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STRENGTH PROPERTIES OF HYBRID FIBRE REINFORCED CONCRETE USING FLY ASH

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Abstract - Concrete is strong in compression and weaker in tension. Therefore, to enhance the tensile strength of concrete certain fibres are added into the concrete. Fibre reinforced concrete (FRC) contains fibrous material, which increase the structural stability and integrity. Nowadays, hybrid fibre reinforced concrete (HFRC), which is the combination of various fibres into the conventional concrete makes it subtle and enhances the mechanical behaviour of the concrete. Aim of the study is to investigate the properties of hybrid steel and basalt fibres with and without fly ash for M25 grade of concrete. Four groups of mixtures containing fly ash (FA) contents of 0%, 10%, 20%, and 30% as cement replacement were produced with the inclusion of 0.50% steel fibres (SF) and 0.50% basalt fibres (BF) by volume of concrete. Fresh properties of mixtures were evaluated by using slump test, compaction factor and vee bee test. Hardened properties were tested at 28 days. Compressive strength, flexural strength, tensile strength, dry unit weight, porosity and water absorption were assessed. According to the results from the study, it is found that hybrid fibre reinforced concrete can act synergistically and increases the strength properties of concrete. The microcracks are checked to a larger extent.

***Key Words*:** Fly ash, Steel fibre and Basalt fibre

1.INTRODUCTION

Concrete has always been a vital building substance that is used since ages to produce long-lasting constructions. It is composite material made up of cement, water, and aggregates like sand, gravel, or crushed stone. This combination results in a solid and durable material with numerous applications while erecting the structures. The concept where the fibres are infused in concrete mix has emerged since 1990's. In early 1990's, the HFRC study was done in Japan by researches which shows the inclusion of steel fibre and polypropylene fibre in concrete will enhance the ductility of concrete and impact resistance.

The hybrid fibres will change the behavior of the concrete by improving the early cracks and withstand the maximum loadings and will not allow sudden failures. Use of combinations of fibres in concrete improves the durability and strength of the concrete as compared to normal concrete. The addition of fly ash to hybrid fibre-reinforced concrete results in a material with increased strength, toughness, fracture control, and durability. As research and development in this sector continues, HRFC with fly ash shows promises for future constructions that are more durable eco-friendly, and long-lasting.

Hybrid fibre reinforced concrete has a widespread application, which involves the tunnels, bridges and other infrastructure projects and implemented in the production of precast concrete structures such as panels and pipes. The major benefit of HFRC is control of cracking. The fibres serve as micro-reinforcements inside the concrete matrix, dispersing stress and reducing fracture growth. This property is especially useful in constructions subjected to dynamic loads, such as bridges, pavements, and earthquake-resistant structures.

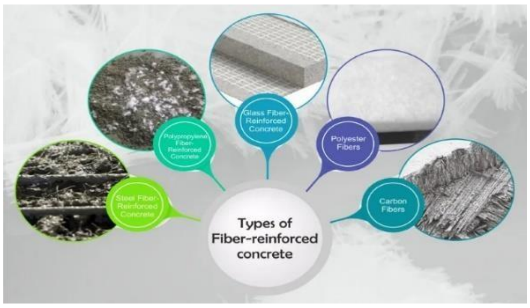

Fig. 1 Types of fibres

In the present study, an attempt is made to investigate the effect of replacement of cement by fly ash on the properties of HFRC. The intended percentage replacements of cement by fly ash are 0%, 10%, 20%, and 30%. (SF + BF) combination of hybrid fibres are added at the rate of (0.5 + 0.5) % by volume fraction. The various laboratory testing on workability characteristics such as slump, compaction factor, and vee-bee test and strength characteristics such as compressive strength, flexural strength, and split tensile strength are carried out on prepared concrete specimens.

Few important literatures in the concerned area is discussed here. [1] This experimental study intended to investigate the influence of hybrid fibres between carbon, basalt, and steel on the torsion behaviour of RC beams. Thirteen RC beams were put to the test subject to pure torsion and loaded until failure. Beams were divided into four series: A to D. Series A consisted of four beams: one without fibres, and others with one type of fibre (CF, BF, and SF). Each one of series B, C, and D contain two types of fibres: (CF and BF), (BF and SF), and (CF and SF) with a varying fibre content of 0.25%, 0.50%, and 0.75% in term of volume. The maximum torsional strength increased by 22.3%, 28.6%, and 65.2% when a hybrid fibre of (0.75% BF and 0.75% CF), (0.75% BF and 0.75% SF), and (0.75% CF and 0.75% SF) added, respectively. [2] The compressive strength, fracture toughness, and impact resistance of HFRC are studied. Altogether 78 compressive strength test cubes, 24 fracture edge notched disc bend specimens, and 20 impact disc specimen were built and tested. Emanate from literature, the replacement of nano-silica was hold on to 2% glass and steel fibres of 50mm length were employed, with cement component of 1-4% by weight. Steel fibre, glass fibre, and nano-silica combinations provided higher strength and performance in concrete, in conferring with results. [3] This study focuses particularly on the implementation of BF in concrete. First, the ideal BF dose is determined by performing numerous strength tests on hardened concrete. BF doses of 0.2%, 0.3%, 0.4%, 0.5%, and 0.6% of concrete volume are shown to be optimal. The permeability qualities, water and chloride ion penetrability, and optimum addition of basalt fibre reinforced concrete are also examined, and it is found that optimum addition lowers the permeability. [4] 16 specimens were tested in single and hybrid groups to access the impact of fibre % on impact qualities. In contrast to single fibre reinforced concrete, the initial strength and energy dissipation of hybrid-fibre reinforced cementitious composite rose by 45.3 and 49.7%, respectively. [6] The purpose of this research is to look at the combined effect of different ratios of waste SF and fly-ash on both rheological and physical behaviour of fibre-reinforced concrete. Cement was partially replaced by fly-ash at rates of 5%, 10%, and 20% of weight, while waste SF was added at 1.5% and 3% by quantity to the concrete. for the fresh concrete, rheological tests are performed. Mechanical properties of the concrete were measured after 7 and 28 days of curing. Among all the combinations, the mixture with a proportion of 10% fly-ash and 3% waste SF provides the best mechanical performance.

2. OBJECTIVES OF THE STUDY

The primary aim of this experimental study is to find the influence of fly ash as substitutive material for cement in the production of HFRC. The intended percentage replacements of fly ash are 0%, 10%, 20%, and 30%, with combination of (0.5 + 0.5) % addition of SF and BF by volume fraction.

Workability properties and strength properties such as compressive strength, tensile strength and flexural strength are studied here.

3. MATERIALS AND METHODOLOGY

3.1 Materials

i. Cement (OPC- 43 grade)

For this experimentation work, OPC of 43 grade cement from Birla A1 is used which is free from lumps and organic matter. Specific gravity of cement is 3.12

ii. Fly ash

Fly ash is the byproduct produced from the combusted coal in thermal power plant. The fly ash is brought from KPCL thermal power station, Raichur. Class-F fly ash is used as a substitute of cement. The specific gravity of fly-ash is 2.43. The chemical compositions of fly-ash are presented in table 1

Table 1 Chemical compaction of fly ash

Oxide	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	LOl
%	50.46	6.51	2.98	58.42	1.21	0.98	0.64	0.32	2.0

iii. Steel fibre

In this experimental study crimped steel fibres are used. The length of steel fibre is 40mm and 1mm thick. It is having the density of 7650 kg/m3. The aspect ratio is 0.025.

iv. Basalt fibre

BF is made from basalt rock. It is a volcanic rock produced from rapid cooling of lava. BF used in concrete enriches the mechanical performance of the concrete by introducing as reinforcement. It is resistance to high tensile strength, corrosion, and good thermal resistance. The chopped basalt fibres used in experimental study are of 18mm length and 1µm thickness. The density is 2650 kg/m3. The aspect ratio is 5.5x10-5.

Fig. 2 Steel fibre & Basalt fibre

v. Fine aggregate

In the experiment, M-sand is used. It is manufactured by crushing rocks to desired sizes. M-sand is used in concrete as alternative to river sand. The M-sand used is having the fineness modulus of 2.508 and specific gravity of 2.65.

vi. Coarse aggregate

The CA used in the experimental study, passes 20mm and retained on 4.75mm sieve. It is having the fineness modulus of 7.94 and specific gravity of 2.79.

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3.2 Mix design

Mix design of M25 grade of concrete yielded a mix proportion as shown in table 2

Table 2 Mix ratio for M25 grade concrete per cubic meter

Materials	Cement	Fine aggregate	Coarse aggregate	Water
Quantity	425.73 kg	650.65 kg	1163.77 kg	191.58 kg
Ratio	1	1.52	2.73	0.45

4. EXPERIMENTAL RESULTS

The following tables will illustrate the results on workability, water absorption, sorptivity and the strength characteristics of HFRC produced by replacing cement by fly ash in various percentages.

4.1 Workability test results – Table 3 gives the workability test results as measured from slump test, compaction factor test and Vee-Bee consistometer test. The variation of slump, compaction factor and Vee-Bee degree are graphically represented in fig. 3, 4, and 5.

Table 3 Test results on workability with (SF+BF) of (0.5%+0.5%)

Percentage replacement of cement by fly-ash	Slump (mm)	Compaction factor	Vee-Bee degree (sec)
0 %	33	0.79	17
10 %	38	0.81	14
20 %	47	0.84	11
30 %	35	0.74	13

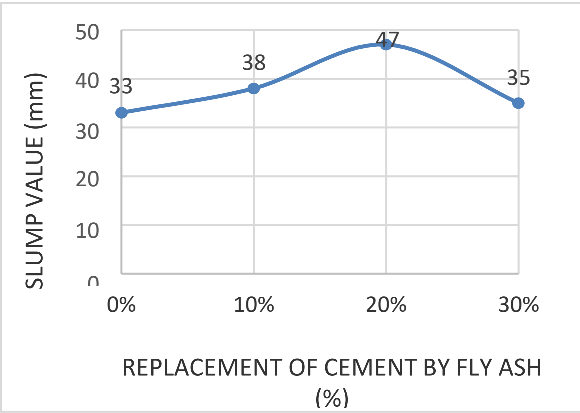

Fig. 3 Slump test results with (SF+BF) of (0.5%+0.5%)

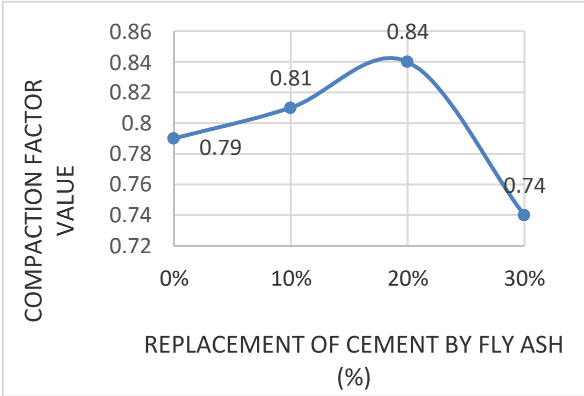

Fig. 4 Compaction factor test results with (SF+BF) of (0.5%+0.5%)

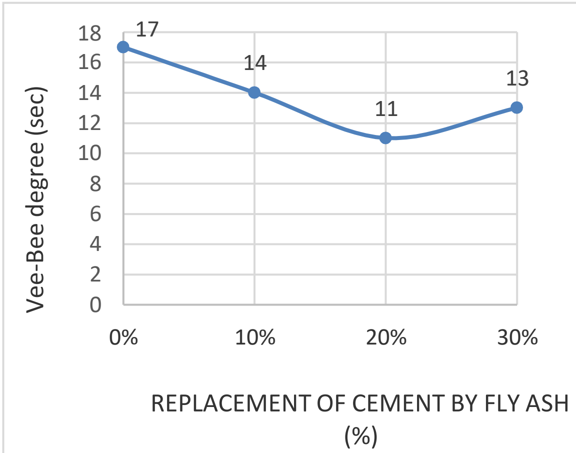

Fig 5 Vee-Bee consistometer test results with (SF+BF) of (0.5%+0.5%)

It is observed that the workability as measured from slump, compaction factor and Vee-Bee degree of HFRC produced with (SF+BF) with (0.5%+0.5%) goes on increasing up to 20% replacement of cement by fly ash. After 20% replacement the workability decreases. Thus, the higher value of workability is obtained when 20% of cement is replaced by fly ash.

This may be due to the fact that, when 20% cement is replaced by fly ash, it may offer maximum ball bearing action, thereby making the concrete to flow.

Thus, it may be concluded that, the HFRC produced with (SF+BF) yields higher workability, when 20% cement is replaced by fly ash.

4.2 Compressive strength test results – Table 4 gives the compressive strength test results. The variation of compressive strength is graphically represented in fig 6.

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Table 4 Test results on compressive strength with (SF+BF) of (0.5%+0.5%)

Replacement of cement by fly-ash	Failure load (kN)	Compressive strength in (N/mm2)	Average compressive strength in (N/mm2)	Increase or decrease of compressive strength in percentage w.r.t ref. mix
0%	790	35.11	35.85	0%
	820	36.44		
	810	36.00		
10%	850	37.78	38.81	+13.91%
	870	38.67		
	900	40.00		
20%	920	40.88	40.89	+14.65%
	890	39.55		
	950	42.22		
30%	860	38.22	38.96	+13.96%
	870	38.67		
	900	40.00		

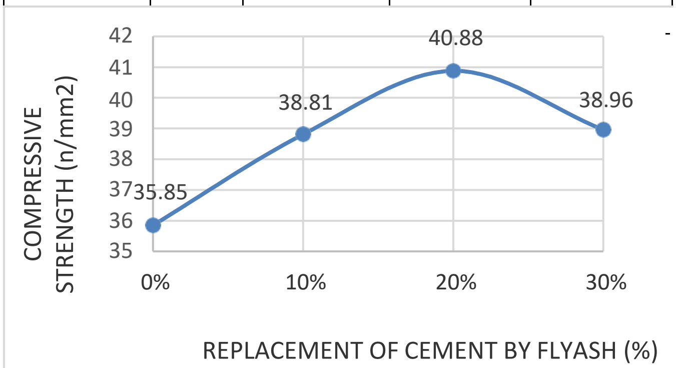

Fig. 6 Compressive strength test results with (SF+BF) of (0.5%+0.5%)

It is observed that the compressive strength of HFRC produced with (SF+BF) with (0.5%+0.5%) goes on increasing up to 20% replacement of cement by fly ash. After 20% replacement the compressive strength decreases. Thus, the higher value of compressive strength is obtained when 20% of cement is replaced by fly ash and its value is 40.89 MPa. And the percentage increase in the compressive strength w.r.t reference mix is found to be 14.65%.

This may be due to the fact that, when 20% cement is replaced by fly ash, it may fill all the pores of the concrete making the concrete more dense. Also it may be due to the fact that, at 20% replacement level, the pozzolanic reaction is at its peak.

Thus, it may be concluded that, the HFRC produced with (SF+BF) yields higher compressive strength, when 20% cement is replaced by fly ash and the value of compressive strength is 40.88 MPa for (0.5%+0.5%) fibres.

4.3 Split-tensile strength test results - Table 6 gives the split tensile strength test results. The variation split tensile strength is graphically represented in fig 8.

Table 5 Test results on split tensile strength with (SF+BF) of (0.5%+0.5%)

Replacement of cement by fly-ash	Failure load (kN)	Tensile strength in f = 2P/πDI (N/mm2)	Average split tensile strength in (N/mm2)	Increase or decrease of split-tensile strength in percentage w.r.t ref. mix
0%	380	5.37	5.37	0%
	360	5.09		
	400	5.65		
10%	490	6.93	6.93	+3.72%
	470	6.65		
	510	7.21		
20%	550	7.78	7.78	+4.17%
	570	8.06		
	530	7.50		
30%	490	6.93	7.21	+3.87%
	510	7.21		
	530	7.50		

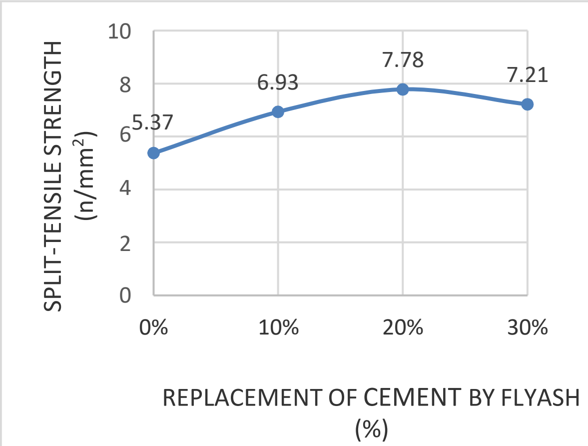

Fig. 7 Split tensile strength tests results with (SF+BF) of (0.5%+0.5%)

It is observed that the split-tensile strength of HFRC produced with (SF+BF) with (0.5%+0.5%) goes on increasing up to 20% replacement of cement by fly ash. After 20% replacement the split-tensile strength decreases. Thus, the higher value of split-tensile strength is obtained when 20% of cement is replaced by fly ash and its value is 7.78 MPa. And the percentage increase in the tensile strength w.r.t reference mix is found to be 4.17%.

This may be due to the fact that, when 20% cement is replaced by fly ash, it may fill all the pores of the concrete making the concrete more dense, Also it may be due to the fact that, at 20% replacement level, the pozzolanic reaction is at its peak.

Thus, it may be concluded that, the HFRC produced with (SF+BF) yields higher split-tensile strength, when 20% cement is replaced by fly ash and the value of split-tensile strength is 7.78 MPa for (0.5%+0.5%) fibres.

4.4 Flexural strength test results - Table 5 gives the flexural strength test results. The variation of flexural strength is graphically represented in fig 7.

Table 6 Test results on flexural strength with (SF+BF) of (0.5%+0.5%)

Replacement of cement by fly-ash	Failure load (kN)	Flexural strength in F = PxL/BxD2 (N/mm2)	Average flexural strength in (N/mm2)	Increase or decrease of flexural strength in percentage w.r.t ref. mix
0%	13.00	5.85	6.60	0%
	14.00	6.30		
	17.00	7.65		
10%	18.00	8.10	8.24	+5.43%
	17.00	7.65		
	20.00	9.00		
20%	21.00	9.5	10.20	+6.73%
	22.00	9.90		
	25.00	11.25		
30%	20.00	9.00	8.69	+5.73%
	19.00	8.55		
	19.00	8.55		

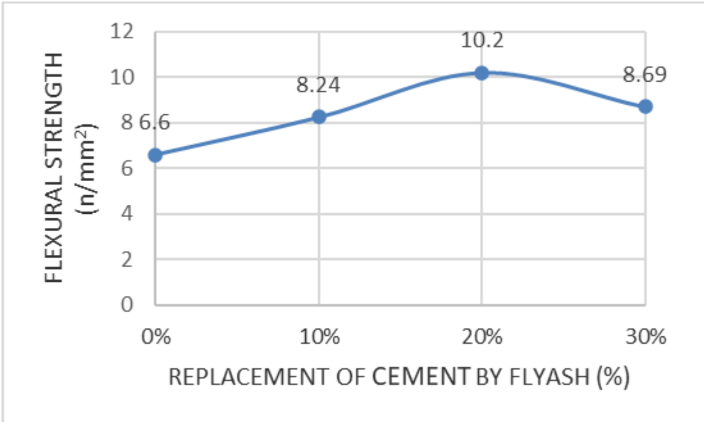

Fig. 8 Flexural strength tests results with (SF+BF) of (0.5%+0.5%)

It is observed that the flexural strength of HFRC produced with (SF+BF) with (0.5%+0.5%) goes on increasing up to 20% replacement of cement by fly ash. After 20% replacement the flexural strength decreases. Thus, the higher value of flexural strength is obtained when 20% of cement is replaced by fly ash and its value is 10.20 MPa. And the percentage increase in the flexural strength w.r.t reference mix is found to be 6.73%

This may be due to the fact that, when 20% cement is replaced by fly ash, it may fill all the pores of the concrete making the concrete more dense, Also it may be due to the fact that, at 20% replacement level, the pozzolanic reaction is at its peak.

Thus, it may be concluded that, the HFRC produced with (SF+BF) yields higher flexural strength, when 20% cement is replaced by fly ash and the value of flexural strength are 10.20 MPa for (0.5%+0.5%) fibres.

5. CONCLUSIONS

1. HFRC produced with (SF+BF) yields higher workability, when 20% cement is replaced by fly ash.

2. HFRC produced with (SF+BF) yields higher compressive strength, when 20% cement is replaced by fly ash and the value of compressive strength is 40.88 MPa for (0.5%+0.5%) fibres.

3. HFRC produced with (SF+BF) yields higher flexural strength, when 20% cement is replaced by fly ash and the value of flexural strength is 10.20 MPa for (0.5%+0.5%) fibres.

4. HFRC produced with (SF+BF) yields higher split-tensile strength, when 20% cement is replaced by fly ash and the value of split-tensile strength is 7.78 MPa for (0.5%+0.5%) fibres.

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BIOGRAPHIES

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