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"AN INVESTIGATION ON MECHANICAL PROPERTIES OF HYBRID FIBER REINFORCED CONCRETE"

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Abstract

In this experimental investigation work is carried out using 2 types of different fibers. They are crimped steel fiber and polypropylene fiber with different mix proportion by volume of concrete is added into mix with replacement of cement by fly ash and silica fume respectively. The work for M30 grade of concrete can be designed according to IS 10262:2009 with three different proportions of fibers and with mineral admixture. The proportion of steel and polypropylene fibers are added are 1% for mono fibers i.e. SF and PPF and hybrid fiber of percentage of (0.5+0.5) % (SF+PPF) with 20% of fly ash and silica fume respectively. The objective is to determine properties of hybrid fiber reinforced concrete with and with different type of mono fibers planned as steel fiber and polypropylene fiber. To find the effect of fly ash and silica fume as replacement of cement with fixed amount of replacement of 20% respectively with different fibers on the strength of concrete. The Strength properties such as compressive strength, split tensile strength and flexural strength after 28 days of curing are studied and compared. From the investigative study the result showed that polypropylene fiber give more workability compared to steel fiber and hybrid fiber and workability of concrete improves with replacement of mineral admixture in concrete and for replacement of cement by silica fume there is good increase compared to fly ash and conventional concrete. The strength of concrete with silica fume was greater with 1% steel fiber but it had low workability. Hybrid fiber with (0.5+0.5) % content showed both better workability and strength in both the parameter with silica fume.

Key Words: Crimped steel fiber, polypropylene fiber, hybrid fiber, fly ash, silica fume, compressive strength, split tensile strength, flexural strength workability.

1. INTRODUCTION

As we know concrete is most widely used material in construction industry. The advancements in technology can reduce the utilization of natural sources. And increase the burden of pollutants on in the surrounding. In Present era large amounts of fly ash and silica fume are generated through industries with cause impact on environment and surroundings. Conventional concrete has two major weaknesses that are low tensile strength and a destructive and brittle failure to overcome this defects fiber reinforced concrete has been introduced. And lot of research and experimental work is been carried out on FRC using different type of fibers to study their improved engineering properties in both mechanical and durability etc. The fibers liable to prevent surface cracks leads to increase in impact resistance of concrete. Most of the fiber used in concrete contains one type of fiber or more than one type of fiber the use of single fiber can improve certain properties of concrete For example steel fiber can increase the structural strength, ductility, impact resistance and abrasion resistance, reduces the steel reinforcement requirement in concrete crack widths and synthetic fibers can improve mix cohesion, freeze- thaw resistance, impact resistance, increase in resistance to plastic shrinkage. In recent years it has been seen there is considerable improvement in fiber hybridization particularly combination of metallic & non-metallic fibers.

The main objective of this experimental investigation is as follows

1. To achieve M30 grade of concrete for the mix.
2. To determine and study the characteristic properties of hybrid fiber reinforced concrete with a fiber content of (0.5%+0.5%) by volume of concrete and with different type of mono fibers planned as steel fiber and polypropylene fiber and with fiber content of 1% by volume.
3. To find the effect of fly ash and silica fume as replacement of cement with fixed amount of replacement of 20% respectively with different fibers on the strength of concrete.

4. The workability properties are studied for different blend concrete (i.e. Plain concrete, fly ash blended concrete and silica fume blended concrete) with SF, PPF and hybrid fiber with slump test, compaction factor and vee-bee degree.
5. The strength properties such as compressive strength, split tensile strength and flexural strength after 28 days of curing are studied and compared.

2. MATERIALS AND METHODS

Cement

Cement used for the study is OPC 43 grade. The cement brand used was JK cement from the local distributors. Cement properties are tabulated in the tabular column.

Properties	Result	Permissible limits as per IS 8112-1989
Fineness	4 %	It should not be more than 11%
Normal consistency	34 %	<34%
Specific gravity	3.0	
Setting time Initial Final	 45 minutes 375 minutes	Should not be less than 30 minutes Should not be more than 600 minutes

Table 1 properties of cement

Fine Aggregates

The sand used is river sand confirming to IS 383-1970 of Zone I. Specific gravity of the fine aggregate is calculated with procedures confirming to IS: 2386 – 1963 and results obtained comply with the code specifications. Physical properties of fine aggregates are in the tabular column as shown below.

Properties	Result
Zone of fine aggregate	I
Specific gravity	2.6
Loose bulk density	1284 kg/m^3
Compacted bulk density	1556 kg/m^3

Table 2 properties of fine aggregate

Coarse Aggregates

Locally available Coarse aggregate of passing through 20mm sieve and retained on 4.75mm sieve were used in the present work confirming to IS: 383–1970. Preliminary tests were conducted on coarse aggregate and its results are recorded in the tabular column.

Properties	Result
Shape of aggregates	Angular
Specific gravity	2.82
Loose bulk density	1509 kg/m^3
Compacted bulk density	1761 kg/m^3

Table 3 properties of coarse aggregate

Water

Portable tap water was used for the preparation of specimens and for the curing of specimens

Super Plasticizer

Conplast-SP 430 sulphonated napthalene formaldehyde manufactured by forsoc chemicals is used. Its use enhances the workability of the mix, helps in providing a better compaction and finishing. It also permits a reduction in water content up to 25%. . The specific gravity of super plasticizer is 1.2 at 20 ^{0}C. A dosage of 0.8 % by weight of cement was used in present work.

Fly ash

The fly ash is obtained from Raichur thermal power plant (RTPSL), Raichur district, Karnataka. The chemical properties and physical properties of fly ash where given by the plant engineer. As tabulated below

Properties	Specification
Colour	Whitish grey
Form	Powder
Bulk density	1047 kg/m^3
Specific gravity	2.2
Fineness	0.4 to 0.04 mm
Moisture	Less than 0.3%

Table 4 physical properties of fly ash

Silica Fume

The silica fume is obtained from Sai Dhurga enterprises Bangalore, Karnataka and meets the requirement of ASTM C-1240 .The chemical properties and physical properties of silica fume are tabulated below

Ingredients	% content
SiO2	93.1%
H_2O (humidity)	1.0%

LOI	1.81%
Retained 45 micron	0.58%
Density	400-720Kg/m^3
BET	23.36m^2/gm
Specific gravity	2.4
Colour	White
Form	Powder

Table 5 physical and chemical properties of silica fume

Fibers

There 2 different types of fiber used in the study i.e. steel fiber and polypropylene fiber.

Steel Fibers

In the present work steel fibers crimped type is used which were brought from M & J International, Mumbai, Maharashtra. The density of the steel fiber is 7850 kg/m^3. The specification of steel fiber is tabulated below.

Properties	Specification
Material	Low carbon cold drawn wire
Fiber type	Crimped type steel fiber
Length of fiber	40 mm
Eqv. Diameter	0.8 mm
Tensile strength	800-900 Mpa (N/mm^2)
Fiber shape	Undulated along its length
Compliance	Conforming ASTM A820

Table 6 Properties of steel fiber

Polypropylene Fibers

Polypropylene fibers are readily available in the market in standard dimensions. The fibers used here are of length 12 mm which is prescribed by the manufacturers for the concrete work. The density of PPF is found to be 910 kg/m^3.

3. MIX DESIGN

As per IS 10262 – 2009 code and using the above test results. The mix design producer was carried out for M30 grade of concrete. A Trail mix for M30 grade was obtained by mix design and the mix proportion obtained for M 30 grade concrete is given in the Table below.

W/C ratio	Cement	Fine aggregate	Coarse aggregate	% of super plasticizer
0.45	351 kg/m^3	733.12 kg/m^3	1243.7kg/m^3	0.8%
0.45	1	2.08	3.54	0.8%

Table 7 mix proportion

Similarly mix design producer was used by replacement of cement as binder by 20 % of fly ash & silica fume respectively for M30 grade of concrete

Combinations of Material with Fibers

The experimentations are designed by replacing the cement by fly ash & silica fume respectively by 20% and with different percentage of fiber as steel fiber (SF) 1%, polypropylene fiber (PPF) as 1% and hybrid fiber (0.5%+0.5%) i.e. (SF+PPF).

4. RESULTS AND DISCUSSION

4.1Workability Test

Slump Test Results

The slump test results for hybrid FRC and mono FRC with replacement of cement by fly ash and silica fume by 20% respectively are given below

SLNO.	FIBER CONTENT %	H 1 (mm)	H 2(mm)	SLUMP (mm)
PLAIN CONCRETE				
1	0%	300	232	68
2	1% SF	300	252	48
3	1%PPF	300	241	59
4	(0.5+0.5)%HYF	300	249	51
REPLACEMENT OF CEMENT BY 20% FLY ASH				
5	0%	300	230	70
6	1% SF	300	248	52
7	1%PPF	300	238	62
8	(0.5+0.5)%HYF	300	244	56
REPLACEMENT OF CEMENT BY 20% SILICA FUME				
9	0%	300	227	73
10	1% SF	300	246	54
11	1%PPF	300	236	64
12	(0.5+0.5)%HYF	300	240	60

Table 8 slump test results

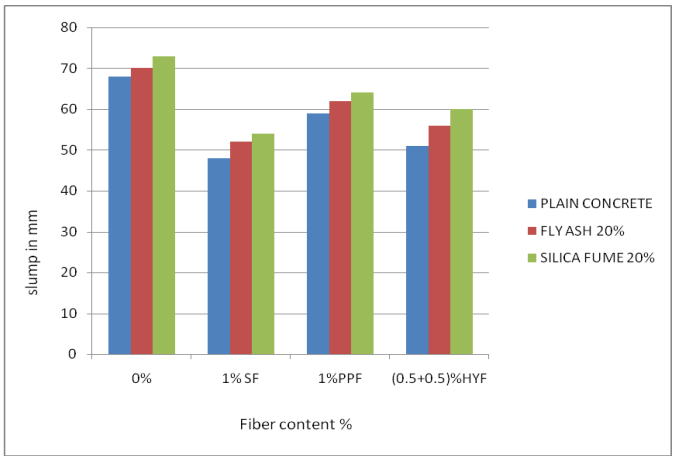

Fig 1 variation of slump test

Compaction Factor Test Results

The compaction factor test result for hybrid fiber reinforced concrete and mono fibers reinforced concrete with replacement of cement by fly ash & silica fume by 20% respectively are given below.

SLNO.	FIBER CONTENT %	W1 EMPTY Kg	W2 LOSSELY COMPACTED Kg	W3 FULLY COMPACTED Kg	COMPACTION FACTOR = (W2-W1)/(W3-W1)
PLAIN CONCRETE					
1	0%	12.14	22.54	24.19	0.863
2	1% SF	12.14	23.18	26.58	0.765
3	1%PPF	12.14	22.74	25.5	0.793
4	(0.5+0.5) %HYF	12.14	23.06	26.35	0.768
REPLACEMENT OF CEMENT BY 20% FLY ASH					
5	0%	12.14	22.74	24.33	0.870
6	1% SF	12.14	23.28	26.65	0.768
7	1%PPF	12.14	23.04	25.8	0.798
8	(0.5+0.5) %HYF	12.14	23.18	26.45	0.771
REPLACEMENT OF CEMENT BY 20% SILICA FUME					
9	0%	12.14	22.85	24.43	0.871
10	1% SF	12.14	23.43	26.73	0.774
11	1%PPF	12.14	23.37	25.91	0.816
12	(0.5+0.5) %HYF	12.14	23.32	26.51	0.778

Table 9 compaction factor results

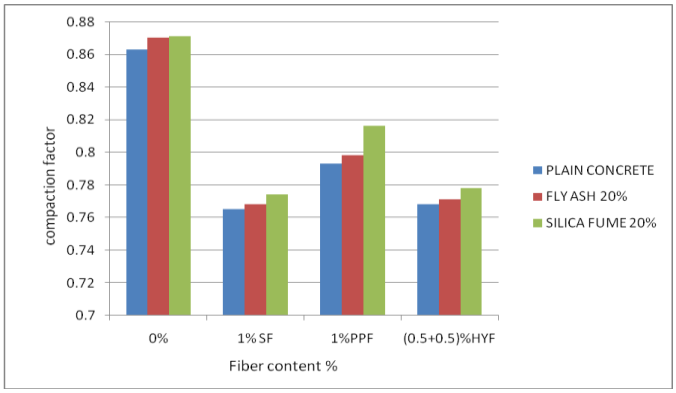

Fig 2 variation of compaction factor test

Vee–Bee Consistometer Test Results

The Vee-Bee consistometer test results for hybrid FRC and mono FRC with replacement of cement by fly ash & silica fume by 20% respectively are given below.

SLNO.	FIBER CONTENT %	VEE BEE SECONDS
PLAIN CONCRETE		
1	0%	14
2	1% SF	27
3	1%PPF	18
4	(0.5+0.5)%HYF	22
REPLACEMENT OF CEMENT BY 20% FLY ASH		
5	0%	12
6	1% SF	23
7	1%PPF	16
8	(0.5+0.5)%HYF	18
REPLACEMENT OF CEMENT BY 20% SILICA FUME		
9	0%	11
10	1% SF	20
11	1%PPF	14
12	(0.5+0.5)%HYF	16

Table 10 Vee bee consistometer results

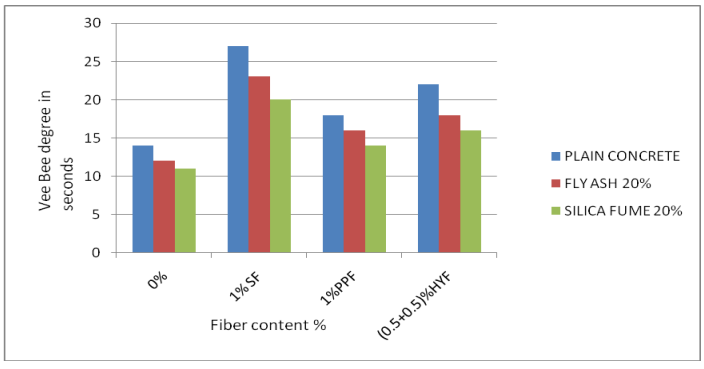

Fig 3 variation of Vee Bee consistometer test

4.2 Strength Test Results

Compressive Strength Test Results

The compressive strength result for hybrid FRC and mono FRC with replacement of cement by fly ash & silica fume by 20% respectively, After 28 days of curing are given below.

FIBER CONTENT %	COMPRESSIVE STRENGTH Mpa	% Increase in strength compared to reference mix
PLAIN CONCRETE		
0% (ref mix.)	31.11	-
1% SF	33.63	8.10
1% PPF	31.70	1.90
(0.5+0.5)% HYF	32.590	4.76
REPLACEMENT OF CEMENT BY 20% FLY ASH		
0%	35.56	14.30
1% SF	38.52	23.82
1% PPF	36.44	17.13
(0.5+0.5)% HYF	37.33	19.99
REPLACEMENT OF CEMENT BY 20% SILICA FUME		
0%	36.89	18.58
1% SF	40	28.58
1% PPF	37.33	19.99
(0.5+0.5)% HYF	38.81	24.75

Table 11 compressive strength results

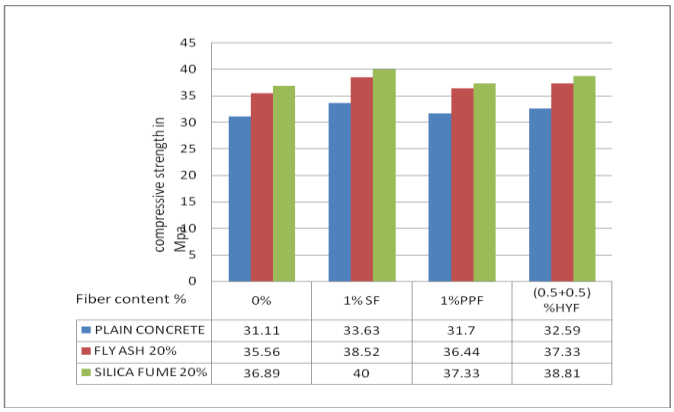

Fig 4 variation of compressive strength

Split tensile strength test results

The split tensile strength test result for hybrid FRC and mono FRC replacement of cement by fly ash & silica fume by 20% respectively, after 28 days of curing are given below.

Fiber content %	Split tensile strength Mpa	% increase in strength compared to reference mix
PLAIN CONCRETE		
0% (ref mix.)	2.32	-
1% SF	3.82	64.66
1% PPF	3.18	37.07
(0.5+0.5)% HYF	3.500	50.86
REPLACEMENT OF CEMENT BY 20% FLY ASH		
0%	2.62	12.93
1% SF	3.89	67.67
1% PPF	3.4	46.55
(0.5+0.5)% HYF	3.73	60.78
REPLACEMENT OF CEMENT BY 20% SILICA FUME		
0%	2.78	19.83
1% SF	4.0	72.41
1% PPF	3.71	59.91
(0.5+0.5)% HYF	3.83	65.09

Table 12 compressive strength results

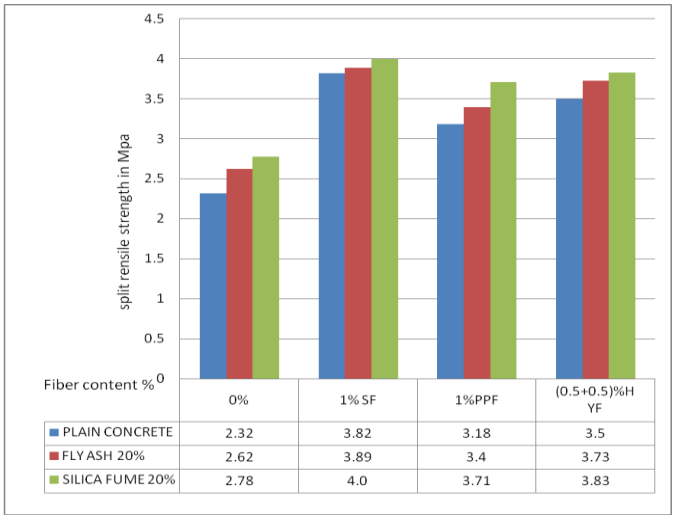

Fig 5 variation of split tensile strength

Flexural Strength Test Results

The flexural strength test result for hybrid FRC and mono FRC with replacement of cement by fly ash & silica fume by 20% respectively, after 28 days of curing are given below.

fiber content %	flexural strength Mpa	% increase in strength compared to reference mix
PLAIN CONCRETE		
0% (ref mix.)	3.34	-
1% SF	5.31	58.98
1% PPF	3.95	18.26
(0.5+0.5)% HYF	4.71	41.02
REPLACEMENT OF CEMENT BY 20% FLY ASH		
0%	3.8	13.77
1% SF	5.92	77.25
1% PPF	4.56	36.53
(0.5+0.5)% HYF	5.01	50.00
REPLACEMENT OF CEMENT BY 20% SILICA FUME		
0%	4.10	22.75
1% SF	6.07	81.74
1% PPF	4.71	41.02
(0.5+0.5)% HYF	5.62	68.26

Table 13 Flexural strength results

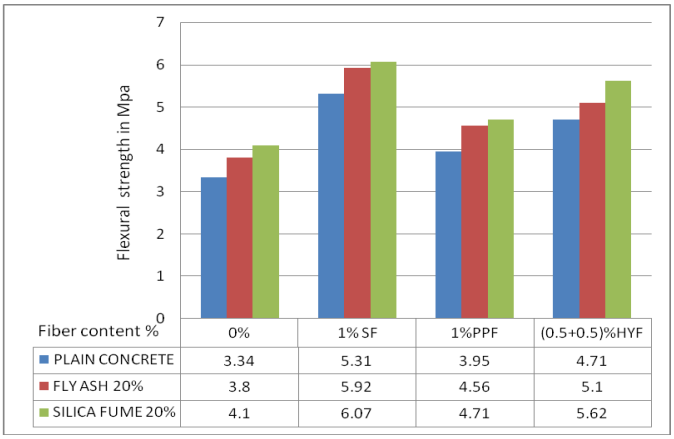

Fig 6 variation of Flexural strength

5. OBSERRVATIONS AND DISCUSSIONS

Following observations seen based on the experiments conducted on the investigation hybrid fiber reinforced concrete.

1. It is seen that the workability of concrete as measured by slump test, compaction factor and vee bee degree goes on decreasing due to addition of fiber in concrete.
   This may be due to length of the fiber and type of fiber i.e. as steel fiber are rigid they decrease the workability more than that of polypropylene fibers as they are synthetic fibers
2. It is observed that the workability of concrete as measured by slump test, compaction factor and vee bee degree increases due to replacement of cement with mineral admixture.
   this may be due to as particles of cement are replaced with finer and smooth particles of mineral admixture by 20% due to this practical size and replacement level it act as micro filler and thus increase the workability.
3. It was found that slump value, compaction factor and vee bee degree for mono fibers and hybrid fibers were very less with steel fiber and moderate with hybrid fiber and good with polypropylene fiber.
   This we can say polypropylene fiber can give good workability comparing hybrid fiber and steel fibers due its smaller length and elastic and synthetic property.
4. It is noticed that compressive strength of polypropylene fiber is less compared to hybrid fiber and hybrid fiber compressive strength is less than steel fiber.
   The percentage increase in the compressive strength is obtained be 8.1%, 1.9%, 4.76% in plain concrete. And with replacement of cement by 20% fly ash the increase in compressive strength was 23.82%, 17.13% and 19.99%. But it also observed that for replacement of cement by 20% silica fume percentages increase was 28.58%, 19.99%, and 24.75% for 1% of SF, PPF, and HYF respectively compared with convectional mix.
   This is due to addition of fiber and mineral admixture into the concrete as the properties of concrete is increased with mineral admixtures which act as micro filler.
5. It was noticed that the split tensile strength percentage increase is 64.66%, 37.07%, 50.86% in plain concrete and with replacement of cement by 20% fly ash the increase in tensile strength was 67.67%, 46.55% and 60.78% and with replacement of cement by 20% silica fume percentages increase was 72.41%, 59.91% and 65.09% for 1% of SF, PPF, and HYF respectively compared with convectional mix.
6. It was noticed that flexural strength increase in percentage due to addition of fibers are 58.89%, 18.26%, 41.02% in plain concrete and with replacement of cement by 20% fly ash the increase in flexural strength was 77.25%, 36.53% and 50.0% and with replacement of cement by 20% silica fume percentages increase was 81.74%, 41.02 and 68.26% for 1% of SF, PPF, and HYF respectively compared with convectional mix.
7. It was also observed that while testing there was brittle failure in concrete without fiber and concrete with fibers there was ductile failure.
   Thus thereby we can conclude that there is increase in stiffness and resist the crack in more efficient

way with addition of fibers and with mineral admixtures.

6. CONCLUSIONS

The conclusions that can with drawn based on the investigative study is as follows

1. The workability of concrete decreases due to addition of fiber into the concrete. But comparing the three types of fibers we say that polypropylene fiber gives good workability compared to other.
2. The workability of concrete improves with replacement of mineral admixture in concrete and for replacement of cement by silica fume there is good increase compared to fly ash.
3. The slump value increases with mineral admixture and it also increase the workability for fiber reinforced concrete.
4. The compaction factor is less for steel fiber and moderate for hybrid fiber and good for polypropylene fiber in concrete.
5. There is vee bee seconds reduce due to addition of mineral admixture in concrete and also with fibers.
6. The compressive strength increases up to 28.58% with 1% steel fiber & 20% replaced silica fume by cement compared with convectional mix.
7. The split tensile strength increases up to 72.41% with 1% steel fiber & 20% replaced silica fume by cement compared with convectional mix
8. The flexural strength increases up to 81.74% with 1% steel fiber & 20% replaced silica fume by cement compared with convectional mix
9. Form the overall study we can say that steel fiber yield better result in strength but not in workability. Polypropylene yield less strength compared steel fibers but good workability. And whereas hybrid fiber yields good strength and workability thus hybrid fiber gives more efficiency in both strength and workability.

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