

Effect of Inclusion of Moderate Volume Fraction Hybrid Fiber Reinforcement in Concrete Deep Beams

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ABSTRACT: To enhance resistance of concrete against crack formation, fiber reinforcement has been the focus of studies. Combining two or more types of fibers for getting high quality hybrid fiber reinforced concrete (HFRC) has been a recent trend. Use of steel fibers improves the strength and resistance against deformation characteristics of concrete members. Polypropylene fibers contribute to enhanced crack resistance, energy absorption and impact strength of concrete. This paper presents data obtained from experiments carried by using combination of steel and Polypropylene fibers in predefined proportions in the concrete and its effect on strength characteristics of HFRC deep beams. The effect on strength of beams due to variation in shear span is also studied. The beams cast & cured are tested in heavy structure laboratory using 1000 kN capacity loading frame. The two-point loading is applied. The shear span to depth ratios considered is 0.43 and 0.56. During experiment, first crack load, ultimate load, and central deflections of deep beams are recorded. It is observed that, in comparison with conventional deep beams, there is improvement of 16.7 % in first crack load and 80 % in ultimate strength of HFRC deep beams having shear span to depth ratio 0.43 for the mix with super plasticizer 1.2% steel fiber and 0.3% PP fiber by volume of concrete.

KEYWORDS: Deep beam, HFRC, polypropylene fiber, shear span, steel fiber, two point loading.

I. INTRODUCTION

A simply supported beam is defined as deep when the ratio of its effective span L to overall depth D is less than 2. Continuous beams are considered as deep when the ratio L/D is less than 2.5. Because the geometry of deep beams, their behaviour is different with slender beam or intermediate beam. A beam shall be deemed to be a deep beam when the ratio of effective span to overall depth is less than two.

The common examples of deep beam are shear walls, transfer girders, pile caps, walls of water tanks, bunkers and silos, etc. Force transfer mechanism in deep beams is quite different from that in slender beams as major part of the external load on deep beam is carried by diagonal strut joining loading point to support point. This leads to non-linear variation of stresses and strains. For arresting the crack mechanism here we use steel and polypropylene (PP) fiber. Where high modulus and high tensile strength steel fibers increase the toughness of concrete. Low modulus and low strength polypropylene fibers help in reducing the shrinkage strain in concrete.

II. RELATED WORK

Clark⁽¹⁾ concluded that shear strength increased with decreasing shear span-to-depth ratio. Ramadevi, K. and Venkatesh Babu⁽¹⁰⁾ use of hybrid fiber improves flexural performance of beam during loading i.e. decrease in mid span deflection with an increase in percentage of hybrid fiber. Tan K. H⁽⁹⁾ et al carried out experiments on High strength Concrete

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Deep Beams and they observed that for beams with shear span-to-depth ratios less than one, failure mode is largely influenced by the shear span-to-depth ratio. Shaikh, M.S., Kulkarni, S.K., Patil, S.S. and Halkude, S.A.⁽¹²⁾ they concluded that using combination of fibers in predefined proportions in the concrete and its effect on strength characteristics of HFRC deep beams and the effect on strength of beams due to variation in shear span is also studied. Strength of deep beams is controlled by shear rather than flexure. When principal tensile stresses exceed the tensile strength of concrete, diagonal cracks occur in the shear span region and results in low first crack load and low shear strength. The use of discrete, randomly oriented fibres provides post-cracking tensile resistance to concrete. An important characteristic of deep beams is requiring high shear strength. The greater shear strength of deep beam is due to internal arch action.

III. OBJECTIVE OF STUDY

- 1) To investigate experimentally the behaviour of steel and polypropylene fibers reinforced concrete deep beams in shear with variations in shear span to depth ratio.
- 2) To compare the change in behaviour of deep beam due to moderate volume fraction of fiber reinforcement with conventionally reinforced deep beam.
- 3) To determine possibility of complete replacement of conventional shear reinforcement by moderate volume fiber reinforcement.

IV. EXPERIMENTAL PROGRAM

Here we study effect of combination of moderate volume fraction of steel fiber content in the range of 0.9% to 2% in deep beam. And Fibrillated Polypropylene fiber ranges from 0.1% to 0.3% is sufficient in minimization of cracks in concrete. Therefore to study the effect of combination of both the fibers in concrete the steel fiber content considered is 0.9, 1.2, 1.5, 1.8 and 2% and for each percentage of steel fiber the PP fiber content taken is 0.1, 0.2 and 0.3% by volume of concrete and use super plasticizer for steel fiber exceeds percentage more than 1.2% steel fiber. Here conventional shear reinforced replaced by flexural reinforcement.

V. MATERIALS PROPERTIES AND MIX PROPORTIONS

The materials used for making the concrete are 43 grade ordinary Portland cement conforming to IS 269:2015, natural sand conforming to zone II of IS 383:1997, and coarse aggregate of maximum size 20 mm. Design mix of M20 grade concrete is carried out in accordance with IS 10262:2009. Mix proportion obtained is 1:2.57:3.5 (by weight) with water cement ratio of 0.50.

Cement: Ordinary Portland cement 43 grade with specific gravity of 3.15 was used.

Fine Aggregate: The fine aggregate used in this investigation was clean river sand passing through 3.75mm sieve with specific gravity of 2.6 and Fineness modulus of sand 2.98 was used.

Coarse Aggregate: Crusher Coarse aggregate of 20mm procured from local crusher with specific gravity is 2.7 and fineness modulus of 7.11 was used.

Water: Potable water free from salts was used for casting and curing as per IS 456-2000 recommendation.

Steel fiber:

Steel Fiber is a small piece of reinforcing material possessing certain characteristic properties. Generally they are circular in cross section. The hooked – end steel fibers are available in water – soluble glued bundles to ensure their good dispersion in the concrete during mixing. A group consists of about 30 steel fibers and these collated fibers create an artificial aspect ratio of approximately 15, thus reducing the balling of fibers.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 8, August 2017

Table 1: Properties of steel fiber

Fiber type	Hooked end fiber
Diameter	0.75 mm
Length of fiber	60 mm
Aspect ratio	80
Tensile strength	1110 MPa
Young's modulus	200 GPa

Polypropylene fiber:

Polypropylene fiber is generally used in structures subjected to impact loads and abrasion. Polypropylene fibers are available in three different forms; Monofilaments, Microfilament, fibrillated. It produces high wear resistance, do not absorb water, float due to the low density and they retain strength when they are wet. Fibrillated fibers are characterized by highly reflective and translucent surface, limited absorption capacity, high stiffness and good tensile strength

Table 2: Properties of polypropylene fiber

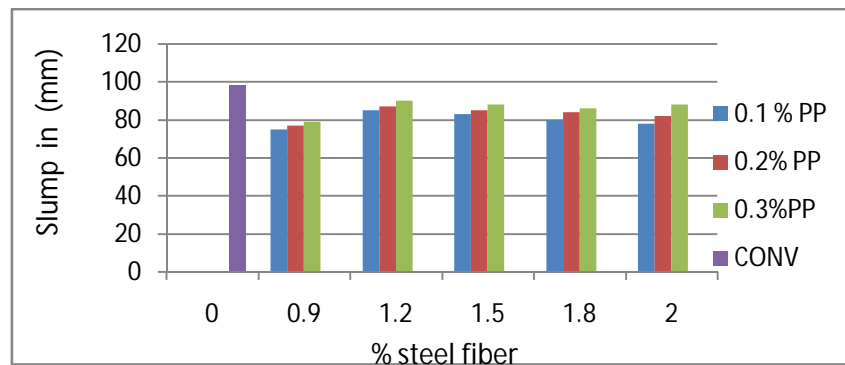
Type	Fibrillated polypropylene fiber
Length of fiber	12 mm
Tensile strength	453 MPa
Young's modulus	3.5 GPa

VI. TESTING OF CONCRETE

Result of slump cone test and compressive test: The slump test characterizes the workability of fresh concrete and Compression test is the important test conducted on hardened concrete because most of the desired characteristics of concrete are qualitatively related to the compressive strength.

Table 3: Variation in slump and compressive strength of concrete with different percentages of steel and PP fiber

Type of Concrete (M20 Grade)	% steel fiber	%PP fiber	% of super plasticizer in concrete	Slump (mm)	Permissible slump for medium workability mm (as per IS 456-2000)	% drop of slump	28 th day compressive strength of cubes (Mpa)	% increase in comp. Strength compared to conventional concrete
Conventional	-	-	--	98	75-100	-	26.9	0
Hybrid Fiber reinforced	0.9	0.1	Nil	75		23.5	28.85	7.25
		0.2	Nil	77		21.4	29.75	10.6
		0.3	Nil	79		19.4	30.9	14.8
	1.2	0.1	0.6	85		13.3	31.25	16.18
		0.2	0.6	87		11.2	32.5	20.8
		0.3	0.6	90		8.2	32.8	21.9
	1.5	0.1	0.8	83		15.3	32	18.95
		0.2	0.8	85		15	33.2	23.42
		0.3	0.8	88		10.2	33.95	26.2
	1.8	0.1	1	70		18.4	33.4	24.16
		0.2	1	68		14.3	34.6	28.62
		0.3	1	60		12.2	35.25	31.1
	2	0.1	1.2	50		20.4	34.3	27.5
		0.2	1.2	45		16.3	35.15	30.66
		0.3	1.2	40		10.2	35.96	33.68



Graph 1: Variation in slump of concrete with different percentages of steel and PP fiber.

Mixes Without addition of super plasticizer

From table no.3 it is observed that in comparison with conventional concrete, there is a drop in slump of 23.5% for combined 0.9% steel and 0.1% PP fibre content. For the same steel fibre content, when PP fibre content was increased as 0.2 % & 0.3 %, slump drop observed was 21.4 % & 19.4% respectively. Due to increase in percentage of polypropylene fiber there is loss in drop of slump. This indicates that workability increases when PP fibres are added to concrete. Same trend is observed in case of 1.2 ,1.5,1.8 & 2 % steel fibre content combined with 0.1,0.2 & 0.3% PP fiber content. The mix containing 0.9% steel and 0.3% PP fibers is producing slump of 79 mm which is within acceptable range (75 to 100 mm) hence this can be considered as the optimum mix.

Mixes With addition of super plasticizer

It is observed that workability of mix with steel fiber percentage beyond 0.9%, the slump value recorded does not satisfy the minimum requirement of 75 mm as per I.S. 456-2000. Mixes with steel fiber content 1.2, 1.5, 1.8 and 2% for all PP fibre contents are found to be not workable mixes. Hence super plasticizer is used for mixes from 1.2 to 2% of steel fiber content in order to increase workability.

Optimum mix from workability considerations: A mix with 0.9% steel fiber and 0.3% PP fiber shows slump of 79 mm which is within acceptable range as per IS 456. Hence from workability point of view this mix seems to be an optimum mix without super plasticizer. From mixes with super plasticizer, optimum mix is observed to be a mix with 1.2% steel and 0.3% PP fiber content having slump value 90mm from workability and strength point of view.

Compressive strength of concrete cubes: The compressive strength of HFRC increased by 7.25% with addition combined 0.9% steel and 0.1% PP fiber as compared to conventional concrete. For the same steel fibre content, when PP fibre content was increased to 0.2% & 0.3%, the increase in compressive strength observed was by 10.6% and 14.8% respectively. This indicates that the compressive strength of concrete for a given steel fibre % increases marginally with increase in PP fiber content however its workability is getting increased with increasing PP fibre content. When steel fiber content is 0.9% and PP fiber content 0.3%, compressive strength of concrete is observed to be 14.8% more in comparison with conventional concrete. Further it is observed that there is a little increase in compressive strength of concrete for 1.2% to 2% steel fiber content with considerable loss in workability, i.e. the slump observed is less than the minimum requirement.

VII. DESIGN OF DEEP BEAMS

Deep beams are designed as per IS 456:2000. The loading considered for design is two point loads of 75 KN each. Two different shear spans to depth ratios (a_v/D) viz. 0.43 and 0.56 are taken into consideration. Design reinforcement used for conventional and HFRC deep beam is as shown in Figure 1 (a) and Figure (b) respectively.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 8, August 2017

Conventional shear reinforcement is completely eliminated (Figure 1 b) for HFRC deep beams, and is replaced by combination of steel fibers (0.9% to 2% by volume of concrete) and PP fibers (0.1% to 0.3% by volume of concrete).

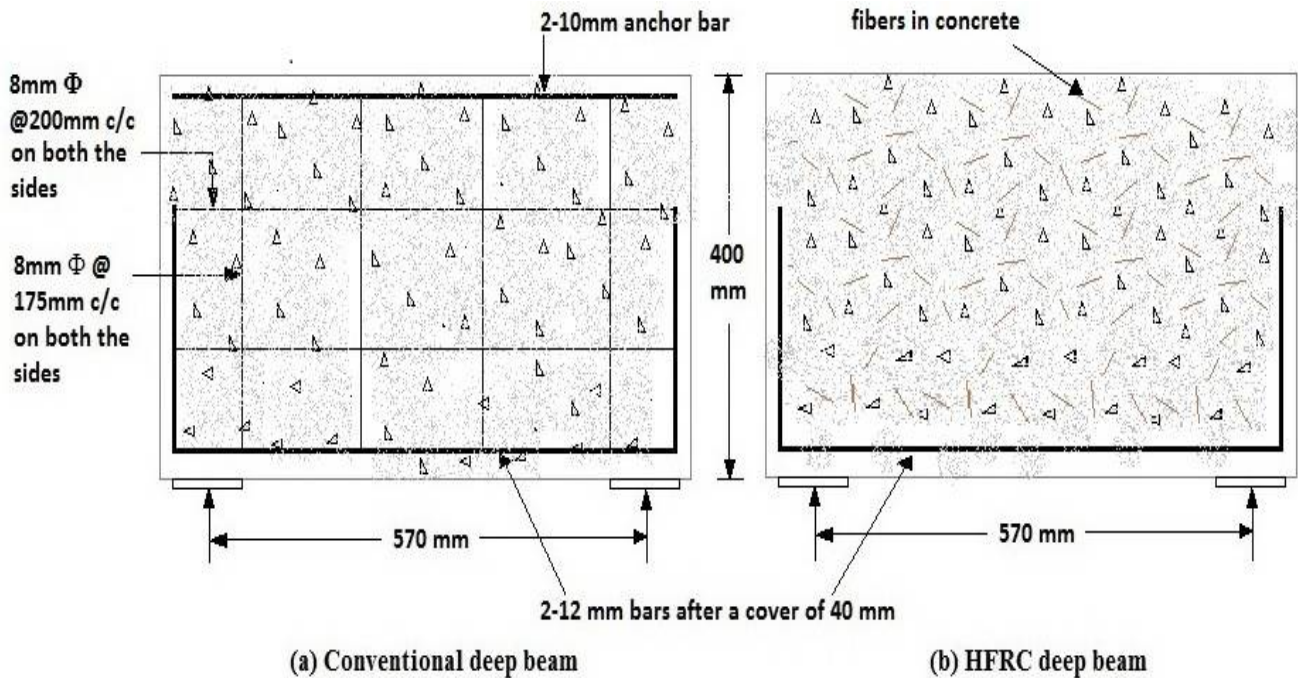


Figure 1: Reinforcement details of deep beam.

Test Specimens:

A total of 92 nos. of HFRC deep beams of length 700 mm, height 400 mm and thickness 150 mm were cast. For comparison purpose, 06 nos. of conventional deep beams of same dimensions were also cast.

Flexural Testing of beams:

Beams were tested using loading frame of capacity 1000kN. Initial arrangements of supports and loading points were checked to confirm design requirements. Bearing plates were placed on roller supports over which the beam is positioned. Initiation was made by checking dial gauge reading. In order to avoid failure at supports and loading points the bearing plates were provided to transfer the point load into pressure on specimen. The size of bearing plate is determined by considering the permissible bearing stress. The rate of loading was 400kg/min as per IS 516:1959. Deflection of beam was observed using dial gauge for each load interval of 50 kN. The first-crack load and ultimate load were observed as presented in Table 4 and 5.

VIII. TEST RESULTS

Shear strength and behaviour of deep beams:

The observations of first crack load, ultimate crack load and deflection for two different shear span to depth ratios are recorded as shown in Table 4 and 5.

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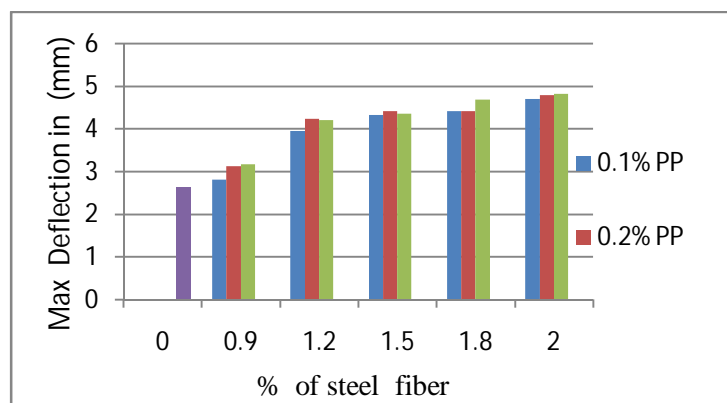
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Vol. 6, Issue 8, August 2017

Table 4: Details of reinforcement type, Fibre percentage, First crack load, Ultimate load and deflections for deep beams with shear span to depth ratio 0.56

Type of beam	% fiber volume fraction (vf)		First crack load (KN)	% increase in first crack load as compared to conventional beam	Ultimate crack load (KN)	% increase in ultimate crack load as compared to conventional beam	Deflection at first crack load (mm)	Max deflection (mm)
	Steel	Polypropylene						
Conventional	0	0	290	-	425	-	2.15	2.74
Fiber	0.9	0.1	330	13.8	590	38.8	2.17	2.82
		0.2	335	15.5	610	43.5	1.82	3.12
		0.3	345	19.0	620	45.9	2.02	3.71
	1.2	0.1	350	20.7	630	48.2	2.14	3.95
		0.2	360	24.1	645	51.8	2.12	4.23
		0.3	370	27.6	670	57.6	2.15	4.21
	1.5	0.1	365	25.9	665	56.5	2.04	4.33
		0.2	375	29.3	680	60.0	2.15	4.41
		0.3	380	31.0	695	63.5	2.05	4.35
	1.8	0.1	385	32.8	710	67.1	1.97	4.42
		0.2	390	34.5	750	76.5	1.81	4.42
		0.3	400	37.9	760	78.8	1.68	4.68
	2	0.1	395	36.2	790	85.9	1.58	4.7
		0.2	410	41.4	820	92.9	1.36	4.79
		0.3	425	46.6	850	100.0	1.32	4.82

(0.9 % steel and 0.1 to 0.3% PP without superplasticizer and above having super plasticizer.)



Graph 2: Variation in Max deflection of deep beams with different fiber percentages for shear span to depth ratio 0.56.

Above table no. 4 and graph no.2 represents that variation in first crack load of deep beams with different fiber percentages for shear span to depth ratio 0.56. It can be observed that there is consistent increase in first crack load with increase in percentages of fibers. It is clearly observed that there is consistent increase in load at permissible deflection with increasing percentages of fibers.

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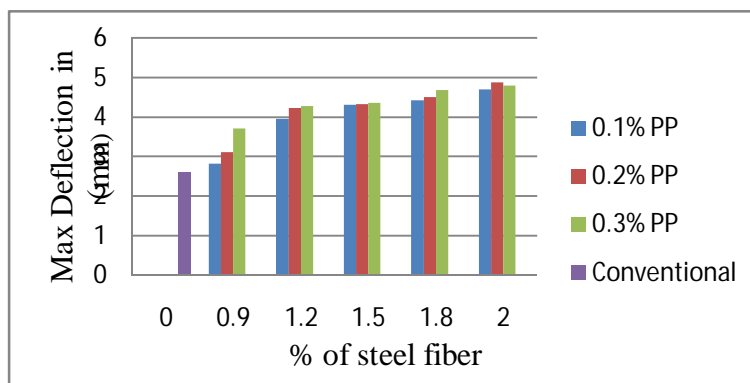
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Vol. 6, Issue 8, August 2017

Table 5: Details of reinforcement type, Fiber percentage, First crack load, Ultimate load and deflections for deep beams with shear span to depth ratio 0.43

Type of beam	% fiber volume fraction (vf)		First crack load (KN)	% increase in first crack load as compared to conventional beam	Ultimate crack load (KN)	% increase in ultimate crack load as compared to conventional beam	Deflection at first crack load (mm)	Max deflection (mm)
	Steel	Polypropylene						
Conventional	0	0	330	-	445	-	2.15	2.62
Fiber	0.9	0.1	335	1.5	680	60.0	2.17	2.82
		0.2	340	3.0	700	64.7	1.82	3.12
		0.3	355	7.6	720	69.4	2.02	3.71
	1.2	0.1	360	9.1	730	71.8	2.14	3.95
		0.2	370	12.1	740	74.1	2.12	4.23
		0.3	385	16.7	765	80.0	2.15	4.28
	1.5	0.1	390	18.2	760	78.8	2.04	4.30
		0.2	400	21.2	775	82.4	2.15	4.33
		0.3	415	25.8	785	84.7	2.05	4.35
	1.8	0.1	420	27.3	800	88.2	1.97	4.42
		0.2	425	28.8	815	91.8	1.81	4.5
		0.3	430	30.3	830	95.3	1.68	4.68
	2	0.1	430	30.3	845	98.8	1.58	4.7
		0.2	435	31.8	860	102.4	1.36	4.87
		0.3	440	33.3	885	108.2	1.32	4.79

(0.9 % steel and 0.1 to 0.3% PP without super plasticizer and above having super plasticizer.)



Graph 3: Variation in Max deflection of deep beams with different fiber percentages for shear span to depth ratio 0.43.

Above table no.5 and graph no.3 represents that variation in first crack load of deep beams with different fiber percentages for shear span to depth ratio 0.43. It can be observed that there is consistent increase in first crack load with increase in percentages of fibers. It is clearly observed that there is consistent increase in load at permissible deflection with increasing percentages of fibers.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor & UGC Approved Journal)

Website: www.ijirset.com

Vol. 6, Issue 8, August 2017

IX. DISCUSSION ON TEST RESULTS

A. Conventional deep beams:

- i) First crack initiated at a load, which was 35 to 46 % of ultimate load. It originated in shear zone near the support and with further increase in load the crack propagated towards the loading point. The failure of beams observed was in shear mode.
- ii) The shear strength of conventional deep beams with shear span to depth ratio 0.43 is 13% more than that of shear span to depth ratio 0.56, as shown in table 4 and 5. It indicates that the shear strength of conventional deep beams is inversely proportional to shear span to depth ratio.

B. Hybrid Fiber reinforced deep beams:

- i) Effect of fibre inclusion: The load at first crack of beams is observed to increase with increase in percentage of fibres. First crack initiated at a load, which is 88 to 101% of ultimate load for HFRC beams (as presented in Table No.4 and 5). Crack originated in shear zone near support and with further increase of load, new cracks developed and propagated in the direction towards the loading point. Fibers meeting in the crack path obstructed continuity of cracks. At higher loads, more diagonal cracks were developed. Majority of the beams failed in shear mode. Consistent improvement in first crack load and ultimate load was observed with increase in percentage of fibres.

Deflection of HFRC beams was more than conventional beams. For fiber content having shear span to depth ratio 0.43 of 0.9% steel and 0.3% PP fiber, the average increase in deflection was 20.99% in comparison with conventional deep beams. Whereas for higher fiber content of 2% steel and 0.3% PP fiber, this average increase in deflection was found to be 68%.

At permissible deflection (as per I.S. 456 for conventional beams), HFRC beams with Shear span to depth ratio 0.43 showed 23% more shear strength than conventional deep beams for combined 0.9% steel and 0.3 %PP fibre. This shows increased ductility and improved post cracking behaviour of beams due to inclusion of fibres.

- ii) Effect of shear span to depth ratio: In case of HFRC deep beams, the shear strength for shear span to depth ratio 0.43 is 16% more than that of shear span to depth ratio 0.56. It indicates that the shear strength of HFRC deep beams is inversely proportional to shear span to depth ratio.

X. CONCLUSION

Based on the experimental results, following conclusions are drawn:

1. From workability and compressive strength point of view, a mix with 0.9% hooked end steel fiber and 0.3% Polypropylene (PP) fiber is observed to be optimum mix without super plasticizer. Where as a mix with 1.2% steel fiber and 0.3% PP fiber is observed to be an optimum mix but with super plasticizer.
2. Workability of concrete mix decreases with addition of hooked end steel fibers. However it is observed that workability of concrete improves slightly due to addition of fibrillated PP fiber. Mixes beyond 1.2% upto 2% steel fiber content need super plasticizer for improvement in their workability.
3. Improvement in compressive strength of concrete due to addition of fiber is observed to be only marginal. In comparison with conventional concrete, improvement in compressive strength of HFRC mix with 1.2% steel & 0.3% PP fiber content is observed to 21.9 %.
4. It is observed that there is very good improvement in first crack load and ultimate load of HFRC deep beam due to addition of steel and polypropylene fibers. For optimum mix with 1.2% steel fiber and 0.3% PP fiber content, improvement in first crack load and ultimate crack load for shear span to depth ratio 0.43 found to be 16.7 % and 80% respectively in comparison with conventional concrete.
5. The shear strength of HFRC deep beams is inversely proportional to shear span to depth ratio.
6. Conventional shear reinforcement in deep beams can be completely replaced by using the optimum mixes found in this research work.

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Vol. 6, Issue 8, August 2017

REFERNCES

- 1) Clark, A.P., Diagonal tension in reinforced concrete beams. In *Journal Proceedings* (Vol. 48, No. 10, pp. 145-156), 1951.
- 2) Morrow, J. and Viest, I.M., Shear strength of reinforced concrete frame members without web reinforcement. In *Journal Proceedings* (Vol. 53, No. 3, pp. 833-869), 1957.
- 3) Manuel, R.F., Slight, B.W. and Suter, G.T., Deep beam behavior affected by length and shear span variations. *Am Concrete Inst Journal & Proceedings*, 68(12), 1971.
- 4) Smith, K.N. and Vantsiotis, A.S., May. Shear strength of deep beams. In *Journal Proceedings* (Vol. 79, No. 3, pp. 201-213), 1982.
- 5) Nojiri, M.I.T.S.Y. and Akiyama, H. Experimental studies on shear strength of large reinforced concrete beams under uniformly distributed load. *Concrete Library International*, 5, p.137, 1985.
- 6) Mindess, S. and Vondran, G., Properties of concrete reinforced with fibrillated polypropylene fibres under impact loading. *Cement and Concrete Research*, 18(1), pp.109-115, 1988.
- 7) Narayan, R. and Darwish, I.Y.S., Fiber concrete deep beams in shear. *Structural Journal*, 85(2), pp.141-149, 1988.
- 8) Mansur, M.A. and Ong, K.C.G., Behavior of reinforced fiber concrete deep beams in shear. *Structural Journal*, 88(1), pp.98-105, 1991.
- 9) Tan K. H., Kong F. K., Weng L. W., "High strength Concrete Deep and Short Beams: Shear Design Equations in North American and UK Practice", *ACI Structural Journal*, V. 95, No. 3, 1998.
- 10) Ramadevi, K. and Venkatesh Babu, D.L., Flexural Behavior of Hybrid (Steel-Polypropylene) Fibre Reinforced Concrete Beams. *European Journal of Scientific Research*, 70(1), pp.81-87, 2012.
- 11) Attarde, P.M. and Parbat, D.D., Shear strength and behavior of RC deep Beams. *International Research Journal of Engineering and Technology (IRJET)*, 2016.
- 12) Shaikh, M.S., Kulkarni, S.K., Patil, S.S. and Halkude, S.A., Effect of Hybrid Fibre Reinforcement In Concrete Deep Beams. *Imperial Journal of Interdisciplinary Research*, 3(2), 2017.