FLEXURAL BEHAVIOR OF HYBRID FIBER REINFORCED CONCRETE DEEP BEAM AND EFFECT OF STEEL & POLYPROPYLENE FIBER ON MECHANICAL PROPERTIES OF CONCRETE

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ABSTRACT

Concrete is most widely used construction material in the world. Fiber reinforced concrete (FRC) is a concrete in which small and discontinuous fibers are dispersed uniformly. The fibers used in FRC may be of different materials like steel, carbon, glass, polypropylene etc. The addition of these fibers into concrete mass can dramatically increase the compressive strength, tensile strength, flexural strength and impact strength of concrete. The effect of addition of mono fibers and hybrid fibers on the mechanical properties of concrete mixture is studied in the present investigation. In this paper hybrid fibres with crimped steel and polypropylene were used in concrete matrix to study its improvements in strength and durability properties. This paper addresses the compressive strength, split tensile strength, flexure behavior of hybrid fibre reinforced concrete deep beams. The shear span to depth ratio of the beams used in this investigation was maintained as 2. The specimens incorporated steel and polypropylene fibres in the mix proportions of 00-00%, 0-100%, 25-75%, 50-50%, 75-25% and 100-00% by volume at a total volume fraction of 1.0%.

Keywords: Deep Beam, Polypropylene Fibre, Flat Crimped Steel Fiber, Split Tensile Strength, Flexural Strength.

I. INTRODUCTION

Portland cement is a very commonly used construction material. Concrete made with this cement has certain characteristics. It is relatively strong in compression but weak in tension and tends to be brittle. Because of the load and environmental changes, a micro crack appears in cement products. Therefore cement based materials have low tensile strength and cause brittle failure. 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. The weakness in tension can be overcome by the use of sufficient volume fraction of certain fibres. In order to improve the mechanical properties of concrete it is good to mix cement with fibre which have good tensile strength. Adding fibres to concrete greatly increases the toughness of the material. The use of fibres also alters the behavior of the fibre matrix composite after it has cracked, thereby improving its toughness.

Fibre Reinforced Concrete is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented. Fibres include steel fibres, glass fibres, synthetic fibres and natural fibres each of which lend varying properties to the concrete. In addition, the character of fibre reinforced concrete changes with varying concretes, fibre materials, geometries, distribution, orientation, and densities. In a hybrid, two or more different types of fibres are rationally combined to produce a composite that derives benefits from each of the individual fibres.

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. Basically fibers can be divided into following two groups

(i) Fibers whose moduli are lower than the cement matrix such as cellulose, nylon, polypropylene

(ii) Fibres with higher moduli than the cement such as asbestos, glass, steel etc.

II. REVIEW OF LITERATURE

V.R.Rathi [1] 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 [2] 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 behavior of hybrid fibre reinforced concrete deep beam in which effective span to depth ratio was maintained as 2.Also mechanical properties of concrete was calculated i.e compressive strength and split tensile strength for different fibre proportions. The variables considered in this study include fibre content.

III. EXPERIMENTAL STUDY

3.1 Selection of Ingredients and Materials

The main ingredients of concrete are as follows:

1) Cement 2) Fine aggregate 3) Coarse aggregate 4) Water 5) Steel and Polypropylene fibres

3.2 Material Properties

3.2.1 Cement

Among The Chemical Constituents of Cement, the Most Important Ones Are C_3A (Tricalcium Aluminate), C_3S (Tricalcium Silicate) and C_2S (Dicalcium Silicate). The C_3A Portion Of Cement Hydrates More Rapidly, Thereby Reducing The Workability Of Fresh Concrete. It also absorb the chemical admixtures quickly which leads to reduction in availability of those admixtures for comparatively slower setting components of cements viz., C_2S and C_3S. This Further Affect the Workability of Fresh Concrete and Also It's Rate of Retention of Workability.

Regarding Particle Size Distribution It May Be Noted That Final Particle Hydrate Faster than Coarser Particle and Hence Contribute More to Early age strength concrete. However at the same time the faster the rate of hydration may lead to quicker loss of workability. Due to rapid and large release of heat of hydration. However with reference to standard FAC test methods for properties of cement such as standard consistency, setting time, heat of hydration etc. 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 Initial setting time Final setting time	 100 minute 293 minute
5.	Soundness test of cement (with Le-Chartelier's mould)	1.7 mm
6.	Compressive strength of cement 3 days 7 days	 25.98 N/mm^2 37.1 N/mm^2

3.2.2 Fine Aggregate (Sand)

Locally available sand, from Pravara River is used as fine aggregate, it confirms to zone II of IS 383-1983 and other necessary properties are given in table.

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	2.63
5	Bulk Density	1793 kg/m^3
6	Surface Moisture	Nil

3.2.3 Coarse Aggregate

Locally available crushed stone aggregates with 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
2	Fineness Modulus of 20 mm aggregates	6.8
3	Specific Gravity	2.77
4	Water Absorption	1.02%
5	Bulk density of 20mm aggregates	1603 k/mm^3
6	Surface moisture	Nil

3.2.4 Flat Crimped Steel Fibers

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

Length =25mm to 50mm

Aspect Ratio=40 to 90

Diameter (d) =0.55

Width=2 to 2.5 mm

Tensile strength=400 to 600Mpa

Photo 3.1: Flat Crimped Steel Fiber

3.2.5 Properties of Polypropylene Fibers

Fibrillated mesh fiber is a chemically surface treated 100% virgin high tenacity fibrillated propropylene mesh fiber based concrete additive and is available in graded length. It provides micro reinforcement to concrete. The material recruitment is done from “Dolphin Floats” situated at Bhosari M.I.D.C. Pune.78

It is used at 0.9 kg per m^3 of concrete (minimum) shortcrete complies with ASTM C1116 and ACT committee report 544-1R.

Photo No. 3.2: Polypropylene Fibre

Table 3.4: Physical 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%

3.2.6 Design Mix Proportion

Table: 3.5 Quantity of materials per cubic meter of concrete (M30 Grade Concrete-IS 10262-2009)

Material	Portion by weight	Weight in kg/m^3
Cement	1	413.3
F.A.	1.61	669.45
C.A	2.789	1152.83
W/C	0.45	0.45

3.3 Testing

3.3.1 Compressive Strength

Cube mould of 150mm × 150 mm ×150mm were casted for finding the compressive strength of HFRC.In which hybrid fibre with different hybridization ratio were added in concrete and compressive strength of cube was calculated by using compression testing machine. Total 24 No. of cube casted. Table No.3.7 shows the result of compressive strength of concrete for different hybridization ratio.

Table 3.6 Compressive strength test on cubes at 28 Day

<table>
<tr><th>Sr No</th><th>Hybridization Ratio (steel-poly %)</th><th>Load (N)</th><th>Compressive strength (MPa)</th><th>Average Compressive Strength (MPa)</th></tr>
<tr><td>1</td><td rowspan="4">0-0%</td><td>741×10^{3}</td><td>32.90</td><td rowspan="4">33.28</td></tr>
<tr><td>2</td><td>761×10^{3}</td><td>33.79</td></tr>
<tr><td>3</td><td>738×10^{3}</td><td>32.76</td></tr>
<tr><td>4</td><td>758×10^{3}</td><td>33.65</td></tr>
</table>

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	

3.3.2 Split Tensile Strength

Cylindrical mould of 150 mm diameter and 300mm long are used for casting the specimen for split tesile strength test. Total 24 No .of cylindrical mould were casted with varying hybridization ratio of steel and polypropylene fibre.

Table No.3.8 shows the result of Split Tensile of concrete for different hybridization ratio.

Table: 3.7 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	

3.3.3 Flexural Strength

In flexure test,the beam specimen is placed in the machine in such a manner that the load is applied to the upper most surface as cast in the mould .All beams are tested under two-point loading in universal testing machine of 100 tonne capacity Table No.3.8 shows the result of Flexural strength of HFRC deep beam for different hybridization ratio of steel and polypropylene fibre.

The flexural strength is calculated from the formula

$F_b=PL/bd^2$

Where,

P=Applied load at failure,

d=depth of specimen,

b=breadth of specimen,

L=Length of specimen.

Table: 3.8 Flexural strength tests on beams at 28 Days

Sr No	Fck	Hybridization Ratio (steel-poly %)	Load (N)	Flexural strength (MPa)	Average Flexural Strength (MPa)
1	30	0-0%	38.21×10^3	2.26	2.29
2			39.60×10^3	2.34	
3			40.32×10^3	2.38	
4			37.42×10^3	2.21	
5	30	0-100%	39.55×10^3	2.34	2.48
6			41.62×10^3	2.46	

7			43.81×10^3	2.59	
8			42.95×10^3	2.54	
9	30	25-75%	44.68×10^3	2.65	2.70
10			43.59×10^3	2.58	
11			47.85×10^3	2.83	
12			46.65×10^3	2.76	
13	30	50-50%	47.90×10^3	2.83	2.87
14			48.35×10^3	2.86	
15			49.34×10^3	2.92	
16			48.91×10^3	2.89	
17	30	75-25%	54.62×10^3	3.23	3.13
18			50.35×10^3	2.98	
19			53.85×10^3	3.19	
20			52.81×10^3	3.13	
21	30	100-0%	46.36×10^3	2.74	2.83
22			47.90×10^3	2.84	
23			48.34×10^3	2.86	
24			49.31×10^3	2.92	

IV. RESULT AND DISCUSSION

4.1 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. Due to hybridization of steel and polypropylene (75-25%) mix provide better response to arrest micro and macro cracks hence improve the compressive strength of concrete as compared to plain concrete and all other combination of hybridization ratio.

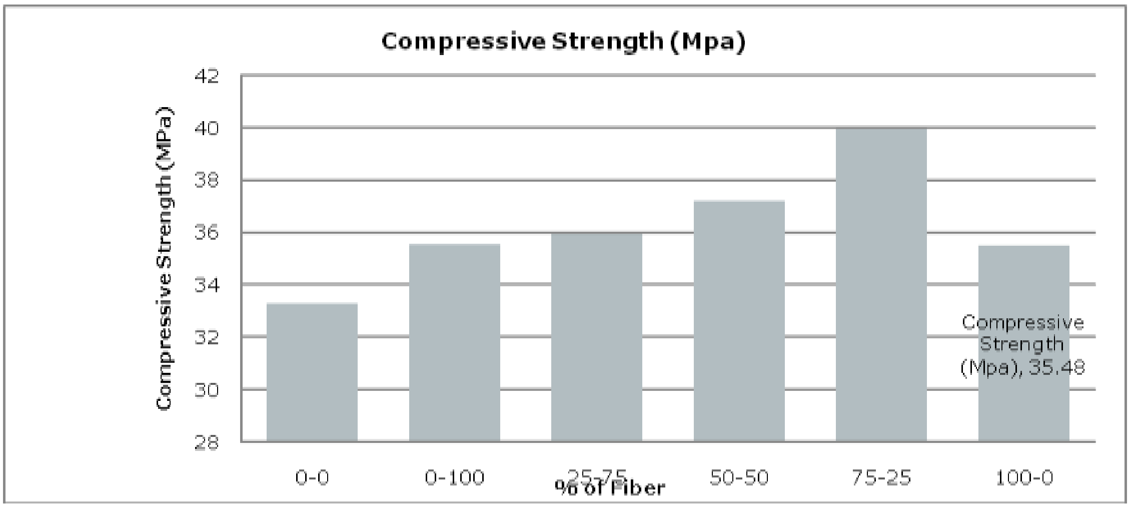

Fig. 4.1 Results for Compressive Strength Test On Cubes at 28 Days

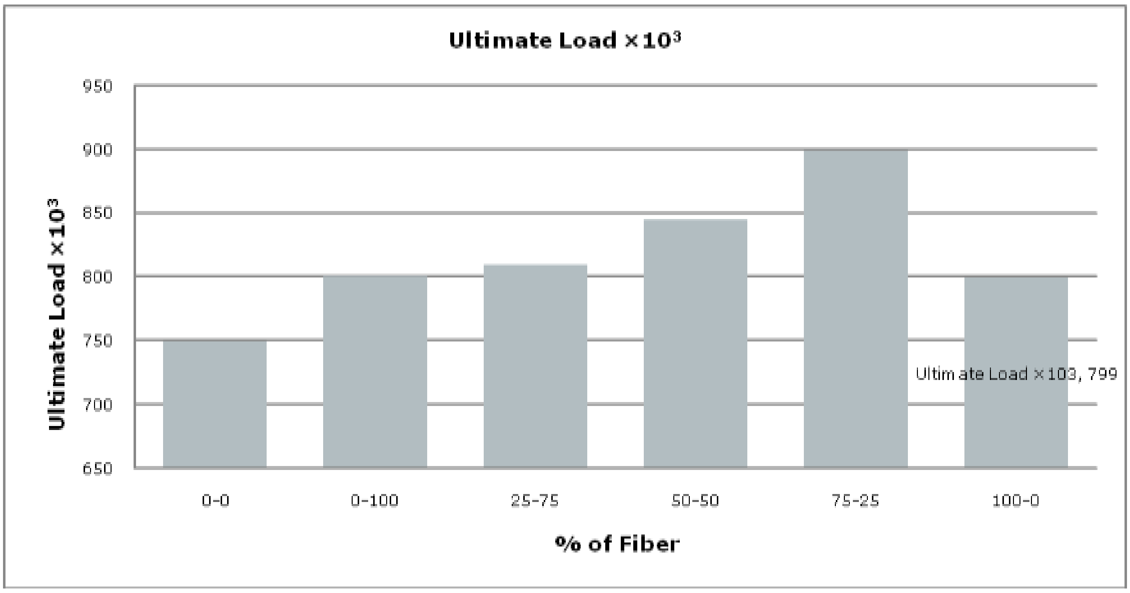

Fig: 4.2 Results for Compressive Strength Test on Cubes at 28 Days

4.2 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 gradual increase in % of steel fibres for different hybridization ratio split tensile strength of concrete also increases. Therefore split tensile strength at 100-0 % (steel – poly) shows greater than plain concrete and other combination of hybridization ratio.

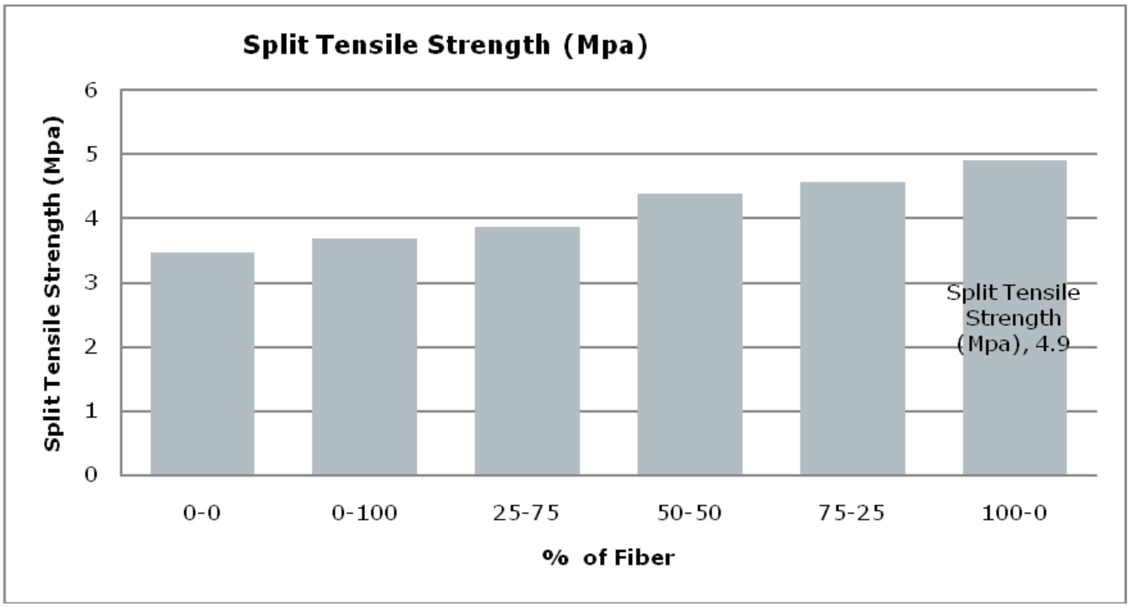

Fig.4.3 Results for Split Tensile Strength Test On Cylindrical Mould at 28 Days

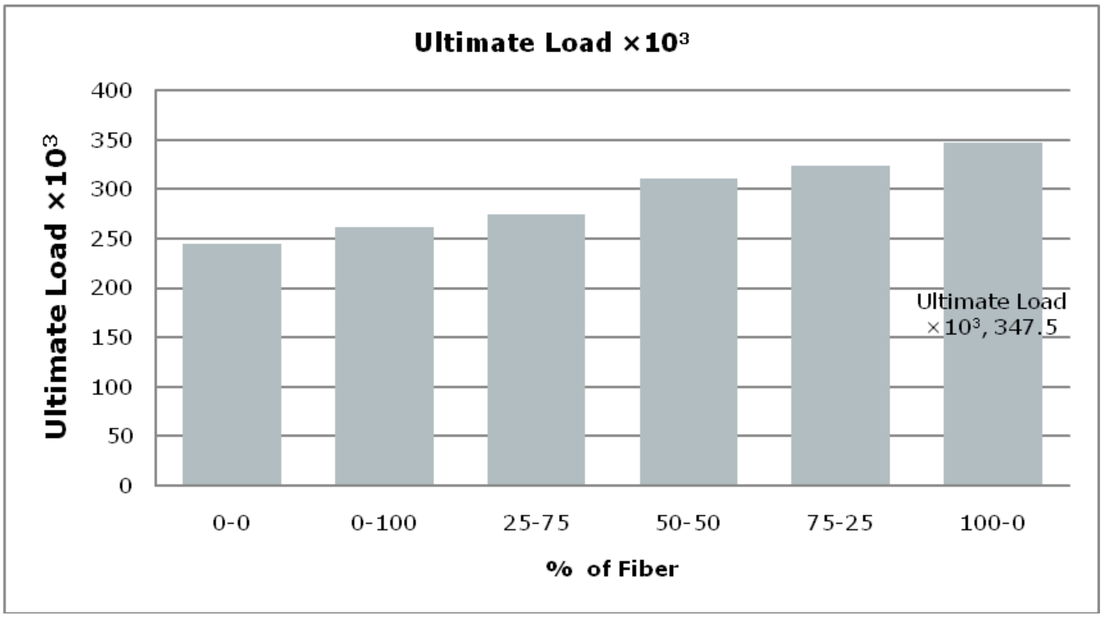

Fig.4.4 Results for Split Tensile Strength Test On Cylindrical Mould at 28 Days

4.3 Results for Flexural Strength Test

The results of flexural strength test are given in table 3.9.Fig.4.5 and Fig.4.6 shows the graphical representation for the variation of the average flexural strength for plain concrete mix and concrete mixes containing different hybridization ratio of steel-polypropylene fibres at volume fraction 1% by volume of concrete. Flexural strength of concrete increases with increase in steel fibre percentage in specimen. It is also seen that the addition of polypropylene fibre increase the flexural strength. Fig.4.5 shows that the flexural strength of beam specimen is maximum for 75-25% (steel-poly) fibres than other combination of hybridization ratio.

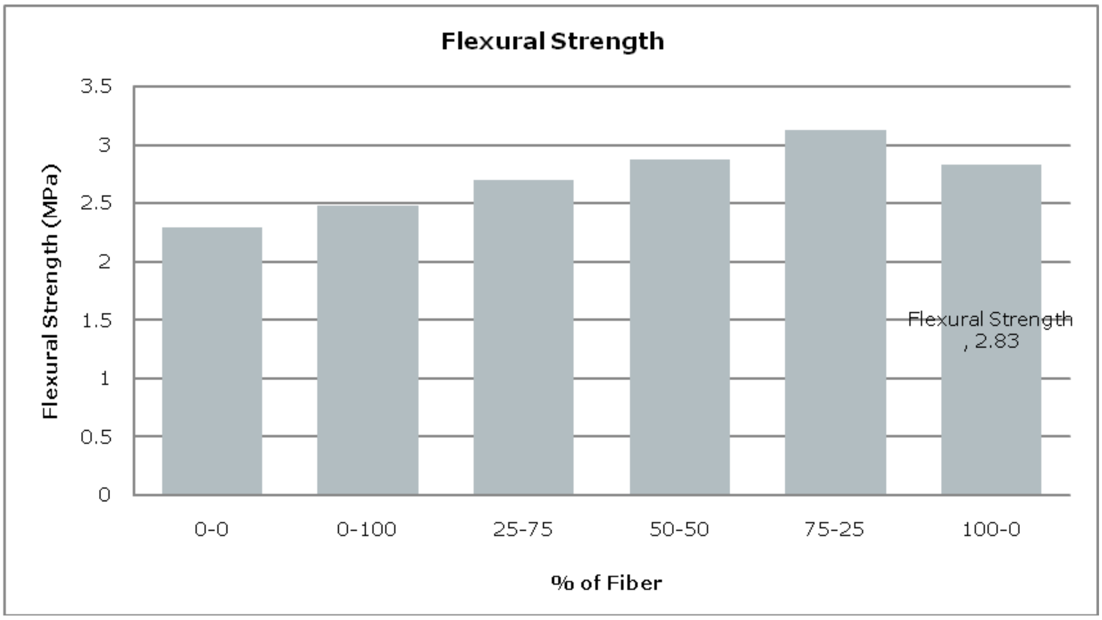

Fig. 4.5 Results for Flexural Strength Test On Beams at 28 Days

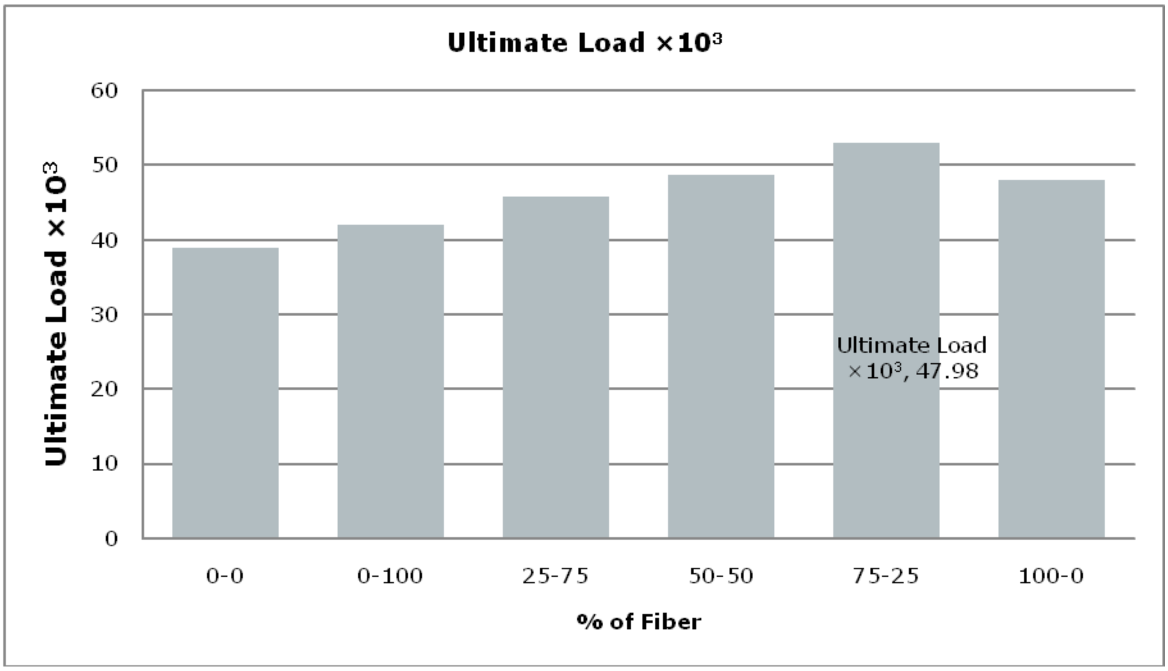

Fig. 4.6 Results for Flexural Strength Test On Beams at 28 Days

V. CONCLUSION

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 50-50% & SFRC i.e. 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 36.68% & 23.58 % respectively than normal cement concrete. Flexural strength of PPFRC (i.e. Hybridization ratio 0-100%) increased by 8.29% with respect to normal concrete.

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