FLEXURAL BEHAVIOUR OF HYBRID STEEL BASALT FIBRE REINFORCED CONCRETE

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Abstract- *Plain concrete is weak in tension and consists numerous micro-cracks. On application of the load, the micro-cracks begin to propagate in the concrete matrix. The addition of randomly spaced discontinuous fibres help in restricting the propagation of the micro-cracks and macro-cracks. Fibres also improve the mechanical properties of plain concrete such as, resistance to impact, resistance to fracture and resistance to dynamic loads [8]. In the modern era, hybridization technology has also been an area of interest to researchers. Hybridization is the process of combining fibers with different characteristics, such as, length, diameter, and aspect ratio, modulus of elasticity, material type and tensile strength, to produce a unique composite that derives benefits from each of the individual fibers [4]. In this study, hybrid fibre reinforced concrete is prepared by combining basalt and steel fibers together according to different volume fraction and aspect ratio. Different experiments were carried out to determine the flexural strength, toughness index and load deflection behaviour of hybrid fibre reinforced beams. For comparison steel fibre reinforced concrete beams and basalt fibre reinforced concrete beams were also casted. All these beams were compared with control beam consisting of no fibres.*

Key Words: Hybrid fibre reinforced concrete beam, Steel fibre, Basalt fibre.

1. INTRODUCTION

Reinforced concrete is increasingly used widely in civil engineering, but the workability, corrosion resistance and crack resistance of concrete have always been the problems difficult to resolve in the engineering industry. Ordinary plain concrete is weak in tension and contains numerous micro-cracks. The micro-cracks begin to propagate in the matrix when load is applied. The addition of randomly spaced discontinuous fibres help in restricting the propagation of the micro-cracks and macro-cracks. Fibres also improve the mechanical properties of plain concrete such as, resistance to impact, resistance to fracture and resistance to dynamic loads. In the present century, hybridization technology has also been an area of interest to researchers. Hybridization is the process of combining fibers with different characteristics, such as, length, diameter, aspect ratio, modulus of elasticity, material type and tensile strength, to produce a composite that derives benefits from each of the individual fibers. In this study, hybrid fibre reinforced concrete is prepared by combining the fibres of different characteristics such as material type, length, diameter, aspect ratio, modulus of elasticity, tensile strength to derive the benefits from individual fibres. Basalt and steel fibers were combined together according to different volume fraction and aspect ratio to form the hybrid fiber reinforced concrete. Different experiments were carried out to determine the flexural strength, load deflection behaviour and toughness of hybrid fibre reinforced beams. For comparison steel fibre reinforced concrete beams and basalt fibre reinforced concrete beams were also casted. All these beams were compared with control beam consisting of no fibres. Therefore, hybrid fibre reinforced concrete is the latest advancements in the construction industry.

2. EXPERIMENTAL PROGRAM

2.1 MATERIALS

Table 2 gives the details of material testing

Table-1 : Material Tests

Tests	Materials	Value obtained
Specific gravity	Cement(PPC)	3.15
Consistency limit	Cement(PPC)	33 %
Fineness	Cement(PPC)	10 %
Initial setting time	Cement(PPC)	45 min
Specific gravity	Coarse aggregate	2.69
Specific gravity	Fine aggregate	2.66

2.2 MIX PROPORTION

The mix design for M25 grade concrete have been chosen as per IS 10262:2009. The same mix proportions were used for all the specimens. In table 2 gives the details of mix proportion.

Table-2: Mix proportion for M25 grade concrete

Cement Kg/m³	Fine aggregate Kg/m³	Coarse aggregate Kg/m³	Water Kg/m³
441.97	706.15	1165.1	159.2

2.3 CASTING OF BEAM

The beam specimen dimensions were 1000mm x 150mm x 150mm with an effective span of 880mm. The beams are designed as singly reinforced beam with 3 nos. of 8mm diameter bars at the tension zone and 2 nos. of 6 mm diameter bars at the compression zone. Table 3 gives the specimen details. Two sets of beams each were cast for 1.5 % steel fibre content and 2 % basalt fibre content respectively. Three sets of beams each were cast for 1.5 % and 2 % hybrid fibre content. The details of specimens are given in table 3.

Table-3: Specimen details.

Sl No	Specimen designation	Mix	Percentage of fibre	Type of fibre
1	control	M25	0	-
2	SF 1.5	M25	1.5	steel
3	SF 2	M25	2	steel
4	BF 1.5	M25	1.5	basalt
5	BF 2	M25	2	basalt
6	HF 60-40 1.5	M25	1.5	steel, basalt
7	HF 70-30 1.5	M25	1.5	steel, basalt
8	HF 80-20 1.5	M25	1.5	steel, basalt
9	HF 60-40 1.5	M25	2	steel, basalt
10	HF 70-30 1.5	M25	2	steel, basalt
11	HF 80-20 1.5	M25	2	steel, basalt

2.4 TEST SETUP AND INSTRUMENTATION

The ultimate load carrying capacity of specimens were tested in UTM with 1000KN loading frame. The tests were carried out under three point loading condition as shown in Fig 4.

Fig-4: Test setup

3. RESULT AND DISCUSSIONS

3.1 Ultimate load in flexure

The ultimate loads obtained for the steel and basalt fibre reinforced concrete beams are shown in Fig 5. The ultimate loads obtained for hybrid fibre reinforced concrete beams are shown in Fig 6. The ultimate loads for steel and basalt fibre reinforced concrete beams are shown in Table 4. The ultimate loads for hybrid fibre reinforced concrete beams are shown in Table 5. From the results, it was found that the ultimate loads obtained for all the fibre reinforcement percentages of steel and basalt reinforced concrete beams were greater than the control beams of grade M25. Similarly, hybrid fibre reinforced concrete beams also had greater ultimate load compared to control beams. An increase of 25 % in the ultimate load was found for the hybrid fibre reinforced concrete beam at 2 % total fibre content consisting of 70 % steel fibre and 30 % basalt fibre in comparison with the M25 grade control beams. In general hybrid fibre reinforced beams were better compared to steel and basalt fibre reinforced concrete beams in case of ultimate loads in flexure. The reason may due to the hybridized effect of steel and basalt fibres thus attaining the strengths of individual fibres.

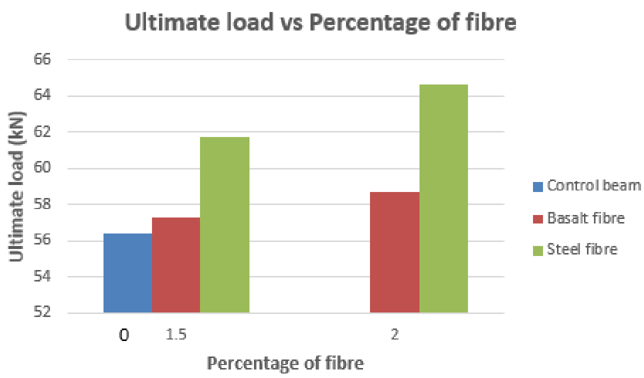

Fig-5: Ultimate loads for steel and basalt fibre reinforced concrete beams

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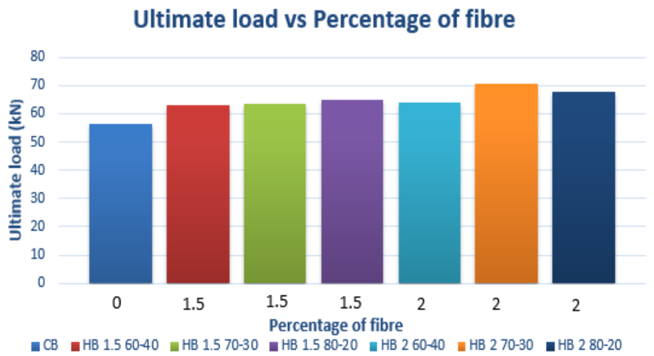

Fig-6: Ultimate loads for hybrid fibre reinforced concrete beams

Table-4 Test results

Sl .No	Type of Fibre	Fibre content	Ultimate load (kN)	Percentage increase in the ultimate load in comparison with control beam
1	No	0	56.4	-
2	Basalt	1.5	57.3	1.59
3	Basalt	2	58.7	4.08
4	Steel	1.5	61.8	9.57
5	Steel	2	64.65	14.63

Table-5 Test results

Sl .No	Type of Fibre	Fibre content	Ultimate load (kN)	Percentage increase in the ultimate load in comparison with control beam
1	No	0	56.4	-
2	Hybrid	1.5	63.25	12.14
3	Hybrid	1.5	63.4	12.41
4	Hybrid	1.5	64.95	15.16
5	Hybrid	2	63.9	13.3
6	Hybrid	2	70.5	25
7	Hybrid	2	67.6	19.86

3.2 Load deflection behaviour of beams

The load deflection curves were plotted for the control beam and for various percentages of fibres of steel fibres, basalt fibres and hybrid fibre reinforced beams. The load vs deflection curves for steel and basalt fibre reinforced beams are shown in Fig. 7. The load vs deflection curves for hybrid fibre reinforced beams are shown in Fig. 8. The deflection of steel fibre reinforced concrete beam corresponding to the maximum ultimate load of 64.65 kN was obtained as 18 mm. For the basalt fibre reinforced concrete beam, the deflection corresponding to the maximum ultimate load of 58.7 kN was 13 mm. The reason may be due to the ductile nature of steel fibres which helps it to sustain more deflection. The maximum deflection was observed as 31 mm for the hybrid fibre reinforced concrete beam at 2 % fibre content consisting of 80 % steel fibre and 20 % basalt fibre. This is because hybrid fibre derives the benefits from both steel and basalt fibres.

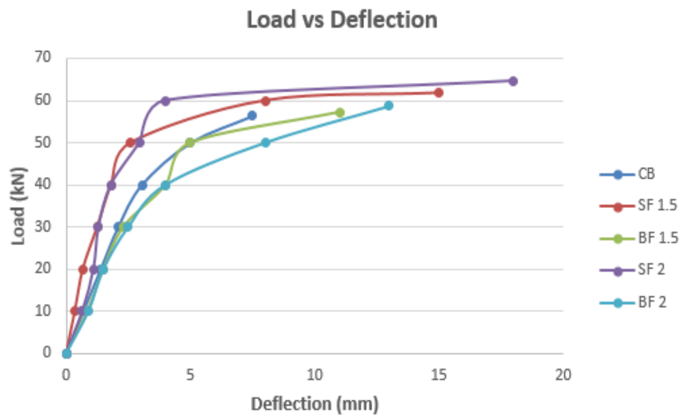

Fig-7: Load vs deflection for steel and basalt fibre reinforced concrete beams

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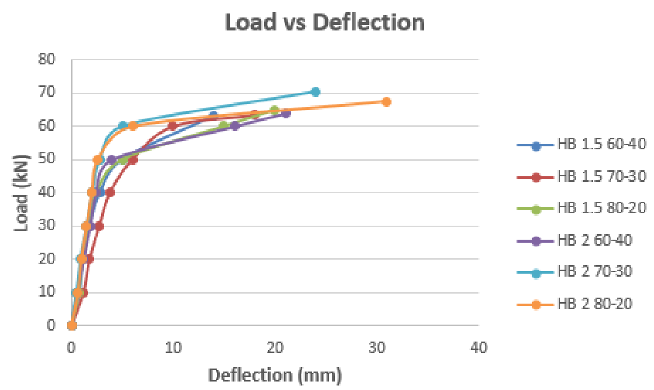

Fig-8: Load vs deflection for hybrid fibre reinforced concrete beams

3.3 Energy absorption

The flexural toughness is the area under the complete load-deflection curve in flexure. Alternatively, toughness may be defined as the area under the load-deflection curve out to some particular deflection or to the point at which the load has fallen back to some fixed percentage of ultimate load. Energy absorption is one of the major indictors of structural response as it indicates the structure's ability to absorb deformations. The toughness index for steel and basalt fibre reinforced beams are shown in Fig. 8. The toughness index for hybrid fibre reinforced beams are shown in Fig. 9. As the steel fibre content increased from 1.5 % to 2%, the toughness index reduced from 2.89 to 2.545. But in case of Basalt fibre reinforced concrete beams, the toughness index increased from 2.155 to 2.517. In case of a hybrid fibre content of 2 %, the toughness index first decreased from 3.913 to 3.55 and then increased to 3.72. The maximum value of toughness index was obtained for the Hybrid fibre reinforced concrete beam at a fibre content of 2% consisting of 60 % steel fibre and 40 % basalt fibre. The reason could be attributed to the increased strength and ductility as a result of hybridizing steel and basalt fibres. Also, both macro and micro cracks of the concrete are arrested ensuring proper toughness.

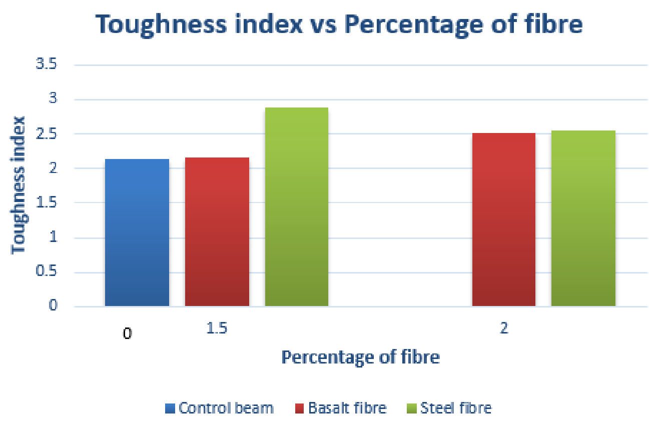

Fig-9: Load vs deflection for steel and basalt fibre reinforced concrete beams

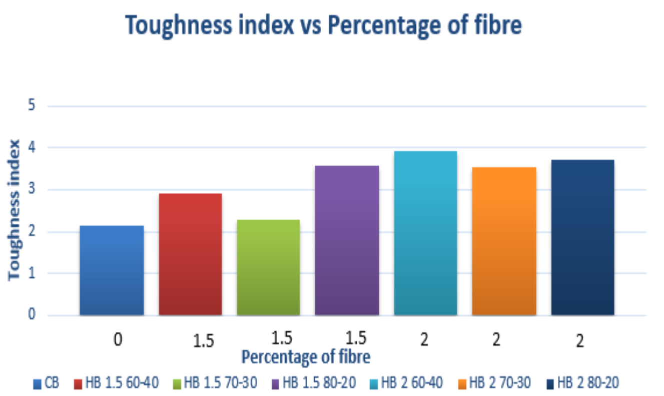

Fig-10: Load vs deflection for hybrid fibre reinforced concrete beams

4. CONCLUSIONS

1. The flexural strength in terms of modulus of rupture was found for M25 grade control beam and the beams reinforced with steel, basalt and hybrid fibres. The ultimate load obtained for hybrid fibre reinforced concrete beams were higher than the steel and basalt fibre reinforced concrete.
2. An increase of 25 % in the ultimate load was found for the hybrid fibre reinforced concrete beam at 2 % total fibre content consisting of 70 % steel fibre and 30 % basalt fibre in comparison with the M25 grade control beams.
3. An increase of 20 % in the ultimate load was found for the hybrid fibre reinforced concrete beam when compared with basalt fibre reinforced concrete beam and an increase of 9.05 % for the hybrid fibre reinforced concrete beam when compared with the steel fibre reinforced concrete.
4. The deflection of all the beams increased with increase in the fibre reinforcement. The hybrid fibre reinforced concrete exhibited more deflection than the corresponding steel and basalt fibre reinforced concrete beams.
5. The modulus of rupture of hybrid fibre reinforced concrete beams were higher than steel and basalt fibre reinforced concrete beams. The maximum modulus of rupture was obtained as 25.29 N/mm^2.

   for steel fibre reinforced concrete beam at a steel fibre content of 2 % and in case of hybrid fibre, the maximum modulus of rupture was obtained as 27.57 N/mm^2.
6. Also, the hybrid fibre reinforced concrete beam exhibited more energy absorption than steel and basalt fibre reinforced concrete beams. The maximum value for the toughness index was obtained as 2.89 for the steel fibre reinforced concrete beam at a fibre content of 1.5 % and 3.913 for hybrid fibre reinforced concrete beam at a fibre content of 2 %.
7. Hybrid fibres bridged the flexural crack in concrete better than the steel and basalt fibre reinforced concrete beam. This is evident from the decreased crack width of hybrid fibre reinforced concrete beams when compared with steel and basalt fibre reinforced concrete beams.

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REFERENCES

1. Yin Chi et al. (2014). "Experimental study on hybrid fiber reinforced concrete subjected to uniaxial compression", Journal of material engineering in civil engineering 2014. 26 : 211-218.
2. Yazan Alrefaei et al. (2016). "Shear strength of beams made using hybrid fiber engineered cementitious composites" Journal of structural engineering , 2018, 144 (1) : 04017177.
3. Susanto Teng et al.(2018) ." Flexural behaviour and durability properties of high performance hybrid fibre reinforced concrete", University of California, CA 94720, USA.
4. Zhiguo You et al.(2011). "Ductility and strength of hybrid fiber reinforced self-consolidating concrete beam with low reinforcement ratios", Systems Engineering Procedia 1 (2011) 28-34.
5. Cory High et al. (2015). "Use of basalt fibers for concrete structures.", University of North Florida, Jacksonville, FL, USA (2015) 37-46.
6. Liaqat A. Qureshi et al. (2013). "Effect of mixing fiber cocktail on flexural strength of concrete" , Bahaudin Zakariya University, Multan, Pakistan (2013) 711-719.
7. Padmanabhan Iyer et al.(2015). "Mechanical properties of fiber reinforced concrete made with basalt filament fibers", University of Windsor, Canada (2015) ASCE.
8. Renaud de Montaignac et al.(2012). "Design of SFRC structural elements : flexural behaviour prediction", Materials and structures (2012) 45: 623-636.
9. Tehmina Ayub et al.(2014). "Mechanical properties of high performance concrete reinforced with basalt fibers", Universiti Teknologi PETRONAS Malaysia (2014), Procedia Engineering 77 131-139.
10. Zhong Xian Li et al.(2017). "Experimental investigation on mechanical properties of hybrid fiber reinforced concrete", Tianjin Chengjian University, china, Construction and building materials (2017) 930-942.