IJIRAE::International Journal of Innovative Research in Advanced Engineering ISSN:2349-2163
Volume 13, Issue 03, March 2026 https://www.ijirae.com/archives
https://doi.org/10.26562/ijirae.2026.v1303.10

Experimental Investigation on the Use of High-Volume Fly Ash as a Partial Replacement for Cement in Concrete

S.Santhosh,
PG Student, Department of Civil Engineering,
Sengunthar Engineering College (Autonomous), Tiruchengode, India

Dr.M.Soundar Rajan
Assistant Professor, Department of Civil Engineering,
Sengunthar Engineering College (Autonomous), Tiruchengode, India
soundarrajan06@gmail.com
https://orcid.org/0000-0003-3362-9529

Publication History
Manuscript Reference No: IJIRAE/RS/Vol.13/Issue03/AEMR26.MRAE10089
Research Article | Open Access | Double-Blind Peer-Reviewed |Article ID:IJIRAE/RS/Vol.13/Issue03/AEMR26.MRAE10089
Received:22,February 2026, Revised: 01, March 2026, Accepted: 16,March 2026,Published Online: 25, March 2026.
https://www.ijirae.com/volumes/Vol13/iss-03/10.AEMR26.MRAE10089.pdf
Article Citation: Santhosh,SoundarRajan (2026), Experimental Investigation on the Use of High-Volume Fly Ash as a Partial Replacement for Cement in Concrete,IJIRAE: International Journal of Innovative Research in Advanced Engineering, Volume 13, Issue 03 of 2026 pages 153-159 **Doi:>** https://doi.org/10.26562/ijirae.2026.v1303.10
BibTeX Key: Santhosh@2026Experimental
IJIRAE papers should be cited as IJIRAE (International Journal of Innovative Research in Advanced Engineering, AM Publications, India 2025, ISSN 2349-2163, https://doi.org/10.26562/ijirae.2026.v1303.10 The journal's official abbreviation is IJIRAE. Orcid: https://orcid.org/0009-0004-9398-7488

Abstract: The high and rising costs of building construction in developing countries have been a source of concern to government and private developers. This study investigated the use of replacement of cement by high volume fly ash (hvfa) in concrete. The hvfa concrete attained satisfactory or higher compressive and tensile strength when compared to opc concrete. With its high strength and low shrinkage properties, hvfa concrete becomes a possible alternative to opc concrete used for road pavements applications and large industrial floors. The concrete is designed to attain 25 mpa.specimens such as cubes, cylinders and prisms were cast and tested for various mixes. Four mixes m1 to m4 are cast with 0%, 40%, 50% and 60% replacement of fly ash in concrete and to study the physical and chemical properties of materials. The compressive strength, flexural strength and, splittensile strength were evaluated at 7, 14 and 28 days.

I. INTRODUCTION

Concrete is a mixture of various materials like one or more binding materials (cement), fine aggregate, coarse aggregate, water, and other supplementary cementing materials (SCMs) like fly ash, slag, pond ash and some other mineral or chemical admixtures (super plasticizer, air entraining admixture). Concrete performs a chemical reaction called hydration which occurs between binding material and water to give appropriate strength and binding nature. When the supplementary cementing materials are used, some secondary chemical reaction happens between some of the hydration products and the SCMs. These two reactions bind the aggregate particle to produce a very hard material is called concrete. Concrete is considered as the most used material in construction works. Fly ash can be used in concrete as a partial replacement for Ordinary Portland Cement (OPC). Fly ash is introduced in concrete directly, as a separate ingredient at the concrete batch plant or, can be blended with the Opc to produce blended cement, usually called Portland-Pozzolana Cement (PPC). Currently in the concrete industry, the percentage of fly ash as part of the total cementing materials in concrete normally ranges from 15 to 25%, although it can goup to30-35%insome applications. The use of fly ash in concrete will improve some aspects of the performance of the concrete provided the concrete is properly designed. The main aspects of the concrete performance with the use of fly ash are increased long-term strength and reduced permeability of the concreten which inform exhibited better durability. The use of fly ash in concrete can also address some specific durability issues such as sulphate attack and alkali silica reaction. The high volume fly ash concrete is the one specific typeof fly ash concrete with higher fly ash contents, lower water-to- cementious materials ratio (W/CM), and lower cement contents. This is to take full advantages of the increased workability and durability provided by fly ash and lower W/CM, and to produce a more environmentally friendly concrete by reducing its cement content. The main difference between the High-Volume Fly Ash Concrete (HVFAC) and the usual fly ash concrete is that in the concrete, the amount of ordinary Portland cement is minimized through proper mixture proportioning using large amounts of fly ash and judicious selection of materials and chemical admixtures while maintaining, and often improving its performance as compared to conventional concrete. There is no fixed percentage of ordinary Portland cement replacement by fly ash in this type of concrete, but in many cases, percentages of 50 and above were found to be usable.

To produce a workable concrete at such low W/CM, the use of super plasticizer is essential. The concrete element was made of the newly developed HVFAC, and its performance exceeded expectations. Extensive investigation were undertaken to determine the mechanical and durability properties of the HVFAC made with cement and fly ash from numerous sources and covering a wide range of physical properties and chemical compositions. It was found from those investigations and field applications that properly designed and cured, HVFAC can demonstrate excellent performance, both in mechanical as well as in durability aspects, and this when it is made with a wide range of materials.

II. MATERIALS USED AND WORK METHODOLOGY

Cement

Ordinary Portland cement of OPC53 grade (Priya Cement) was used to manufacture the (HVFC) concrete. The physical and chemical properties are presented in table 3.1 & 3.2

Table 1 Physical properties of cement

Test conducted	Observed values
Specific gravity of cement	3.15
Consistency	35%
Initial setting time	28 min
Final setting time	60min

Table 2 Chemical properties of cement

Test conducted	Observed values
Calcium oxide	62.68%
Silica	20.36%
Alumina	6.87%
Iron oxide	3.67%
Magnesia	1.77%
Sulphurican hydride	2.24%
Tricalcium silicate	42.57%
Dicalcium silicate	26.33%
Tricalcium aluminate	12%
Tetracalcium aluminoferrite	2.24%

Table 3 Chemical properties of Flyash

Test Conducted	Observed Values (%)
Losonignition	3.74
Silica as Sio2	35.87
Iron as Fe2O3	4.00
Alumina as Al2O3	34.14
Calcium as CaO	14.25
Magnesium as MgO	3.64
Sulphate as SO3	3.4
Sodium as Na2O	0.90
Potassium as K2O	0.06
Chloride	-

Table 4 Physical properties of Crushers and

Test Conducted	Observed Values (%)
Sio2	34.06
Al2O3	18.8
Fe2O3	0.70
CaO	32.40
MgO	10.75
SO3	0.85
S	0.65
MnO	0.49
Na2O	0.31
K2O	0.98
Cl	0.008

IJIRAE::International Journal of Innovative Research in Advanced Engineering ISSN:2349-2163
Volume 13, Issue 03, March 2026 https://www.ijirae.com/archives
https://doi.org/10.26562/ijirae.2026.v1303.10

Table 5

Test conducted	Observed Values
Specific gravity	2.74
Water absorption	1.8%
Bulk density	1.64gm/cc
Percentage of voids	40%
Fineness modulus	2.49
Gradation	zoneII

Chemical properties of Crushers

Fly Ash

ClassF fly ash of high volume was used and it is obtained from Mettur Thermal Power Plant. The fly ash is in conformity with the general requirements of pozzolana. The specific gravity of flyash is 2.2 chemical properties is presented in table 3.3

Crusher Sand

Crusher sand is obtained from RPP Ltd., Erode. The physical and chemical properties is as follows,

Coarse Aggregate

Coarse aggregate of hard blue granite of size 20mm aggregates were used to manufacture the concrete. The aggregates are in angular shape. The physical properties is given table 3.6

Table 3.6 Physical properties of coarse aggregate

Test conducted	Observed values
Specific gravity	2.75
Water absorption	0.9%
Moisture Content	10%
Bulk density	1.66g/cc
Fineness modulus	7.4

EXPERIMENTAL INVESTIGATIONS

Mix proportions

Proportioning of concrete mixtures consist of determination of respective ingredients necessary to produce concrete having adequate workability, strength and durability for the particular strength and for various exposure conditions. The mix proportions for the controlled M40grades were arrived from the trial mixes as per the DOE method of mix design. These mixtures were used throughout the study. The details of mix proportions are givenin Table 3.4 .Appendix shows the detailed mix design for M40grade concrete mixtures. Table7Mix Proportions for M40 Grade Concrete After 48 hours of

Material	Conventional concrete	High Volume Fly-Ash Concrete		
	0 % Weight of fly ash replacement by cement	40 % Weight of fly ash replacement by cement	50 % weight of fly ash replacement by cement	60 % weight of fly ash replacement by cement
Cement (kg/m3)	383	274.82	245.499	212.76
Fly Ash (kg/m3)	--	183.21	245.499	319.14
Fine aggregate (kg/m3)	773.67	646.45	585.28	558.96
Coarse aggregate (kg/m3)	1113.34	1200.55	1243.72	1244
Water content (kg/m3)	180	155	150	145
Super plasticizer (kg/m3)	5.74	6.87	7.364	7.978
Water cement ratio	0.47	0.34	0.30	0.27

Casting

All the test specimens were casted in steel moulds. The inside of the moulds was applied with oil to facilitate the easy removal of specimens. Concrete mixer was adopted throughout the experimental work. First the materials cement, fly ash, fine aggregate and coarse aggregate were weighed exactly, cement and fly ash were mixed first. Then C.A and crusher sand, cement, fly ash is added and thoroughly mixed. A solution is prepared by adding the required dosage of super plasticizer to required quantity of water and mixed well. At this stage this solution was added to the concrete was then placed in the moulds in three layers of equal thickness and a table vibrator was employed to compact the concrete in the moulds.

Fig: HVFC Concrete casted in Mould

Specimen Casting Details

Specimens were cast to study the mechanical properties of the mixture.

- 36 Nos of Cubes specimen of size 150mm X 150mm X 150mm for Compressive Strength test.
- 36 Nos of Cylinders specimen of size 150 mm diameters X 300mm height for Splitting Tensile Strength test.
- 36 Nos of Prisms specimen of size 100mm X 100mm X 500mm for Flexural Strength test.
- 36 Nos of Cylinders specimen of size 150mm diameters X300mm height for young's modulus of Elasticity of concrete

TESTING OF SPECIMENS

Compressive Strength of concrete

The strength of the concrete depends on the properties and proportions of the constituent materials, degree of hydration, and rate of loading, method of testing and specimen geometry. The properties of the constituent materials which affect the strength are the quality of fine and coarse aggregate, the cement paste and the paste-aggregate bond characteristics (properties of the interfacial, or transition, zone). These, in turn, depend on the macro- and microscopic structural features including total porosity, pore size and shape, pore distribution and the bond between individual solid components. The strength of saturated specimens can be 15 to 20 percent lower than that of dry specimens. After the curing period before testing, the specimen should be surface dry. Cube specimens generally exhibit 20 to 25 percent higher strengths than cylindrical specimens. Larger specimens exhibit lower average strengths. Hydraulic Digital compression testing machine was used with a capacity of 2000KN and the pace rate of 2.5 KN/sec.

Fig: Testing of cube specimen for compressive

Split Tensile Strength of concrete

The split tensile strength is the indirect measurement of the tensile strength by placing a cylindrical specimen horizontally between the loading surfaces. This method consists of applying a diametric compressive force along the length of a cylindrical specimen. This loading induces tensile stresses on the plane containing the applied load. Tensile failure occurs rather than compressive failure. Plywood strips are used so that the load is applied uniformly along the length of the cylinder and the load is applied until failure of the cylinder, along the vertical diameter shown in Figure 3.4. The maximum load is divided by appropriate geometrical factors to obtain the splitting tensile strength of concrete are the ASTM C 496 splitting tension test and the ASTM C 78 third- point flexural loading test. The test setup was shown in figure 3.2 2P

Flexural Strength of Concrete

Flexural strength is the ability of a beam or slab to resist failure in bending. It is measured by loading un-reinforced concrete beam of size 500*100*100mm. Flexural MR is about 12 to 20percent of compressive strength. Hydraulic Flexural testing machine was used for the test and with a capacity of 10 tones. The bearing surfaces of the supporting, loading rollers are wiped clean and make contact with the rollers. The specimen is then placed in the machine is such a manner that the load is applied to the uppermost surface as cast in the mould, along two lines spaced 20cm apart. The load was applied gradually until the specimen fails and the maximum load applied to the specimen during the test is noted. The flexuralstrength of the specimen is expressed as the modulus of rupture fband the formula used to calculate the flexural strength depends on the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen. Since the failure distance 'a' is greater than13.3cmtheformulaused shown below

Pl Flexural Strength (fb) = bd2

Where P= Load (Kg) ; l = Length of the specimen; b = Breadth of the Specimen; d = Depth of the Specimen split Tensile strength (T)= Where ____ πLD

P – Compressive load on the cylinder in N, L - Length of the cylinder in mm, D - Diameter of the cylinder in mm,

Fig: Testing of Cylindrical Specimen for Split Tensile Strength

Fig: Failure Pattern of Beam in Flexural Strength Test

III. RESULTS AND DISCUSSION

Concrete must be relatively impervious so as to enable it to withstand the service condition for which it has been designed, without serious deterioration over the lifespan of the structure. The loss of concrete durability may be caused by the severity of the environment to which it is exposed or by internal changes within the matured concrete itself. The external causes may be physical, chemical or mechanical and attack by natural or industrial aggressive liquids and gases. The fresh and hardened concrete properties of all the concrete mixtures, designed for a concrete grade of M40 with and without fly ash are described in this chapter. In this chapter the mechanical properties such as compressive strength, splitting tensile strength, flexural strength of concrete was discussed with 40%, 50% and 60% fly Ash replacement by cement.

Discussions

1. Work ability normal concrete measures are 45mm, which is well in the design range of 30 to 60mm.
2. Work ability of fresh concretes increased by adding super plasticizer to attain the design slump value.
3. 7 days compressive of fly ash concretes are much less than the normal concrete especially beyond 40% replacement of fly ash.
4. At 28 days fly ash concrete upto 50% replacement attains the target mean strength of 48.25N/mm^2.
5. Flexural strength of fly ash concrete at 28 days is determination and its around 4.86 N/mm^2. As per IS 456- 2000the flexural strength of concrete=0.7(fck)$^{0.5}$= 0.7(40)$^{0.5}$= 4.5N/mm^2
6. Thus the flexural strength of fly ash concrete are also conforms the codal provisions.
7. Young's of Elasticity for normal concrete (M40grade)from test is from IS 456-2000 (6.2.1) 24785 N/mm^{2}and for fly ash concrete it decrease. Ec=5000(fck)$^{0.5}$ =5000X(400) 0.5 =31622.77N/mm^2

IV. CONCLUSION

Experiments were conducted as narrated in chapter 3 to find out the mechanical properties of concrete mixtures with and without HVFA by conducting compressive strength test, Splitting tensile test and Flexural strength test. The following conclusions have been drawn based on the experimental investigation carried out on concrete mixtures with and without fly ash...

1. Initial day strength (7 to 28 days) of HVFA concrete was lesser than the control mix concrete due to presence of water soluble alkalies, sulphate, and lime and organic in the fly ash which affects the surface reaction and crystallization process of HVFA concrete. Hence this resulting in lowering mechanical properties in initial days.
2. HVFA Concrete with Super plasticizers showed good compatible and good workability in fresh stage and also retarding the setting time of concrete.
3. It has been found that 40% of replacement of cement by HVFA can be conveniently used for the structural concreting works and 50% and can be used for the minor concreting works.

SUMMARY RESULTS

1. Mix design procedure incorporating fly ash properties is suggested with reference to DOE method.
2. Work ability of concrete decreases as percentage of fly ash increases in cement.
3. Work ability increases with the addition of super plasticizer.
4. The development of compressive strength is less in 7 days and reduces the target mean strength at 28 days.
5. Fly ash replacement upto 60% is studied.
6. Up to 40% replacement there is no mark able strength loss.
7. Beyond 40% up to 60% there is sudden decrease in strength. The initial strength of fly ash concrete is less after 28 days the strength of fly ash concrete is higher than normal concrete.

SUGGESTION FOR FURTHER STUDIES

1. A detailed study may be taken to arrive a suitable mix design of HVFA concrete for the required strength.
2. A detailed investigation may be done on structural behavior of reinforced HVFA concrete and flexural members to assess thefailure mode, bond characteristics of rebar, crack spacing and ultimate strength.
3. Other concrete properties such as drying shrinkage, pore size distribution, heat of hydration, transition zone characteristics of HVFA based concrete mixtures need a detailed study. Study on long-term durability properties of HVFA based concrete mixtures is important and to be carried out.

REFERENCES

1. Atis, C.D.,'(2000) abrasion resistance of High volume fly ash concrete: digest 2000 of Turkigh chamber of civil engineers
2. Behera. J.P. sarangj.B.D. and Ray.H.S."Investigation" on the development of blended cement using activated fly ash "Indian concrete journal, May 2000, PP260-263.
3. B.Fourier ,D.Lu,J.P.Charland and J.Li" of Indian fly ashes for use in HVFA concrete",ICJ,V.78,NO.11,Nov 2004.
4. Camoes.A., aquiar, B.Jalai, S.,(2003)'Durability of low cost High performance fly ash concrete, proceedings of IAUS International Ash utilization symposium
5. Malhotra.V.M. " Role of supplementary cementing materials in reducing green house emission" can met, Ottawa, Canada, march1998.
6. Praveen kumar,mohd .Ajaful Haq and S.K Kaushik",Early strength of SSC with large volumes of fly ash",ICJ, June 2004
7. S.Qian,D.Qu,G.P.Gu and N.Bouzoubaa,"Reinforcingsteel corrosion in HVFA Concrete"ICJ,V.78,NO.11,Nov 2004
8. Dr.A.K.Saxena,Manager Production,P.K.Kaku,Senior vice President, The Associated cement companies ltd ,Madukkarai cement works, "Usage of fly ash in cement industry"
9. P.Srinivasan,A.K Tiwari and Anil Banchhor ,"Suitability of HVFA concrete for Pavements "ICJ,V.78,NO.11,Nov 2004
10. Berry,E.E.andMalhotra,V.M.(1980) "Flyash for use in concrete "ACI journal, processdings,
11. Bilodeau, A.Malhotra V., (2000) "High volume fly ash system: concrete solution for sustainable development" ACI material journal Vol.97 No:1 Jan- Feb2000.
12. Haque,M.,Langan,B.,wardm.(1984)"High fly ash content ACI material journal.
13. Naik,T.Ramne,B.krauj,R.siddque,R.(2003)"Long-term performance of High volume fly ash concrete pavements ".ACI materials journal No.2,Vol.100

14. Peled,ACyr,M.F:andshap,S.P.,"High content of fly ash (class F) in extruded cementitious composites," ACI material journal V.97
15. Reiner, M.,and Rens, K,(2006)'High volume fly ash concrete: analysis and applications "practice periodical on structural design and construction V.11,No.16
16. Sivasunfaran,V.,curette,G.C.,andMalhara,V.M., "Long term strength development of High volume fly ash concrete' composites/.V.12
17. Malhora,V.M.,and Mehta.,P.k(2002) High performance High volume fly ash concrete materials, mixture proportioning, properties, construction practices and case Histories.
18. Concrete technology By M.S.Shetty
19. Concrete Mix Design By N.Krishnaraju
20. IS-3812-1981,"SpecificationsforFlyAshforuseas Pozzolonic and Admixtures BIS: New Delhi.
21. IS-456-2000,"plainandReinforcementcementconcrete- Code of practice.