Strength and Durability of High Performance Concrete

R.Vivek[1], K .Thamizh thendral[2], Dr. G.Dhanalakshmi[3]

[1]ME(Structural Engineering) Dept. of Civil Engineering, Oxford Engineering College Tiruchirappalli, Tamilnadu, India
[2]Assistant Professor, Dept. of Civil Engineering, Oxford Engineering College Tiruchirappalli, Tamilnadu, India
[3]Professor and Head, Dept. of Civil Engineering, Oxford Engineering College Tiruchirappalli, Tamilnadu, India

---***---

Abstract - *In today's world concrete is probably the most extensively used construction material in the world. But the conventional concrete is losing its uses with time and High performance concrete is taking that place. There is a growing awareness all over the world about the waste material like fly ash from thermal power plants, silica fume, and blast furnace slag etc. high performance concrete taking this waste material to be produced. The paper presents experimental studies conducted on HPC mix of M60 grade using Silica Fume as a mineral admixture to replace the cement by 2.5%, 5%, 7.5%. Effect of adding mineral admixture to concrete were studied.*

***Key Words*: High- Performance, Silica Fume, Admixture, High – Strength, Durability**

1.INTRODUCTION

High-performance concrete is a concrete that having meets special qualities like performance and uniformity that cannot be achieved using conventional concrete making methods. Ever since the term high-performance concrete was introduced into the industry, it had widely used in large-scale concrete construction that demands high strength, high flow ability, and high durability. Durable concrete Specifying a high-strength concrete and does not ensure that a durable concrete will be achieved. It is very difficult to get a product which simultaneously fulfills all of the properties. Concrete is considered as durable and strong material. Reinforced concrete is the most popular material that used for construction.

Reinforced concrete is exposed to deterioration in some regions especially in coastal regions. There for researchers around the world are directing their efforts towards developing a new material to overcome this problem. Large construction plants now using more materials for construction. This scenario led to the use of additive materials to improve the quality of concrete HPC concretes are usually designed by using some admixtures to achieve these requirements, such as Fly Ash (from the coal burning process), Ground Blast Furnace Slag (from the steel making process), or Silica Fume (from the reduction of high quality quartz in an electric arc furnace). Different amounts of these materials are combined with Portland cement in varying percentages depending on the specific HPC requirements.

In the production of High Performance Concrete admixtures plays a major role. Both Chemical and Mineral Admixtures form a part of the High Performance Concrete mix. The major difference between Conventional Cement Concrete and High Performance Concrete is essentially the use of Mineral Admixtures in the latter Chemical composition determines the role of Mineral Admixtures in enhancing properties of concrete. Fly Ash (FA) and Silica Fume (SF) act as Pozzolanic materials as well as fine fillers; thereby the microstructure of the hardened cement matrix becomes denser and stronger. Silica Fume fills the space between cement particles and aggregate It does not impart any strength to it, but acts as a rapid catalyst to gain the early age strength.

2. MATERIALS USED

2.1 Cement

PPC 43 grade cement is used for this study, this grade was introduced by BIS in the year 1987 and commercial production started from 1991. The advent of this grade in the country owes it to the improved technology adopted by modern cement plants. Design Strength of PPC 43 grade cement is should be minimum 43 MPa or 430 kg/sqcm at 28 days.

Table -1: Properties of Cement

Test	Result	Requirement of IS 12269 - 1987
Fineness: Specific surface	285 m^2/kg	Should be not less than 225 m^2/kg
Setting time Initial set	30 minutes	Should be not less than 30 minutes
Final set	225 minutes	Should not exceed 600 minutes

2.2 Silica Fume

Silica fume is a by-product of the silicon and ferrosilicon alloy production and the average size of particle has a diameter of 150nanomicron. It is very effective in lowering the water-cement ratio, so superplasticizers should be used while silica fume used as an admixture. The main application of a pozzolanic material for high-performance concrete. Particles of silica fume are allowed to fill the space between the cement grains, denser concrete is achieved when silica fume used as an admixture or a cement replacement material. The compressive strength of silica fume is more than 150MPa. The compressive strength of silica fume is more than 150MPa. Using of Silica Fume, with superplasticizers will improve the bonding between paste and aggregate by forming a dense microstructure in the interfacial transition zone.

Table -2: Properties of Silica Fume

Property	Result
Specific surface area	20,000 m^2/kg
Size	Less than 1 micron
Density	250 kg/mm^3

2.3 M-Sand

Manufactured sand (M-Sand) was used as a substitute for the river sand for construction works. M- Sand was produced by crushing the hard granite stone cubical shape and grounded edges are achieved form crushing, these stones are washed and graded as a construction material. The manufactured sand (M Sand) having the size less than 4.75mm. Due to fast growing construction industry, the demand for sand has increased tremendously, causing deficiency of suitable river sand in most part of the word. M-Sand is easily available and transportation cost of the sand is less. It can be dust free and the size of the m-sand is controlled easily to achieve the required grading for the construction.

Table -3: Sieve Analysis of M-Sand

Sieve size	% of Passing	IS Grading limits
4.75mm	96	90-100
2.36mm	78	75-100
1.18mm	71	55-90
600µm	48	35-59
300µm	20	08-30
150µm	06	00-10

2.4 Coarse Aggregate

Aggregate are the important constituents in concrete. They give body to the concrete, reduce the shrinkage and effect economy. Earlier, aggregates were considered as chemically inert materials but now it has been recognized some of the aggregates are chemically active also some aggregates exhibit chemical bond at the interface of aggregate and paste. The aggregates will occupy the 70 -80% of the concrete volume.

Aggregate bigger than 4.75mm considered as coarse aggregate having the size bigger than 4.75mm, Aggregates having the size less than 4.75mm is consider as the fine aggregate. Generally maximum size of aggregate should be as large as possible within the limits specified, but any case not greater than one – fourth of the minimum thickness of the member.

Table -4: Sieve Analysis of Coarse Aggregate

IS sieve size (mm)	Percentage of passing (%)	IS grading limits (%)
12.5	90	85-100
10	38.5	0-45
4.75	04	0-10

3. MIX DESIGN AND CASTING

Materials confining to IS standards are selected and casting is done with proper mix proportioning as per the mix design. Mineral admixtures are added to the concrete by replacing the cement to achieve the high strength concrete.

Table -5: Mix Design of Concrete

Water	140 kg/m^3
PPC 43 Grade	504.21 Kg/m^3
Sand	683.24 Kg/m^3
12.5 mm crushed aggregate	1108.13 Kg/m^3
28-day cube strength N/mm^2	60 X 10^3 N/mm^2
Mix Ratio Cement : FA : CA	1: 1.35 :2.19

3.1 Preparation of Concrete Specimen

Concrete mix is prepared as per the mix design. Cement is replaced by Silica Fume in the ratio of 0%, 2.5%, 5% and 7.5% . Materials are mixed as per the mix design and casted in the cube and cylindrical specimen and proper curing were done.

Table -6: Mix Proportion for the Specimen

mix	Cement (Kg/m^3)	Silica Fume		Aggregates (Kg/m^3)	
		%	Kg/m^3	Coarse	Fine
HPC0	504.21	0	0	1108.13	683.24
HPC1	491.61	2.5	12.60	1108.13	683.24
HPC2	478.99	5	25.21	1108.13	683.24
HPC3	466.39	7.5	37.81	1108.13	683.24

4. RESULTS AND DISCUSSION

4.1 Slump Flow Test

To determine the reference slump value for concrete and to calibrate it against an equivalent measure using a flow table. Mould is the shape of a truncated cone with the internal dimensions 200 mm diameter at the base, 100mm diameter at the top and a height of 300 mm. Concrete is poured in three layers. Each layer is tampered about 25 times. Immediately the cone is lifted in an upward direction.

Fig -1: Slump Cone Test

4.2 Compressive Strength Test

Compressive strength test is used to determine the hardness of a specimen. Strength of a concrete specimen is tested for various time periods. Mineral admixtures added to the concrete do a great role in controlling the strength of concrete. After curing the concrete cube specimen was surface dried for 24 hours. Then the compression tests were taken using the Compression Testing Machine (CTM). Using the below formula the compressive strengths were calculated. Compressive strength = Load/Area.

Table -7: Compressive Strength Test Results

Sl. NO	Mix Proportion	Compressive Strength		
		7 days (N/mm^2)	14 days (N/mm^2)	28 days (N/mm^2)
1	HPC0	14.20	29.56	38.14
2	HPC1	31.33	48.43	55..24
3	HPC2	28.56	44.53	58.54
4	HPC3	33.52	52.53	62.12

The cube Compressive Strength results of High Performance Concrete mixes at the ages of 7, 14, 28 days are presented in Table 7. The development of Compressive Strength of M60 grade of HPC mixes containing 2.5, 5, 7.5, percent of Silica Fume at the various stages are plotted in the form of graphs are shown in F Chart 1.

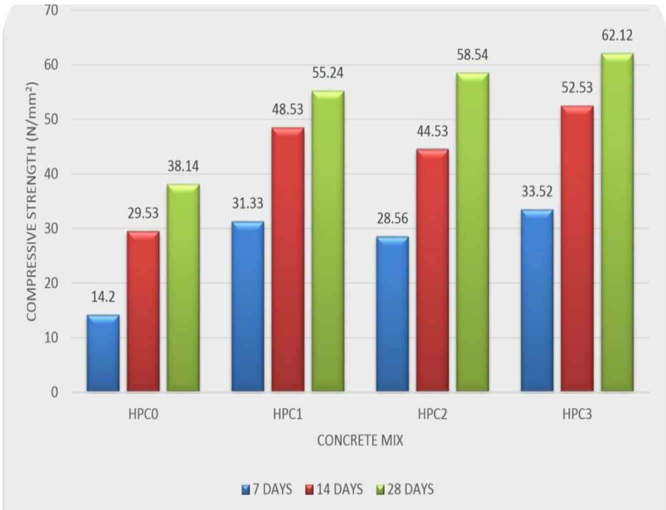

Chart -1: Compressive Strength Test Results

Results shows that of Silica Fume mixed with cement gives higher compressive strength than normal HPC0 (HPC with 0% replacement of cement). It is interesting to see that the compressive strength of HPC with 7.5% Silica Fume was higher than that of the Controlled mix. This result shows the benefit of using Silica Fume to produce HPC with higher replacement of cement about 7.5%. When compared with the conventional concrete, HPC3 showed 19.3%, 23.3% and 23.98% increase in Compressive Strength for 7 days, 14 days and 28 days curing.

4.3 Split Tensile Strength Test

The tensile strength will affect the cracking behavior, stiffness, damping action, durability of concrete, based on the split strength the behavior of concrete under shear loads are determined. The tensile strength is determined either by direct tensile tests or by indirect tensile tests such as split cylinder tests. In split tensile test cylinders after 28 days were removed from the curing tank and was left to dry for 24 hours after that cylinder is placed in CTM for testing. The load is applied until the cracks were in the cylinder specimen. The split tensile strength result of concrete was presented in Table 8.

The split tensile strength results of High Performance Concrete mixes at the ages of 7, 14, 28 days are presented in table 8. The split tensile strength of M60 grade of HPC mixes containing 2.5, 5, 7.5, percent of Silica Fume at the various stages are plotted in the form of graphs are shown in Chart 2

Fig -3: Split Tensile Strength Testing Machine

Table -8: Split Tensile Strength Test Results

Sl. NO	Mix Proportion	Split Tensile Strength		
		7 days (N/mm²)	14 days (N/mm²)	28 days (N/mm²)
1	HPC0	1.37	2.56	3.21
2	HPC1	1.24	2.88	3.44
3	HPC2	2.26	3.52	4.27
4	HPC3	2.71	3.91	4.33

According to result the combination of concrete mix with Silica Fume gives a high tensile strength than the normal High Performance Concrete (HPC with 0% replacement of cement). It is interesting to see that the tensile strength of HPC with 7.5% Silica Fume was higher than that of the Controlled mix. When compared with the conventional concrete, HPC3 showed 1.34%, 1.35% and 1.12% increase in Tensile Strength for 7 days, 14 days and 28 days curing.

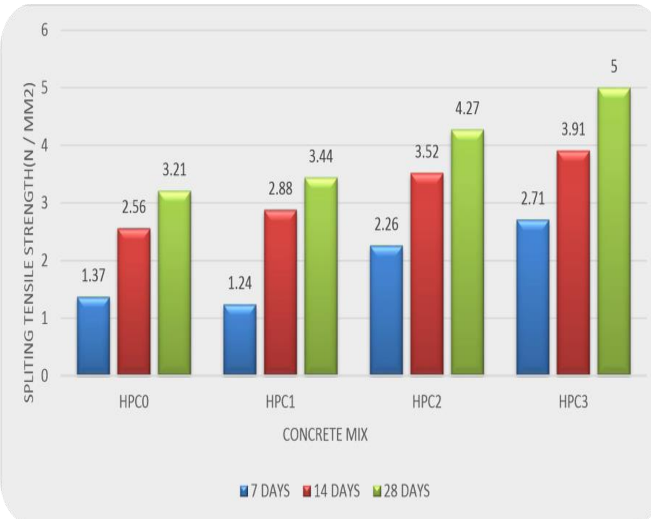

Chart -2: Split Tensile Strength Test Result

5. CONCLUSION

This project work is primarily focused on the properties of materials used, mix proportion of High Performance Concrete, making of concrete specimen, curing and testing of harden concrete.

On performing the various tests the physical properties of the specimens are studied and the following conclusions are arrived.

On comparing the result high performance concrete having 7.5% Silica Fume gives a maximum compressive strength value.

Maximum splitting tensile strength value is achieved when cement is replaced with 7.5% of Silica Fume.

Hence it is concluded 7.5% of Silica Fume gives the maximum compressive and tensile strength to the concrete we can say that concrete mix is high strength concrete. Performance properties of the concrete need to be studied.

REFERENCES

[1] Dr. B.Vidivelli and A. Jayaranjini. Prediction of Compressive Strength of High Performance Concrete Containing Industrial by product Using Artificial Neural Networks, International Journal of Civil Engineering and Technology, 7(2), 2016, pp.302–314.

[2] Himanshu Kumar and G. Premkumar, Behaviour of High Performance Concrete By Using Recycled Aggregate on Beam Under Static and Cyclic Loading International Journal of Civil Engineering and Technology, 8(3), 2017, pp. 210–219

[3] Sundararajan R (2004), "Effect of Partial Replacement of Cement With Silica Fume on The Strength And Durability Characteristics of High Performance Concrete" our World in Concrete and Structures, pp. 397-404.

[4] Pazhani.K, Jeyaraj.R, "Study on durability of high performance concrete with industrial waste", Applied Technology and Innovation, Vol 2, Issue 2, Aug 2010, pp 19-28.

[5] Muthupriya, "Experimental study on high performance reinforced concrete column with silica fume and fly ash admixtures", Journal of Structural Engineering, Vol 38, No.1, April–May 2011, pp- 46-59

[6] Berntsson, L., Chandra, S., and Kutti, T., "Principles and Factors Influencing High Strength Concrete Production," Concrete International, December, pp.59-62, 1990.

[7] Carrasquillo, R. L., “Production of High Strength Pastes, Mortars, and Concrete,” Very High Strength Cement-Based Materials.

[8] Mehta, P. K., and Aïtcin, P.C., “Principles Underlying Production of High-Performance Concrete,” Cement, Concrete, and Aggregates, ASTM, Vol. 12, No. 2, winter, pp. 70-78, 1990.

[9] Gambhir.M.L., “concrete technology” Tata McGraw-Hill Publishing company Ltd, New Delhi,2004.

[10] Zhou Mingkai (2008), “Influence of natural sand, M-sand and StoneDust on Workability and Strength properties of High Strength Concrete”, International Journal of Civil and Structural Engineering.

[11] IS:1489(Part I)-1991, “Portland Pozzolana Cement Specification” Bureau of Indian Standards, New Delhi.

[12] IS:2386-1963, “Methods of Test for Aggregates for Concrete” Bureau of Indian Standards, New Delhi

[13] IS:456-2000, “Plain and Reinforced Concrete - Code of Practices” Bureau of Indian Standards, New Delhi.