INVESTIGATION ON FLEXURAL STRENGTH OF HIGH STRENGTH SILICA FUME CONCRETE

Pranab Chakraborty[1]

1.M.Tech Scholar, Department of Civil Engineering, Narula Institute of Technology, Kolkata, India

---***---

Abstract - *Concrete as we know is relatively strong in compression and weak in tension. In reinforced concrete members, little dependence is placed on the tensile strength of concrete since steel reinforcing bars are provided in all tensile forces. however, tensile stresses are likely to develop in concrete due to drying shrinkage, rusting of steel reinforcement, temperature gradients and many other reasons. The deflection and cracking behavior of concrete structure depend on flexural properties of concrete. Therefore, the knowledge of flexural strength of concrete is of importance.*

In the present work a detailed experimental study on the mechanical properties i.e. the flexural 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 prisms(100mmX100mmX500mm) were considered in the investigation. The investigations revealed that the use of waste material like silica fume improved the flexural strength characteristics of high strength concrete at the age of 28-days & reached a maximum value of 12%
replacement level for M40 concrete which is otherwise hazardous to the environment.

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

1.INTRODUCTION

High-strength and High-performance concrete are being widely used throughout the world and to produce them it is necessary to reduce the water/cement ratio and increase the cement content. Engineers are continually pushing the limits to improve its performance with the help of innovative chemical admixtures and supplementary cementitious materials because production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for greenhouse effect and the global warming. Silica fume 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. In cementations compounds, silica fume works on two levels, the first one described here is a chemical reaction called the "pozzolanic" reaction. The hydration (mixing with water) of Portland cement produces many compounds, including calcium silicate hydrates (CSH)and calcium hydroxide (CH). The CSH gel is known to be the source of strength in concrete. When silica fume is added to fresh concrete it chemically reacts with the CH to produces additional CSH. The benefit of this reaction is to increased strength and chemical resistance. The bond between the concrete paste and the coarse aggregate, in the crucial interfacial zone, is greatly increased resulting in compressive strengths that can exceed 15,000 psi. The additional CSH produced by silica fume is more resistant to attack from aggressive chemicals then the weaker CH. Thus it is one of the world's most valuable and versatile admixtures for concrete and cementitious products.

Flexural strength, a mechanical parameter is defined as ability to resist deformation under load. The deflection and cracking behavior of concrete structure depend on these properties of concrete. Due to many reasons such as temperature gradients, drying shrinkage, rusting of steel reinforcement stresses developed. A concrete road is called upon to resist tensile stresses from two principal sources-wheel load s and volume changes in the concrete. Wheel loads may cause high tensile stresses due to bending, when there is an inadequate sub grade support. Volume changes, resulting from changes in temperature and moisture, may produce tensile stresses, due to warping and due to the movement of the slab along the subgrade. Stresses due to volume changes alone may be high. The longitudinal tensile stresses in the bottom of the pavement caused by restraint and temperature warping, frequently amounts to as much as 2.5 MPa at certain periods of the year and the corresponding stress in the transverse direction is approx.0.9 MPa. These stress are additive to those produced by wheel loads on unsupported portions of the slab. For those reasons investigation of flexural strength is of importance in high strength silica fume concrete.

2.BRIEF LITERATURE REVIEW

Silica fume (micro-silica) has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties and improving the chemical durability of concrete (Khedr and AbouZaid). The use of silica fume is growing in various parts of the world to produce economical high strength and/or chemical-resistant concrete [1]. Since the beginning of its use in concrete in Canada, silica fume has been used as a cement replacement material in normal strength concrete so as to obtain a desired 28-day compressive strength. It is presently used in the produced form or in the form of blended cement. The two major cement producers in Canada are presently marketing what is called type 10SFsilica-fume blended cement. Whether it is used in the as-produced form at a concrete plant or blended with Portland cement, its dosage is always less than 10% by weight of cement. In fact, 10% is the maximum dosage that is permitted by the A23.6 Canadian standards (Isabelle 1986). On some occasions, it has been deliberately used for other applications, such as to control potential alkali/aggregate reaction and to make very high-strength concrete (Aitcin et al. 1985; Ryell and Bickley 1987) [2]. Silica fume is a fine-grained (30-100 times finer than cement) by-product of silicon-metal production. Silicon oxide (Si02) usually makes up more than 90% of silica-fume constituents. Silica has basically three roles in concrete paste: it reacts with free lime, which results from hydration of cement; it fills in pores for better inter particle arrangement; and it may improve aggregate-paste bonding. In its chemical reaction with the free calcium hydroxide, a stronger cementitous compound of calcium silicate hydrate and water is produced. This reaction reduces the alkali content in the pores; i.e., it reduces the pH of the pore fluid in concrete. According to Diamond (l986) and Hausmann (I969), alkaline environment of concrete pores (pH > 13) is essential to guard against the destruction of the passive protection of steel embedded in the concrete. This fact raises a question about the effect of using silica fume on the corrosion of reinforcing steel. Specially whether corrosion-related damage in concrete has been of significant concern in many situations [3].

On the other hand, silica fume in concrete increases its impermeability, electrical resistivity, and tensile strength. These three fold improvements in concrete properties can enhance its resistance to corrosion-related damage. The first hinders water, oxygen, and chloride ingression to the steel electrode. Higher electrical resistivity reduces ionic conduction [4].Since many of the high strength concretes are formulated by using pozzolans, and the silica fume might be included in this category, there is always the concern to what extent are these concretes more sensitive to the water curing procedures than concretes prepared with Portland cement only. This is particularly important in hot-dry climactic conditions, where the concrete is dried more readily, thus perhaps eliminating the moisture that is needed for the progress of the pozzolanic reaction which can continue to occur beyond the initial few days of the water curing period. In evaluating the effect of curing, one should consider the overall strength of the concrete, as well as the properties of the concrete skin (i.e. outer layer), which protects the steel reinforcement [5]. The object of the present work is to characterize high strength silica fume concretes from the points of view of heat generation, shrinkage and sensitivity to curing, and to compare their performance with that of concretes made of Portland cement only, having either the same cement content or the same water to cementitious materials ratio [6].Hooton [7] investigated on influence of silica fume replacement of cement on physical properties and resistance to sulphate attack, freezing and thawing, and alkali-silica reactivity. He reported that the maximum 28-day compressive strength was obtained at15% silica fume replacement level at a w/b ratio of 0.35 with variable dosages of HRWRA. Prasad et al. [8] has undertaken an investigation to study the effect of cement replacement with micro silica in the production of High-strength concrete. Yogendran etal.[9] investigated on silica fume in High-strength concrete at a constant water-binder ratio (w/b) of 0.34 and replacement percentages of 0 to 25, with varying dosages of HRWRA. The maximum 28-day compressive strength was obtained at 15% replacement level. Lewis [10] presented a broad overview on the production of micro silica, effects of standardization of micro silica concrete-both in the fresh and hardened state. Bhanja and Gupta [11] reported and directed towards developing a better understanding of the isolated contributions of silica fume concrete and determining its optimum content. Their study intended to determine the contribution of silica fume on concrete over a wide range of w/c ratio ranging from 0.26 to 0.42 and cement replacement percentages from 0 to 30%. Tiwari and Momin [12] presented a research study carried out to improve the early age compressive strength of Portland slag cement (PSC) with the help of silica fume. Silica fume from three sources- one imported and two indigenous were used in various proportions to study their effect on various properties of PSC.

Venkatesh Babu and Natesan [13] Investigated on physio-mechanical properties of High-performance concrete (HPC) mixes, with different replacement levels of cement with condensed silica fume (CSF) of grade 960-D.

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 Table 1.

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 aggregate are shown in Table 2.

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 of size 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 Table 4.

Table 4: Properties of super plasticizer

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

*As per manufacturers manual

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. EXPERIMENTAL PROCEDURE.

The experimental program was designed to investigate flexural 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 prisms(100mmX100mmX500mm) were cast with and without silica fume. Universal 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 flexural 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

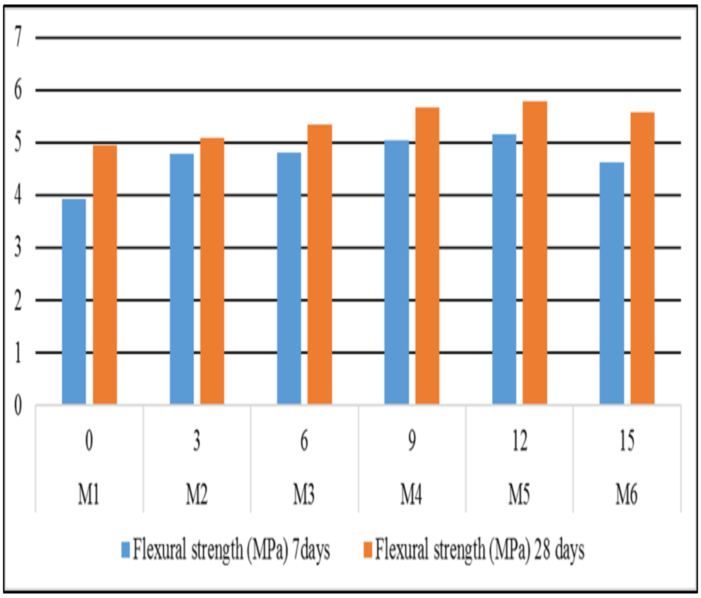

FIG.1. Influence of silica fume on flexural strength of concrete

6.1. Flexural Strength of Concrete:

The flexural strength test was carried out conforming to IS 516-1959 to obtain Flexural strength of concrete at the age of 7 and 28 days. The prism specimens were cast for each replacement level and tested under two-point loading. The experimental results of flexural strength are shown in Table 7.

Table 7. Results of flexural strength of M40 grade concrete

Mix	**% of Silica Fume added (%)**	**Flexural strength (MPa)**	
		7days	**28 days**
M1	0	3.92	4.95
M2	3	4.78	5.08
M3	6	4.82	5.35
M4	9	5.05	5.67
M5	12	5.17	5.79
M6	15	4.62	5.58

From the results it has been seen that the maximum increase in flexural strength is observed as 5.17 N/mm^2 and 5.79 N/mm^2 at 7 and 28 days respectively when silica fume is replaced by 12% to that of cement. The conclusion is that when silica fume is incorporated, the rate of cement hydration increases at the early hours due to the release of OH ions and alkalis into the pore fluid. The C±S±H gel thus improved the strength characteristics of concrete.

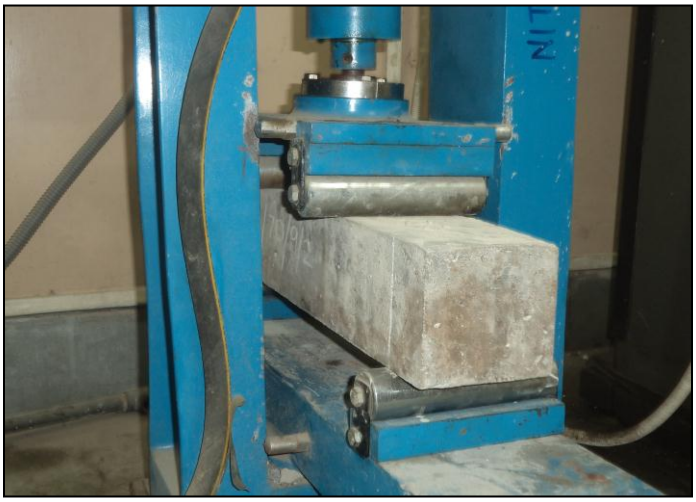

FIG.2. Test for flexural strength of Concrete

7. CONCLUSIONS

Silica fume is having greater fineness than cement and greater surface area. 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.
The optimum 7 and 28-day flexural strength have been obtained in the range of 9-12 % silica fume replacement level. Increase in flexural tensile strength has been found upto 12% replacements

8.REFERENCES

[1.] Safwan A. Khedr, and Mohamed NagibAbou-Zeid (1994). ―Characteristics of Silica-Fume Concrete.‖ ASCE Mat. J(6) 357-375.

[2.] P. C. Aitcin, and P. Laplante (1990). ―Long – Term Compressive Strength of Silica-Fume Concrete‖. ASCE Mat. J(2) 164-170.

[3.] Yazdani, M. Filsaime, and S. Islam (2008). ―Accelerated Curing of Silica-Fume Concrete.‖ ASCE Mat. J(20) 521-529.

[4.] Amitava Roy, Nicholas Moelders, Paul J. Schilling, and Roger K. Seals (2006). ―Role of an Amorphous Silica in Portland Cement Concrete.‖ ASCE Mat. J(18) 747-753.

[5.] Xianyu Jin, and Zongjin Li (2003). ―Effects of Mineral Admixture on Properties of Young Concrete.‖ ASCE Mat. J(15) 435-442.

[6.] David B. McDonald, A. S. AI-Gahtani, Rasheeduzzafar, A. A. AI-Mussallam, Yacoub M. Najjar, and Imad A. Basbeer (1996). ―Discussion of Resistance of Silica-Fume Concrete to Corrosion-Related Damages.‖ ASCE Mat. J(8) 177-178

[7.] Hooton RD. Influence of silica fume replacement of cement on physical properties and resistance to Sulphate attack, Freezing and Thawing, and alkali-silica reactivity, *ACI Material Journal*, No. 2, **90**(1993) 143-51.

[8.] Prasad AS, Santanam D, Krishna Rao SV. Effect of micro silica on high strength concrete, National conference-emerging trends in concrete construction, 22-24 Jan.2003, CBIT, Hyderabad, India.

[9.] Yogendran V, Langan BW, Haque MN, Ward MA. Silica fume in High- strength concrete, *ACI Material Journal*, No. 2, **84**(1987) 124-9.

[10.] Lewis RC. Ensuring long term durability with high performance micro silica concrete,*The Indian Concrete Journal*, October 2001, pp. 621-26.

[11.] Bhanja S, Sengupta B. Optimum silica fume content and its mode of action on concrete, *ACI Materials Journal*, September- October 2003, pp. 407-712.

[12.] Tiwari A, Momin I. Improving early age strength of PSC with indigenous silica fume,*The Indian Concrete Journal*, October 2000, pp. 595-98.

[13.] Venkatesh Babu DL, Nateshan SC. Some investigations on silica fume concrete, The *Indian concrete Journal*, September 2004, pp. 57-60.