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EXPERIMENTAL SYUDY OF MFRC DEEP BEAM UNDER SHEAR FAILURE

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Abstract- Concrete is a largely used construction material all over world due to its compressive strength, high mold ability and durability, structural stability and economic consideration. Generally structure is subjected mainly four forces or load i.e. Tensile, compressive, shear, & flexure, but concrete is very weak in tensile and in shear. Shear strength of concrete we can't calculate directly like a compressive strength due to its complexity. There for the main target of this paper is to study the increase in shear strength of the deep beams due to addition of the mixed fibers (steel-synthetic) without any shear reinforcement. In this study we test 27 reinforced concrete deep beams. For these we add a mixed fiber in different percentages (0%,1.5% and 2.5%), with the shear span to depth ratio is also varies i.e. (0.78, 0.73 and 0.69)by keeping a compressive strength and tensile reinforcement constant. All these specimens are tested under four-point bending test set-up up to failure and record the 1st crack load, failure load and central deflection after 28 day's curing period. The obtained results are compared with the results of the equations proposed by different codes & authors find which equation gives accurate results. From this study it is clear that the shear strength of the longitudinally reinforced deep beam increases considerably due to the addition of the mixed fibers. It is also observed that shear strength increases with increase in the fiber content and decrease in the shear span to depth ratio (a/d).

Keywords: Deep beam, mixed (steel-synthetic) fiber, shear strength, diagonal tension, concrete, compressive strength, crack, shear span to depth ratio, tensile reinforcement etc.

Introduction

In civil engineering structure the concrete is mostly used as a construction material due to its compressive strength, high mould ability, high durability, structural stability and economic consideration. The structure are mainly subjected or carry a four types of forces or loads i.e. tensile, compressive, shear & flexure, but we know that the concrete is very strong in compression and weak in tension and shear. We can directly calculate the comp. strength of concrete by using a CTM 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 [1]. As a result of this concrete does not possible to apply a shearing action i.e. direct shearing force in a plane. Therefore the various debates and controversies take place from the beginning of 20th century. The shear and flexural failures are very sudden and unexpected and sometimes violent and catastrophic. Therefore whole knowledge of different modes of shear failure and mechanism involved is necessary to prevent them [2].

Deep beams are the structural element or members are generally used in the heavily loaded structures like high rise building, pile caps, load bearing wall and irrigation project [3]. So how to differ the deep beams form the slender or normal beams, for that we use a IS codes. According to Indian standard code method the deep beam is a beam having a ratio of clear span to overall depth ratio is less than 2 for simply supported beam and 2.5 for continuous beams [4]. The load transformation of deep beam is quite different than slender beam or normal beam. In slender beam load will transfer by the bending action and in deep beam load is transfer by shearing action by forming a diagonal cracks. The shear failure or flexural failures are the two main failures occur in reinforced concrete beam. Flexural failure occurs when bending stresses is more than shear stresses obtain mostly in long span i.e. slender or normal beams and deep beams fails in shear below the ultimate flexural capacity of beam. The simple beam theory not consider the effect of shear & the effect of stresses on planes parallel to neutral axis due to this it cannot applicable to deep beam. A result of these the plane section do not remain plane and perpendicular to the neutral axis after deformation. The natural of final non-linear bending stress distribution and location of neutral axis depends on the span to depth ratio and type and positions of loading and support reaction. In deep beams a large amount of load is taking by the compressive thrust joining the loading point and support reaction. The failure mode of deep beams could be diagonal failure and bearing failure [5].

We know that concrete is a brittle material, to decrease brittleness of concrete and increase ductility of concrete for that increase the mechanical properties of concrete. Therefore to increase mechanical properties of concrete fibers are used in concrete. This type of concrete we called as "Fiber reinforced concrete" (FRC). There are various types of fibers like steel, glass, natural and synthetic etc. When we use two different fibers in concrete we called as a "Mixed fiber reinforced concrete (MFRC)". This will be done when accurate result is needed [6]. Generally a micron cracks are already present in concrete, this micron cracks are converted in micro cracks by joining the cracks to each other when external load is applied due to these rapid fracture and unstable propagation is occurs. Therefore in this paper for good result we combine steel fibers [crimped] and synthetic fibers (polypropylene). Steel fiber can be used to boost the shear load carrying capacity and replace the shear reinforcement in conventional RCC deep beam and polypropylene fiber used to control the micro cracks present in to the concrete [7].

The effect of mixed fiber on concrete depends on the types of fibers, aspect ratio (length to diameter ratio) and orientation of fibers in concrete. The strength of deep beams is generally considered by the shear not by flexure [8].The shear strength of MFRC deep beams is depend upon the types of fibers, aspect ratio of fibers, percentage of longitudinal reinforce, a/d ratio and amounts of fibers. The addition of small fibers into the concrete mix helps to improve the post cracking tensile strength of concrete. Therefore the main objective of doing this work is to study the main effect of addition of different percentage of mixed fiber with varying a shear span to depth ratio (a/d) [9].

Research Significance

We know that the tensile strength and shear strength of concrete is very low, therefor they will break in small pieces at failure or breaking load, due to these it is consider at a brittle material. To increase the tensile and shear strength of concrete various fibers is add into the concrete mixture. As mention above when two different fibers is mixed in to the concrete for getting accurate result then these concrete is called as MFRC. In this recent work we take a steel (crimped) and synthetic (polypropylene) fiber for study. Out of these the steel fibers are replace the shear reinforcement and increase the tensile strength by making a braking through developing cracks and also providing more resistance. Synthetic (polypropylene) fibers are used to arrest a micron crack which is already present into the concrete also both these fibers helps to remove the sudden failure and allow a large progressive failure in concrete. The shear and tensile strength of MFRC deep beam is depend on many parameters such as 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 we study the effect of shear span to depth ratio (a/b) and volume fraction of fiber on shear strength of deep beam.

Experimental Program

Material Property:-

In this experimental work for casting the test specimens we use a cement, sand, aggregate, portable water and mixed fibers are used. This material used after confirming the specification given in the relevant Indian standard code. For this test we use a cement of 53 grade by confirming to is 12269:1987. The maximum size of course aggregate used was 20mm and minimum size 12.5mm of same parent rock with 60-40% fraction. Krishna river sand was used as a fine aggregate. The specific gravity of sand 2.83 and fineness modulus is 3.10. In this the steel (crimped) fiber of length 50mm and thickness 1mm and synthetic (polypropylene) fibers of length 12mm & diameter 0.6 mm were used. For main tensile reinforcement fe-500 grade of steel was used which is easily available in market.

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Concrete Mix Design:-

The concrete mix design was prepared for M-35 grade of concrete and the design of this is done by using an Indian standard code methods. For this design the water cement ratio was kept 0.41. The mix proportion is given in table no-1

TABLE I
MIX PROPORTION

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

Test Specimens:-

The total length of the beam specimen is 700 mm, the center to center distance (span) between the support was keep 600mm. The depth of beam is 320mm, 340mm and 360mm and shear span is kept 200mm for achieving a desired a/d ratio. Totally 27 numbers of simply supported deep beams were casted. This beams divided into the three groups i.e. Group A, Group B and Group C. Group A, Group B and Group C beams reinforced with 402.12mm^2, 452.16 mm^{2}and 512.13mm^{2}area of steel. The width of beam 100mm.The detail of test beams is given in table-II.

TABLE II
TEST BEAM DETAILS

Beam Designation	Beam Size (L x D) mm	Fiber content (%)	a/d ratio	Effective depth "d" mm
A	700 X 320	0	0.78	256
A	700 X 320	1.5	0.78	256
A	700 X 320	2.5	0.78	256
B	700 X 340	0	0.73	272
B	700 X 340	1.5	0.73	272
B	700 X 340	2.5	0.73	272
C	700 X 360	0	0.69	288
C	700 X 360	1.5	0.69	288
C	700 X 360	2.5	0.69	288

Test Procedure:-

For the test beam specimen is subjected in four bending test set-up up to failure. This beam was tested after completion of the curing period 28 days. The all sides of the beams are white washed for clear observation of the crack. Test set up for beam is show in "fig.-1"

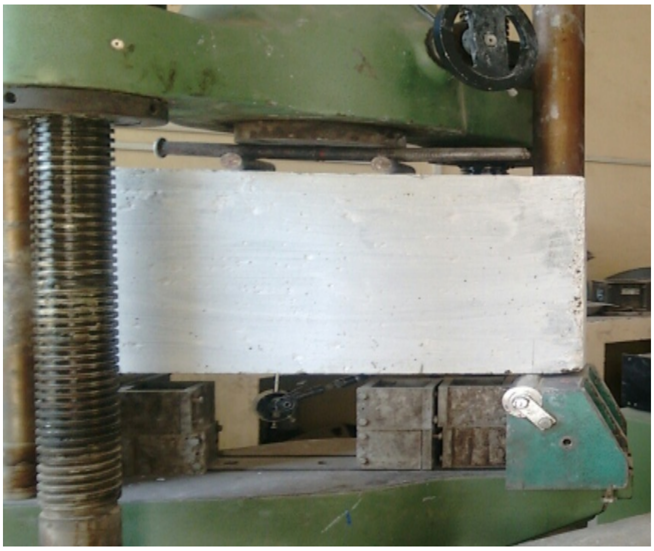

Figure1. Two point loading test set-up.

Shear Design Models

The verification of the strength of MFRC deep beams the various shear strength models has been used.

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.

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.

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

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.

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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, α_1 = 2.5(d/a), and

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

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

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.

Test Results and Discussion

The test results obtained are tabulated in table III

TABLE – III
DETAILS OF TEST RESULTS

Test Beam Designation	a/d Ratio	Cracking Shear Stress (Mpa)	Ultimate Shear Stress (Mpa)
A-0 %	0.78	2.578	3.789
A-1.5 %	0.78	3.118	4.370
A-2.5 %	0.78	3.411	4.603
B-0 %	0.73	2.941	4.301
B-1.5 %	0.73	3.603	4.994
B-2.5 %	0.73	3.983	5.380
C-0 %	0.69	3.327	4.825
C-1.5 %	0.69	4.172	5.642
C-2.5 %	0.69	4.606	6.180

Shear Span to Depth Ratio and Fiber Volume Fraction:-

The variations of ultimate shear stress and cracking shear stress for different fiber volume and shear span to depth ratio are show in above table III. It is observed from that the ultimate and cracking shear strength is increases with the increasing the fibers volumes and decreasing shear span to depth ratio. The ultimate and cracking shear stress of deep beam is calculated by dividing the failure and cracking load to the nominal cross sectional area (b x 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".

Central Deflection of Deep Beam:-

The load defection graph for the beams of Group A, Group B and Group C are shown in "fig-3", "fig-4" & "fig-5" from this graph it seen that the central deflection of beam increases with increasing fiber content. The beam carries a considerable amount of load even after First crack due to addition of fibers.

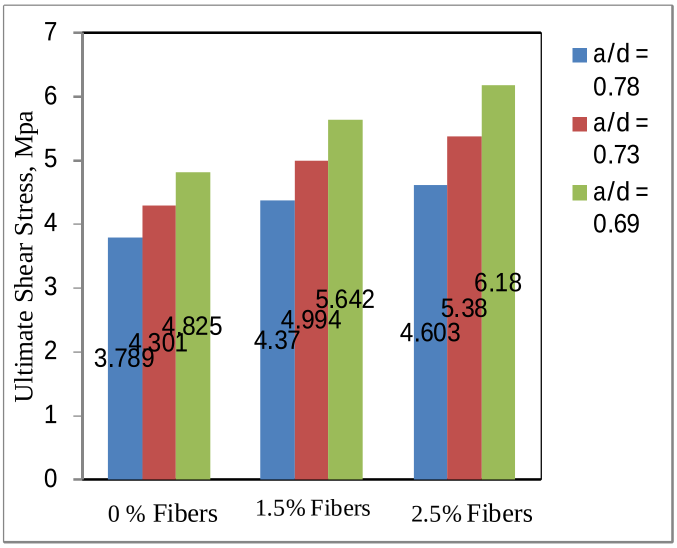

Fig – 2 Ultimate Shear Strength of Beam With Respect to a/d Ratio and Fiber Content.

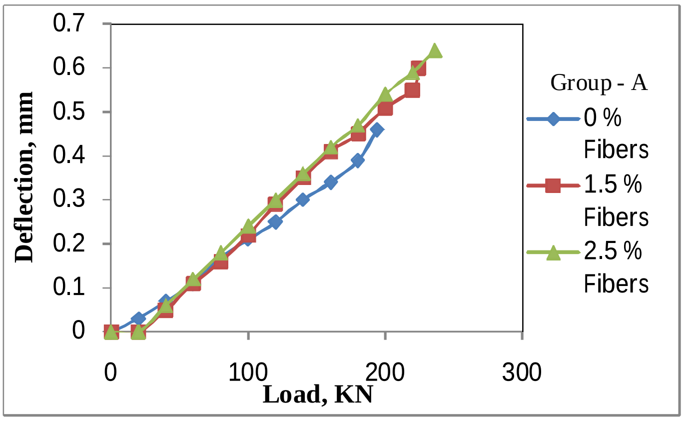

Fig – 3 The Graph of Central Deflection With Respect To Load, Group – A

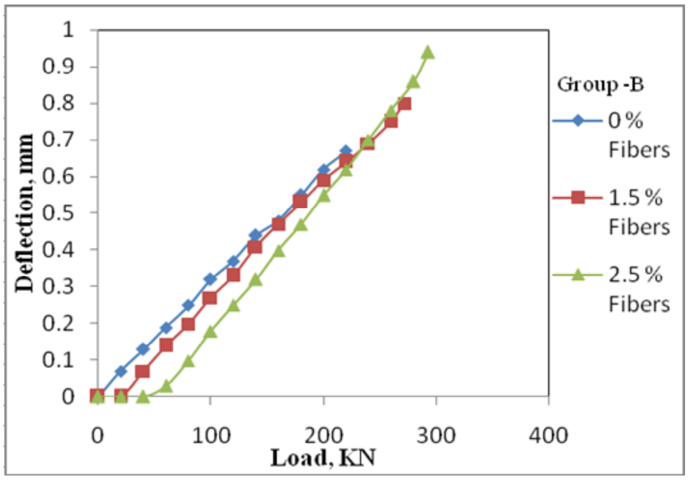

Fig – 4 The Graph of Central Deflection With Respect To Load, Group - B.

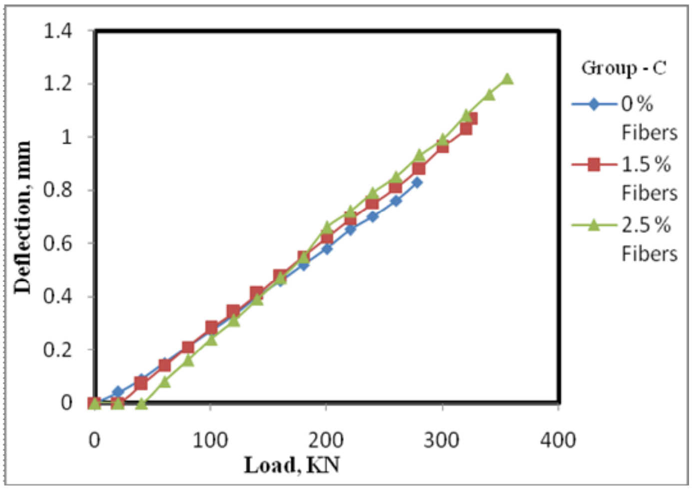

Fig – 5 The Graph Of Central Deflection With Respect To Load, Group C.

Comparison of Test Results with Shear Design Equation

Comparison of test result with shear design is shown in Table IV and Table V

TABLE – IV
Shear Strength of Design Equation and Test.

Beam Designation	**Shear Strength (KN)**				
	$V_{EUROCODE}$	V_{CIRIA}	$V_{KHUNTIA}$	V_{MANSUR}	V_{TEST}
A-0%	92.82	56.91	90.17	39.40	97
A-1.5%	100.24	59.15	126.68	76.08	112.17
A-2.5%	106.99	61.10	153.56	102.7	117.83
B-0%	96.92	61.12	101.02	42.46	117
B-1.5%	105.08	63.64	139.83	81.22	135.83
B-2.5%	112.22	65.80	168.51	109.4	146.33
C-0%	104.45	66.29	114.19	46.08	139
C-1.5%	112.61	68.83	155.65	87.29	162.5
C-2.5%	120.02	71.06	186.16	117.2	178

TABLE – V
Shear Strength Ratio Design Equation and Test.

Beam Designation	**Shear Strength Ratio**			
	$V_{TEST}/V_{EUROCODE}$	V_{TEST}/V_{CIRIA}	$V_{TEST}/V_{KHUNTIA}$	V_{TEST}/V_{MANSUR}
A-0%	1.045	1.704	1.076	2.462
A-1.5%	1.119	1.896	0.885	1.474
A-2.5%	1.101	1.928	0.767	1.147
B-0%	1.207	1.914	1.158	2.755
B-1.5%	1.293	2.134	0.971	1.672
B-2.5%	1.304	2.224	0.868	1.337
C-0%	1.331	2.097	1.217	3.016
C-1.5%	1.443	2.361	1.044	1.862
C-2.5%	1.483	2.505	0.956	1.519

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Conclusion

1) The use of mixed fibers in concrete deep beams provide a better crack control and deformation characteristics of beam, out of these steel (crimped) fiber gives effective shear reinforcement & synthetic (polypropylene) fiber controls cracks.
2) The ultimate and cracking shear strength increases with the increasing the percentage of fibers content and decreasing the a/d ratio, it happens due to the grad resistance to propagation of cracks.
3) From table IV of comparison of test results with shear design equation, it is observed that the equation proposed by *Draft Eurocode* gives good results for shear strength of concrete deep beams as compared to the equation proposed by *Ciria Guide-2*.The equation proposed by *Khuntiaet al.* gives good results for shear strength of fiber reinforced concrete deep beams as compared to the equation proposed by *Mansur et al.*
4) The cracking shear stress of Group C beams containing a 2.5% of fibers increases with the 38.44% maximum.
5) The ultimate shear stress of Group C beams containing a 2.5% of fibers increases with 28.08% maximum.

Future Scope

1) Large experimental studies are required for shear strength of mixed fibers deep beams with more variability in their parameters that affect their shear strength.
2) To discover empirical equation to find the shear strength value nearer to the experimental shear strength value.
3) Determine the exact fibers volume fraction for which the maximum shear strength is achieve i.e. beyond this limit if we increase the fiber volume the shear strength can't increases.

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