Effect of Hybridization on Reinforced Concrete Deep Beams in Flexure

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Abstract-This paper addresses the flexure and shear behavior of hybrid fibre reinforced concrete deep beamsConcrete is most widely used construction material in the world. The addition of fibers into concrete mass can dramatically increase the compressive strength, tensile strength, flexural strength, shear strength and impact strength of concrete.Hybrid Fiber Reinforced Concrete (HyFRC) is formed from a combination of different types of fibres, which differ in material properties, remain bonded together when added in concrete and retain their identities and properties. The combining of fibers, often called hybridization. In this paper the strength of concrete cubes, cylinders and beams cast using M 30 grade concrete and reinforced with flat crimped steel and polypropylene fibres are presented. The shear span to depth ratio of the beams used in this investigation was maintained as 1.66. The characteristic strength of concrete considered as fck30 MPa.The specimens incorporated steel and polypropylene fibres in the mix proportions of 0-0%,0-100 %,25-75%,50-50%,75-25%, 100-0% by volume at a total volume fraction of 1.0%.

Keywords - Deep Beam, Polypropylene Fibre, Flat Crimped Steel Fibre, Split Tensile Strength, Flexural Strength, Shear Strength

I. INTRODUCTION

1.1 General

Cement mortar and concrete made with Portland cement is a kind of most commonly used construction material in the world. These materials have inherently brittle nature and have some dramatic disadvantages such as poor deformability and weak crack resistance in the practical usage. Also their tensile strength and flexural strength is relatively low compared to their compressive strength.In order to improve the mechanical properties of concrete it is good to mix cement with fibre which have good tensile strength. Concrete is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented. The hybrid combination of metallic and non-metallic fibres can offer potential advantages in improving concrete properties as well as reducing the overall cost of concrete production

II. LITERATURE REVIEW

V.R.Rathi [10] presented the result of glass fiber reinforced moderate deep beam with and without stirrups. Six tee beams of constant overall span and depth 150mm, 200mm, 250mm, 300mm with span to depth (L/D) ratios of 4,3,2.4, & 2 and glass fibers of 12mm cut length and diameter 0.0125mm added at volume fraction of 0%, 0.25%, 0.50%, 0.75% & 1 %.The beams wear tested under two point loads at mid span. The results showed that the addition of glass fiber significantly improved the compressive strength, split tensile strength, flexural strength, shear stress and ductility of reinforced moderate deep beam without stirrups.
M.V. Krishna Rao [11] Presented the behavior of deep beams is different from that of shallow beams in which the bending stress distribution is linear across the depth and the shear failure is ductile. He also addresses the flexure and shear behaviour of polypropylene fibre reinforced fly ash concrete (PFRFAC) deep beams. The shear span to depth ratio of the beams used in these investigations was maintained as 2.0. The variables of study include the Characteristic strength of concrete, fck (15.0 MPa, 20.0 MPa, and 25.0 MPa) and polypropylene fibre (Recron 3s) content (0%, 0.5% and 1%). The test results indicate that compressive strength of concrete

increases with the increasing percentage of fibre. There has been a significant increase in flexural and shear strengths of PFRFAC, in all the mix proportions, as fibre content increased from 0% to 1.0%. However, the ultimate failure was observed to be gradual in all the beams.

This paper addresses the flexure and shear behavior of hybrid fibre reinforced concrete deep beam in which effective span to depth ratio was maintained as 1.66.The load deflection response of the beams with varying fibre content is investigated. Also mechanical properties of HyFRC were calculated i.e compressive strength and split tensile strength for different fibre proportions. The variables considered in this study include fibre content (steel and polypropylene %) i.e 0-0%,0-100%,25-75%,50-50%,75-25%,100-0%.

III. SELECTION OF INGREDIENTS AND MATERIALS

3.1 Material Properties

3.1.1 Cement

After reviewing all requirements 53 grade Ultra tech ordinary Portland cement is used throughout experiment. Cement is tested in laboratories and test results are as follows:

Table- 3.1 Cement properties

Sr No	Description of Test	Results
1.	Fineness of cement (residue on IS sieve No.90 micron)	3 %
2.	Specific Gravity	3.15
3.	standard consistency of cement	29%
4.	Setting time of cement a) Initial setting time b) Final setting time	 100 minute 293 minute
5.	Soundness test of cement (with Le-Chatelier'smould)	1.7 mm
6.	Compressive strength of cement a) 3 days b) 7 days	 25.98 N/mm^2 37.1 N/mm^2

3.1.2 Fine Aggregate (Sand)

River sand of PravaraRiver is used as a fine aggregate

Table-3.2 Physical Properties of Fine Aggregates (Sand)

Sr. No	Property	Results
1	Particle Shape, Size	Round 4.75 mm down
2	Fineness Modulus	3.17
3	Silt Content	2 %
4	Specific Gravity	2.65
5	Bulk Density	1793 kg/m^3
6	Surface Moisture	Nil
7	Water absorption	1 %

3.1.3 Coarse Aggregate

Locally available crushed stone aggregates with size 5mm to 12.5 mm and of maximum size 20 mm are used. The test results are as follows:-

Table-3.3 Physical Properties of coarse Aggregate

Sr No	Property	Results
1	Particle Shape, Size	Angular, 20mm, 10mm down
2	Fineness Modulus of 20 mm aggregates	7.4
3	Specific Gravity	2.68
4	Water Absorption	0.6%
5	Bulk density of 20mm aggregates	1603 kg/m^3
6	Surface moisture	Nil

3.2 Physical Properties of Flat Crimped Steel Fibers

Material Purchase: M&J International E, Hatkesh industrial Estate, Mira Bhayander Road, Mira Road (East) Mumbai.

Table-3.4 Physical properties of steel fibers (supplied by manufacturer)

Sr. No	Property	Values
1.	Diameter	0.55 mm
2.	Length of fiber	25mm to 50mm
3.	Width	2 to 2.5 mm
4.	Average aspect ratio	40 to 90
5.	Deformation	Continuously deformed circular segment
6.	Tensile Strength	400 to 600Mpa
7.	Specific Gravity	7.8
8.	Bond Factor	1

3.3 Properties of Polypropylene Fibers

The material recruitment is done from “Dolphin Floats” situated at Bhosari M.I.D.C. Pune.It is used at 0.9 kg per m^3 of concrete (minimum).

Table -3.5Physical Properties of polypropylene fibers

Sr. No	Properties	Remark
1	Length	12 mm
2	Construction	Fibrillated
3	Melting Point	165^0 C
4	Absorption	Nil
5	Elongation	15%

IV. RESULT AND DISCUSSION

In present study cube compression test, split tensile test, flexure and shear test on beams on plain and varying hybridization ratio of steel and polypropylene fibres reinforced concrete at 1% fibre volume fraction by volume of concrete are carried out.The experimental results and discussion for various test results are described below.

4.1 Compressive strength

Cube moulds of 150mm × 150 mm ×150mm werecasted for finding the compressive strength of HyFRC.

Table -4.1 Compressive strength test on cubes at 28 Day

Sr No	Hybridization Ratio (steel-poly %)	Load (N)	Compressive strength (MPa)	Average Compressive Strength (MPa)
1	0-0%	741×10^3	32.90	33.28
2		761×10^3	33.79	
3		738×10^3	32.76	
4		758×10^3	33.65	
5	0-100%	776×10^3	34.45	35.32
6		809×10^3	35.92	
7		790×10^3	35.11	
8		806×10^3	35.79	
9	25-75%	816×10^3	36.23	35.95
10		841×10^3	37.34	
11		861×10^3	38.23	
12		721×10^3	32.01	
13	50-50%	876×10^3	38.89	37.2
14		851×10^3	35.48	
15		825×10^3	37.78	
16		827×10^3	36.725	
17	75-25%	901×10^3	40.00	39.92
18		870×10^3	38.63	
19		942×10^3	41.82	
20		883×10^3	39.21	

21	100-0%	800×10^3	35.52	35.48
22		781×10^3	34.68	
23		823×10^3	36.54	
24		792×10^3	35.16	

4.2 Split Tensile strength

Cylindrical mould of 150 mm diameter and 300mm long are used for casting the specimen for split tensile strength test. Table No.4.2 shows the result of Split Tensile strength of concrete at 28 days for different hybridization ratio.

Table-4.2 Split Tensile strength test on cubes at 28 Days

Sr No	Hybridization Ratio (steel-poly %)	Load (N)	Split tensile strength (MPa)	Average Split tensile strength (MPa)
1	0-0%	232×10^3	3.27	3.46
2		244×10^3	3.44	
3		263×10^3	3.71	
4		242×10^3	3.41	
5	0-100%	261×10^3	3.68	3.68
6		252×10^3	3.55	
7		271×10^3	3.82	
8		260×10^3	3.67	
9	25-75%	269×10^3	3.79	3.87
10		282×10^3	3.98	
11		281×10^3	3.96	
12		265×10^3	3.74	
13	50-50%	311×10^3	4.39	4.38
14		322×10^3	4.54	
15		318×10^3	4.48	
16		293×10^3	4.12	
17	75-25%	321×10^3	4.53	4.57
18		338×10^3	4.77	
19		316×10^3	4.46	
20		321×10^3	4.53	
21	100-0%	361×10^3	5.09	4.9
22		359×10^3	5.06	
23		339×10^3	4.78	
24		331×10^3	4.67	

4.3 Flexural strength

In flexure test, All beams are tested under two-point loading in universal testing machine of 100 tonne capacity Table No.4.3 shows the result of Flexural strength of HyFRC deep beam for different hybridization ratio of steel and polypropylene fibre.

Table- 4.3 Test Result for flexure

% of fiber (St-Pol)	Beam No	Load at 1st crack W_w(kN)	Ultimate Load W(kN)	Avg. Ultimate Load W (kN)	P=W+2.25 (kN)	BM_E (atcentre) kN.m	F_b=Flexure strength= PL/bd^2 N/mm^2
0-0	B_1	196	495	491.5	493.75	82.57	9.143
	B_1	187	488				
0-100	B_2	200	511	518	520.25	86.98	9.63
	B_2	210	525				
25-75	B_3	225	541	533	535.25	89.48	9.9120
	B_3	231	534				
50-50	B_4	239	554	556	558.25	93.32	10.33
	B_4	242	558				
75-25	B_5	281	590	594	596.25	99.65	11.04
	B_5	278	598				
100-0	B_6	256	569	570	572.25	95.65	10.59
	B_6	268	571				

4.4 Test result for shear

In shear test, All beams are tested under two-point loading in universal testing machine of 100 tonne capacity Table No.4.4 shows the result of shear strength of HyFRC deep beam for different hybridization ratio of steel and polypropylene fibre.

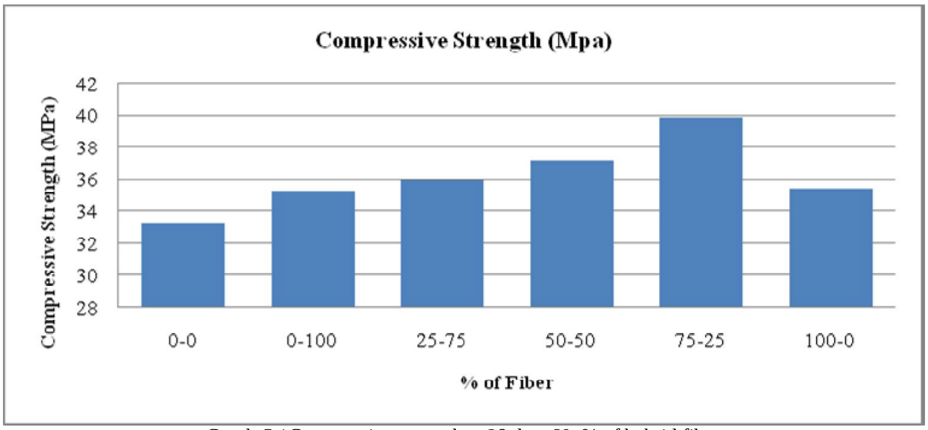
Table- 4.4 Test results for shear

% of fiber (St-Pol)	**Beam No**	**Load at 1st crack W_w(kN)**	**Ultimate Load W(kN)**	**Avg. Ultimate Load W (kN)**	**P=W+2.25 (kN)**	**SF_A kN**	**Shear strength N/mm^2**
0-0	B_1	230	544	547.5	549.75	276	3.066
	B_1	245	551				
0-100	B_2	261	563	567	569.25	285.75	3.166
	B_2	265	571				
25-75	B_3	273	578	584.5	589.75	294.5	3.2722
	B_3	278	591				
50-50	B_4	285	598	600	602.25	302.25	3.358
	B_4	298	602				
75-25	B_5	329	646	642.5	644.75	323.5	3.59
	B_5	335	639				
100-0	B_6	315	613	610.5	612.75	307.5	3.4166
	B_6	319	608				

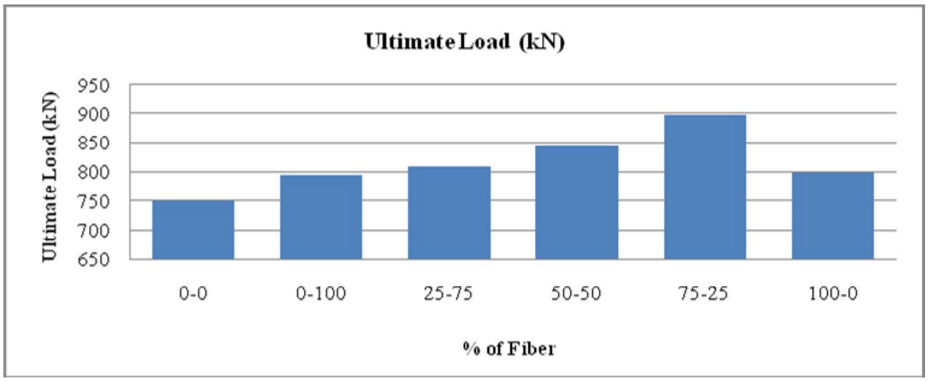
V. DISCUSSION

5.1 Results for Compressive strength test

The results of compressive strength at 28 days show that the HFRC with 75-25 % (steel and polypropylene) hybridization ratio is maximum as compared with respect to normal concrete.



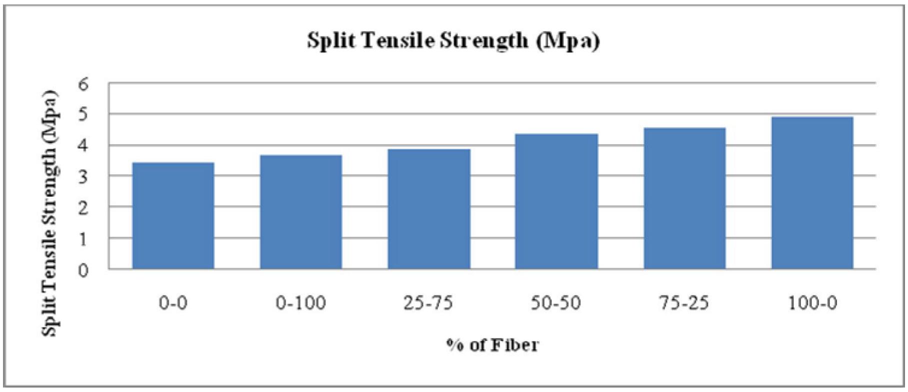
Graph-5.1Compressive strength at 28 days Vs % of hybrid fibre



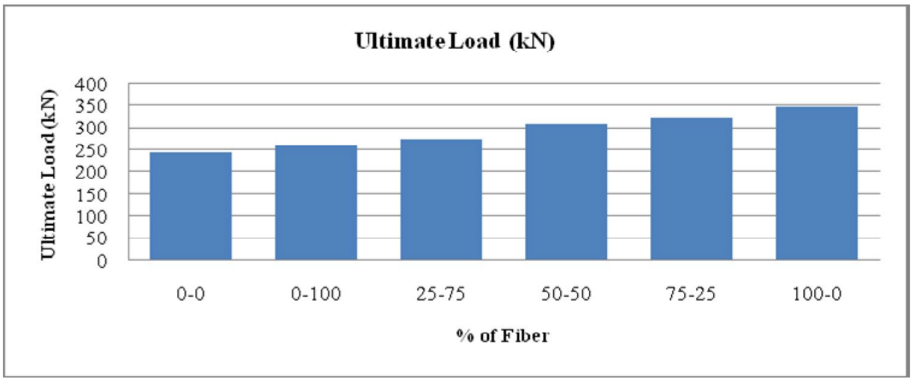
Graph- 5.2 Ultimate loads for Compressive strength test at 28 days Vs % of hybrid fibre content

5.2 Results for Split Tensile strength test

The increase in split tensile strength due to incorporation of steel fibre is greater than polypropylene fibre. High modulus of elasticity of steel fibre makes the concrete more ductile. Tensile strength of ductile material is higher than brittle materials. Therefore split tensile strength at 100-0 % (steel – poly) shows greater than plain concrete and other combination of hybridization ratio.



Graph- 5.3 Results for split tensile strength test on cylindrical mould at 28 days

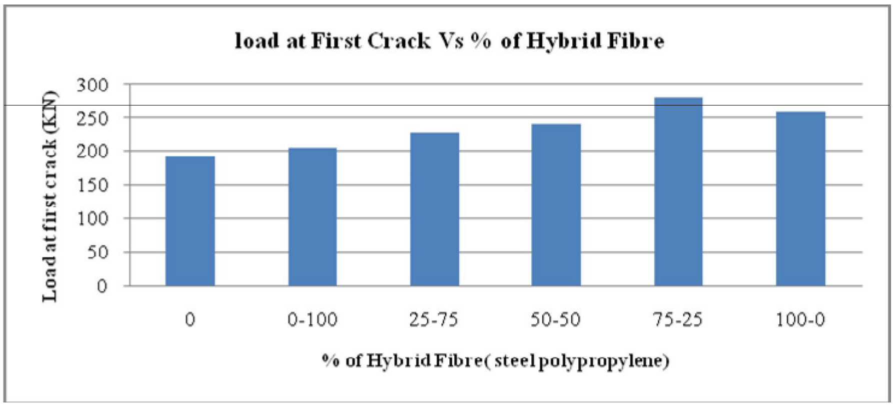


Graph- 5.4 Ultimate loads for split tensile strength test at 28 days Vs % of hybrid fibre content

5.3 Flexure strength

5.3.1 Load at first crack in flexure

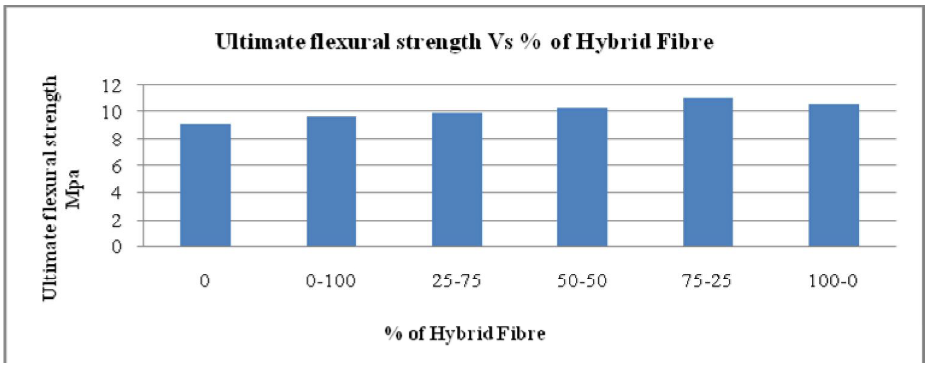
The variation in load at first crack with percentage of hybrid fibre is shown in graph 5.5 for75-25 % hybridization ratio of steel and polypropylene fibre in reinforced concrete deep beam the load at first crack is greater than remaining fibre content.



Graph-5.5 Variation of load @ first crack in flexure with percentage of hybrid fibre(steel-polypropylene)

5.3.2 Ultimate flexural strength

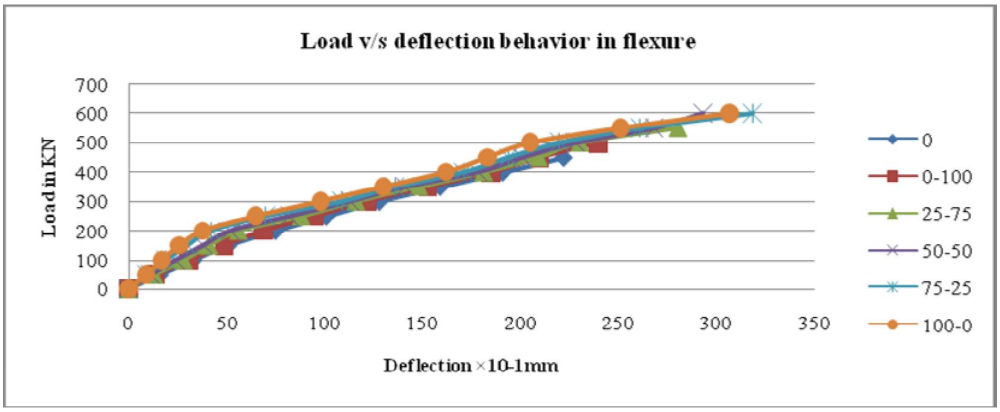
Graph 5.6 depicts the variation of ultimate flexural strength with percentage of hybrid fibrecontent.Forfibre percentage 75-25 % the flexural strength is higher than all fibrecontent.The flexural strength for 75-25 % (steel and polypropylene fibre) is increased by 17.09 % than plain reinforced concrete deep beams and all other fibre proportions.



Graph-5.6 Variation of flexural strength with percentage of hybrid fibre(steel-polypropylene)

5.3.3 Load deflection behavior in flexure

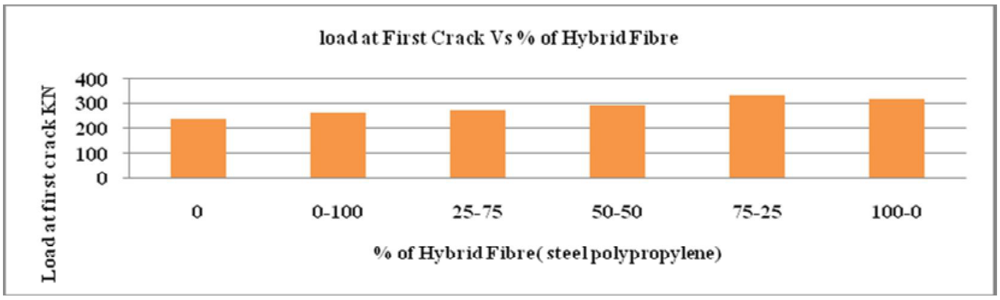
Graph 5.7 depicts the variation of deflection with load in flexure of HyFRC deep beams. Hybridfibre content is varied in the range(steel-polypropylene fibre) 0-0%,0-100 %,25-75%,50-50%,75-25%, 100-0% .The load deflection curve is observed to be linear upto first crack and nonlinear beyond that. An increase in ultimate deflection is noticed for HyFRC beams as compared to those of plain concrete.



Graph-5.7 Loadv/s deflection behaviors in flexure

5.3.4 Load at first crack in shear

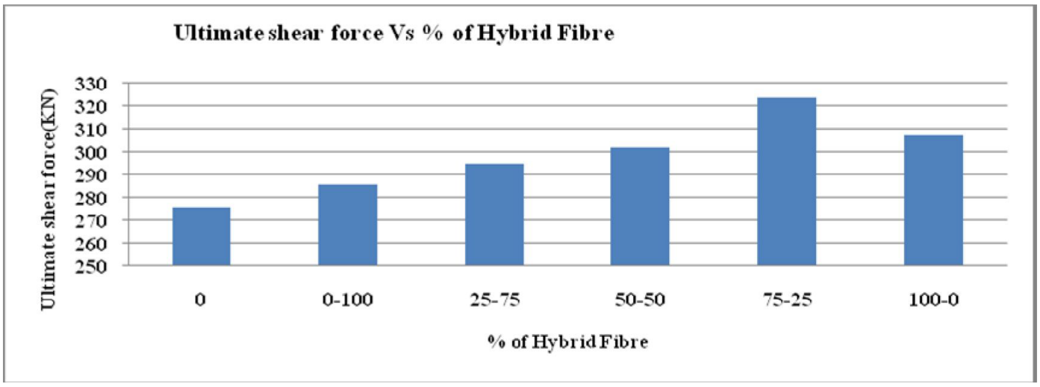
The variation in load at first crack with percentage of hybrid fibre is shown in graph 5.10for75-25 % hybridization ratio of steel and polypropylene fibre in reinforced concrete deep beam the load at first crack is greater than remaining fibre content.



Graph- 5.8 Variation of load @ first crack in shear with percentage of hybrid fibre(steel-polypropylene)

5.3.5 Ultimate shear force

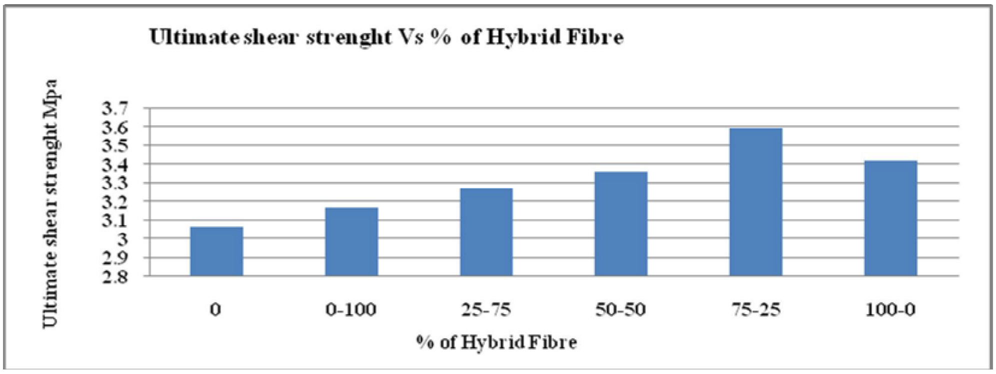
Graph 5.9 depicts the variation of ultimate shear force with percentage of hybrid fibre. For hybridization ratio 75-25 %(steel–polypropylene) the shear force is maximum than remaining fibrecontent.The shear force for 75-25 % fibre content is increased by 15.94% than plain reinforced concrete deep beams.



Graph- 5.9 Variation of Ultimate shear force with percentage of hybrid fibre(steel-polypropylene)

5.3.6 Ultimate shear strength strength

Graph 5.10 depicts the variation of ultimate shear strength with percentage of hybrid fibrecontent. Forfibre percentage 75-25% the shear strength is higher than all fibrecontent. The shear strength for 75-25 % (steel and polypropylene fibre) is increased by 18% than plain reinforced concrete beam.



Graph- 5.10 Variation of shear strength with percentage of hybrid fibre(steel-polypropylene

VI. CONCLUSIONS

Based on results of experimental investigation's conducted on HyFRCcubes, cylinders and beams the following conclusion are drawn,

1) Compressive strength of HyFRC after 28 days for 75-25% (steel-polypropylene) hybridization ratio is maximum. It is increased by 19.95% with respect to normal concrete (i.e. Hybridization ratio 0-0%). At 28 days Compressive strength of SFRC (i.e. Hybridization ratio 100-0 %) is increased by 6.61% with respect to normal concrete & compressive strength of PPFRC (i.e. Hybridization ratio 0-100 %) increased by 6.21% with respect to normal concrete.

2) Split Tensile Strength of HyFRC Concrete for 28 Days Increases with Increasing Contribution of Steel Fiber in hybridization ratio. Split tensile strength of SFRC (i.e. Hybridization ratio 100-0%) is maximum. split tensile strength of SFRC (i.e. Hybridization ratio 100-0%) increases 41.61% & Split tensile strength of PPFRC (i.e. Hybridization ratio 0-100%) increases 6.35% with respect to normal concrete respectively.3) Flexural strength of HyFRC for 75-25% &100-0% after 28 days is nearly same. Flexural strength of HyFRC with75-25% hybridization ratio and SFRC i.e. hybridization ratio 100-0% is increases 20.78% &15.86% respectively than normal cement concrete. Flexural strength of PPFRC (i.e. Hybridization ratio 0-100%) increased by 5.36% with respect to plain reinforced concrete deep beams.

4) The Load at first crack for shear of HyFRC (75-25%) deep beams is maximum than plain reinforced concrete deep beam having steel and polypropylene fibre content (0-0%) and different hybrid fibre content.

5)The ultimate shear strength of hybrid fibre reinforced concrete deep beam having (75-25%)steel and polypropylene fibre is increased 17.09 % than plain reinforced concrete deep beams having steel and polypropylene fibre content (0-0%).

6) The Load at first crack for flexure of HyFRC (75-25%) deep beam is maximum than plain reinforced concrete deep beam having steel and polypropylene fibre content (0-0%) and different hybrid fibre content.

7) The ultimate flexural strength of hybrid fibre reinforced concrete deep beam having (75-25%)steel and polypropylene fibre is increased 20.74 % than plain reinforced concrete deep beam having steel and polypropylene fibre content (0-0%).

8) The failure of hybrid fibre reinforced concrete deep beams was observed to be more ductile and gradual in comparison to plain reinforced concrete deep beams.

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