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RESEARCH ARTICLE

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STRENGTH STUDIES ON SHORT TERM MECHANICAL PROPERTIES OF HYBRID FIBER REINFORCED CONCRETE

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ABSTRACT

The present investigation is mainly focused on finding the short term mechanical properties of M_{20} grade hybrid fiber reinforced concrete (HFRC) mixes with different fibers blending. Crimped steel and chopped mat glass fibers are blended in different proportions (0:0, 0.25:0.25, 0.5:0.5, 0.75:0.75 and 1:1) by percentage of volume of concrete and weight of cement. Coarse aggregates of size 20 mm and 10 mm are blended in 60:40 proportions by percentage of weight of total coarse aggregate. Ordinary Portland cement of grade 53(OPC) was used as a binding material. Compressive strength and splitting tensile strength (STS) were studied after 7, 28 and 90 days of curing period. Impact strength and sorptivity were also studied after 28 and 45 days of curing. From the results, it is revealed that the mechanical properties were increased till fibers blending of 0.75:0.75 and decreasing trend has been observed at 1:1 fibers blending. Impact strength and sorptivity results have shown improvement till the fibers blending of 1:1. It is concluded that optimum fiber blending was 0.75:0.75 by percentage of volume of concrete and weight of cement.

Keywords: Hybrid fiber reinforced concrete, crimped steel fiber, chopped mat glass fiber, compressive strength, splitting tensile strength, impact strength, sorptivity.

1. INTRODUCTION

In India, the construction industry plays an important role due to the construction of buildings and also for developing infra structures in that the most commonly used material is concrete [1]. The ingredients like cement, coarse aggregates, and fine aggregates along with water are used for the homogenous mix of concrete [2]. The variations in strength properties of concrete can be achieved by changing the proportions of ingredients like fly ash, ground granulated blast furnace slag and rice husk ash etc are added to the concrete for better strength properties and these ingredients are commonly called as admixtures[2&3].Due to its high compressive strength, better durability characteristics along with low construction as well as maintenance cost it has been used in large amounts for various civil engineering applications.

The well known fact of concrete is very strong in compression but when it comes to the tensile property it is very weak and tends to fail because of its deficiencies such as low tensile strength, low strain at fracture [4]. The weakness of concrete is due to the presence of micro cracks at mortar aggregate interface [5].

1.1 Fiber reinforced concrete (FRC)

Due to the weakness properties of concrete a special type of concrete has been developed known as Fiber reinforced concrete [5]. In FRC the fibers are added to the concrete mix so that those are discontinuous fibers will be uniformly distributed in the mix. Thus due to the addition of fibers there will be improvement in concrete in all directions. Because of fiber inclusion in the concrete mix fibers acts as crack arrester so that there will be a restriction for the development of cracks [6]. The addition of two or more different fibers in the concrete mix is termed as Hybridization [6&7].

1.2 Concept of hybridization

The different fibers are chosen based on their inherent properties i.e. if two different fibers are added in the mix one fiber should strong and stiff properties whereas the other should possess flexibility and ductility [8]. Thus due to the combination there will be improvement in initial crack stress, ultimate strength and toughness after cracking [8-10]. Thus hybridization results in bridging of both micro cracks and macro cracks in the different stages by choosing an appropriate fiber to the concrete mix [7]. Ranjith Kumar.R et al.[11] has done experiments on strength of concrete by adding steel and glass fibers having different aspect ratios with 2% of weight of cement. They concluded that as the aspect ratio is increased strength properties have been increased and the maximum results are for fibers having aspect ratio 100. Chandra mouli K.et al. [12] has studied on the addition of glass fibers in concrete. Glass fibers are added at 0.03% of volume of concrete for different grades and concluded that there will be 20 to 25% improvement in compressive strength and 15 to 20% in tensile and flexural strengths due to the addition. Wakchaure M. R et al [13] has studied compressive strength and flexural strength by hybridizing with steel and glass fibers and compared with normal concrete. They concluded that at optimum percentage addition the mix will gain maximum strength.

2. EXPERIMENTAL STUDY

2.1. Materials

Our objective was to determine the optimum percentage of addition of fibers to HFRC and study the strength properties viz. compressive strength, spliting tensile strength, impact strength and sorptivity of HFRC, to analyse the properties after the addition of fibers and comparing that to conventional concrete. The hardened properties that were determined are compressive strength and splitting tensile strength after 7, 28 and 90 days of curing at room temperature and also impact strength and sorptivity were studied after 28 and 45 days of curing respectively.

Ordinary Portland cement of 53 grade (OPC) having initial and final setting time of 50 min and 270 min respectively and specific gravity of 3.10 was used as a binding material, conforming to IS 12269- 1987 [14]. The normal consistency [15] and soundness [16] of cement are 38% and 7 mm respectively. Crushed granite stones of size 20mm and 10mm are used as coarse aggregate, natural river sand is used as a fine aggregate. As per IS: 2386 (Part III)-1963 [17], the bulk specific gravity in oven dry condition, water absorption and fineness modulus of the coarse aggregate and fine aggregate are presented in Table 1.

Table 1: Material properties

Properties	**Coarse aggregate**		**Fine aggregate**
	20 mm	**10 mm**	
Specific Gravity	2.56	2.56	2.7
Water absorption (%)	0.3	0.3	1
Fineness modulus	3.36	1.98	2.58

In the present investigation crimped steel and chopped mat glass fibers are used to improve the strength properties of hybrid fiber reinforced concrete. The length and diameter of steel fiber are of 25 mm and 0.5 mm. The length of glass fiber is 40-50 mm. The tensile strength of steel and glass fibers are 500-700 MPa and 110 MPa respectively.

Ordinary tap water is used in the investigation during the period of casting as well as curing.

2.2. Mix design of HFRC

The strength properties of hardened concrete are studied by casting cube and for impact test L/4 of cylinder specimens were casted. For M_{20} concrete mix proportion specimens were cast and tested after 7, 28 and 90 days of curing. The materials for the mix proportion were calculated as per IS codes [18&19] for grade like M_{20}.In this study, the steel fibers and glass fibers are added in mix with different proportions by volume of concrete and weight of cement in mix. The percentage addition of fibers is presented in Table 2.

Table 2 : Different variations of fibers in the mix

Fiber added in concrete mix (%)	**Steel Fibers by Volume of Concrete (%)**	**Glass Fibers by Weight of Cement (%)**
0	0	0
0.5	0.25	0.25
1	0.50	0.50
1.5	0.75	0.75
2	1	1

2.3. Test specimens

Three cubical and cylindrical specimens of size 150 mm x 150 mm x 150 mm and length 300 mm, 150 mm diameter were cast and tested for each age and each mix for compressive strength and split tensile strength. The compressive and split tensile strength of a HFRC was tested after 7, 28 and 90 days of curing. For impact test L/4 of cylinder i.e., 75 mm of length and diameter of 150 mm specimens were casted and cured for a period of 28 days. In case of sorptivity, the specimens having 150X150mm surface area were casted and cured for a period of 45 days and it is coated with non absorbent material on all sides except on side of contact with the water.

2.4. Curing of Test Specimens

After casting and demoulding, the test specimens were kept in normal water for curing at room temperature till the execution of the testing on the specimens.

3. METHODOLOGY

The strength studies on short-term mechanical properties of the hybrid fiber reinforced concrete are evaluated by using Compressive strength test, Spliting tensile test, impact strength and sorptivity. The Compressive strength test [20&21], Spliting tensile test [22&23], impact strength [24] and sorptivity [25&26] of all specimens were evaluated by using respective codes.

4. RESULTS AND DISCUSSIONS

4.1. HFRC fresh properties

Table 3 shows the HFRC fresh properties i.e., slump cone test and compaction factor test. These fresh properties give the workability of the concrete.

Table 3: Slump and Compaction factor test results

% of fibers	**Slump (mm)**	**Compaction factor**
0	94	0.96
0.5	90	0.91
1.0	85	0.89
1.5	83	0.87
2	80	0.85

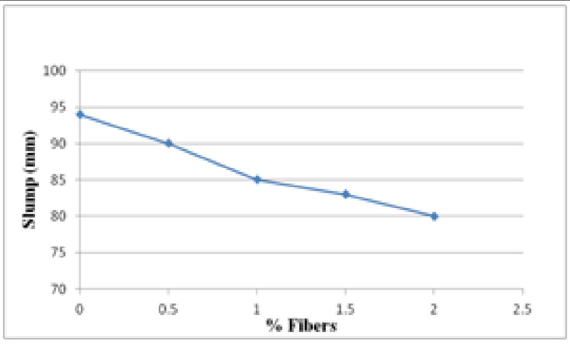

Figure 1. Slump Test

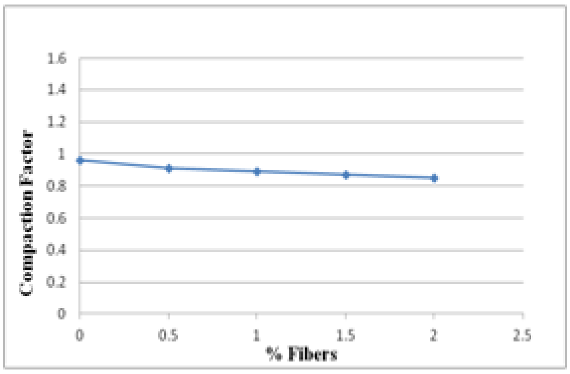

Figure 2. Compaction factor Test

Table 3 & Figs. 1 and 2. present the results of fresh properties of HFRC. It shows an addition of fibers in concrete gives decrease in the slump values. The reason behind the results is the fibers are added to the concrete, bleeding will be reduced and the mix will become harsh. From this we can conclude that the percentage of fiber content is increased then the workability will be decreased.

It can be observed from Fig 2, the fiber content in the mix increase the compaction factor values will be decreases. From this we can conclude that the workability of the mix decreases as the content of the fiber in the concrete increases.

4.2. Mechanical properties

Compressive strength and splitting tensile strength of HFRC were tested on cubes and cylinders with different percentages of steel and glass fibers for M20 grade mix are tabulated. The strength of HFRC has been tested after 7, 28 and 90 days of normal curing.

4.2.1. Compressive strength

Table 4 and Fig. 3 shows the compressive strength of HFRC mixes (0%, 0.5%, 1%, 1.5% and 2%) at different curing periods and % variation of compressive strength of HFRC over controlled concrete.

Table 4: Compressive strength of HFRC

% of Fibers	Age (days)	Compressive strength (MPa)	% Variation of compressive strength of HFRC
0	7	19.542	0
0.5		21.255	8.76
1		23.435	19.92
1.5		24.824	27.02
2		20.332	4.04
0	28	27.596	0
0.5		30.253	9.62
1		31.692	14.84
1.5		32.359	17.25
2		29.324	6.26
0	90	32.254	0
0.5		34.442	6.78
1		35.991	11.58
1.5		37.642	16.7
2		34.224	6.1

Compressive strength was tested for the mixes with the addition of various percentage of fibers i.e., of 0%, 0.5%, 1%, 1.5% and 2% by volume and weight of cement in concrete. The samples were tested after curing periods of 7, 28 and 90 days. It was observed that there was a significant increase in compressive strength with the increase in percentage of fibers from 0% to 1.5% in all curing periods. After 7 days of curing, 1.5% fibers sample exhibited a compressive strength of 24.82 MPa, whereas after 28 days of curing it was 32.35 MPa and after 90 days of curing it was 37.64 MPa.

It is to be noted that the significant improvement in compressive strength is mainly due to the addition of fibers in concrete. From the results it is concluded that the fibers blending will enhance the initial crack stress, ultimate strength and toughness after cracking. Thus hybridization results in bridging of both micro cracks and macro cracks in the different stages by choosing an appropriate fiber to the concrete mix gives the best results. However, when the percentage fibers were increased to 2% a drastic fall in compressive strength was evidenced irrespective of the time of curing. The compressive strength values of the mixes with 2% addition of fibers were found to be 20.33 MPa, 29.32 MPa and 34.22 MPa respectively after 7, 28 and 90 days of curing.

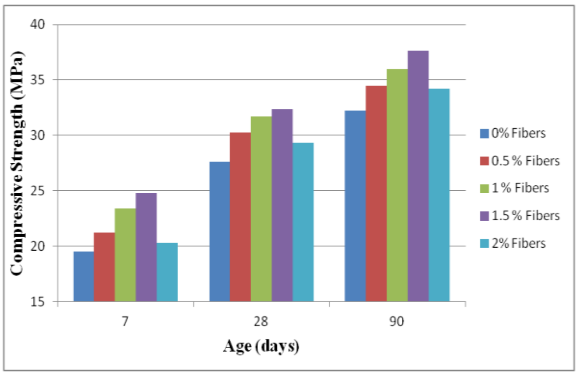

Figure 3. Compressive strength versus Age

4.2.2. Split tensile strength

Table 5 and Fig. 4 shows the split tensile strength of HFRC mixes (0%, 0.5%, 1%, 1.5% and 2%) at different curing periods and % variation split tensile strength of HFRC over controlled concrete.

Split tensile strength was also tested for the same mixes with the addition of various percentage of fibers i.e., of 0%, 0.5%, 1%, 1.5% and 2% by volume and weight of cement in concrete. The samples were tested after curing periods of 7, 28 and 90 days. It was observed that there was a significant increase in tensile strength with the increase in percentage of fibers from 0% to 1.5% in all curing periods. After 7 days of curing, 1.5% fibers sample exhibited a tensile strength of 2.95 MPa, whereas after 28 days of curing it was 3.41 MPa and after 90 days of curing it was 3.67 MPa.

Table 5: Split tensile strength of HFRC

% of Fibers	Age (days)	Split tensile strength (MPa)	% Variation of split tensile strength of HFRC over controlled
0	7	2.59	0
0.5		2.74	5.79
1		2.88	11.20
1.5		2.95	13.90
2		2.62	1.16
0	28	3.09	0
0.5		3.25	5.18
1		3.34	8.09
1.5		3.41	10.36
2		3.21	3.88
0	90	3.35	0
0.5		3.47	3.58
1		3.55	5.97
1.5		3.67	9.55
2		3.42	2.09

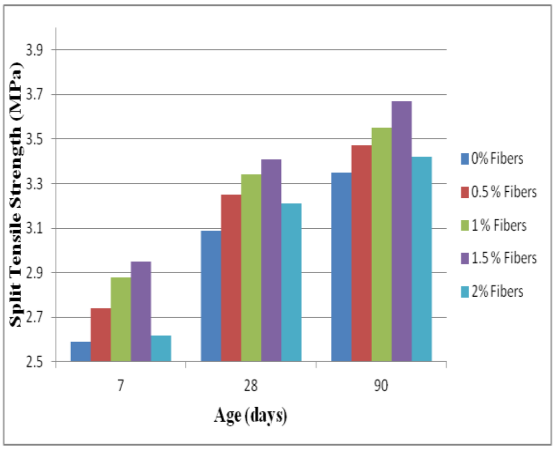

Figure 4. Split tensile strength versus Age

It is to be noted that the significant improvement in split tensile strength is mainly due to the addition of fibers in concrete. From the results it is concluded that the fibers blending will enhance the initial crack stress, ultimate strength and toughness after cracking. Thus hybridization results in bridging of both micro cracks and macro cracks in the different stages by choosing an appropriate fiber to the concrete mix gives the best tensile strength results as compare to conventional concrete. However, when the percentage fibers were increased to 2% a drastic fall in tensile strength was evidenced irrespective of the time of curing. The tensile strength values of all the mixes with 2% addition of fibers were found to be 2.62 MPa, 3.21 MPa and 3.42 MPa respectively after 7, 28 and 90 days of curing.

4.3. Impact strength

Table 6 and Fig. 5 show the impact strength results of HFRC mixes (0%, 0.5%, 1%, 1.5% and 2%) at 28 days of curing period.

Table 6: Impact strength of HFRC

% Fibers	First visible crack in no. of blows	Final failure in no. of blows
0	4	15
0.5	7	29
1	9	48
1.5	16	61
2	17	64

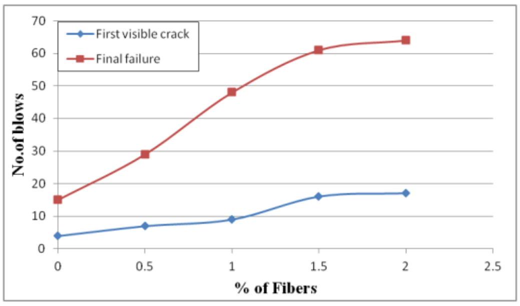

Figure 5. Impact strength test results

From the Table 6 and Fig.5, It is clear that the number of blows required for the failure of impact specimen had been increasing when the percentage of fibers in concrete mix is increased. The number of blows required for visible crack for 0.5% is 7 and for failure is 29.As the fiber percentage is increased to 1% ,1.5% and 2% the number of blows required to initial crack and also final failure are noted as 9,16,17 and also 48,61,64 respectively. Thus from the above results it resembles that as fiber percentage in concrete mix increases the impact resistance of concrete increases.

4.4. Sorptivity

Table 7 and Fig. 6 shows the sorptivity results of HFRC mixes (0%, 0.5%, 1%, 1.5% and 2%) at 45 days of curing period.

Table 7: Sorptivity test results of HFRC

% Fibers	Dry weight (gm)	Wet weight (gm)	Sorptivity (10^{-5} mm/min$^{0.5}$)
0	8108	8112	3.24
0.5	9036	9044	6.49
1.0	8624	8636	9.73
1.5	8642	8655	10.54
2	8672	8687	12.17

From the Table 7 and Fig. 6, it is clear that the sorptivity values have been increasing from 0% to 2%. At 0.5% fiber percentage the sorptivity value is 3.24. As the fiber percentage is increased from 0.5%, 1%, 1.5% and 2% the values of sorptivity are 6.49, 9.73, 10.54 and 12.17 respectively. Finally I concluded that the percentage of fibers influence the sorptivity of HFRC directly. Here, the sorptivity values are in 10^{-5} mm/ min$^{0.5}$

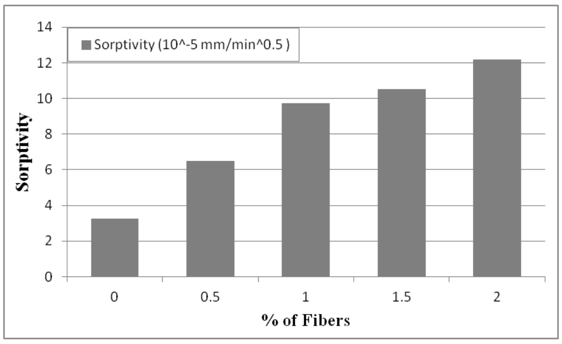

Figure 6. Sorptivity test results

5. CONCLUSIONS

Based on the investigation, the following conclusions have been drawn.

1. As the fibers content in the mix increases, there is a decrement in the workability of the concrete. Bleeding property also reduced due to the addition of fibers.
2. There was a significant increase in compressive strength and split tensile strength with the increase in percentage of fibers from 0% to 1.5% in all curing periods.
3. When the percentage of fibers was increased to 2% a drastic fall in compressive strength and split tensile strength were evidenced.
4. The significant improvement in mechanical properties up to 1.5% fibers addition in concrete mixes is mainly due to nullifying the micro and macro cracks developed in the HFRC.
5. The impact strength and sorptivity of HFRC have been improved, when the fibers are added in the mix. It resembles that as fiber percentage in concrete mix increases the impact resistance and sorptivity of concrete will be increases.

REFERENCES

[1]. Chetna M, Darshana R, Concept of green concrete using construction demolished waste as recycled coarse aggregate, *International Journal of Engineering Trends and Technology* ,**4** (2013) 3160-65.

[2]. Sreenivasulu C, Guru Jawahar J, Vijaya Sekhar Reddy M and Pavan Kumar D, Effect of fine aggregate blending on short-term mechanical properties of geopolymer concrete, *Asian Journal Of Civil Engineering (Building and Housing),***17**(2016) 537-550.

[3]. Vijai K, Kumutha R, Vishnuram B G. Effect of inclusion of steel fibres on the properties of geopolymer concrete composites, *Asian Journal of Civil engineering*, **13**(2012) 377-85.

[4]. Khaloo A.R, Sharifian M, Experimental investigation of low to highstrength steel fiber reinforced lightweight concrete under pure torsion, *Asian Journal Of Civil Engineering (Building and Housing,* **6**(2005) 533-547.

[5]. Shende A.M, Pande A.M, Gulfam Pathan M, Experimental study on steel fiber reinforced concrete for M-40 grade,

International Refereed Journal of Engineering and Science,**1** (2012) 043-048.

[6]. Prasad M.L.V, Rathish Kumar P, Strength studies on glass fiber reinforced recycled aggregate concrete , *Asian Journal of Civil Engineering (Building and Housing)*, **8**(2007) 677-690.

[7]. Oucief H, Habita M.F, Redjel B, Hybrid fiber reinforced self-compacting concrete: hardened properties, *International Journal of Civil Engineerng*, **8**(2006) 77-85.

[8]. Ghorpade Vaishali G, Sudarsana Rao H, Strength and permeability characteristics of fiber reinforced high performance concrete with recycled aggregates, *Asian Journal of Civil Engineering (Building and Housing),* **13**(2012) 55-77.

[9]. Sreenivasa Rao A, Appa Rao G, Fracture mechanics of fiber reinforced concrete: An overview, *International Journal of Engineering Innovation & Research*, **3**(2014) 517-524.

[10]. Miloud B, Permeability and porosity characteristics of steel fiber reinforced concrete, *Asian Journal of Civil Engineering (Building and Housing)*, **6**(2005) 317-330.

[11]. Ranjith Kumar R, Vennila A, Southamirajan S , Experimental investigation on hybrid fiber reinforced concrete, *International Journal of Emerging Trends in Engineering and Development*, **3**(2013) 39-45.

[12]. Chandra mouli K, Srinivasa Rao P, Pannirselvam N, Seshadri Sekhar T, Sravana P, Strength properties of glass fibre concrete, *ARPN Journal of Engineering and Applied Sciences*, **5(**2010) 1-6.

[13]. Wakchaure M. R, Rajebhosale S. H, Satpute M. B, Kandekar S. B, Comparison of compressive strength and flexural shear strength for hybrid fiber reinforced concrete with controlled concrete, *International Journal of Engineering and Technical Research*, **2(**2014) 172-175.

[14]. I.S-12269. Indian standard ordinary Portland cement, 53 grade – specification (Bureau of Indian Standards), New Delhi, 2013.

[15]. I.S-4031(Part 4). Bureau of Indian Standards, Indian standard code of practice methods of physical tests for hydraulic cement, New Delhi, India, 1988.

[16]. I.S-4031(Part 3). Bureau of Indian Standards, Indian standard code of practice methods of physical tests for hydraulic cement, New Delhi, India, 1988.

[17]. IS 2386. Indian standard methods of test for aggregates for concrete: Part-III specific gravity, density, voids, absorption and bulking, Bureau of Indian Standards, New Delhi, 1963.

[18]. IS 10262-2009. Indian standard concrete mix proportioning – guidelines (Bureau of Indian Standards), New Delhi, 2009.

[19]. IS 456. Indian standard plain and reinforced concrete code of practice (Bureau of Indian Standards), New Delhi, 2000.

[20]. IS 516. Bureau of Indian Standards, Indian standard code of practice methods of test for strength of concrete, New Delhi, India, 1959.

[21]. ASTM C39. Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, ASTM International, West Conshohocken, PA, 2014.

[22]. IS 5816. Bureau of Indian Standards, Indian standard splitting tensile strength of concrete -method of test, New Delhi, India, 1999.

[23]. ASTM C496. Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, ASTM International, West Conshohocken, PA, 2004.

[24]. ACI 544.2R-89: Measurement of Properties of Fiber Reinforced Concrete. American Concrete Institute, 2009.

[25]. ASTM C1585-13, Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes, ASTM International, West Conshohocken, PA, 2013, www.astm.org

[26]. Jayeshkumar Pitroda, Umrigar F S, Evaluation of sorptivity and water absorption of concrete with partial replacement of cement by thermal industry waste (Fly ash), *International Journal of Engineering and Innovative Technology,* **2(**2013) 245-249.