Effect of hybrid fibers and mineral admixture on properties of high strength concrete

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High strength concrete with fibers offers several economic and technical benefits: the use of fibers extends its possibilities. It can reduce thermal, shrinkage cracks and increases strength as compared to conventional concrete. The main aim of the study was to investigate the effect of hybrid fibers and mineral admixture on properties of high strength concrete. Hybridization of steel and polypropylene fibers by incorporating with high strength concrete to find out flexural and compressive strength of concrete was investigated. Fiber volume fraction (VF) 1%, 1.5% and 2% by volume of concrete was added with mineral admixture (from a good company) contribution of 5% and 10% by weight of cement. Hybrid fibers contribute to increase the flexural strength while the mineral admixture boosts the compressive strength of concrete.

1. INTRODUCTION

Concrete is widely acclaimed for its high level of strength, toughness, workability and durable performance. However, concrete's heterogeneous structures do create some undesirable effects. The incorporation of fiber into cementitious material improves flexural strength and resists cracking. Thus, the inclusion of fibers into concrete not only provide more ductility but also improves structural properties such as tensile strength, static flexural strength, impact strength, flexural toughness and the energy absorption capacity of the concrete [1]. Incorporating the hybridization of two or three different types of fibers in a cement system, results in a composite with higher engineering performance and better mechanical properties [2].

The objective of this study was to evaluate the mechanical properties of fiber reinforced concrete, containing hybrid fibers combinations of steel and non-metallic fibers such as polypropylene. The total dosage of fibers was maintained as 1%, 1.5% and 2% by volume of concrete to provide good workability based on previous literature review [2]. A comparative evaluation of various hybrid fibers concrete was made based on hardened concrete properties –compressive strength and flexural strength.

2. MATERIALS AND MIX DESIGN

The primary difference between high-strength concrete and normal-strength concrete relates to the compressive strength that refers to the maximum resistance of a concrete sample to applied pressure. The concrete of the order of 200MPa has become a reality at least at the laboratory conditions and concrete of the order of M60 to M120 are commonly used at sites. The production of high strength concrete requires more research and more attention to quality control than conventional concrete.

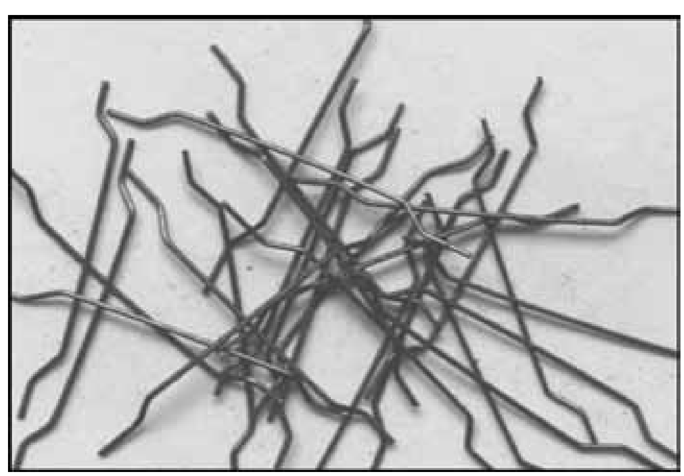

Figure 1. Steel fibers

Several experimental works were planned to achieve the objective of the current study. Experiments were carried out to find out the various mechanical properties such as compressive strength and flexural strength. High strength concrete (M60) is normally prepared for longer service life and less maintenance. Hybrid fibers (steel fibers shown in Figure 1 and polypropylene fibers shown in Figure 2) are used to increase the ductility, strength and makes crack resistance. The mineral admixture was used to get early strength [3].ACI method was used to prepare high strength concrete mixture [4].

Figure 2. Polypropylene fibers

Table 1. Characteristics of steel fibers

Properties	Steel
Average fiber length	35mm
Average fiber width	0.56mm
Aspect ratio(L/d)	65
Breaking strength	>1100Mpa
Tensile stress	>800N
Ultimate elongation	<2%
Specific gravity	7.5

Table 2. Characteristics of polypropylene fibers

Properties	Polypropylene
Length	25mm
Construction	Fibrillated
Elongation	15 %
Tenacity	5.5 GPD
Dosage	Min 0.9 kg/m^3 of concrete
Thermal Conductivity	Low
Electrical Conductivity	Low
Melting Point	165 degree Celsius

Table 3. Characteristics and properties of mineral admixture

Chemical Analysis	Mass %	Physical analysis	Range
CaO	32-34	Bulk Density	600-700 kg/m^3
Al_2O_3	18-20	Surface Area	12000 cm^2/gm
Fe_2O_3	1.8-2	Particle shape	Irregular
SO_3	0.3-0.7	Particle Size,d10	< 2 μ
MgO	8-10	d50	< 5μ
SiO_2	33-35	d90	< 9 μ

Ordinary Portland cement 53 grade was used for the concrete mixtures. The mineral admixture obtained from good company was used for the high strength concrete mixtures [3]. River sand conforming to zone I with a specific gravity of 2.6 was used as the fine aggregate, while crushed aggregate of specific gravity 2.7 was used as coarse aggregate [5]. A super plasticizer was used to obtain the desired workability. The hybrid fibers used in the study were glued hooked steel fibers and polypropylene fibers. Characteristics of steel fibers, polypropylene fibers and mineral admixture are mentioned in Tables 1, 2 and 3 respectively.

Trial mixtures were prepared to obtain compressive strength of 60 MPa at 28 days, along with a workability of 50– 75 mm. In order to obtain the desired workability, super plasticizer was added. The detailed mixture proportions for the study are presented in Table 4.

Table 4. Concrete mixture proportions used in the study

Cementitious material (kg/m^3)	Mineral admixture (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)		Water (kg/m^3)	Super plasticizer (kg/m^3)
			10mm	20mm		
575	28.75 (5%) 57.5 (10%)	655	392	588	190	3.45

Figure 3. Specimens for compressive and flexural test

3. TEST PROCEDURE

3.1 Test for compressive strength of concrete (IS 516:1959)

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. For this test, 150mm x150mm x 150mm size specimens were used as shown in Figure 3. The concrete cubes were tested on compression testing machine of capacity 2000kN as shown in Figure 4. The load was applied to opposite sides of specimen. The load at which concrete cube was failed, considered as ultimate load and noted. The compressive strength was obtained by

Compressive strength = P/A

where, P = Cube compressive load causing failure in N
A = Cross sectional area of cube in mm. The average of number of specimen strength is calculated and it was taken as compressive strength of one set [6].

Figure 4. Compressive strength test on specimen

Figure 5. Flexural strength test on specimen

3.2 Test for flexural strength of concrete (IS 516:1959)

Flexural strength also known as modulus of rupture, a mechanical parameter for brittle material, is defined as a materials ability to resist deformation under load. The flexural strength represents the highest stress experienced within the material at its moment of rupture. For this test 100mmx100mm x500mm size specimens were used. The specimens were tested by using universal testing machine as shown in Figure 5. The load at which control specimen ultimately fails is noted. The flexural strength is calculated by

Flexural strength = $pl/bd2$(MPa)

where, p = maximum load in N, l = Length between the support in mm, d = Depth of specimen in mm, b = Width of specimen in mm [6].

4. EXPERIMENTAL RESULTS AND DISCUSSION

Tables 5, 7, 8 and Figures 6, 7 shows the compressive strength of concrete containing hybrid fibers and mineral admixture. The strength increased with increasing replacement of cement up to 10%. The specimen with 10% mineral admixture and 1.5% hybrid fibers showed maximum compressive strength than the compressive strength of specimen with 1% and 2% hybrid fibers.

Table 5. Compressive strength test results for cube specimens

Sr. no	Specimen no.	Mineral admixture (%) by wt. of cement	Total fiber volume Fraction (%)	Steel fibers (%)	Polypropylene fibers (%)	Compressive strength (MPa)	Average compressive strength (MPa)
1	5C1	5	1	100	0	64, 60 ,62	62
2	5C2			90	10	65, 61, 60	62
3	5C3			80	20	61, 63, 63	62.33
4	5C4			70	30	60, 59, 58	59
5	5C5			60	40	68, 71, 65	68
6	5C6		1.5	100	0	69, 67, 65	67
7	5C7			90	10	65, 63, 62	63.33
8	5C8			80	20	63, 62, 66	63.67
9	5C9			70	30	61, 59, 60	60
10	5C10			60	40	55, 54, 56	55
11	5C11		2	100	0	62, 65, 65	64
12	5C12			90	10	60, 61,59	60
13	5C13			80	20	58, 56, 60	58
14	5C14			70	30	59, 62, 58	59.67
15	5C14			60	40	54, 52, 56	54
16	10C16	10	1	100	0	71, 75, 72	72.67
17	10C17			90	10	67, 70, 70	69
18	10C18			80	20	62, 66, 65	64.33
19	10C19			70	30	62, 58, 62	60.67
20	10C20			60	40	64, 66, 68	66
21	10C21		1.5	100	0	69, 70,65	68
22	10C22			90	10	69, 70, 66	68.33
23	10C23			80	20	69, 72, 70	70.33
24	10C24			70	30	63, 66, 64	64.33
25	10C25			60	40	66, 70, 68	68
26	10C26		2	100	0	70, 69, 66	68.33
27	10C27			90	10	66, 66, 69	67
28	10C28			80	20	58, 64, 59	60.33
29	10C29			70	30	63, 60,61	61.33
30	10C30			60	40	54, 53, 56	54.33

Table 6. Flexural strength test results of beam specimen

Sr. no.	Specimen no	Mineral admixture (%) by wt. of cement	Total fiber volume fraction (%)	Steel fiber (%)	Polypropylene fiber (%)	Flexural strength (MPa)	Average flexural strength (MPa)
1	5B1	5	1	100	0	7.9, 6.1, 5.5	6.5
2	5B2			90	10	7.2, 7.3, 7.4	7.3
3	5B3			80	20	6.6, 7.44, 6.0	6.68
4	5B4			70	30	6.0,7.2,7.2	6.8
5	5B5			60	40	8.3,7.1,7.2	7.53
6	5B6		1.5	100	0	8.5,8.6,8.5	8.53
7	5B7			90	10	8.2, 8.1	8.15
8	5B8			80	20	7.90,7.22,7.4	7.51
9	5B9			70	30	7.1,7.6,7.8	7.5
10	5B10			60	40	7.6,7.2,7.38	7.39
11	5B11		2	100	0	8.5,8.7,8.44	8.55
12	5B12			90	10	8.4,8.7,8.2	8.43
13	5B13			80	20	8.7, 8.5,8.2	8.46
14	5B14			70	30	7.6,7.5	7.55
15	5B15			60	40	8.6,7.2	7.9
16	10B16	10	1	100	0	4.8,5.9,4.59	5.1
17	10B17			90	10	4.6, 5.3,6.4	5.43
18	10B18			80	20	5.9,4.3,4.8	5.
19	10B19			70	30	4.8,4.8,6.7	5.47
20	10B20			60	40	5.1, 6.3,8.2	5.16
21	10B21		1.5	100	0	6.9, 7.5, 7.32	7.24
22	10B22			90	10	7.2,5.8,6.7	6.56
23	10B23			80	20	7.1,5.9,6.3	6.43
24	10B24			70	30	5.78,5.9,5.7	5.79
25	10B25			60	40	5.4,5.2,5.24	5.28
26	10B26		2	100	0	7.3,6.1,6.7	6.7
27	10B27			90	10	7.8,5.8,5.2	6.3
28	10B28			80	20	6.3,6.7,6.5	6.5
29	10B29			70	30	6,9.6.0,6.15	7.26
30	10B30			60	40	7.3,7.32,7.33	7.32

Tables 6, 9, 10 and Figures 8, 9 shows the flexural strength of concrete containing hybrid fibers and mineral admixture. The strength increased with increasing percentage of volume fraction of hybrid fibers. The specimen with 5% mineral admixture and 1.5% hybrid fibers showed maximum flexural strength than the flexural strength of specimen with 1% and 2% hybrid fibers.

Table 7. Average compressive strength test results for 5% mineral admixture

For 5% Mineral admixture		Avg. compressive strength in MPa		
Mix number	% fibers	1% VF	1.5% VF	2% VF
1	100-0	62	67	64
2	90-10	62	63.33	60
3	80-20	62.33	63.67	58
4	70-30	59	60	59.67
5	60-40	68	55	54

Table 8. Average compressive strength test results for 10% mineral admixture

For 10% mineral admixture		Avg. compressive strength in MPa		
Mix number	% fiber	1% VF	1.5% VF	2% VF
1	100-0	72.67	68	68.33
2	90-10	69	68.33	67
3	80-20	64.33	70.33	60.33
4	70-30	60.67	64.33	61.33
5	60-40	66	68	54.33

Table 9. Average flexural strength test results for 5% mineral admixture

For 5% mineral admixture		Avg. flexural strength in MPa		
Mix number	% fibers	1% VF	1.5% VF	2% VF
1	100-0	6.5	8.53	8.55
2	90-10	7.3	8.15	8.43
3	80-20	6.68	7.51	8.46
4	70-30	6.8	7.5	7.55
5	60-40	7.53	7.39	7.9

Table 10. Average flexural strength test results for 10% mineral admixture

For 10% Mineral admixture		Avg. Flexural strength in MPa		
Mix number	% fibers	1% VF	1.5% VF	2% VF
1	100-0	5.1	7.24	6.7
2	90-10	5.43	6.56	6.3
3	80-20	5	6.43	6.5
4	70-30	5.47	5.79	7.26
5	60-40	5.16	5.28	7.32

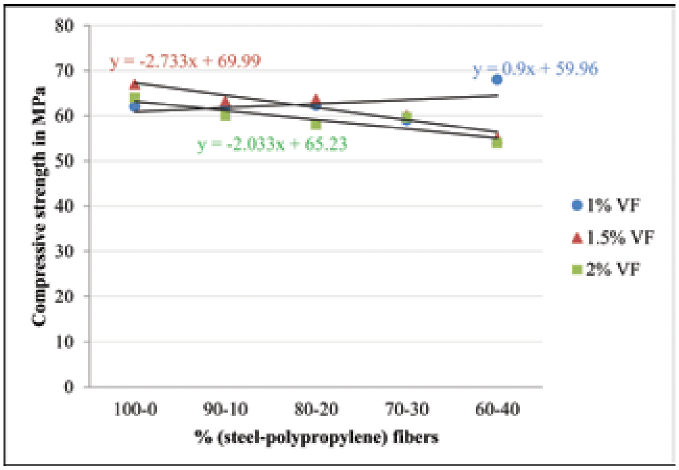

Figure 6. Variation of compressive strength for 5% mineral admixture

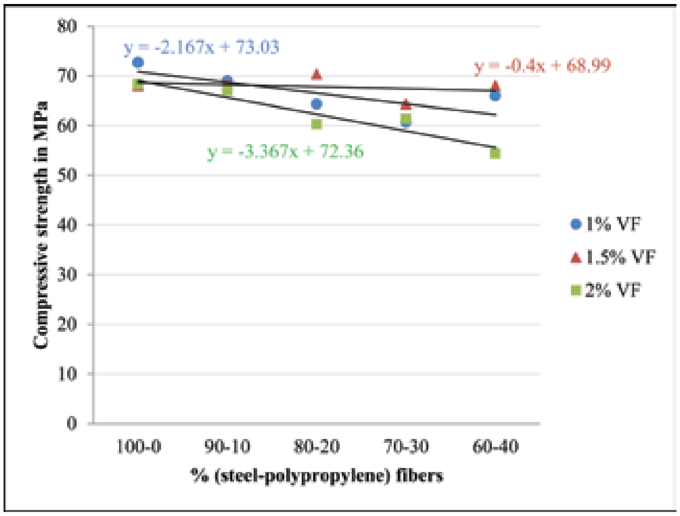

Figure 7. Variation of compressive strength for 10% mineral admixture

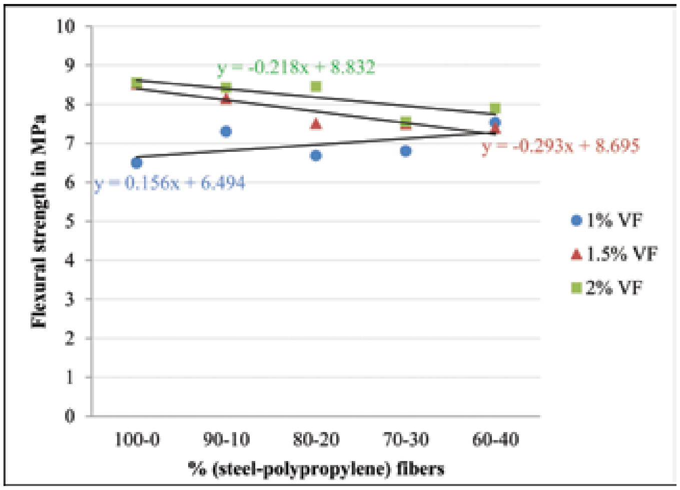

Figure 8. Variation of flexural strength for 5% mineral admixture

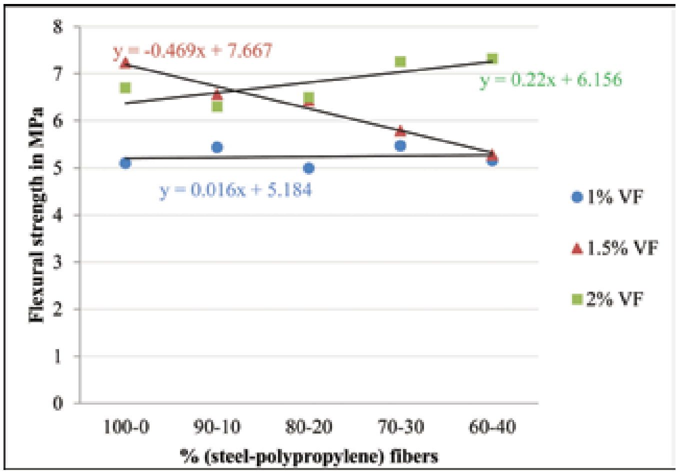

Figure 9. Variation of flexural strength for 10% mineral admixture

6. CONCLUSION

This paper presents mechanical properties of high strength concrete developed by hybrid fibers and mineral admixture for different mix combinations. The mechanical properties of the concrete mixtures were evaluated based on compressive and flexural strength. The following conclusions were drawn from the study:

- Experiments with M60 grade of concrete suggest that 10% replacement of cement with mineral admixture and 1.5% hybrid fibers resulted in best concrete compressive strength. Compressive strength was increased with increase in percentage of mineral admixture.
- As we increase the fiber volume fraction, flexural strength increases. The flexural strength of concrete with 5% replacement of cement with mineral admixture and 2% hybrid fibers resulted in maximum.
- It is recommended that the utilization of mineral admixture in concrete as cement replacement is possible.
- The results indicated that the use of hybrid fibers with mineral admixture enhance the mechanical properties of concrete.

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