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Enhancement the Strength of Fly Ash Concrete by using Hybrid Fibers

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Abstract: These fibers have been used in different percentages and the cement in concrete is replaced by 50% class f flyash. Steel fibers are added in the order of 0.5%& 1% polypropylene fibers are added in the order of the 0.5% & 0.75% and the basalt fibers are added in the order of 0.5% 0.75% and 1% by volume of concrete and the mix designs were formulated and specimens were cast and tested for computing compressive strengths indirect tensile strengths and flexural strengths at various periods from 3 to 56 days. In the experiments, hybrid fiber reinforced high volume flyash concrete results were compared with the individual fibers which provided good results. Test results show that improvement in strength of flyash concrete with hybrid fiber reinforcement (1%steel fiber 0.75% polypropylene fiber and 0.75% basalt fiber) can be quite significant as compared to that of individual fibers and other hybrid fiber combinations. In the experiments, while using maximum percentages of fibers in hybrid combination (by adding steel fiber, polypropylene fiber and basalt fiber together) in a mix, workability is slightly affected and this paper has identified that using hybrid fibers in high volume flyash concrete gives rise to enhanced strength characteristics. It is observed that workability is affected when fiber percentages exceed 1% limit by volume of concrete.
Keywords: fly ash, hybrid fiber, steel fibers, polypropylene fiber, workability, mechanical properties.

I. INTRODUCTION

The concrete is the most popular artificial material on the earth and mixture of cement sand and aggregate (fine aggregate (sand) coarse aggregate (gravel or crushed stone)) concrete is a composite material composed of coarse aggregate bonded together with a fluid cement that hardens over time most concretes used are lime-based concretes such as Portland cement concrete or concretes made with other hydraulic cements such as ciment fondu however asphalt concrete which is frequently used for the road surfaces is also a type of the concrete where the cement material is bitumen and polymer concretes are the sometimes used where the cementing of material is a polymer. Concrete is a widely used of the construction material in the world. nowdays the world witnessing the construction of the more and more challenging and difficult engineering structures and so the concrete need to posse's very high strength and sufficient workability the researches all the world developing of high performance concrete by adding various fibres and admixtures in the different proportion. various fibres like glass ,carbon, polypropylene, nylon fiber and provide improvement in concrete properties like tensile strength fatigue characteristic, durability, shrinkage, impact erosion resistance and the serviceability of concrete

Concrete in general and high performance concrete in particular is brittle. To make the concrete ductile different kinds of fibres can be used. Replacing cement by at least 50% or more than 50% of ISTM class F or class C fly ash by mass is known as high volume fly ash concrete. Low-calcium fly ash has been used in this experimental investigation. Fly ash results from burning bituminous coal consisting of a major part of glass phase with crystalline inclusions, called class F fly ash according to ISTM. Globally researchers produce high performance concrete with the replacement of cement by 50%.

A. Fly Ash Concrete

Concrete is the most widely used construction material and has high compressive strength. But it is very brittle due to weak tensile strength, low flexural strength and impact strength and has low resistance against cracking. Today, industrial and agricultural waste by-products such as flyash, ground granulated slag and rice husk ash are used as supplementary cementitious materials in concrete. The incorporation of supplementary cementitious materials not only improves the mechanical properties of concrete but also reduces the cement consumption by replacing part of cement with these pozzolanic materials [Ramesh et al, 2013]. Concrete strength increases with increasing amount of flyash up to an optimum value, beyond which strength starts to decrease with further addition of flyash. As the cement content in the concrete mixture increases, hydration product will also increase and hence the amount of $Ca(OH)_2$ with which the flyash will enter into increased reaction, then an increased amount of C–S–H gel will result, so

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the flyash will be used more efficiently and as well as acts as a binder in both fresh and hardened concrete. Flyash/cement ratio is an important factor determining the efficiency of flyash in concrete.

B. Hybrid Fibers

The main focus of this research is the composite comparison of steel fiber, polypropylene fiber and basalt fiber as it is a new category of hybrid fiber reinforcement in high performance high volume fly ash concrete. Also many other researchers have studied incorporating individual fibers in high volume fly ash concrete to improve the mechanical properties. The use of hybrid fibers (steel fiber, polypropylene fiber and basalt fiber) in high performance high volume fly ash concrete does not appear to be examined. Therefore, this experimental investigative study focuses on using hybrid fibres comprising of steel fibers combined with polypropylene fibers and basalt fibers in high volume class F fly ash concrete mixture to enhance the mechanical properties with 50% replacement of cement

II. MATERIALS AND PROPERTIES

A. Materials

1) *Cement:* GP cement is used in the experiment as per India standard classification.
2) *Flyash:* Flyash from Tarong power plant as per India standard. It is classified as low calcium flyash or ISTM class F flyash as the sum of SiO2 + Al2O3 + Fe2O3 is more than 70% and the CaO content of the flyash is less than 10%. Particle size of flyash is ≤7 micron in diameter given by the supplier. Chemical compositions of binders are presented in Table 1.

Table 1: Chemical composition of binders (A)

ISTM class F fly ash	
Oxides	Proportion
SiO2	65.9
Al2O3	28.89
Fe2O3	0.38
TiO2	1.97
MgO	0.15
CaO	0.06
Na2O	0.05
K2O	0.26
P2O5	0.08
SO3	0.03
LOI	1.24

Table 2: Chemical composition of binders (B)

Portland cement	
Chemical name	Proportion
Portland cement (Clinker)	<97%
Slag	0-80%
CaSO42H2O	3-8%
CaCO3 (limestone)	0-7.5%
Ca(OH)2 (lime) (where applicable)	0-50%
Flyash (where applicable)	0-50%
Crystalline silica (Quartz)	<1%
Hexavalent chromium (Cr VI)	<10 ppm

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3) *Fine Aggregate:* The fine aggregate (sand) used was natural river sand.
4) *Coarse Aggregate:* The hard broken granite stone passing through 12 mm sieve and retained on 10 mm sieve was used as the coarse aggregate with the specific gravity of 2.70 and graded as per IS. Material properties of aggregate is shown in Table

Table 3: Material properties of aggregate

Properties	Fine aggregate	Coarse aggregate
Specific gravity(SSD)	2.6	2.89
Water absorption	0.80%	0.40%

5) *Super Plasticizer:* The water reducing admixture – Napthalene Formaldehyde Sulphonate (Sikament) was used in all mixing in the experimental work.
6) *Lime Powder:* Used to improve the alkali substance in HVFAC.
7) *Water:* The normal tap water is used for mixing the concrete throughout the experimental work having density of 0.9908 and pH value of 7.3
8) *Fibers:* Three types of fibers have been used in this investigation as listed below:
a) Steel fiber
b) Polypropylene fiber (Fibrillated)
c) Basalt fiber

Table 4: Mechanical and physical properties of fibers

Property	Steel fiber	Polypropylene fiber	Basalt fiber
Length (mm)	40	20	12
Diameter	0.3mm	100 µm	20µm
Tensile strength (MPa)	2100	450	3000- 4840
Specific gravity	7.6	0.9	2.65-2.8
Elastic modulus (GPa)	160	5	93 - 110
Density (g/cm$^{3)}$	7.8	0.9	1.75

Table 5: Fiber volume in the concrete mixes

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Sl.no	Mix No	Fibers		
		Steel fiber	Polypropylene fiber	Basalt Fiber
1	C	0%	0%	0%
2	S1	0.50%	0%	0%
3	S2	1%	0%	0%
4	P1	0%	0.50%	0%
5	P2	0%	0.75%	0%
6	B1	0%	0%	0.50%
7	B2	0%	0%	0.75%
8	B3	0%	0%	1%
9	X1	0.50%	0.50%	0.50%
10	X2	0.50%	0.75%	0%
11	X3	0.50%	0.75%	0.75%
12	X4	0.50%	0%	1%
13	Y1	1%	0.50%	0.50%
14	Y2	1%	0.75%	0%
15	Y3	1%	0.75%	0.75%
16	Y4	1%	0%	0.75%
17	Y5	1%	0%	1%
18	Y6	1%	1%	1%

III. TEST METHODS

A. *Compressive Strength Test*

The compressive strength test was carried out in accordance with India standard using MTS machine having a loading capacity of 1000kN and a loading rate of 20 $\pm$2 MPa/minute. Three cylindrical specimens (100mm diameter x 200mm length) were tested for compressive strength at the age of 3 days, 7 days, 14 days, 28 days and 56 days after casting. The average result of the three cylindrical specimens is reported.

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Fig 3.4 Crack pattern at ultimate failure load of cylindrical specimen

B. Indirect Tensile Strength Test

The Indirect tensile strength test was carried out in accordance with India standard using MTS machine with a loading capacity of 1000kN and a loading rate of 1 $\pm$0.1 MPa/minute provided with indirect tensile strength test equipment. Three cylindrical specimens (150mm diameter x 300mm length) were tested for flexural strength at the age of 28 days after casting. The average result of the three cylindrical specimens is reported.

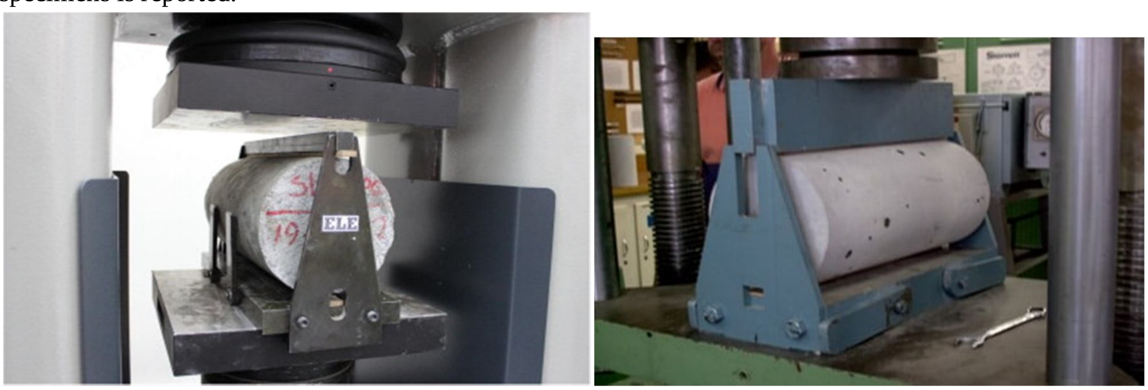

Fig 3.5 Indirect Tensile Strength Test on the cylindrical specimen

C. Flexural Strength Test - Four Point Bending Test

The Modulus of rupture development of concrete test was carried out in accordance with India standard using hydraulic MTS testing machine having a loading capacity of 1000kN. Three beam specimens were tested for flexural strength until the maximum load is reached at the age of 28 days after casting. The average result of the three beam specimens is reported.


Fig 3.9 Flexural strength setup before testing

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IV. EXPERIMENTAL RESULTS

Table 6: Summary of 28-day strength results for fiber reinforced high volume flyash concrete with individual and hybrid fibers.

	Mix no	Addition of all individual fibers in %	Compressive strength (MPa) 28days	Indirect tensile strength (MPa) 28days	Flexural strength (MPa) 28days
Steel Fiber only	C	0%	30.5	3.87	5.16
	S1	0.50%	38.2	4.25	6.41
	S2	1%	43.8	5.51	6.83
Polypropylene Fibre only	C	0%	30.5	3.87	5.16
	P1	0.50%	43.1	4.35	6.16
	P2	0.75%	45.9	4.79	6.49
Basalt Fiber only	C	0%	30.5	3.87	5.16
	B1	0.50%	39.9	3.95	5.38
	B2	0.75%	41.3	4.54	5.56
	B3	1.00%	42.2	4.91	5.92
Hybrid fiber (with min 0.5% Steel fixed)	C	0.00%	30.5	3.87	5.16
	S1	0.50%	38.2	4.25	6.41
	X2	1.25%	42.2	4.74	6.49
	X4	1.50%	40.5	5.47	6.98
	X3	2.00%	50.3	6.26	7.53
Hybrid fiber (with min 1% Steel fixed)	C	0.00%	30.5	3.87	5.16
	S1	0.50%	38.2	4.25	6.41
	S2	1.00%	43.8	5.51	6.83
	Y1	2.00%	49.5	7.7	8.63
	Y3	2.50%	53.6	8.1	9.19
Hybrid fiber (with min 0.5% Basalt fixed)	C	0.00%	30.5	3.87	5.16
	B1	0.50%	39.9	3.95	5.38
	B2	0.75%	41.3	4.54	5.56
	B3	1.00%	42.2	4.91	5.92
	X1	1.50%	43.3	5.95	6.36
	Y4	1.75%	47	4.53	6.93
	Y1	2.00%	49.5	7.7	8.63
	Y3	2.50%	53.6	8.1	9.19
	Y6	3.00%	47.75	6.03	5.7

Table 6 clearly shows that maintaining 1% steel fiber constant in the mix of hybrid fiber combination improves the mechanical properties of high volume flyash concrete when mixed with other individual fibers. As keeping 1% steel fiber constant in the mix Y1, Y2, Y3, Y4, Y5, Y6 but Y3 (1% steel fiber, 0.75% polypropylene fiber and 0.75% basalt fiber) has totally 2.5% of fibers inclusive of all three individual fibers together shows the improvement in strength characteristics when compared to other hybrid format. Y6 (1% steel fiber, 1% polypropylene fiber and 1% basalt fiber) has totally 3% of fibers inclusive of all three individual fibers together but no obvious increase in the strength as the workability of concrete is affected by the maximum percentage of

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fibers together in a mix in which it end up in less compressive strength than Y3.

V. CONCLUSIONS

This research has shown that three fibers can be added in hybrid combination of 1% steel fiber, 0.75% polypropylene fiber and 0.75% basalt fiber to achieve higher compressive strength. It has also shown that significant increase in tensile strength and flexural strength can be observed simultaneously leading to the suggestion that some of the negative effects of individual fiber additions can be negated. A limiting percentage for this combination at 3% overall has also been determined based on the workability of concrete.

A. Based on the experimental analysis of test results, it is confirmed that cement in concrete can be replaced upto 50% by class F flyash with incorporation of hybrid fibers (steel, polypropylene & basalt).

B. It was found that the compressive strength, indirect tensile strength and flexural strength of high volume flyash concrete increases by the addition of steel fiber, polypropylene fiber and basalt fiber in hybrid form as opposed to individual fibers.

C. Favourable effects on mechanical characteristics were also observed from the study and there is substantial benefit with the addition of three fibers in combination in high volume flyash concrete.

D. From the analysis presented, it can be concluded that a hybrid combination of 1% steel fiber, 0.75% polypropylene fiber and 0.75% basalt fiber provides best overall results. However other hybrid combinations were found to provide close strength values that were slightly less than the Y3 hybrid fiber combination.

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