IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 06, Issue 1, January 2016, ||V-5|| PP 19-26

Experimental Investigation on High Performance Concrete Using Silicafume and Flyash

[1]Bharathi R [2]Ajay Ganesh [3] Hari Krishnan [4] Jagan Kumar
[1] (Assistant Professor of Civil Engineering, Dhanalakshmi Srinivasan College of Engineering & Technology, Chennai-603104)
[2 3 4] (UG Student, Department of Civil Engineering, Dhanalakshmi Srinivasan College of Engineering & Technology, Chennai-603104)

ABSTRACT: *In this experimental investigation the behavior of High-Performance Concrete (HPC) with silicafume and flyash were studied. HPC used in this study was manufactured by usual ingredients such as pozolonic cement, fine aggregate, coarse aggregate, portable water and admixtures both mineral and chemical such as Silica Fume (SF) and Fly ash at various replacement levels and with Super Plasticizer. The water cement ratio (w/c) adopted is 0.30. In this investigation the concrete was proportioned to target a mean strength of 60 MPa. Specimens such as cubes, cylinders and prism beams were cast and tested for various mixes. Seven mixes M1 to M7 were cast with 0%, 5%, 7.5% and 10% replacement of silica fumeand 10% constant replacement of Fly ash to study the mechanical properties such as compressive strength, split tensile strength and flexural strength at 7 and 28 days.*

KEYWORDS: *High performance concrete, silica fume, fly ash, superplasticizer,compressive strength, split tensile strength, flexural strength*

I. INTRODUCTION

High Performance Concrete (HPC) has been developed over the last two decades, and was primarily introduced through private sector architectural design and construction such as high rises and parking garages. Public agencies tend to be more conservative than the private sector when it comes to changing specifications, but the public sector now is committed to incorporating this technology in the field [1].HPC is used for concrete mixtures, which possess high workability, high strength, and high modulus of elasticity, high density, high dimensional stability, low permeability and resistance to chemical attack. HPC is also, a high strength concrete but it has a few more attributes specifically designed as mentioned above. HPC is often called "durable" concrete because its strength and impermeability to chloride penetration makes it last much longer than conventional concrete. It's an engineered concrete made up of the classic elements of water, Portland cement and fine and coarse aggregates, but with added admixtures. According to ACI " High Performance Concrete is defined as concrete which meets special performance and uniformity requirements that cannot always be achieved routinely by using conventional materials and normal mixing, placing and curing practices".The expression „durability of concrete‟ is usually used to characterize, in general terms, the resistance of concrete to the attack of physical or chemical aggressive agents. When concrete is subjected to external chemical attack, there is only one way to reduce the intensity of this external aggression to lower the porosity and the permeability of the concrete in order to reduce or to slow down as much as possible the penetration of the aggressive agents.Under compressive loads, failure in normal concrete occurs either within the hydrated cement paste or along the interface between the cement paste and aggregate particles[2]. This interface is called transition zone, is a weak area in normal concrete.Improved properties of high performance concrete are due to change in the microstructure of concrete composite, particularly due to change in the microstructure of the transition zone reduction of its thickness, associated voids and micro cracks as well as uniform particle distribution. Such modifications in microstructure are achieved by using both chemical and mineral admixtures. Appropriate grading of solid material starting from coarse aggregate to the finest one and low water binder ratio (w/b) also has the significant effect on the modification of microstructure [3].Silica fume and fly ash are common mineral admixtures used in developing high performance concrete mix. Silica fume as its size is smaller than cement grains, fills the voids in between the cement grains. This leads to a decrease in water demand. But its high specific area increases the water demand. Combination of these two effect results in net increase in water demand compared to normal strength concrete for a given level of workability. Super plasticizer is used to reduce the water demand. This also help the silica fume to be well dispersed in concrete mix.Mineral admixtures in concrete mix affect the physical arrangement of the system, particularly near the aggregate surface where porosity exists. Inert fines act as filler material only [4]. Owing to its spherical shape and small size, silica fume disperses easily in presence of super plasticizer and fills the voids between cement particles resulting in well-packed concrete mix.The combination of pozzolanic and filler action leads to increase in compressive, split tensile, flexural and bond strengths; reduction in bleeding and segregation of fresh concrete; leading to increased durability and reduction in heat of hydration. Fly ash also contributes in a similar way. However its particle size being larger than that of silica fume reduces its efficiency compared to that of silica fume.Water reducing admixtures, super plasticizer creates conducive condition for complete hydration of cement by deflocculating the cement lump and making cement water mixtures as well dispersed system [5]. This reduces the risk of anhydrous cement grain to be present in the structure of concrete and to improve the pore structure during hydration process by bringing almost all cement particles fully in contact with water. Superplasticizers are capable of reducing the water requirement by about 30%.

II. MATERIAL AND METHODS

Ordinary Portland cement of 43 Grade conforming to IS: 12269 – 1987was used for the study. Locally available river sand conforming to Grading zone II of IS: 383 –1970 was used as the fine aggregate. Locally available crushed blue granite stones conforming to graded aggregate of nominal size 20 mm as per IS: 383 – 1970 was used as coarse aggregate. Fly ash Confirming to IS: 3812 – Part 1 – 2003 was used as mineral admixture in dry powder form. Silica fume was used as mineral admixture in dry densified form. Super plasticizer was used as chemical admixture to enhance the workability of the concrete. Also ordinary potable water was used.The main objective of the present investigation is to study the behaviour of high performance reinforced concrete columns (replacement of cement with silica fume and fly ash). Silica fume and fly ash are used as a partial replacement of cement and super plasticizer is used to achieve require workability.The compressive strength, split tensile strength, and flexural strength of high performance concrete are to be determined.To produce high performance concrete, the utilization of high strength cements is necessary. Different types of cement have different water requirements to produce pastes of standard consistence. Different types of cement also will produce concrete have a different rates of strength development. The choice of brand and type of cement is the most important to produce a good quality of concrete. The type of cement affects the rate of hydration. It is also important to ensure compatibility of the chemical and mineral admixtures with cement**.**Tests were conducted to find the specific gravity, consistency, setting time and compressive strength of OPC and the results are shown in Table I

Table I: Properties of 43 grade OPC

Test particulars	Result obtained	Requirements as per IS:8112-1989
Specific gravity	3.15	3.10-3.15
Normal consistency (%)	31	30-35
Initial setting time (min)	29	30 minimum
Final setting time (min)	540	600 maximum
Compressive strength (MPa)		
a) 3 days	26	23
b) 7 days	35	33
c) 28 days	47	43

Aggregates generally occupy about 70 to 80% of the volume of concrete and combine with the binder (cement and pozzolana) and water to produce concrete. Therefore it can be expected to have an important influence on its properties. Clearly it is important that the chosen aggregate should contain no constituent who might adversely affect the hardening of the cement or the durability of the hardened mass [6].Tests were conducted to obtain specific gravity and fineness modulus of the fine aggregate and coarse aggregate used in this study as per IS: 2386-1983 and the results are tabulated in Table II.

Table II: Properties of Aggregates

Test particulars	Result obtained	Result obtained
	Fine Aggregate	Coarse Aggregate
Specific gravity	2.67	2.81
Fineness modulus	2.34	5.74
size	Passing through 4.75mm sieve	Passing through 20mm sieve and retained in 16mm sieve

Mix Proportioning Details

The concrete used in this study was proportioned to attain strength of **60 MPa**. The mixes M1, M2, M3 and M4 were obtained by replacing 0, 5, 7.5 and 10 percent of the mass of cement by silica fume, Then mix M5, M6 and M7 were obtained by replacing the mass of cement by the above percentage of silica fume and with 10% of fly ash. The water binder ratio (w/b) is taken as 0.30**.** The description of mixes used in this study is given in table III.

Table III Description of Mixes

Mix	% of silica fume	% of Flyash
M1	0	0
M2	5	0
M3	7.5	0
M4	10	0
M5	5	10
M6	7.5	10
M7	10	10

Mix design was done as per the ACI mix design and appropriate mix proportion was obtained. The mix proportions in quantities are shown in table IV.

Table IV Mix ProportionsQuantities in kg/m^3

Mix	Cement	Silica Fume	Fly Ash	Fine Agg.	Coarse Agg.	SP
	kg/m3	kg/m3	kg/m3	kg/m3	kg/m3	Lit/m3
M1	571.57	0	0	610.27	1171.8	6.97
M2	542.99	28.58	0	599.81	1171.8	8.83
M3	528.7	42.87	0	594.58	1171.8	9.23
M4	514.41	57.16	0	589.35	1171.8	9.75
M5	485.83	28.58	57.16	577.28	1171.8	16.72
M6	471.55	42.87	57.16	572.05	1171.8	17.19
M7	457.26	57.16	57.16	566.82	1171.8	17.19

Experimental Procedure

Experimental investigations carried out on the test specimens to study the workability and strength-related properties of high performance concrete using Silica fume and fly Ash.All the test specimens such as cubes and cylinders were cast using steel moulds. The cube specimens were used for compressive strength and water absorption, whereas cylinder specimens were used to study, split tensile strength, flexural strength and modulus of elasticity. The beam specimens were used to study the flexural as well as shear behavior. The details of test specimen are tabulated in the Table V

Table V: Details of test specimen

S.NO	Properties studied	Specimen Shape	No.of specimens	Specimen size (mm)
1	Compressive strength	Cube	105	100 x 100 x 100
2	Flexural strength	Prism	21	100 x 100 x 500
3	Split tensile strength	Cylinder	21	100 x 200
4	Water Absorption	Cube	14	100 x 100 x 100
5	Modulus of Elasticity	Cylinder	14	100 x 200

Compressive Strength Test

III. RESULTS & DISCUSSION

The compressive strength of concrete cube was determined based on IS: 516 –1959. The specimen was placed in the compression testing machine in such a manner that the load applied should be to the opposite sides of the cubes as cast, that is not to the top and bottom.The compressive strength test is conducted in the Compression Testing Machine of 2000 kN capacity, the test set up is shown in Figure1. The test results are listed in table VI.

Figure1 Specimen in Compression testing Machine **Table VI:** Cube Compressive Strength

Mix	Silica fume %	Flyash %	7days (MPa)	28days (MPa)
M1	0	0	42.33	54.67
M2	5	0	40.67	55.00
M3	**7.5**	**0**	**44.67**	**61.33**
M4	10	0	40.33	56.33
M5	5	10	42.33	58.67
M6	7.5	10	41	57.33
M7	10	10	39.33	55.33

The compressive strength for various mixes M1 to M7 at the age of 7 and 28 days are obtained from the test results. When Silica fume is added as additional admixture, there is a significant improvement in the strength of concrete because of high pozzolanic action. The maximum compressive strength obtained for Mix M3 (contains 7.5% of Silica fume) was 61.33MPa whereas for Mix M5 with 5% of Silica fume and 10% of fly ash the 28 days strength is 58.67 MPa. The increase in compressive strength for the HPC is 0.6 %, 12.18 %, 3.03%, 7.31 %, 4.86 % and 1.2%. The cube compression strength containing partial replacement of silica fume and fly ash are higher than control specimen at 28 days.The maximum cube compressive strength is obtained for Mix M3 with 7.5% of silica fume.Silica fume concrete attains high early strength than flyash and Silica fume combined concrete.Figure 2 shows the cube compressive strength at 7 and 28 days.

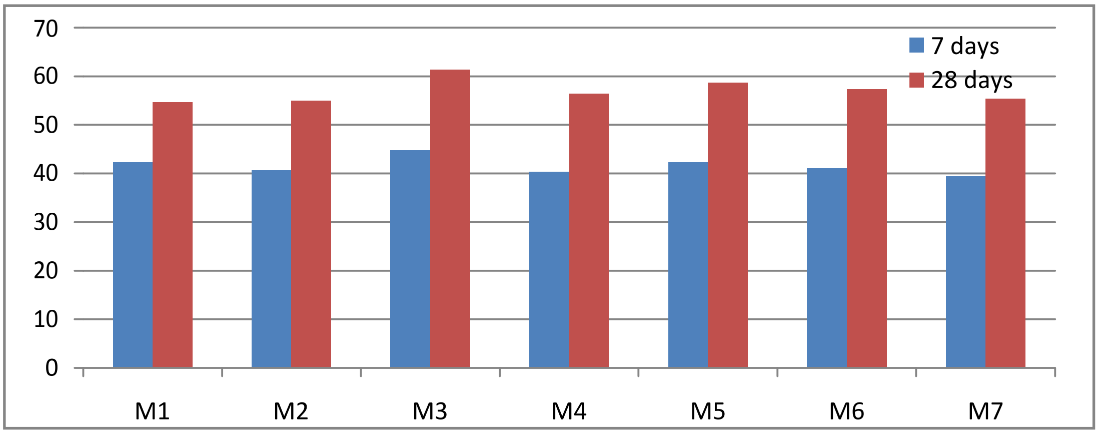

Figure 2 Compressive strength at 7 and 28 days.

Split Tensile Strength Test:

The splitting tensile strength of concrete cylinder was determined based on IS: 5816 –1999. The load shall be applied nominal rate within the range 1.2 N/(mm^2/min) to 2.4 N/(mm^2/min).the test setup for split tensile streng th test is shown in figure 3 and the split tensile strength test results for 28 days are given in table VII

Figure3 Testing of Cylinder for Split Tensile Strength Test Table VII: Split Tensile Strength Result

Mix	silica fume (%)	Flyash (%)	28 Days (MPa)
M1	0	0	4.98
M2	5	0	5.03
M3	**7.5**	**0**	**5.83**
M4	10	0	5.09
M5	5	10	5.62
M6	7.5	10	5.19
M7	10	10	5.01

Cylinders were cast to determine the split tensile strength. The split tensile strength at the age of 28days for various mixes varies from 4.98 to 5.83 MPa. It was observed that mix M3 with 7.5% Silica fume shows higher split tensile strength. The maximum 28 days split tensile strength of 5.83MPa is obtained for M3 mix with 7.5% of Silica fume. The strength of M3 is about 17.06% more at 28 days of curing compared to the control concrete mix. The variation of tensile strength at 28 days is shown in figure4. The split tensile strength increase are 1 %, 17.06 %, 2.20 %,12.85 %, 4.21 %, 0.6%. The split tensile strength of cylinders containing partial replacement of silica fume and fly ash are higher than control specimen at 28 days. The maximum split tensile strength is obtained for Mix M3 with 7.5% of silica fume. Its 28 days strength is 5.83 MPa.

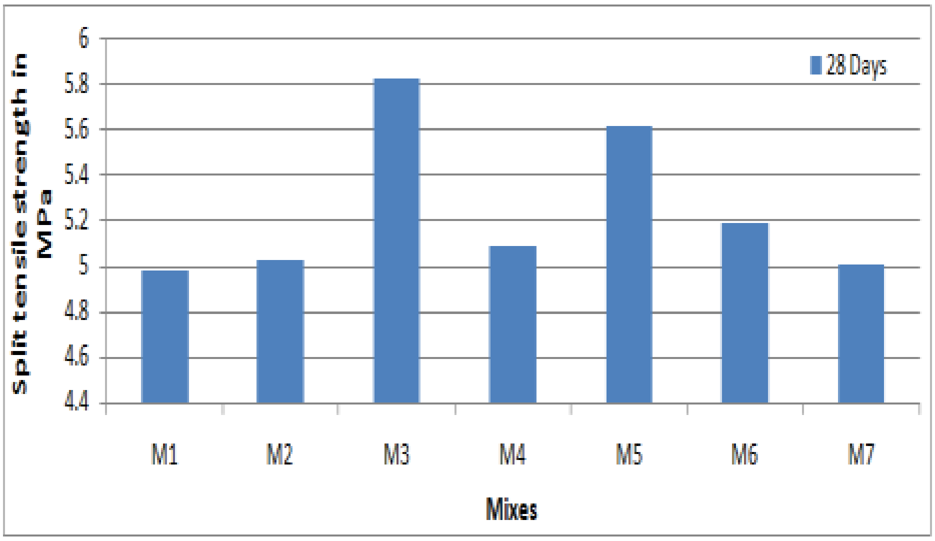

Figure 4 Split tensile strength of various mixes

Flexural strength Test

The flexural strength of concrete prism was determined based on IS: 516 –1959. Place the specimen in the machine in such a manner that the load is applied to the upper most surface as cast in the mould along two lines spaced 13.3cm a part. Measure the distance between the line of fracture and nearest support. The test setup for flexural strength test is shown in figure 5 and the test results of flexural strength are given in table VIII

Figure5 Testing of Prism for Flexural strength Table VIII Flexural Strength Result Mix

Mix	Silica fume (%)	Flyash (%)	28 Days (Mpa)
M1	0	0	4.59
M2	5	0	5.13
M3	**7.5**	**0**	**5.96**
M4	10	0	5.23
M5	5	10	5.71
M6	7.5	10	5.36
M7	10	10	5.09

The flexural strength of various mixes at 28 days are shown in figure 6

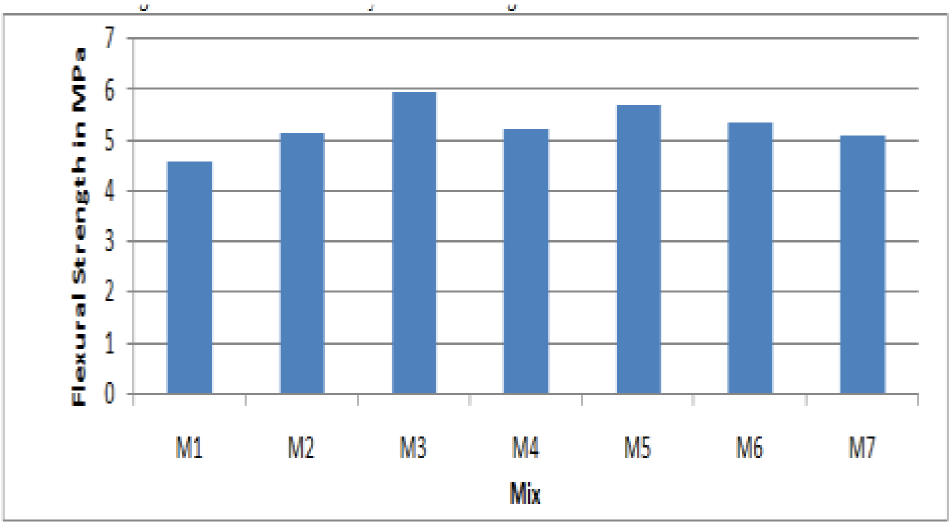

Figure 6 Flexural Strength of various mixes

Prisms were cast to determine flexural strength. The flexural strength at the age of 28days for various mixes varies from 4.59 to 5.96 MPa. It was observed that for mix M3 with 7.5% Silica fume shows higher flexural strength, the maximum 28 days strength of 5.96MPa. The strength is about 29.8 % more at 28 days of curing compared to the control concrete mix. Flexural strength development was 11.76 %, 29.80 %, 13.94 %, 24.40%, 16.77%, 10.90 %. The flexural strength of cylinders containing partial replacement of silica fume and fly ash are higher than control specimen at 28 days.The Maximum Flexural strength is obtained for M3 with 7.5% of silica fume is 5.96 MPa.

Water Absorption Test

The water absorption of concrete cube based on ASTM C 642 - 81was determined. After curing, Specimens were dried in an oven at 105º C for 24 hours. The dry specimens were cooled to room temperature and weighed accurately and noted as dry weight. Dry specimens were immersed in water container. Weight of the specimens was taken after wiping the surface with dry cloth. This process was continued not less than 48 hours or up to constant weight was obtained in two successive observations. The water absorption results of Mixes M1 to M7 are given in table IX. The variation of water absorption is shown in figure 6.

Table IX Water Absorption Result

Mix	Silica fume (%)	Fly ash (%)	Wet weight of cube (gms)	Dry weight of cube (gms)	Water Absorption (%) in 24 Hrs
M1	0	0	2518	2435	3.40
M2	5	0	2530	2452	3.18
M3	7.5	0	2534	2463	2.88
M4	10	0	2555	2494	2.44
M5	5	10	2568	2527	1.62
M6	7.5	10	2586	2551	1.37
M7	10	10	2597	2565	1.24

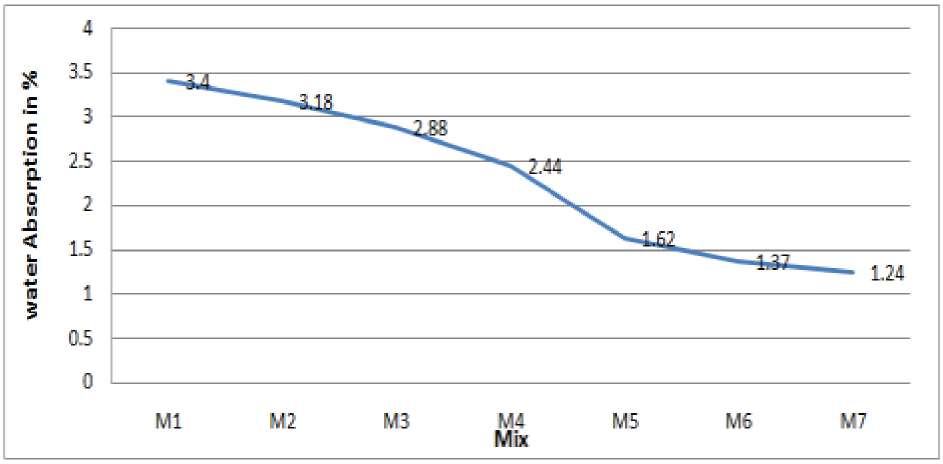

Figure7 Water Absorption for various mixes

The results of the water absorption test of concrete cubes are listed in Table 2.12. Result shows that the water absorption reduces when the percentages of Silica fume and flyash increases. The maximum value of water absorption obtained for M1 which is 3.40 %.The mix M7 shows lowest value of water absorption than control concrete mix, is 1.24 %.Adding mineral admixture to the normal concrete the porosity of the concrete is reduced this is the main reason for decrease in water absorption. The use of mineral admixtures such as fly ash and Silica fume, results in denser microstructure of the concrete matrix which enhance the durability properties.The test indicates that when more pozzolanic material is added to concrete, the Water Absorption will reduce.

Modulus of elasticity

In the case of concrete, since no part of the graph is straight, the modulus of elasticity is found out with reference to the tangent drawn to the curve at the origin. The modulus found from this tangent is referred as initial tangent modulus. This gives satisfactory results only at low stress value [7]. For higher stress value it gives misleading picture.The modulus of elasticity most commonly used in practice is secant modulus. There is no standard method of determining the secant modulus. Sometime it is measured at stresses ranging from 3 to 14MPa and sometime the secant is drawn to point representing a stress level of 15, 25, 33 or 50 per cent of ultimate strength. Since the value of secant modulus decreases with increase in stress, the stress at which the secant modulus has been found out should always be stated. The modulus of elasticity is determined by subjecting a cube or cylinder specimen to uniaxial compression and measuring the deformations by means of dial gauges fixed between certain gauge length.

Modulus of elasticity = Stress / Strain N/mm^2

Table 2.13 Modulus of Elasticity (MPa)

Mix	**Stress N/mm^2**	**50% ofUlt stress N/mm^2**	**Corresponding Strain**	**Modulus of elasticity N/mm^2**
M1	57.32	28.66	0.00070	40946.31483
M2	56.05	28.03	0.000725	38655.83132
M3	**67.52**	**33.76**	**0.00075**	**45010.61571**
M4	63.69	31.85	0.0008	39808.91720
M5	66.24	33.12	0.000775	42736.79885
M6	64.97	32.48	0.00085	38216.56051
M7	57.32	28.66	0.00085	33720.49457

IV. CONCLUSION

The super plasticizer demand of concrete containing fly ash and silica fume increases with increasing amount of fly ash and silica fume. The increase is primarily due to the high surface area of the fly ash and silica fume. Fresh concrete containing fly ash and silica fume is more cohesive and less prone to segregation. From the experimental results it is evident that the compressive strength of high performance concrete containing 7.5% of silica fume is 12.18 % higher than the normal concrete.The split tensile strength of high performance concrete containing 7.5 % of silica fume is 17.06 % higher than the normal concrete. Also the flexural strength of high performance concrete containing 7.5 % of silica fume is 29.8 % higher than the normal concrete. It is found that as the age of concrete increases, the compressive strength also increases. Silica fume concrete attains high strength than silica fume with fly ash concrete. Durability test indicates that when more pozzolanic material is added to concrete, the Water Absorption will reduce.

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