Performance of Additive Blended High Volume Fly Ash Concrete - A Systematic Literature Study

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Abstract. Replacing cement with fly ash has recently created huge popularity among the construction field because of its huge production, efficient resources and sustainability aspect. This study is made to determine the High-Volume fly-ash concrete (HVFC) performance by adding additives. The general used concrete mixture is prepared by proportioning fly ash (40-50%) as a replacement. The concrete specimen was found to have better compressive strengths and hence, passed the strength tests. By incorporating additive Nano-SiO_2 and superplasticizer the following compression, flexural rigidity, splitting tensile strength and elasticity modulus were observed in the specimen to establish the cement and fly ash bond. The concrete performance mix with replacement fly ash at different percent was found to have good compressive strength during test and stayed undamaged during the entire period of exposure.

Introduction

The gigantic increment of populace alongside the enormous improvement these days prompted the extraordinary demand for concrete these days. Kanvic's recommended that the Cement request will raise by around 660 MMT (million metric tons) in India by 2030. Cement which is the essential constituent of concrete contributes the significant CO_2 discharge into the climate and furthermore an unnatural weather change. To satisfy the emerging need, in this paper the high-volume fly ash solid execution joining added substances is to be broke down. Fly-ash is collected as residue of coal obtained from power stations. Cement is more expense and important part of concrete. The Cement cost for a unit can be decreased by fractional supplanting of concrete by fly-ash. Fly-ash which is the remains collected from ignition of pummelled coal and gathered from electrostatic power stations wherein coal is used as main fuel source. Fly-ash removal is an important issue as unloading of fly ash as residue might lead to serious ecological issues/risks[1]. The fly ash usage as opposed to unloading it as a non-use material can be mostly utilized on monetary grounds as cement for incomplete substitution of concrete and somewhat in view of its gainful impacts, for example, lower water interest for comparable usefulness, decreased dying and last lower development of warmth. It is being utilized especially in huge applications of solids cum enormous volume situation aiming at controlling development because of hydration warmth and furthermore helps at decreasing breaking at initial ages. HVFC has arisen as development material with its self-potential right. This sort of cement typically contains over half fly-ash by a mass having absolute cement materials nature. Numerous specialists have utilized Class-C and Class-F

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fly-ash in concrete. In the study, an exertion is carried out to introduce the consequences of conducting an examination completed to contemplate the impact of supplanting concrete with HVFC on the properties of cement and an exertion is made to examine the impact of nano-SiO_2 in improving the properties of high strength high HVFC.

Experimental details

Materials

Cement material used here is Ordinary Portland (grade 43). It adjusted to the prerequisites of IS: 8112-1989, and Table 1, shows the results. The cement utilized here is Type-I cement (ASTM C-150). Fly-ash type Class-F (gravity 2.72) is utilized in this examination. It is tried for compound creation per ASTM C-311, and result is presented in Table 2. Natural sand having a 4.75-mm nominal greatest size is utilized as FA[6]. The coarse aggregate utilized was 12.5 mm size. The two totals which was tried per IS: 383-1970, and the actual properties along with strainer examination is given in Table 3 and Table 4, individually. A monetarily accessible superplasticizer which is melamine-based was utilized. Nano-SiO_2 utilized in this paper was purchased from alpha composites, its real properties are given in Table 5.

TABLE 1: *Portland cement characteristics*

Test conducted	Obtained Results	IS: 8112-1989 Requirements
Cement Fineness which is retained on 90-Am sieve	7.7	Maximum of 10
Cement Fineness: specific surface (m^2/kg)	266	Minimum of 225
Normal consistency	30 %	–
Vicat setting time (minutes) Initial time Final time	 107 197	 Minimum of 30 Maximum of 600
Strength due to Compression (MPa) 7 days 28 days	34.9 45.1	Minimum of 33.0 Minimum of 43.0
Specific gravity	3.15	–

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TABLE 2: *Fly-ash composition*

Chemical parameters	% of Fly ash	ASTM C 618 (%) Requirements
Silicon-dioxide, SiO_2	54.2	-
Aluminum-oxide, Al_2O_3	25.6	-
Ferric-oxide, Fe_2O_3	5.0	-
$SiO_2 + Al_2O_3 = Fe_2O_3$	84.7	Minimum of 70.0
Calcium-oxide	5.2	-
Magnesium-oxide	2.0	Maximum of 5.0
Titanium-oxide	1.27	-
Potassium-oxide	.58	-
Sodium-oxide	.43	Maximum of 1.5
Sulphur-trioxide	1.28	Maximum of 5.0
Ignition loss (1000 ºC)	1.68	Maximum of 6.0
Moisture	.26	Maximum of 3.0

Mixture proportions

In the study, a combination M1 is planned per, IS:10262-1982 is casted and found with 28th day strength of compression as 37.2 MPa as a conventional concrete. The other three specimens are casted by substituting cement in concrete by 40, 45 and 50% mass of Class-F fly-ash with differing superplasticizer measurements for every example projecting. Maintaining the constant quantity of additive nano-SiO2 for every sample mixture ratio. In doing as such, water-cement material proportions were kept practically same, so as to explore concrete impacts due to the substitution with high Class-F fly-ash when different boundaries are nearly maintained same. Table 6 represents the mix proportion of concrete. The Fig.1 represents the material mixing.

Fig. 1: Materials mixing

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TABLE 3: *Aggregates physical properties*

Property	Fine aggregate	Coarse aggregate
Specific gravity of aggregate	2.61	2.79
Fineness modulus	2.27	6.59
SSD absorption	0.86%	1.10%
Voids	36.0%	39.8%
Unit-weight (kg/m^3)	1680	1613

Preparing and specimens casting

Compression strength is tested with 150×150mm size concrete cubes. Cylinders of size 150×300-mm is tested for split tensile strength, beams of 101.4×101.4× 508-mm is tested for flexural strength and cylinders of size 150×300-mm is used for testing elasticity modulus. Every concrete example was set up as per IS: 516-1959. In the wake of projecting, specimens are covered using plastic sheets, they are left free in projecting space for a period 24 hrs with 24 ±1 ⁰C temperature. They are demoulded after a day (24 hrs) and are immersed into the water-storing room till the test hour. The casted specimens are shown in the Fig.2.

TABLE 4: *Sieve analysis of aggregates*

Fine aggregate			Coarse aggregate		
Sieve number	% passing	IS: 383-1970 Requirements	Sieve sizes	% passing	IS: 383-1970 Requirements
4.75 mm	95.4	90-100	12.5 mm	97	95-100
2.36 mm	92.7	85-100	10 mm	69	40-85
1.18 mm	77.0	75-100	4.75 mm	5	0-10
600 mm	61.1	60-79			
300 mm	34.3	12-40			
150 mm	5.7	0-10			

TABLE 5: *The physical properties of nano-Sio$_2$*

Type	Total surface area/unit mass (m^2/g)	pH-value	Average size of the particle (nm)	SiO$_2$ content (%)	Density of Surface (g/ml)
Class F	100±25	6.5-7.5	10-25	≥ 99.7	≤ 0.15

Properties of fresh concrete

Properties of Freshly casted concrete namely Slump, temperature, unit weight is determined per IS: 1199-1959. The results are tabulated in Table 6.

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TABLE 6: *Concrete mixture proportion*

Mixture number	M1	M2	M3	M4
Fly-ash	0 %	40 %	45%	50 %
Cement in kg/m^3	405	230	210	200
Fly-ash in kg/m^3	0	170	185	190
Water in kg/m^3	165	161	165	161
W/ (FA+C)	.41	.40	.41	.40
SSD aggregate (kg/m^3)	615	613	609	615
CA (kg/m^3)	1227	1225	1227	1226
SP(Superplasticizer) (l/m^3)	2	2.2	2.4	2.5
Nano-SiO_2	20	20	20	20
Slump in mm	60	80	85	95
Air-content in %	3.1	3.5	3.4	3.5
Air-temperature in ºC	26	25	27	25
Temperature of concrete (ºC)	29	27	28	29
Density of Concrete (kg/m3)	2405	2397	2401	2400

Specimen testing

Compressive strength is tested for concrete cubes of 150 mm normal size, split tensile strength is tested with cylinders of size 150×300-mm, beams with size, 101.4×101.4× 508-mm is used for testing flexural strength, finally cylinder with size 150×300-mm is again used for testing the elasticity modulus in the concrete specimen as per IS:516-1959[3].

Fig. 2: *Casted specimens*

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Discussion and results

Compressive strength

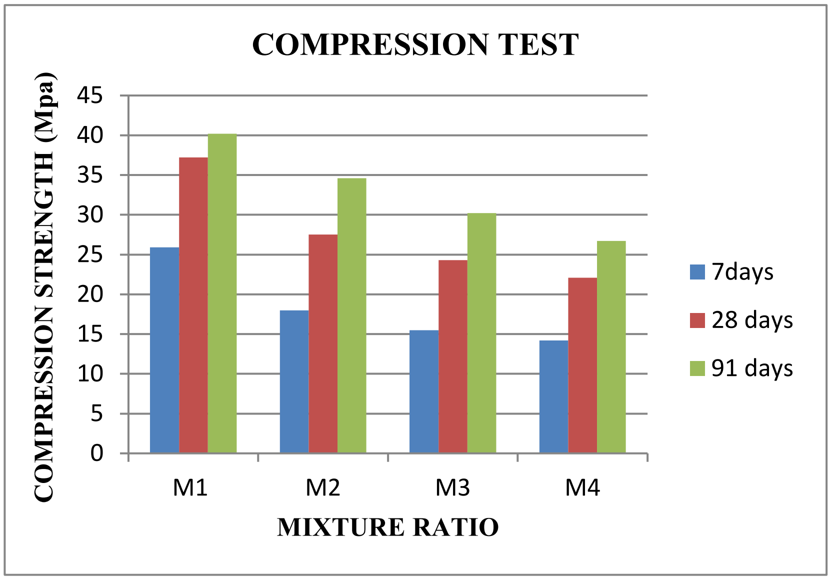
Concrete mixture having various ages like 7,21 and 91 days were tested for compressive strength. Result obtained are tabulated in Table 7 and in Fig.3[4]. The specimen compressive strength was found to be 37.2 MPa at the 28th day followed by 27.5,24.3 and 22.1MPa at the fly-ash replacement with percent reduction of 26%,35% and 41% respectively comparing to the strength of the concrete of control mixture M1(with fly-ash 0%). Results of compressive strength by the day 91 was found to increase gradually beyond day 28 with a varying strength increase between 21% and 26%. The continued cement hydration is the main reason for the strength increase. The chemical reaction occurring by adding of pozzolans with fly-ash present in concrete is the main significant cause for the steady increase of compressive strength of HVFC. Though reduction of compressive strength occurs due to fly-ash replacement at end of 28 days the mixture M4(50% fly-ash) might be used for the construction of concrete, M3(45% fly-ash) and M2 (40% fly-ash) can be used well for the structural construction of concrete[2]. This shows that the HVFC can maintain a very long-term retaining of strength.

TABLE 7: *Compression test result*

Mix ratio	Compressive strength (MPa)		
	7th day	28th day	91th day
M1 (0% fly-ash)	25.9	37.1	40.2
M2 (40% fly-ash)	18	27.5	34.6
M3 (45% fly-ash)	15.5	24.3	30.2
M4 (50% fly-ash)	14.2	22.1	26.7

TABLE 8: *Result of Splitting tensile strength*

Mix ratio	Splitting tensile strength (MPa)		
	7th day	28th day	91th day
M1 (0% fly-ash)	2.6	4.1	4.3
M2 (40% fly-ash)	1.7	3.2	3.9
M3 (45% fly-ash)	1.5	2.7	3.4
M4 (50% fly-ash)	1.4	2.1	2.7

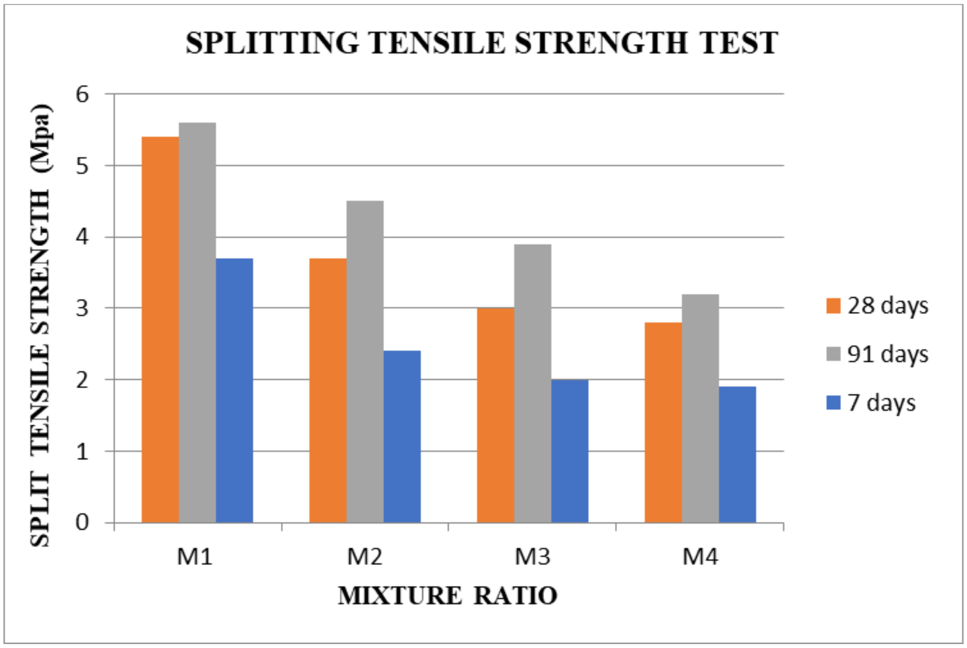


M1(0% fly-ash) M3(45% fly-ash)
M2(40% fly ash) M4 (50% fly-ash)
Fig. 3: *Compressive strength vs mix proportion*

Splitting tensile strength:
The splitting tensile strength of the specimen is calculated for the ages 7th, 28th and 91st days and the results were tabulated in Table 8 and Fig. 4. The strength difference depending on ages are analysed similar to the compressive strength analysis [5]. At age 28 days the splitting tensile strength of the cylinders at M1(0% fly-ash) was found to be 4.1 MPa followed by 3.2,2.7 and 2.1MPa for M2(40% fly-ash), M3(45% fly-ash) and M4 (50% fly-ash) which shows the reduced strength of about 22%, 34% and 49% respectively. At 91th day the strength increased to be 4.3, 3.9, 3.4 and 2.7 for M1(0% fly-ash), for M2(40% fly-ash), M3(45% fly-ash) and M4 (50% fly-ash) respectively which showed an increase of about 5%, 21%, 26% and 29% respectively when compared to the age of 28th day. It can be observed there is a % increase in strength is much higher during 91 days and for concrete mixture M1 compared to early strength at 28th day. This can cause pozzolanic action because of the presence of fly ash.

TABLE 9: *Flexural strength results*

Mix ratio	Flexural strength (MPa)		
	7th day	28th day	91th day
M1 (0% fly-ash)	3.7	5.4	5.6
M2 (40% fly-ash)	2.4	3.7	4.5
M3 (45% fly-ash)	2	3.0	3.9
M4 (50% fly-ash)	1.9	2.8	3.2

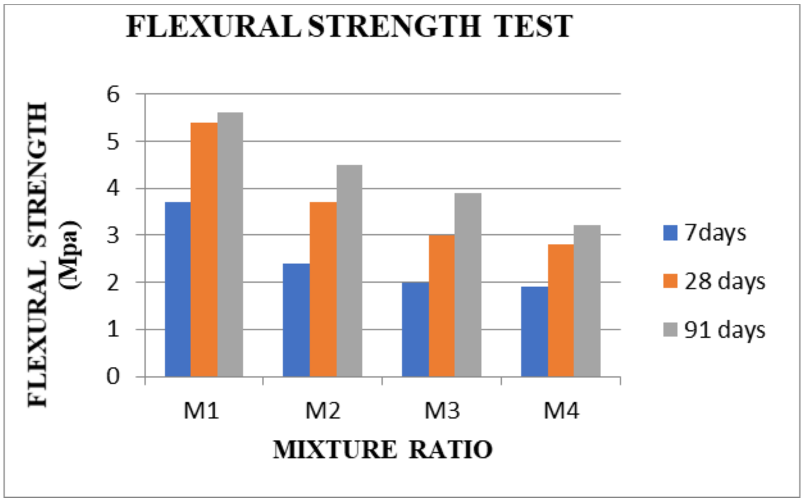


M1 (0% fly-ash) M3(45% fly-ash)
M2(40% fly ash) M4 (50% fly-ash)
Fig. 4: *Splitting tensile strength vs mix proportion*

Flexural strength:
The flexural strength of the concrete specimen for 7th, 28th and 91st days are analysed and results are presented in Table 9 and Fig. 5. Similar to the compressive and splitting tensile there is also an increase in the flexural strength with age. Control mixture M1(0% fly-ash) was observed to have a strength of 5.4 MPa at 28 days and %.6 MPa at 91 days which is an increase of strength. M2(40% fly ash), M3(45% fly-ash) and M4(50% fly-ash) were observed with 3.7, 3 and 2.6 MPa respectively at 28 days respectively. The strength of M2(40% fly-ash), M3(45% fly-ash) and M4 (50% fly-ash) was found to possess 4.5,4,3.2 MPa respectively at 91 days which is observed to have a successive increase of strength compared to the 28th day. It is finally observed from the results that there is a consecutive strength increase beyond 28th day. The flexural strength of concrete from day 28-91 were found to have continuous increase between 14% and 30%, depending on fly ash replacement.

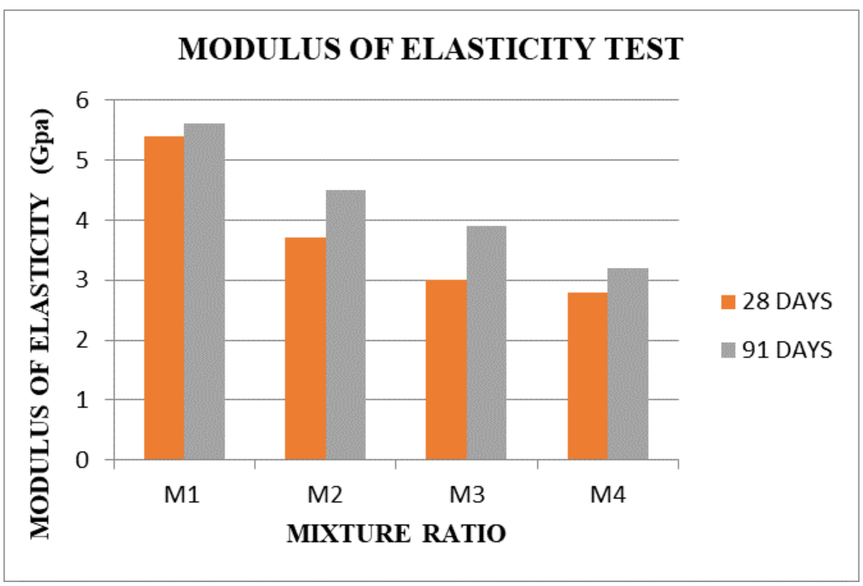
TABLE 10: *Results of Modulus of elasticity*

Mix ratio	Modulus of elasticity (GPa)	
	28th day	91th day
M1 (0% fly-ash)	29.7	30.9
M2 (40% fly-ash)	19.8	22.2
M3 (45% fly-ash)	19.6	20.8
M4 (50% fly-ash)	18.9	19.1



M1 (0% fly-ash) M3(45% fly-ash)
M2(40% fly ash) M4 (50% fly-ash)
Fig. 5: *Flexural strength vs mix proportion*

Modulus of elasticity:
In the examination, the elasticity modulus, that additionally called secant modulus, is taken as the slant of harmony from cause to some discretionary point on the stress – strain curve. The secant modulus determined in this examination is for 33% of the most extreme pressure. Elasticity modulus for day 7,28 and 91 were observed and the results are presented in Table 10 and Fig. 6. The test results indicated that the increasing amount of fly ash decreases the modulus strength compared to that of M1 concrete mixture. The modulus value of at age 28 for M1(0% fly-ash), M2(40% fly-ash), M3(45% fly-ash) and M4(50% fly-ash) was calculated to be 29.7, 19.8,19.6,18.9 MPa respectively. However, there is a successive increase in the modulus strength with ages.



M1 (0% fly-ash) M3(45% fly-ash)
M2(40% fly ash) M4 (50% fly-ash)
Fig.6: *Modulus of elasticity vs mix proportion*

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Conclusion

The conclusion obtained from the investigation:

1. The replacement of fly ash in three different percentage at initial stage caused the decrease in strength of compression, Split tensile strength, Flexural strength and modulus of elasticity at 28th day. But still strength gradually increased beyond 28th day.
2. Though the concrete strength gradually decreases at 40%,45% and 50% fly ash replaced concrete at 28 days has much good strength for construction of concrete structure.
3. Incorporation of nano-SiO_2 into the HVFC increases both the short and long-term concrete strength.
4. Fly-ash causes high porosity at short time of curing whereas the accelerating additive nano SiO_2 produce compact structure even at the shorter time of curing.

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