International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 04 | Apr -2017 www.irjet.net p-ISSN: 2395-0072

DETERMINATION OF COMPRESSIVE STRENGTH PARAMETER OF HIGH STRENGTH SILICA FUME CONCRETE

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Abstract - *Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to the tensile strength, which withstands loads tending to elongate. Compressive strength is a key value for design of structures. Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, quality control during production of concrete etc.*

In the present work a detailed experimental study on the mechanical properties i.e. the compressive strength of high-strength concrete of grades M40 at 7 days and 28 days characteristic strength with different replacement levels viz., 3%, 6%, 9%, 12% and 15%of cement with silica fume are considered. Standard cube (150mmX150mmX150mm) were considered in the investigation. It can be seen that the compressive strength is increased upto 12% of replacement of cement with silica fume which displays silica fume is one of the good cementitious material & reduces the production of Portland cement & save our environment.

***Key Words*: High Performance; Workability; Silica Fume; Compressive strength Characteristics and partial replacement.**

1.INTRODUCTION

High-strength concrete means good abrasion, impact and cavitation resistance. Using High-strength concrete in structures today would result in economical advantages. Most applications of high strength concrete to date have been in high-rise buildings, long span bridges and some special structures. Major application of high strength concrete in tall structures have been in columns and shear walls, which resulted in decreased dead weight of the structures and increase in the amount of the rental floor space in the lower stories. In future, high range water reducing admixtures (super plasticiser) will open up new possibilities for use of these materials as a part of cementing materials in concrete to produce very high strengths, as some of them are finer than cement. In cases of Indian scenario silica fume has become one of the necessary ingredients for making high strengths and high performance concrete. Nuclear Power Corporation was one of the first to use silica fume concrete in their kaiga and kota nuclear power project.

Compressive strength or compression strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate. In other words, compressive strength resists compression (being pushed together), whereas tensile strength resists tension (being pulled apart). Some materials fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structures. For those reasons investigation of compressive strength is of importance in high strength silica fume concrete.

Silica fume an overview: Silica fume, also known as micro silica, is an amorphous (non-crystalline) polymorph of silicon dioxide. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete. Silica fume is an ultrafine airborne material with spherical particles less than 1 μm in diameter, the average being about 0.1 μm. This makes it approximately 100 times smaller than the average cement particle. The unit weight, or bulkdensity, of silica fume depe1nds on the metal from which it is produced. Its unit weight usually varies from 130 to 430 kg/m .The specific gravity of silica fume is generally in the range of2.20 to 2.5. In order to measure the specific surface area of silica fume a specialized test called the "BET method" or nitrogen adsorption method must be used. Based on this test the specific surface of silica fume typically ranges from 15,000 to30, 000m_/kg.

Mechanism: Silica fume improves concrete through two mechanism:-

Pozzolonic effect: When water is added to cement, hydration occurs forming two products, as shown below:

$$OPC + H2O \rightarrow CSH \text{ (Calcium silicate hydrate)} + Ca(OH)2.$$

In the presence of SF, the silicon dioxide from the ORISIL SF will react with the calcium hydroxide to produce more aggregate binding CSH as follows:

$$Ca(OH)2 + SiO2 \rightarrow H2O + CSH.$$

The reaction reduces the amount of calcium hydroxide in the concrete. The weaker calcium hydroxide does not contribute to strength. When combined with carbon

dioxide, it forms a soluble salt, which will leach through the concrete causing efflorescence, a familiar architectural problem. Concrete is also more vulnerable to sulphate attack, chemical attack and adverse alkali-aggregate reactions when high amounts of calcium hydroxide is present inconcrete.

Micro filler effect: Silica Fume is an extremely fine material, with an average diameter 100 times finer than cement. At a typical dosage of 8% by weight of cement, approximately 100,000 particles for each grain of cement will fill the water spaces in fresh concrete. This eliminates bleed and the weak transition zone between aggregate and paste found in normal concrete. This micro filler effect greatly reduces permeability and improves paste-to aggregate bond in SF concrete compared to conventional concrete. The silica fume reacts rapidly providing high early strength and durability. The efficiency of silica fume is 3-5 times that of OPC and consequently concrete performance can be improved drastically.

2. BRIEF LITERATURE REVIEW

In this paper, Verma Ajay, Chandak Rajeev and Yadav R.K. (2012) [1] studied that the Silica fume increases the strength of concrete more by 25%. As all of us knows that, Concrete is the most important engineering material and addition of some other materials may change the properties of concrete. With increase in trend towards the wider use of concrete for prestressed concrete and high rise buildings there is a growing demand of concrete with higher compressive strength. There are two types of materials crystalline and non-crystalline. Micro silica or silica fume is very fine non crystalline material We are adding 0%, 5%, 10%, and 15% by wt of cement in concrete. Silica fume improves concrete through two mechanisms that are Pozzolonic effect & Micro filler effect. Silica Fume is an extremely fine material, with an average diameter100 times finer than cement. At a typical dosage of 8% by weight of cement, approximately100, 000 particles for each grain of cement will fill the water spaces in fresh concrete. This eliminates bleed and the weak transition zone between aggregate and paste found in normal concrete. Silica fume is much cheaper than cement therefore it is very important form economical point of view. Silica fume also decrease the voids in concrete.

Influence of Micro silica on Concrete Performance:

In this M. Nili, A.Ehsaniand K. Shabani (2012) [2], in the present work, in which the different content of micro silica and colloidal nanosilica; as partial replacement of cement in the concrete mixture with 0.45 water-cement ratios were used simultaneously. It was concluded that 6% micro silica and 1.5% nanosilica as partial replacements of cement, improved compressive strength and also diminished capillary absorption of the concrete specimens seriously. The results shows that by increasing in nanosilica content as 1.5% to 4.5% by weight, leads to an increase of compressive strength at all stages. The results also indicate that the specimens which contain both nano and micro silica, due to the high pozzolanic activity, have higher compressive strength than reference ones. In the capillary absorption coefficient of the concrete mixtures, the result indicates that incorporation of nano and micro silica is an efficient way for decreasing the permeability. And, the capillary absorption rate is also decreased to a lowest level, when 3% micro silica and 1.5% nano silica were used in the mixtures. Consequently, based on the present results, it can incorporated that the colloidal nanosilica and micro silica as partial replacements of cement have advantage effect on concrete performance.

Effect of Water and Cement Ratio on Compressive Strength and of silica fume Concrete:

In this study Kamal Rahmani, AbolfazlShamsai, BahramSaghafian and Saber Peroti (2012) [3], due to development of hydraulic structures such as dams, the durability issue of concrete is very important parameter of hydraulic structures. The key issue in this regard is the concrete resistance against abrasion which is related to water and cement and the crystalline formation of the particles in concrete. To enhance the abrasion resistance of Concrete, various issues have been proposed by number of investigators. Those include use of aggregates which are resistance against abrasion, reduce the water and cement ratio, use of micro and nano-silica in concrete and proper curing time for the concrete. In this investigation, concrete cubic sample size of (15×15×15 cm) were prepared with different combination of nano -silica samples and variable water and cement ratio. An Overview on the Influence of Silica in Concrete and a Research Initiative:

In this study by Maheswaran S, and Bhuvaneshwari B(2011)[4], presents a critical review of the literature on the influence of nanosilica in concrete and its application for the development of sustainable materials in the construction industry and to study the pore filling effect and its pozzolanic activity with cement towards improvement of mechanical properties and durability aspects. Thus, there is a scope for development of crack free concrete towards sustainable construction. The addition of NS along with cement, cement mortars, concretes, and other cementatious materials, there is a considerable improvement in the properties of permeability, pore filling effects, reduction of CH leaching, rheological behaviour of cement pastes, heat of hydration, the pozzolanic activity or reactions and workability, strength and durability.

Application of nano-silica (NS) in concretemixtures

In this paper G. Quercia and H.J.H Brouwers (2010) [5] studied that a nano-silica (NS) can be produced in high quantities and for low prices that allows for a mass application in concrete. It may replace cement in the mix, which is the most costly and environmentally unfriendly component in concrete. The use of NS makes concrete financially more attractive and reduces the CO_2 footprint of the produced concrete products. The NS will also increase the product properties of the concrete, the

workability and the properties in hardened state, enabling the development of high performance concretes for extreme constructions. That means that a concrete with better performance, lower costs and an improved ecological footprint can be designed.

Silica fume and its influence on fresh and hardenconcrete.

This is one of the topics from the Concrete Technology Book by M.S.Shetty (2009)[6] in which, silica fume; influences the fresh concrete, hardened concrete & properties of silica fume and its application. As, it is very fine with particle size less than1micron and with an average diameter of about 0.1 micron, about 100 times smaller than average cement particles. It will create dense packing and fill the pores of cement paste contribute to the strength dramatically, improves durability, resistant against frost action, effective for alkali-aggregate reaction in hardened concrete. In the fresh concrete, there will be increase in water content in proportion to the amount of micro silica added, it makes concrete sticky in nature, large reduction in bleeding and transported without segregation and its use, simplifies the production of high performance concrete and makes it easier to achieve compressive strengths in the range of 60 to about 90 MPa .And, the various properties of silicafume are high strength, better water resistant, Improves workability, Improvement in transition zone etc. And, its application is best in slurry form, which is easy to store and dispense. It is so, because slurry produced significantly higher compressive and tensile strength.

Effect of nano-silica on properties of blendedcement:

In this study G. Reddy BabuVol 03 (2010) [7], the properties of blended cement with nano-SiO2 (NS) were experimentally studied. The silica, which is the major component of a pozzolana, reacts with calcium hydroxide formed from calcium silicates hydration. The rate of pozzolanic reaction is proportional to the amount of surface area available for reaction. Results indicated that setting times were increased with increase in percentage of nano-SiO2 in cement blended with silica fume. A combination of 6% SF + 3%NS was given the best performance in compressive strength. XRD was used to analyze the results.

Comparative Study of the Effects of Microsilica and Nanosilica in Concrete:

In this study ParamitaMondal, Surendra P. Shah, Laurence D. Marks**,** and Juan J. Gaitero,(2009)[8]use of mineral admixtures such as silicafume enhances the strength and durability of concrete. This research compares the effects of adding silica fume and nano- silica to concrete and provides a better understanding of the changes in the concrete nano- structure. Nano indentation with scanning probe microscopy imaging was used to measurethe local mechanical properties of cement pastes with 0% and 15% replacement of cement with silica fume. A reduction in the volume fraction of calcium hydroxide in a sample with silica fume provides evidence of pozzolanic reaction. Furthermore, replacing 15%cement by silica fume increased the volume fraction of the high-stiffness calcium silicate hydrate (C-S-H) by a small percentage that was com-parable with the decrease in the volume fraction of calcium hydroxide.

3. MATERIALS USED:

3.1 Ordinary Portland Cement: Ultratech brand of 53 grade confirming to IS: 12269 was used in the present study. The properties of cement are shown in Table1.

Table 1: Properties of Cement

Sl. No	Property	Result
1.	Normal Consistency	32%
2.	Initial Setting time	42 mins
3.	Specific Gravity	3.15
4.	Fineness of cement	6%

3.2 Fine Aggregate: Natural sand as per IS: 383-1987 was used. The properties of fine aggregateare shown in Table2.

Table 2: Properties of fine aggregate

Sl. No	Property	Result
1.	Specific Gravity	2.64
2.	Fineness modulus	2.42
3.	Grading zone	II

3.3.Coarse Aggregate: Crushed aggregate confirming to IS: 383-1987 was used. Aggregates ofsize 20mm and 12.5 mm were used. The physical properties of CA are given below in Table No.3.

Table 3: Properties of Coarse aggregate

1.	Specific gravity	2.85
2.	Bulk density (kg/m3)	1535
3.	Water absorption (%)	0.52
4.	Fineness Modulus	7.626
5.	Impact value	13.7(strong)

3.4.Silica Fume (Grade 920 D): Silica fume used was confirming to ASTM- C(1240-2000) and was supplied by "ELKEM INDUSTRIES" was named Elkem – micro silica 920 D. The Silica fume is used as a partial replacement of cement.

3.5.Super Plasticizer: In this investigation super plasticizer-ALSTACON SP 40 in the form of Polymelamine Formaldehyde Sulfonate based concrete superplasticizer is used. The properties of super plasticizer are shown in Table4.

Table 4: Properties of super plasticizer

*As per manufacturers manual

1	Specific Gravity	1.05(min)
2	Chloride content	NIL
3	Air entrainment	Not increased

4.MIX PROPORTIONING:

Concrete mixes was designed to a compressive strength of 40MPa with a water-cementitious ratio of 0.36, as per IS code. In the cases, the Portland cement was replaced with silica fume by 0%, 3%,6%, 9%, 12%, and 15%. The water reducing agent ALSTACON SP-40, 600 ml per 50kg of cement was added, to get the desired workability. The proportions of constituent materials i.e., cementitious material (cement and silica fume), aggregates (coarse and fine), water and chemical admixture (superplasticizer) for the mixes is presented in Table 5.

Table 5. Proportions of Constituent materials of M40 Grade Concrete

Grade of mix	w/c ratio	Proportions of constituent materials		
		Cement	Fine Aggregate	Coarse Aggregate
M40	0.36	1	0.98	2.93

5.EXPERIMENTALPROCEDURE.

The experimental program was designed to investigate compressive strength of high strength concrete with M40 grade of concrete and with different replacement levels of ordinary Portland cement (OPC) with silica fume. The program consists of casting and testing the M40 grade concrete specimens. The specimens of standard cubes (150mmX150mmX150mm) were cast with and without silica fume. Compression testing machine was used to test all the specimens. The specimens were cast with M40 grade concrete with different replacement levels of cement as 0%, 3%, 6%, 9%, 12% and 15% with silica fume. Workability test like Slump test and Compacting factor test is being performed with above mentioned grade concrete with different replacement levels of cement as with silica fume. Then the prisms are casted, cured and tested to investigate the strength at 7 days and 28 days.

6.TEST RESULTS AND DISCUSSIONS:

The present and below investigation report described a study on workability parameters of M40 grade concrete with different replacement levels of cement as 0%, 3%, 6%, 9%, 12% and 15% with silica fume. The workability tests are presented in Table 6.

Table 6. Slump and compaction factor values of M40

Mix	% of Silica Fume added (%)	Slump (mm)	Compaction factor
M1	0	50	0.86
M2	3	44	0.83
M3	6	42	0.81
M4	9	39	0.79
M5	12	35	0.76
M6	15	33	0.71

6.1. Compressive Strength of Concrete:

The compressive strength test was carried out conforming to IS 516-1959 to obtain compression strength of concrete at the age of 7 and 28 days. The cubes were cast for each replacement level & the experimental results are shown in Table 7.

Table 7. Results of compressive strength of M40 grade concrete

Mix	% of Silica Fume added (%)	Compressive strength (MPa)	
		7days	28 days
M1	0	33.87	51.29
M2	3	35.17	53.42
M3	6	37.05	56.17
M4	9	38.45	58.47
M5	12	40.98	62.04
M6	15	37.95	57.65

From the results it has been seen that the maximum increase in strength is observed as 40.98 N/mm^2 and 62.04 N/mm^2 at 7 and 28 days respectively when silica fume is replaced by 12% to that of cement.

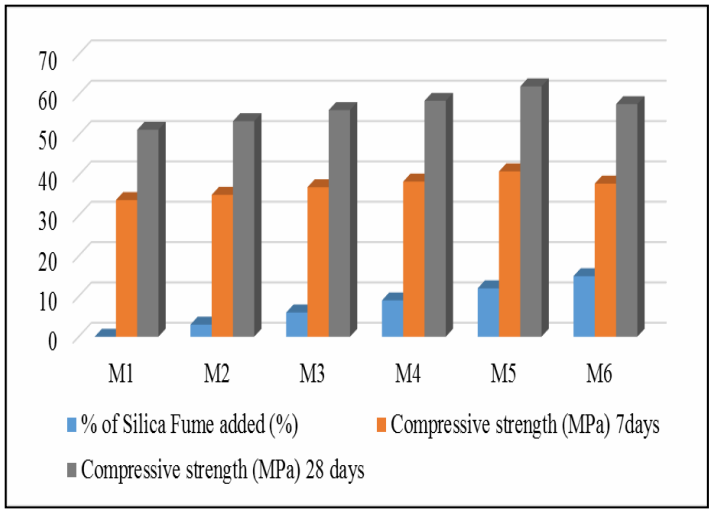

FIG.1. Effect of silica fume on Compressive strength of concrete

FIG.2. Test for Compressive strength of Concrete

7.CONCLUSIONS:

Cement replacement up to 12% with silica fume leads to increase in compressive strength for M40 grade of concrete. Beyond 12% there is a decrease in compressive strength for 28 days curing period. There is a decrease in workability as the replacement level increases, and hence water consumption will be more for higher replacements.

8.REFERENCES:

[1] By Verma Ajay, Chandak Rajeev and Yadav R.K. Structural Engineering Department, Jabalpur Engineering College, Jabalpur, MP. Research Journals of Engg.sciences, vol 1(3), 1-4 sept(2012)

[2] M. Nili, A. Ehsani , and K. Shabani Civil Eng., Dept., Bu-Ali Sina University, Hamedan,I.R. Iran Eng., Research Institute of Jahad-Agriculture Ministry, Tehran, I.R. Iran, June 28-June 30, 2010

[3] Kamal Rahmani, RbofaziShamsai, BahramSaghafian and Saber Peroti ; 2012; Indian Streams Research Journal.

[4] Maheswaran S., Bhuvaneshwari B., Palani G.S., Nagesh R Iyer and Kalaiselvam S. CSIR- Structural Engineering Research Centre, CSIR Campus, Taramani, Chennai, Department of Mechanical Engineering, College of Engineering, Anna University, Chennai, Research Journal of Recent Sciences, Vol. 2(ISC-2012), 17-24(2013)

[5] G.Quercia and H.J.H. Brouwers Materials Innovation Institute – M2i and Eindhoven University of Technology Eindhoven, The Netherlands 8th fib PhD Symposium in Kgs.Lyngby, Denmark June 20 – 23, 2010

[6] M.S.Shetty, Concrete Technology S.chand publications 2009.

[7] G Reddy, A. Ehsani , and K. Shabani Civil Eng., Dept., Bu-Ali Sina University, Hamedan,I.R. Iran Eng., Research Institute of Jahad-Agriculture Ministry, Tehran, I.R. Iran Middle- East Journal of Scientific Research 12 (8): 1056-1061, 2012ISSN 1990-9233© IDOSI Publications, 2010

[8] Gaitero, J. J., I. Campillo, and A. Guerrero. Reduction of the CalciumLeaching Rate of Cement Paste by Addition of Silica Nanoparticles.Cement and Concrete Research, Vol. 38, 2009, pp. 1112–1118.