strength by forming a bridge through developing cracks and also provide more resistance. Polypropylene is used to arrest a micro crack which is all ready present in to the concrete. Also this removes the possibility of sudden failure in concrete and allow for large progressive failure. The shear strength of mixed fiber reinforced concrete deep beam is influenced by many parameters such as l/d or a/d ratio, fiber volume fraction, geometry of fibers etc. These parameters are does not take in to consideration by current design model. In this paper shear strength influencing parameters are clear span to depth ratio (l/d) and volume fraction (percentage) of fibers taken into consideration.

EXPERIMENTAL PROGRAM

A) Material Property

Cement, Fine aggregate, coarse aggregate, water admixture and mixed (Crimped steel - Polypropylene) fibers are used for casting the test specimen. The above material used for casting is confirmed to the specifications given into the relevant Indian standard codes . For grading of fine and coarse aggregate sieve analysis is done.

Ordinary Portland cement of 53 grade confirming to IS 12269:1987 was used throughout the experimental work. The maximum size of coarse aggregate used was 20 mm and minimum size 12.5 mm of same parent rock with 60 – 40 % fraction. Locally available Krishna river sand was used as fine aggregate. The specific gravity of sand 2.83 and fineness modulus 3.10. Crimped steel fibers of length 50 mm and thickness is 1 mm were used throughout the experiments. Reinforcing steel of grade Fe 500 was used as a tensile reinforcement.

B) Concrete Mix Design

The concrete mixes were designed in accordance with IS recommended method of concrete mix design. The concrete mix was prepared for M-35 grade of concrete. The water cement ratio is kept 0.415. The mix proportion is given in Table I.

TABLE I
MIX PROPORTION
www.ijergs.org

Sr No.	Description	Quantity (Kg)
1	Cement	380
2	Sand	869
3	Coarse Aggregate	1217.50
4	Water	157.6

C) Test Specimens

The totally 27 simply supported deep beams were casted. The span of deep beam has been kept constant at 600 mm with 50 mm overhangs on either side of supports. The shear span is kept 200 mm. The depth of beam is kept 320 mm, 340 mm, and 360 mm to achieve desired l/d ratio. The beam specimens divided into three groups namely series I, series II and series III. All the beams of series I were reinforcement with $A_{st} = 402.12 \text{ mm}^2$ (16 mm diameter two bars). All the beams of series II were reinforcement with $A_{st} = 452.16 \text{ mm}^2$ (12 mm diameter Four bars). All the beams of series III were reinforcement with $A_{st} = 515.13 \text{ mm}^2$ (16 mm diameter two bars and 12 mm diameter one bar). All beams were rectangular in cross section 100 mm width. Standard cubes (150 mm x 150 mm x 150 mm) were cast with each mix to know the compressive strength of concrete. The details of test beams are given in Table II.

TABLE II
 TEST BEAM DETAILS

Beam Designation	Beam Size (L x D) mm	Fiber content (%)	l/D ratio	Effective depth "d" mm
I – 0 %	700 X 320	0	1.87	256
I – 1.5 %	700 X 320	1.5	1.87	256
I – 2.5 %	700 X 320	2.5	1.87	256
II – 0 %	700 X 340	0	1.76	272
II – 1.5 %	700 X 340	1.5	1.76	272
II – 2.5 %	700 X 340	2.5	1.76	272
III – 0 %	700 X 360	0	1.66	288
III – 1.5 %	700 X 360	1.5	1.66	288
III – 2.5 %	700 X 360	2.5	1.66	288

D) Test Procedure

The beam specimen were removed from curing tank after completion of 28 days curing period and white wash all sides of beams for observation of crack development during testing. Two point loading is applied on the beams up to failures. The cube specimens were tested for compression strength in CTM. Test set up for beam is shown in "Fig-1".

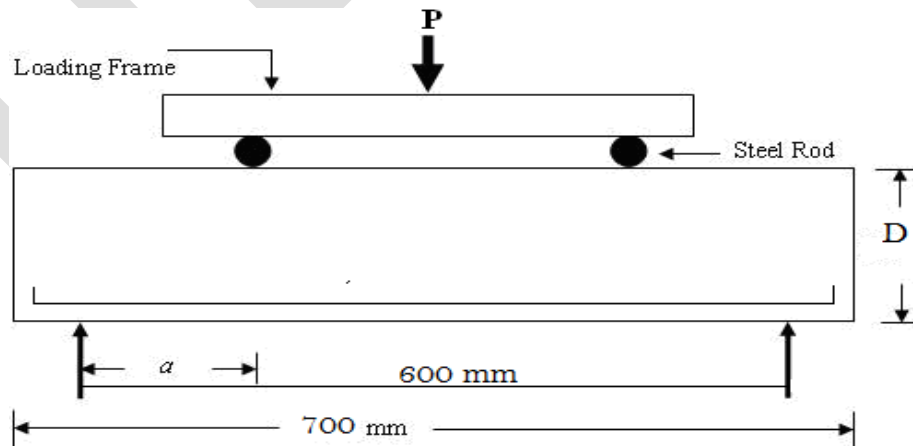


Figure 1. Two point loading test set-up.

E) Shear Design Models

For verify the strength of mixed FRC deep beams in the present investigation the various shear strength model have been used.

1) Mansur's proposed equation

The equation proposed by Mansur for shear strength of FRC is follows.

$$V_{frc} = (0.16\sqrt{f'c} + 17.2\rho\frac{d}{a} + 0.41\tau F)bd$$

where $f'c$ is characteristic compressive strength of concrete, ρ is the longitudinal reinforcement ratio, F is the fiber factor and equal to $V_f(l_f/d_f)$, V_f is the fiber volume fraction, l_f and d_f are the length and diameter of the fiber, a is the shear span, b is the width and d is the effective depth of beam.

2) Khuntia's Proposed Equation

The shear strength of FRC beams is governed by the concrete contribution in the shear without stirrups and contribution of fibers. The shear strength FRC beam is given as follows,

$$V_{frc} = (0.167\alpha_1 + 0.25F)\sqrt{f'c}bd$$

where, V_{frc} = Shear strength of FRC, $\alpha_1 = 2.5(d/a)$, and

$$F = V_f \frac{l_f}{d_f} = \text{fiber factor in which}$$

V_f = fiber volume fraction, l_f = length of fiber and d_f = diameter of fiber.

3) CIRIA Guide – 2 Design Model

CIRIA Guide-2 applies to simply supported beams of span-to-depth ratio (L/D) less than 2 and to continuous beams of span-to-depth ratio (L/D) less than 2.5.

The shear strength of beam without shear reinforcement is given as follows.

$$V_c = \lambda \left[\left(1 - 0.30 \frac{a}{d} \right) \sqrt{f'c} b d \right]. \quad (2)$$

Where b is the width, d is the effective depth of beam, $f'c$ is the characteristic compressive strength of concrete and λ (=0.44) is empirical coefficient for normal weight concrete.

4) Draft Eurocode-2 Design Model [34]

The shear strength of beam without shear reinforcement is given as follows

$$V_c = 0.10bD \frac{f'c}{\gamma_m}$$

Where, b is the width, D is the beam depth, $f'c$ is the characteristic compressive strength of concrete and γ_m is a partial safety factor for material.

TEST RESULTS AND DISCUSSION

The results obtained from experimental investigation are tabulated in Table III. From the results obtained the effects of various parameter on shear strength of concrete deep beam are analyzed and discussed below.

A) Effect Of Depth Of Beam In Terms Of Shear Span To Depth Ratio And Fiber Volume Fraction

The Table III Shows the ultimate and cracking shear stress of concrete for different fiber volume fraction and shear span to depth ratio at 28 days. The variation of ultimate shear strength of deep beam with respect to the fiber volume fraction for beam series – I, II, III also given in Table III. It is observed that the ultimate shear strength of deep beam increases with increase in fiber content. It is proof from graph that the higher shear strength is developed at lower value of shear span to depth ratio.

Ultimate shear stress of deep beam at diagonal cracking, which calculated by dividing the failure load to the nominal cross sectional area ($b \times d$). The shear load is directly transmitted to the support by inclined strut in case of deep beam. This mechanism is called the Arch action.

B) Influence On Cracking Shear Stress

Results of cracking shear stress of deep beam are given in Table III. From these it is concluded that the cracking shear strength of deep beam increases with increase in fiber content and decreases with increase in l/D ratio.

C) Central Deflection Of Deep Beam

“Fig – 3”, “Fig – 4” and “Fig – 5” shows the typical load – deflection relationship for the beam specimen I, II, III. From these graph it is observe that the central deflection of beam increases with increase in fiber content. Due to addition of mixed fibers (Crimped steel - Polypropylene) beam carried considerable load even after First cracking.

D) Influence On Cube Compressive Strength

Compressive strength of cube for different fiber content is given in Table III. Compression strength of concrete cube increases with increase in fiber content.

TABLE – III
DETAILS OF TEST RESULTS

Test Beam Designation	Effective Depth (d) mm	l/D Ratio	Compressive Strength (Mpa)	Cracking Shear Stress (Mpa)	Ultimate Shear Stress (Mpa)
I-0 %	256	1.87	43.51	2.578	3.789
I-1.5 %	256	1.87	46.99	3.118	4.370
I-2.5 %	256	1.87	50.15	3.411	4.603
II-0 %	272	1.76	42.76	2.941	4.301
II-1.5 %	272	1.76	46.36	3.603	4.994
II-2.5 %	272	1.76	49.51	3.983	5.380
III-0 %	288	1.66	43.52	3.327	4.825
III-1.5 %	288	1.66	46.92	4.172	5.642
III-2.5 %	288	1.66	50.01	4.606	6.180

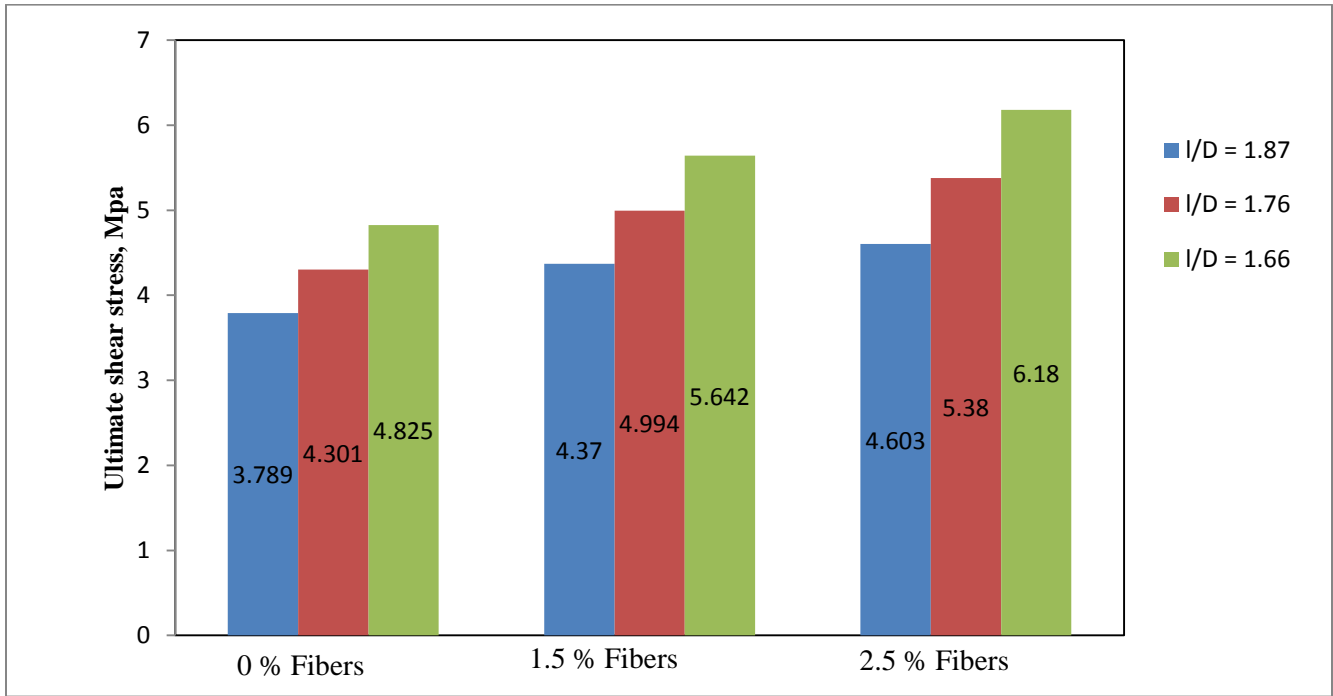


Fig – 2 Ultimate Shear Strength of Beam With Respect To l/D Ratio and Fiber Content.

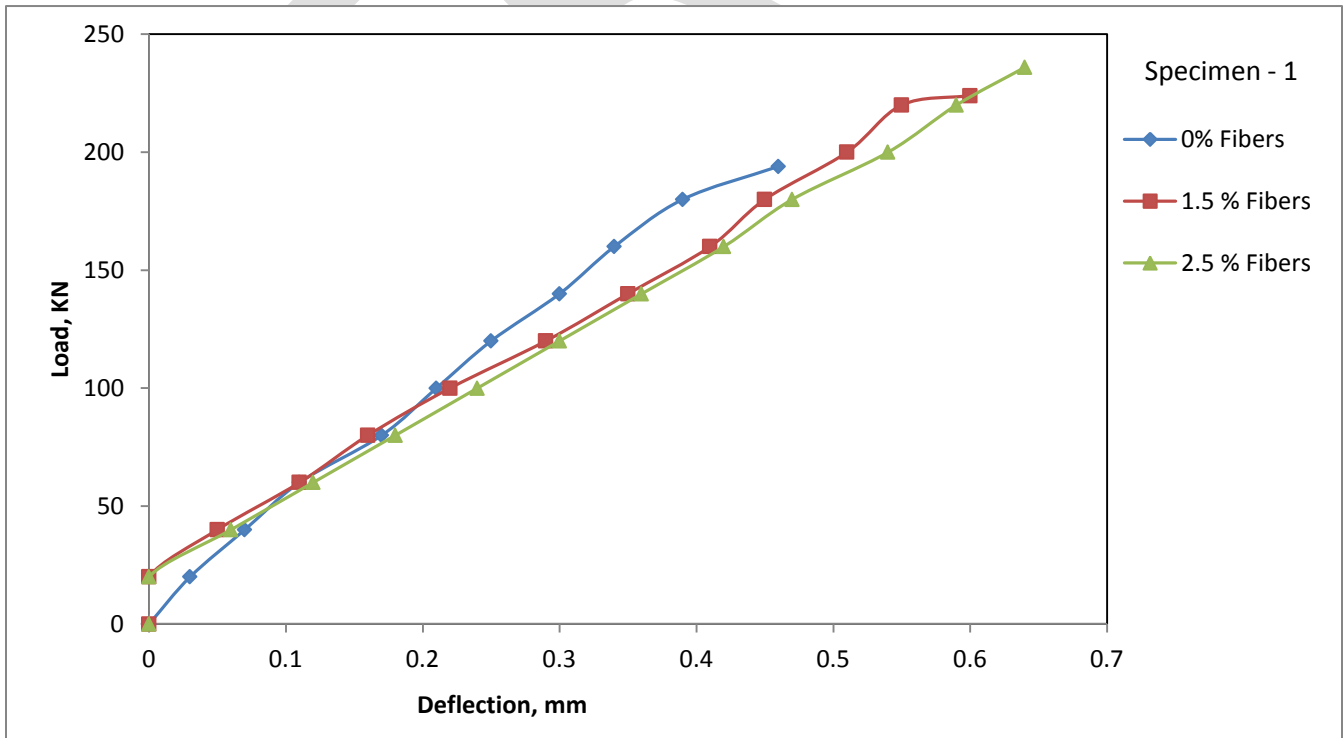


Fig – 3 The Graph Of Central Deflection With Respect To Load, Series I.

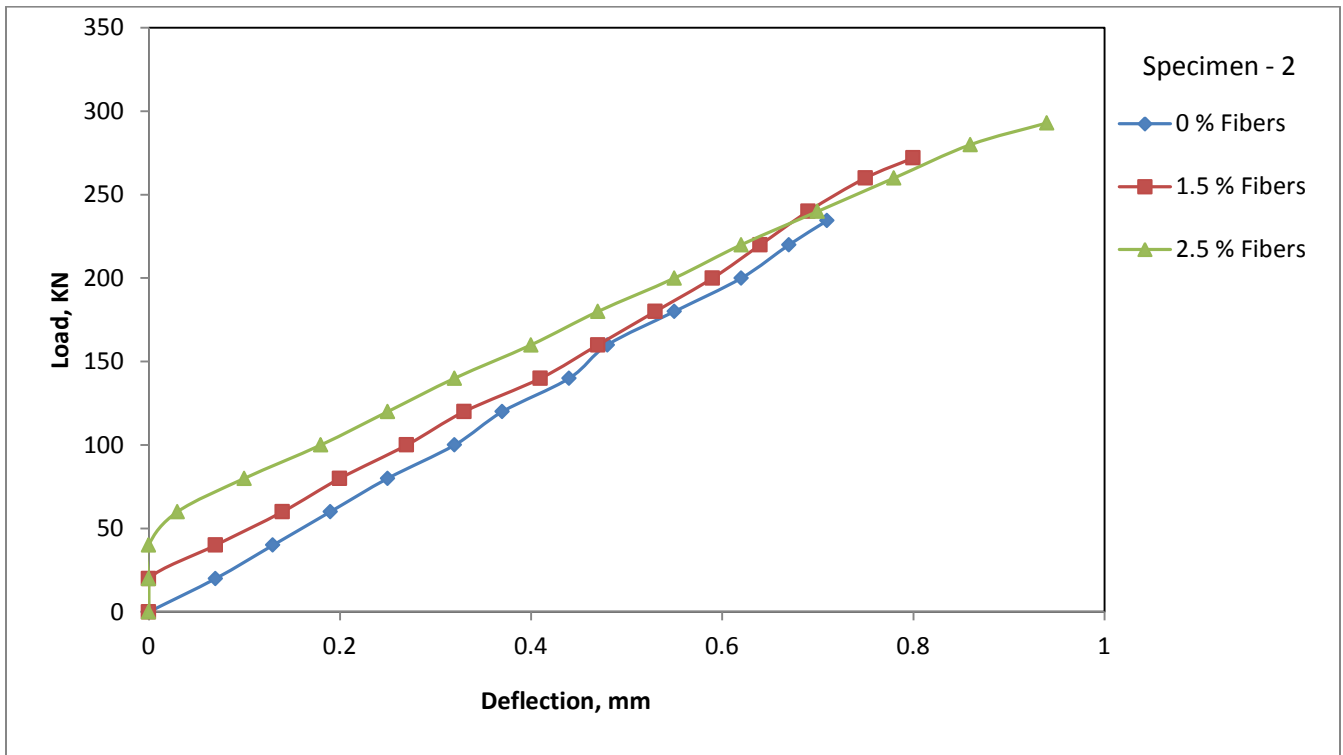


Fig – 4The Graph Of Central Deflection With Respect To Load, Series II.

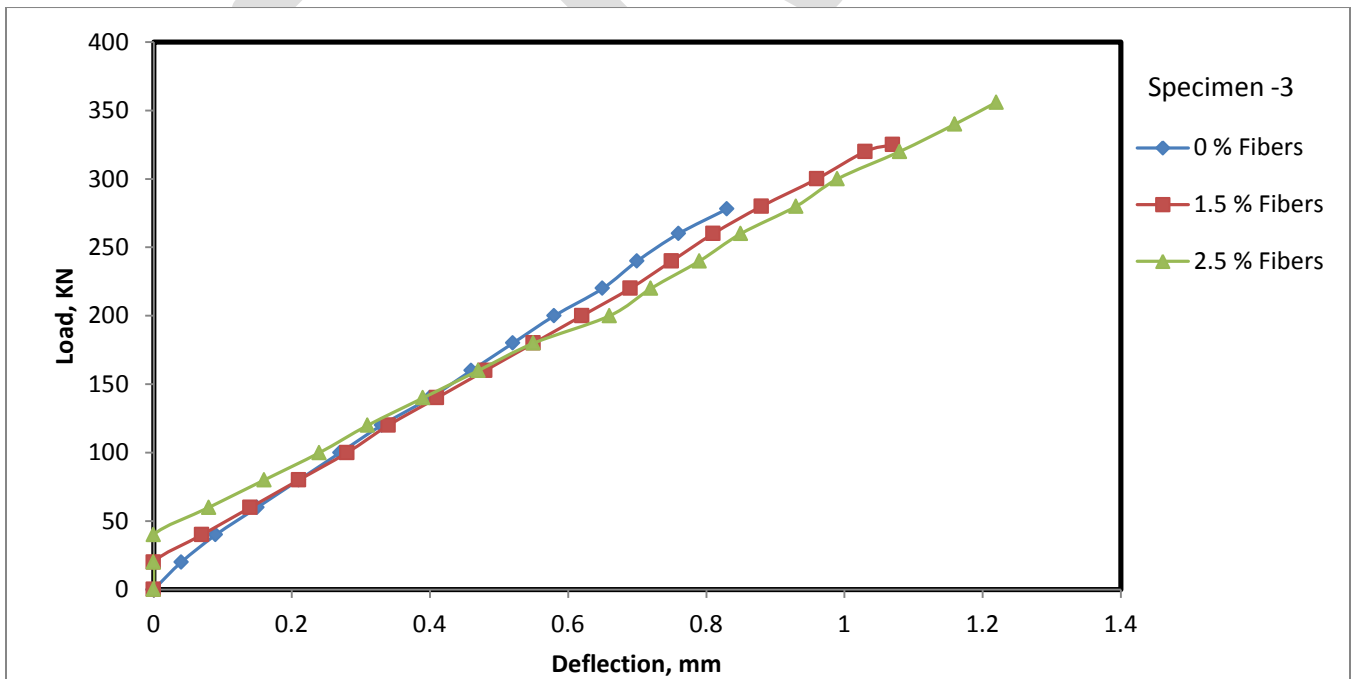


Fig – 5The Graph Of Central Deflection With Respect To Load, Series III.

E) Comparison Of Test Results With Shear Design Equation

Four design equations's namely the ACI Code, CIRIA Guide code, Khuntia and Mansur are used to estimate ultimate shear capacity. Comparison of test results with shear design is provided in Table IV.

TABLE – IV
COMPARISON OF TEST RESULTS WITH SHEAR DESIGN EQUATION'S

Beam Designation	Shear Strength (KN)					Shear Strength Ratio			
	V_{MANSUR}	$V_{KHUNTIA}$	V_{CIRIA}	$V_{EUROCODE}$	V_{TEST}	$\frac{V_{TEST}}{V_{MANSUR}}$	$\frac{V_{TEST}}{V_{KHUNTIA}}$	$\frac{V_{TEST}}{V_{CIRIA}}$	$\frac{V_{TEST}}{V_{EUROCODE}}$
I-0%	39.40	90.17	56.91	92.82	97	2.462	1.076	1.704	1.045
I-1.5%	76.08	126.68	59.15	100.24	112.17	1.474	0.885	1.896	1.119
I-2.5%	102.71	153.56	61.10	106.99	117.83	1.147	0.767	1.928	1.101
II-0%	42.46	101.02	61.12	96.92	117	2.755	1.158	1.914	1.207
II-1.5%	81.22	139.83	63.64	105.08	135.83	1.672	0.971	2.134	1.293
II-2.5%	109.40	168.51	65.80	112.22	146.33	1.337	0.868	2.224	1.304
III-0%	46.08	114.19	66.29	104.45	139	3.016	1.217	2.097	1.331
III-1.5%	87.29	155.65	68.83	112.61	162.5	1.862	1.044	2.361	1.443
III-2.5%	117.19	186.16	71.06	120.02	178	1.519	0.956	2.505	1.483

ACKNOWLEDGMENT

I would like to sincere thanks to my guide Assistant Prof. Kadam S. S. for the support & guidance they have provided to us enduring patience, motivation & valuable time.

I also grateful to Prof. Pise C.P. Head of Department of civil Engineering Department for providing all necessary facility. I extend sincere thanks to Principal Dr. K. J. Karande for his guidance & inspiration.

I express deep sense of gratitude to all staff member for their co-operation. I finally sincere thanks to all those who directly or indirectly help me.

CONCLUSION

- 1) The addition of Mixed (Crimped steel - Polypropylene) fibers in concrete mix out of this crimped steel fibers gives effective shear reinforcement and polypropylene fiber controls crack.
- 2) Mixed (Crimped steel - Polypropylene) fibers in concrete deep beams provide better crack controls and deformation characteristics of beam.
- 3) Due to Mixed (Crimped steel – Polypropylene) fibers both first crack strength and ultimate strength in shear increases with increase in fiber content because of their great resistance to propagation of cracks.
- 4) Also cracking shear strength and ultimate shear strength increases with the increasing percentage of fiber content and decreasing l/D ratio.
- 5) From Table IV of Comparison of test results with shear design equations, it is observed that the equation proposed by *Khuntia et al.* gives good results for shear strength of fiber reinforced concrete deep beams as compared to the equation proposed by *Mansur et al.* The equation proposed by *Draft Eurocode* also gives good results for shear strength of concrete deep beams as compared to the equation proposed by *Ciria Guide-2*.
- 6) Maximum increase of 28.08 % in ultimate shear stress for beam series III containing 2.5 % fibers was observed when compared it with beam without fibers.
- 7) Maximum increase of 38.44 % in cracking shear stress for beam series III containing 2.5 % fibers was observed when compared it with beam without fibers.

FUTURE SCOPE

- 1) Extensive experimental study are required on the shear strength testing of mixed (Crimped steel - Polypropylene) fibers deep beams with more variability in their identified parameters that affect their shear strength.
- 2) To develop an empirical equation to predict the shear strength value that is nearer to the experimental shear strength value.
- 3) Determining fiber volume fraction upper bounds for different types of steel fibers. That is the bound beyond which the increase in shear strength does not justify the increase on fiber volume fraction.

REFERENCES:

- [1.] T. M. Roberts & N. L. Ho (1982). "Shear failure of deep fiber reinforced concrete", The International Journal of Cement Composites and Lightweight Concrete, Vol-4, pp. 145-152.
- [2]. M.V. Krishna Rao, N.R. Dakshina Murthy and V. Santhosh Kumar "Behaviour of Polypropylene fibre reinforced Fly ash concrete deep beams in Flexure & Shear" ASIAN JOURNAL OF CIVIL ENGINEERING (BUILDING AND HOUSING) VOL. 12, NO. 2 (2011)[3.] K. Ramadevi& D. L. VenkateshBabu "Flexural Behavior of Hybrid (Steel-Polypropylene) Fibre Reinforced Concrete Beams" European Journal of Scientific Research ISSN 1450-216X Vol.70 No.1 (2012), pp. 81-87 © EuroJournals Publishing, Inc. 2012
- [4].S. K. Madan, G. Rajesh Kumar and S. P. Singh (2007). "Steel fibers as replacement of web reinforcement for RCC deep beams in shear", Asian Journal of Civil Engineering, Vol-8(5), pp. 479-489.
- [5]. Vinu R. Patel, Pandya "Ultimate shear strength of Fibrous moderate deep beams without stirrups" Int. Journal of Applied Sciences and Engineering Research, Vol. 1, No. 2, 2012 © 2012 by the authors – Licensee IJASER- Under Creative Commons License 3.0 Research article
- [6]. Abhishek Kumar Singh, Anshul Jain and Deependra Singh " Evaluation Of Mechanical Properties For Polypropylene And Steel Fiber Reinforced Concrete" International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 4, April - 2013 ISSN: 2278-0181
- [7] Emma Slater, Moniruzzaman Moni and M. Shahria Alam (2012). "Predicting the shear strength of steel fiber reinforced concrete beams", Construction of Building Materials, Vol-26, pp. 423-436.
- [8] Vengatachalapathy (2010). "Behavior and ultimate strength of steel fiber reinforced concrete (SFRC) deep beams with and without openings", International Journal of Civil and Structural Engineering, Vol-1(3), pp. 509-517.
- [9] Londhe R. S. (2010) Experimental investigation on shear strength of SFRC beams reinforced with longitudinal tension steel rebar's: Asian Journal of Civil Engineering and Housing, 11(3):385-395.
- [10] American Concrete Institute Committee (2005) Building code requirements for structural concrete (ACI 318-05) and commentary (ACI 318R-05): American Concrete Institute, Detroit, Michigan, USA.
- [11] Dinh H. and Wight J. K. (2011) Shear strength model for steel fiber reinforced concrete beams without stirrup reinforcement: Journal of Structural Engineering, ASCE, 137(10):1039-1051.
- [12] K. Ramadevi& D. L. VenkateshBabu "Flexural Behaviour of Hybrid (Steel-Polypropylene) Fibre Reinforced Concrete Beams" European Journal of Scientific Research ISSN 1450-216X Vol.70 No.1 (2012), pp. 81-87 © EuroJournals Publishing, Inc. 2012
- [13] Marijan Skazlić "Development and Application of Hybrid Fibre Reinforced Concrete" The university of Wisconsin Milwaukee centre for by product utilisation, on sustainable construction material & technology, June 28-June 30 2010.

- [14] Jimmy Susetyo, Paul Gauvreau, and Frank Vecchio (2011). "Effectiveness of steel fiber as minimum shear reinforcement", *ACI Structural Journal*, Vol-108(4), pp. 488-496.
- [15] Yoon-KeunKwak, Eberhard, Woo-Suk Kim and Jubumkim (2002). "Shear strength steel fiber reinforced concrete deep beams without stirrups", *ACI Structural Journal*, Vol-99(4), pp. 530-538.
- [16] Leong C.L. and Tan K.H. (2003) proposed revision on CIRIA design equation for normal and high strength concrete deep beams: *Mag. Concrete Res.*, 55(3): 267-278.
- [17] American Concrete Institute Committee (2005). Building code requirements for structural concrete(ACI318-05) and commentary (ACI 318R-05): American Concrete Institute, Detroit, Michigan, USA.
- [18] IS 456: 2000, "Indian Standard Code of Practice for Plain and Reinforced Concrete, (fourth Revision)," *Bureau of Indian Standard*, New Delhi, India.
- [19] F. K. Kong, *Reinforced Concrete Deep Beams*. Blackie and Son Ltd, London, 2002.