An Experimental study on fiber reinforced concrete with varying percentages of cement replacement with flyash

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Abstract - *Nominal concrete and high strength concrete with or without flyash exhibit brittle behavior. Substitution of flyash to cement in concrete is a widely adopted construction practice underlain by the aim to reduce CO2 emissions of cement production. Researchers have identified that the addition of fibers to concrete increases the ductility and strength. While there is evidence of use of single type of fibers in concrete, the use of hybrid fibers in high volume flyash concrete to enhance the strength and other properties appears to be lacking. Therefore, an experimental investigation has been undertaken to study the high performance high volume flyash concrete reinforced with hybrid fibers: steel fibers and basalt fibers. Effect of replacing 40%, 50%, 60% cement with fly ash and addition of fibers by volume of concrete for M40 grade of concrete. Steel fibers are added in the order of 0.5%, 0.75% & 1% and basalt fibers are added in the order of 0.5%, 0.75% and 1% by volume of concrete. Mix design were formulated and specimens were casted and tested for computing compressive strengths Split tensile strengths and flexural strengths at various periods from 7, 28 and 90days and durability conditions also.*

KEYWORDS: Basalt Fibers, cement, Flyash, Hybrid Fiber reinforced concrete, Hybrid Fibers, steel Fibers.

1 INTRODUCTION

There are two ways that the fly ash can be used in cement and concrete. One way is by blending with cement clinker and gypsum in the manufacturing plant of ordinary Portland cement. Alternatively, at the construction site fly ash can be added to ordinary Portland cement. The ash that is disposed from the plant causes pollution. High Volume Fly ash (HVFA) is generally defined as that with at least 50% of the Portland cement replaced with fly ash. It is necessary to use super plasticizer because of very low water content in High Volume Fly Ash concrete(HVFAC).

Fiber reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers. Fibers are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce bleeding of water. Steel fiber (SF) is the most popular type of fiber used as concrete reinforcement. Initially, SFs are used to prevent/control plastic and drying shrinkage in concrete. The addition of Steel Fibers in concrete significantly increases its flexural toughness; energy absorption capacity, ductile behavior prior to the ultimate failure, reduced cracking, and improved durability. Basalt fiber is a high performance non-metallic fiber made from basalt rock melted at high temperature. Basalt rock can also make basalt rock, chopped basalt fiber, basalt fabrics and continuous filament wire.

2 EXPERIMENTAL DETAILS

In the present experimental program, the first step is selecting of raw materials. Number of conventional trails is prepared and the mix proportions for M40 grade is selected by changing different water Cement ratios. By replacing the cement with flyash in the range of 40%, 50%, 60% and Hybrid Fibers (0.5, 0.75 and1%) are added for concrete mix of cement replaced with flyash as 50%. The experimental program was carried out on cubes, cylinders and beams. The details of the materials used for these specimens and testing procedure incorporated in the test program are presented in the subsequent sections.

2.1 High Volume Fly Ash

High Volume Fly Ash (HVFA) is generally defined as that with at least 40% of the Portland cement replaced with fly ash.

Table 1 Composition of cement and Fly ash

Oxides	Ordinary Portland Cement	Class-F Flyash
	Proportions (%)	portions (%)
Lime (CaO)	60-67	6
Silica (SiO_2)	17-25	55
Alumina (Al_2O_3)	3-8	26
Iron oxide (Fe_2O_3)	0.5-6	7
Magnesium oxide (MgO)	0.1-3	2
Sulphur (SO_3)	1-3	1-3
Sodium oxide	0.4	0.8
Potassium oxide	0.4	0.7
Loss of ignition	2	0.3

2.2 Super plasticizer

The Super plasticizer used was a Master Glenium SKY 8233 high range water reducing agent suitable for flyash concrete.

2.3 Hybrid Fiber reinforced concrete

Hybrid fiber reinforced concrete is two or more fibers will be added to concrete by volume in hybrid form.

2.3.1 Steel Fibers

Steel fiber reinforced concrete is a composite material that can be sprayed. It consists of hydraulic cements with steel fibers that are dispersed randomly and possess a rectangular cross-section. The flexural strength of fiber reinforced concrete is greater than the un-reinforced concrete.

2.3.2 Basalt Fibers

Basalt fiber is a continuous fiber made of melting basalt stone at 1450 to 1500 degrees through Platinum rhodium alloy bushing. It is a new environmental protection fiber which is known as the twenty-first Century "Volcano rock silk", it is also called golden fiber because its color is golden brown. It is similar to fiberglass, having better physic-mechanical properties than fiberglass, but being significantly cheaper than carbon fiber.

3 EXPERIMENTAL INVESTIGATION AND AUTHENTICATION

In this experimental investigation cubes are casted of size 150X150X150mmfor compressive strength, 300×150mm cylinders for splitting tensile strength, 500 ×100 ×100mm beams for flexural strength, after casting, test specimens were covered with plastic sheets and left in the casting room for 24 hours. They were de- moulded after 24 h and were put into a water-curing room until the time of the test.

Following material proportion and various dosage combination of admixture for 0.38 w/c ratio have been studied. For nominal mix of M40 grade of concrete (1:1.61:2.87)

- Cement – 430(kg/m^3)
- Fine aggregate – 692(kg/m^3)
- Coarse aggregate – 1245.58(kg/m^3)
- Water: W/c ratio is0.38
- Super plasticizer – 0.62% by the weight of cement.
- Fly ash: Replacement of cement 40%, 50%, and 60% by weight of cement.
- Addition of Hybrid Fibers (Steel &Basalt) of 0.5%, 0.75%, 1% by the volume of concrete.

3.1 Concrete Mixture Composition

The proportions of the control OPC concrete mixtures were 1:1.61:2.87.Table presents the composition of the concrete mixtures produced and tested: M1 mixture is corresponding control Portland cement concrete; M2- M7 are High Volume Fly Ash Concrete mixtures; M2 mixture is made with 40% Flyash replacement; M3 mixture is made with 50% Flyash replacement; M4 mixture is made with 60% Flyash replacement; M5 mixture is made with 50% Flyash replacement and addition of 0.5% of steel fibers and 0.5% of basalt fibers by volume of concrete;M6 mixture is made with 50% Flyash replacement and addition of 0.75% of steel fibers and 0.75% of basalt fibers by volume of concrete; M7 mixture is made with 50% Flyash replacement and addition of 1% of steel fibers and 1% of basalt fibers by volume of concrete.

Table 2 Concrete Mixture Composition

Mix	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**
Cement(kg/m^3)	430	258	215	172	215	215	215
Fly Ash(kg/m^3)	-	172	215	258	215	215	215
F.A(kg/m^3)	692	692	692	692	692	692	692
C.A(kg/m^3)	1245.58	1245.58	1245.58	1245.58	1245.58	1245.58	1245.58
W/C ratio	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Superplasticizer (%)	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Steel Fibers (%)	-	-	-	-	0.5	0.75	1
Basalt Fibers (%)	-	-	-	-	0.5	0.75	1

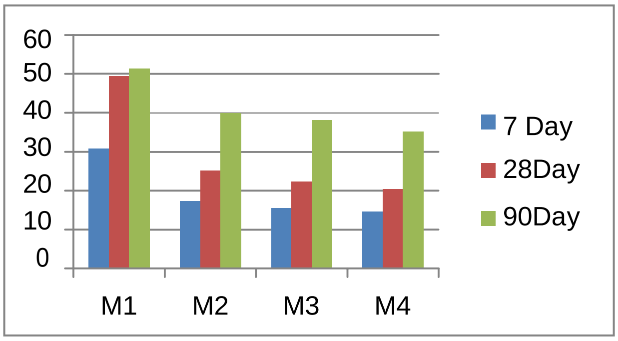
4 RESULTS AND DISCUSSION

4.1Compressive Strength

Compressive strength of concrete mixtures of conventional, high volume fly ash concrete and hybrid reinforced high volume fly ash concrete was determined at the ages of 7, 28, 90 days. Results are given in Table 3 and shown in Fig. 1 and Fig. 2 At 28 days, control mixture M-1 (0% fly ash) achieved compressive strength of 49.43 MPa, whereas mixtures M-2 (40% fly ash), M-3 (50%fly ash), M-4 (60% fly ash) achieved compressive strength reduction of50%, 55%, and 59% respectively, in comparison with the strength of the control mixture M- 1 (0% fly ash). The results at 90 days indicated that there was continuous and significant improvement in strength beyond the age of 28days. The increase in strength from 28 to 90 days was between 37% and 42%.The mixtures M-5 (50% flyash and 0.5% of hybrid fibers),M-6 (50% flyash and 0.75% of hybrid fibers),M-7 (50% flyash and 1% of hybrid fibers) achieved compressive strength reduction of 42%,35%,37% respectively, in comparison with the strength of the control mixture M-1 (0% fly ash) and strength increased as compared to High volume fly ash concrete mixture M-3(50% fly ash). The increase in strength is, of course, due to the cement that continued to hydrate. The significant increase in strength of high-volume fly ash concrete is due to pozzolanic reaction of fly ash.

Table 3 Compressive Strength

Mixture number	**Compressive Strength (N/mm^2)**			**% increase of strength from 28 days to 90 days**
	7 Days	**28 Days**	**90 Days**	
M1	30.82	49.43	51.31	3.5
M2	17.3	25.12	39.87	37
M3	15.52	22.28	38.12	41.5
M4	14.60	20.46	35.11	41.7
M5(0.5% of hybrid fibers)	20.26	28.38	39.52	28.2
M6(0.75% of hybrid fibers)	26.20	32.27	46.92	31.3
M7(1% of hybrid fibers)	24.22	30.75	44.5	30



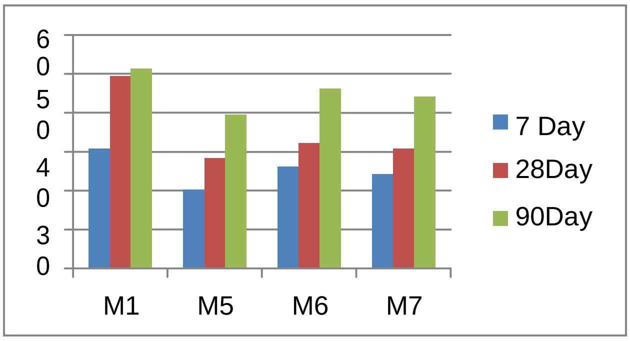


Figure 1 Compressive strength of High Volume Fly Ash Concrete

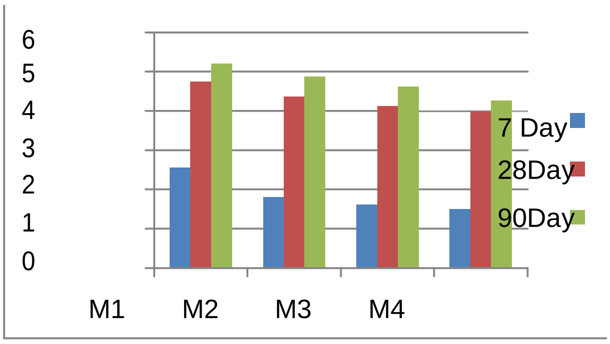
Figure 2 Compressive strength of Hybrid Fiber Reinforced high Volume Fly Ash Concert

4.2 Splitting Tensile Strength

Split tensile strength of concrete mixtures of conventional, high volume fly ash concrete and hybrid reinforced high volume fly ash concrete was determined at the ages of 7, 28, 90 days. Results are given in Table 4 and shown in Fig. 3 and Fig. 4 At 28 days, control mixture M-1 (0% fly ash) achieved Split tensile strength of 49.43 MPa, whereas mixtures M-2 (40% fly ash), M-3 (50% fly ash), M-4 (60% fly ash) achieved split tensile strength reduction of nearly 10% to15% respectively, in comparison with the strength of the control mixture M-1 (0% fly ash). The results at 90 days indicated that there was continuous and significant improvement in strength beyond the age of 28days. The increase in tensile strength from 28 to 90 days nearly 10%.Whereas mixtures M-5 (50% flyash and 0.5% of hybrid fibers), M-6 (50% flyash and 0.75% of hybrid fibers), M-7 (50% flyash and 1% of hybrid fibers) achieved split tensile strength 5-10% more. At the 90 days of curing the split tensile strength is increased by nearly 80% as compared with conventional concrete and high volume fly ash concrete due to presence of fibers.

Table 4 Splitting Tensile Strength

Mixture number	**Splitting Tensile Strength (N/mm²)**			**% increase of strength from 28 days to 90 days**
	7 Days	**28 Days**	**90 Days**	
M1	2.56	4.75	5.2	9
M2	1.8	4.37	4.88	10.5
M3	1.6	4.12	4.62	11
M4	1.5	3.98	4.27	7
M5(0.5% of hybrid fibers)	2.31	4.76	8.73	46
M6(0.75% of hybrid fibers)	3.12	5.12	9.67	47
M7(1% of hybrid fibers)	2.96	4.91	9.14	46.3



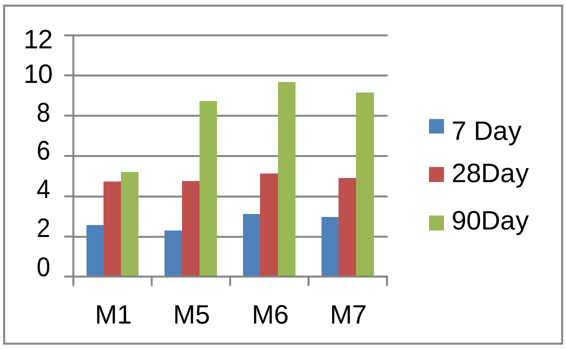


Figure 3 Split Tensile Strength of High volume fly ash concrete

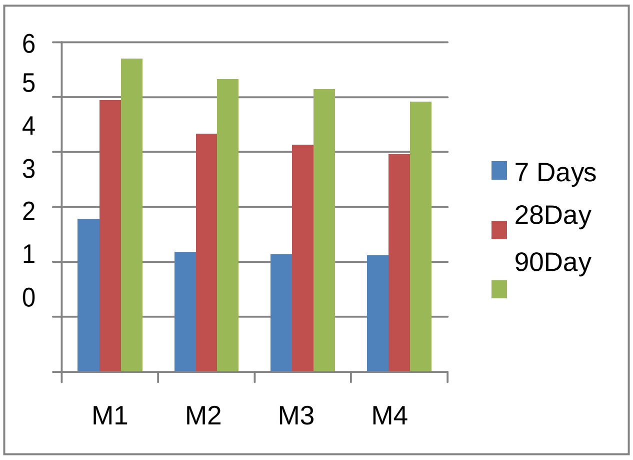
Figure 4 Split tensile strength of hybrid fiber high volume fly ash concrete

4.2 Flexural Strength

Flexural strength of concrete mixtures of conventional and high volume fly ash concrete was determined at the ages of 7, 28, 90 days. Results are given in Table 5 and shown in Fig. 5 and Fig. 6 At 28 days, control mixture M-1 (0% fly ash) achieved flexural strength of 4.94 MPa, whereas mixtures M-2 (40% fly ash), M-3 (50% fly ash), M-4 (60% fly ash) achieved flexural strength reduction of nearly 15% to20% respectively, in comparison with the strength of the control mixture M-1 (0% fly ash). The results at 90 days indicated that there was continuous and significant improvement in strength beyond the age of 28days. The increase in flexural strength from 28 to 90 days nearly 20%.Whereas mixtures M-5 (50% fly ash and 0.5% of hybrid fibers), M-6 (50% fly ash and 0.75% of hybrid fibers), M-7 (50% flyash and 1% of hybrid fibers) achieved flexural strength 15-20% more. At the 90 days of curing the flexural strength is increased by nearly 70% as compared with conventional concrete and high volume fly ash concrete due to presence of fibers.

Table 5 Flexural Strength

Mixture number	**Flexural Strength (N/mm²)**			**% increase of strength from 28 days to 90 days**
	7 Days	**28 Days**	**90 Days**	
M1	2.79	4.94	5.7	14
M2	2.19	4.34	5.32	18
M3	2.14	4.14	5.14	20
M4	2.12	3.96	4.92	20
M5(0.5% of hybrid fibers)	2.49	4.72	8.96	50
M6(0.75% of hybrid fibers)	2.54	4.81	10.3	45
M7(1% of hybrid fibers)	2.52	4.78	9.15	50



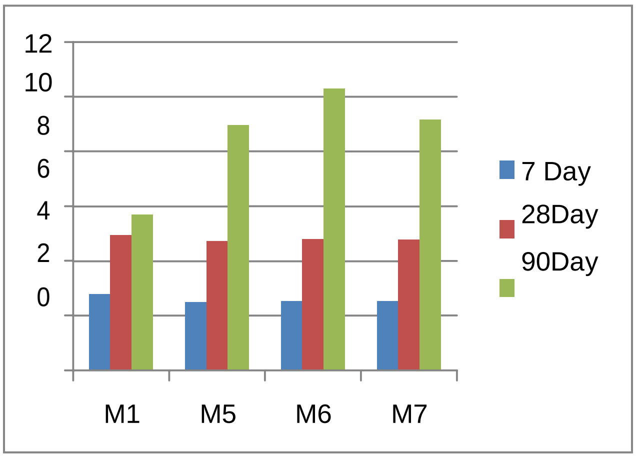


Figure 5 Flexural strength of high volume fly ash concrete

Figure 6 Flexural strength of hybrid fiber high volume flyash concrete

4.3 Durability of Concrete

Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties.

4.3.1 Chemical resistance test

4.3.1.1 Acid resistance –HCl and H_2SO_4

Acid attack test was conducted as per ASTM C267- 01(2012). For acid resistance, the cube specimens were immersed in 2% HCl solution by volume added to water and the pH observed in the solution was 3.10 at the initial stage. Similarly another set of cube specimens were immersed in 2% of H_2SO_4 solution by volume added to water and the pH observed in the solution was 2.10 at the initial stage.

4.4 Percentage Weight loss results

Table 6 Weight reduction in acids

Mixture Number	HCl (2%)			H2SO4 (2%)		
	Average weight of cube before immersion in Acid (Kg)	Average weight of cube after immersion in Acid (Kg)	weight loss in %	Average weight of cube before immersion in Acid	Average weight of cube after immersion in Acid	weight loss in %
M5	8.98	8.65	3.7	8.88	8.51	4.2
M6	8.95	8.69	3.0	8.99	8.68	3.6
M7	8.79	8.48	3.6	8.75	8.41	3.9

4.4 Percentage Strength loss results

Table 7 Strength reduction in acids

Mixture Number	HCl (2%)			H2SO4 (2%)		
	Average strength of cube immersion in water (Kg)	Average strength of cube after immersion in Acid (Kg)	weight loss in %	Average strength of cube immersion in water	Average strength of cube after immersion in Acid	strength loss in %
M5	39.52	33.6	15	39.52	31.69	20
M6	46.92	42.52	10.5	46.92	39.34	17
M7	44.5	39.11	12.4	44.5	36.25	20

5 CONCLUSION

The following conclusions are obtained from this experimental investigation.

1. The replacement of cement with three percentages (40%, 50%, and 60%) of fly ash content reduced the compressive strength, Split tensile Strength, and Flexural strength of concrete at 28 days of curing but there was a continuous and significant improvement of strength properties beyond 28days.
2. The setting time of flyash concrete increased in conjunction with the addition of flyash content.
3. Compressive strength of partial replacement of cement with 50% flyash reinforced with 0.75% steel fiber and 0.75% basalt fiber in hybrid form was found to have been increased by 20% in 90 days compared to partial replacement of cement with 50% flyash without adding fibers.
4. Indirect tensile strength of partial replacement of cement with 50% flyash reinforced with 0.75% steel fiber and 0.75% basalt fiber in hybrid form was found to have been increased by 50% in 90 days compared to partial replacement of cement with 50% flyash without adding fibers.
5. Flexural strength of partial replacement of cement with 50% flyash reinforced with 0.75% steel fiber and 0.75% basalt fiber in hybrid form was found to have been increased by 50% in 28 days compared to partial replacement of cement with 50% flyash without adding fibers.
6. In the durability studies the weight losses are obtained for 90 days of curing in acids HCl is nearly 3- 4% and in $H_2SO_4$is nearly3.5-5%.

7 In the durability studies the strength losses are obtained for 90 days of curing in acids, HCl is nearly 10-15% and in H_2SO_4 is nearly15-20%.

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