International Journal of Engineering Innovation & Research
Volume 2, Issue 5, ISSN: 2277 – 5668

Influence of Silica Fume on Different Mechanical Properties of Concrete

Debabrata Pradhan
Lecturer, Civil Engineering Department,
A.J.C.Bose Polytechnic, Berachampa,
North 24 Parganas, West Bengal, India,
Email: dpdpradhan175@gmail.com

D. Dutta
Asst. Professor, Camellia School of
Engineering & Technology,
Barasat, Kolkata, West Bengal, India

Partha Ghosh
Asst. Professor, Department of
Construction Engineering,
Jadavpur University, Kolkata, India

***Abstract* – It is a usual practice in the present days to produce the high strength as well as high performance concrete by the use of silica fume; the industrial by-product, into the conventional concrete. The mix design variables are augmented as the silica fume is incorporated in conventional concrete; hence the mix proportioning is becoming multifaceted. The foremost intention of this paper is to study the different mechanical properties mainly on workability and strength. Slump and compacting factor tests are performed for workability and compressive strength test only is performed for strength of silica fume concrete. For this paper 5 (five) mixes of silica fume concrete are used to cast for experiments. Different cement replacement levels by silica fume for a single invariable water-cementitious materials ratio of 0.45 are used on experimentations while other mix design variables are kept constant. The cement replacement levels by silica fume are 0%, 5%, 10%, 15% and 20% for only water-cementitious materials (w/cm) ratio of 0.45. Compacting factors and slumps are evaluated for all mixes of concrete. Compressive strengths are evaluated at 24 hours, 7 and 28 days for 100 and 150 mm cubes.**

***Keywords* – Silica Fume, High Strength Concrete, High Performance Concrete, Strength, Slump.**

I. Introduction

Now-a-days incorporation of mineral admixtures in the new generation concrete is a usual practice and the concrete making processes have undergone a radical change; hence the supplementary cementitious materials play an important role to develop strength as well as other special properties. It was observed that the various parameters like w/c ratio, chemical composition and pore geometry of the cementitious materials, aggregate properties, the properties of cement aggregates interfacial zone and cement / aggregate ratio influence the properties of cement based materials [1]. Several researchers showed that the strengths, durability, protection against corrosion, modulus of elasticity, chemical and abrasion resistance are increased due to incorporation of silica fume in concrete. But no distinct conclusion of the optimum silica fume replacement percentages is obtained, even if some researchers have reported various replacement levels [1-4].

Bhanja and Sengupta experimented on high performance concrete incorporating silica fume and reported that the isolated effect of SF increases the compressive, splitting tensile and flexure strengths and the highest increase has been found in the flexure strength [5 – 7]. Apart from the water-cementitious material ratio, host of other parameters like the mixing water, the ratio of cement to aggregate, grading, maximum size of aggregate, stiffness and surface texture etc. in relation to compressive strength have been attempted by many other researchers in relation to generalize Abrams' water/cement ratio law [1-7]. The different mechanical properties including durability of concrete have been improved due to incorporation of pozzolanic materials in concrete as the extra calcium silicate hydrate (C – S – H) are produced from reaction between the free calcium hydroxide during the hydration of cement and silica present in pozzolans [8].

N. K. Amudhavalli and Jeena Mathew observed that the performance of concrete in respect of strength and durability aspect has been improved significantly due to inclusion of silica fume in concrete at various percentages. The authors observed that silica fume have a more prominent effect on the flexural strength than the split tensile strength and surveyed that 10-15 % cement replacement by silica fume produce the optimal values for (7 and 28-days) compressive strength and flexural strength [9]. The size and shape of aggregate plays important role in the development of high strength concrete. The rounded shape and smaller sizes of aggregate should be used for high strength of concrete than other sizes and shape respectively [10]. Addition of silica fume in concrete has an undesirable effect on workability i.e workability is reduced due to incorporation of silica fume; hence for higher percentage addition of silica fume in concrete demands higher percentages of super plasticizer [11 – 12]. In this paper our effort is made to study the various mechanical properties like slump, compacting factor and compressive strength of silica fume concrete considering a fixed water-cementitious material ratio of 0.45.

II. Experimental Investigation

A. Materials

- *Cement*

Ordinary Portland Cement of ACC brand of 43 grade is used in the present investigations that surpasses BIS Specifications – IS: 8112-1989 on compressive strength levels.

- *Fine Aggregate*

Natural sand (i.e. locally available river sand) is used as per IS: 383-1970 and having bulk density 2610 kg/m^3. The properties of fine aggregate are shown in Table 1.

Copyright © 2013 IJEIR, All right reserved

Table 1: Properties of fine aggregate

S.No.	Property	Result
1.	Specific Gravity	2.61
2.	Fineness modulus	3.10
3.	Grading zone	II

- *Coarse Aggregate*

Crushed aggregate conforming to IS: 383-1970 is used. The size of coarse aggregate used is 12.5 mm having specific gravity 2.83 and fineness modulus 6.28.

- *Super Plasticizer*

In these observations to improve the workability of concrete, super plasticizer- CONPLAST-SP 430 in the form of sulphonated Naphthalene polymers in compliance to IS: 9103-1999 and ASTM 494 type F is used. Conplast SP 430 has been specially formulated to report high range of water reductions up to 25% without loss of workability or to produce excellent quality concrete of reduced permeability. The properties of super plasticizer are shown in Table 2.

Table 2; Properties of super plasticizer

S.No.	Physical Tests	Analysis
1	Specific Gravity	1.224
2	Chloride content	NIL
3	Air entrainment	11.73 lb/ft^3

*As per manufacturers manual

- *Silica Fume (Grade 920 D)*

Silica fume used is conforming to ASTM- C (1240-2000) which has been supplied by "ELKEM INDUSTRIES" and named as Elkem – micro silica 920 D. The cement is partially replaced by silica fume. The properties of silica fume are shown in Table 3. To support the particle morphology with elemental existence, Figure 1 and Figure 2 are reportedby a Scanning Electron Microscopy (SEM) and EDAX spectrum respectively.

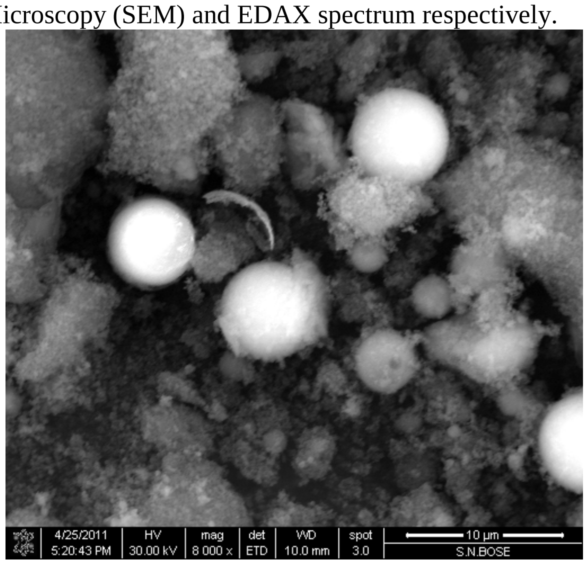

Fig.1. SEM image of Silica fume

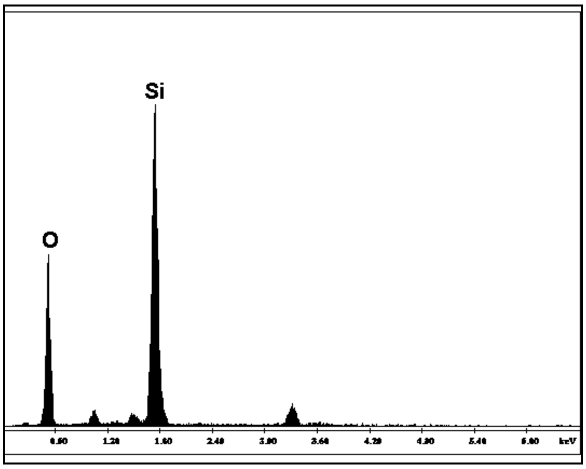

Fig.2. EDAX Spectrum of Silica fume

Table 3: Silica fumechemical & physical analysis report

Chemical Analysis	Analysis
SO_2	95.00 %
SO_3	0.18 %
CL	0.12 %
Total Alkali	0.66%
Moisture Content	0.16%
Loss of ignition	1.92%
pH	7.90%

Physical Tests	Analysis
Oversize - % retained on 45 µm sieve (wet sieved)	1.13%
Density – (specific gravity)	2.27
Bulk Density – (per ASTM) 187.91 kg/m^3	11.73 lb/ft^3
Specific Surface Area (by BET)*	22.21 m^2/kg
Accelerated Pozzolanic Activity Index with Portland Cement	134.90%

*As per manufacturers manual

B. *Mix Proportioning*

In these experiments design mix of concrete is obtained as per the guidelines specified in I.S. 10262-1982 though some ceiling is enforced by restricting the cementitious material content is to 450 Kg/m^3. The Table 4 shows mix proportion of concrete (Kg/m^3):

In this present paper investigations are made on 5 (five) mixes of silica fume concrete where undensified silica fume is used to cast concrete for experiments. In these experimentation coarse aggregate as small as 12.5 mm size is used since smaller size has bigger exposed surface area and consequently, improved bond at the interfacial zone(i.e. between paste matrix and coarse aggregate) is obtained. Accordingly, high strength is observed at the interfacial zone of paste matrix and coarse aggregate and thus high strength is obtained in silica fume concrete than the conventional one (i.e. concrete without silica fume) due to more dense of interfacial zone.

Copyright © 2013 IJEIR, All right reserved

Table 4: Mix Proportioning

W/cm	Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Water (Kg/m^3)	Compacting factor
0.45	450	609.3	1114.2	202.5	0.82 – 0.856

III. Results and Discussion

Table 5: Workability of mixes

W/cm	Cementitious material (Kg/m^3)	% of MA (SF)	% of SP	Slump (mm)	Compacting factor
		0	0.50	18,20,17	0.820
		5	0.80	15,15,16	0.821
0.45	450	10	1.10	20,25,26	0.856
		15	1.50	13,13,14	0.820
		20	1.90	15,16,18	0.856

Table 6: Compressive strength of cubes

W/cm	Cementitious material (Kg/m^3)	% of MA (SF)	Compressive Strength (MPa)						Compressive Strength (MPa) 150 mm cubes
			150 mm cubes			150 mm cubes			
			24 Hrs.	24 Hrs.	24 Hrs.	24 Hrs.	24 Hrs.	24 Hrs.	
		0	22.96	33.20	51.12	24.33	35.00	53.33	0.50
		5	25.58	37.10	52.33	25.80	38.67	56.67	0.80
0.45	450	10	28.40	37.63	55.33	28.90	37.67	59.33	1.10
		15	33.00	39.70	57.21	33.20	39.90	59.50	1.50
		20	37.48	40.11	61.55	40.80	40.97	62.95	1.90

These experiments are performed at a single invariable water-cementitious material ratio of 0.45 for constant other mix design variables at different cement replacement levels by silica fume of 0%, 5%, 10%, 15% and 20%. Compacting factor and slump are determined for five mixes of concrete results of which are shown in table 4. Results obtained for slump is low which indicates that the mixes are cohesive in nature. Compressive strengths of 100 and 150 mm cubes for all mixes shown in table 5 are evaluated at the age levels of 24 hours, 7 days and 28 days.It is found from experimental results represented in table 5 that at all age levels (i.e. at 24 hours, 7 and 28 days) for 0 – 20%cement replacement level by silica fume higher compressive strength is observed than control concrete (i.e. concrete without silica fume).

It is observed from experimental results that higher compressive strengths of 100 mm cubes are obtained at all age and replacement levels than 150 mm cubes. It is noticed that at 20% cement replacement by silica fume, the optimum compressive strength is observed. Table 5 shows that the values of optimum compressive strength at 28 days are 61.55 MPa and 62.95 MPa for 150 and 100 mm cubes respectively at 20% cement replacement by silica fume wherein for control concrete (i.e. concrete without silica fume) 28 days compressive strengths are obtained as 51.12 MPa and 53.33 MPa for 150 and100 mm cubes respectively.It is noticed that 28 days compressive strengths are increased by 20.40% and 18.40% for 150 and100 mm cubes respectively than control concrete i.e. concrete without silica fume. We obtain the compacting factor ranges from 0.82 to 0.856 and the slump value ranges from 10 to 30 mm.

IV. Conclusion

We conclude from experimental results that at 20% cement replacement by silica fume the optimal compressive strength is observed at all age levels (i.e. at 24 hours, 7 and 28 days) and lower slump values indicate the mixes are cohesive in nature though the range of compacting factor is good for using concrete in field in control system.But in further observations, workability of concrete may possibly be increased by ever-increasing the dosages of superplasticizer with no loss of strength. According to IS code recommendations, high compressive strength obtained for silica fume concrete than conventional one resembles it as high strength concrete (HSC). It seems that as pore structures at transition zone of silica fume concrete is improved so it is named as high performance concrete but tests for durability are yet to be observed. It can be concluded that much higher strength is obtained at the interfacial zone than control concrete (i.e. concrete without silica fume) since the failure plane cuts the aggregates during the testing of cubes at 28 days but not along the interfacial zone.

References

[1] H. Katkhuda, B. Hanayneh and N. Shatarat, (2009)"Influence of Silica Fume on High Strength Lightweight Concrete". *World Academy of Science, Engineering and Technology*, 34,

[2] F.P. Zhou, B.I.G. Barr, F.D. Lydon, (1995) "Fracture Properties of High Strength Concretes with Varying Silica Fume Content and Aggregates", *Cement and Concrete Research*, 25 (3), pp. 543–552.

Copyright © 2013 IJEIR, All right reserved

[3] S.A. Khedr, M.N. Abou-Zeid, (1994) "Characteristics of silica-fume concrete", *J. Mater. Civ. Eng. ASCE*, 6 (3), pp. 357–375.
[4] V. Yogendran, B.W. Langan, M.N. Haque, M.A. Ward, (1982) "Silica Fume in High strength concrete", *ACI Material Journal*. 84 (2), pp. 124–129.
[5] S. Bhanja,*, B. Sengupta,(2005) "Influence of Silica Fume on the Tensile Strength of Concrete," *Cement and Concrete Research*, 35, pp. 743- 747.
[6] S. Bhanja, B. Sengupta, (2002) "Investigations on The Compressive Strength of Silica Fume Concrete Using Statistical Methods", *Cement and Concrete Research*, 32, pp. 1391-1394.
[7] S. Bhanja, B. Sengupta, (2003) "Modified Water–Cement Ratio Law for Silica Fume Concretes", *Cement and Concrete Research*, 33, pp. 447-450.
[8] Sensualle GR. (2006)"Strength development of concrete with rice husk ash", Cement and Concrete Composites
[9] N. K. Amudhavalli andJeena Mathew. (2012)"Effect of silica fume on strength and durability Parameters of concrete", *International Journal of Engineering Sciences & Emerging Technologies*, 3(1), pp. 28-35.
[10] M. Yaqub, Imran Bukhari, (16 - 17 August 2006)"Effect of Size of Coarse Aggregate on Compressive Strength of High Strength Concerets", *31st Conference on Our World in Concrete &Structures*, Singapore.
[11] Bayasi, Ziad, and Zhou, Jing, (1993) "Properties of Silica Fume Concrete and Mortar". *ACI Materials Journal*, 90(4), pp. 349 - 356.
[12] Hooton, R.D. (1993) "Influence of Silica Fume Replacement of Cement on Physical Properties and Resistance to Sulfate Attack, Freezing and Thawing, and Alkali-Silica Reactivity". *ACI Materials Journal*, 90 (2), pp. 143 - 151.

AUTHOR'S PROFILE

Debabrata Pradhan

is a lecturer of West Bengal Govt. Polytechnic working as Officer-in-Charge & HOD, Civil Engineering Department of A.J.C. Bose Polytechnic, Berachampa, North 24 Parganas under "The Directorate of Technical Education & Training", Bikash Bhavan (10th floor), Salt Lake City, Kolkata-700091. He has been received his Degree of B.C.E. (Civil) from Jadavpur University and M.E. (Structural Engineering) from B.E. College (D.U.). He is continuing his research works on advanced concrete. His area of research is on Conventional and High Performance Concrete and Optimization of Structures using Linear and Non-Linear Techniques.

D. Dutta

is working as an Assistant Professor in Camellia School of Engineering and Technology, Barasat, Kolkata. He is also an Honorary Academic Director of The Council of Engineering and Technology (India).He is the founder of DRD Educational and Consultancy Pvt. Ltd. He did BE (Civil Engg.), ME (Structural Engg.) MBA (Construction Management).He is pursuing Doctor in Philosophy from Jadavpur University, Kolkata. At the very outset of his professional career; he gathered experience regarding Metro-Railway Project. He has an experience as a trainee in Variable Energy Cyclotron Centre; Kolkata. He has 21 international publications in the field of Civil and Mechanical Engineering. He is a life time member of CET (India), formerly known as IET (India). His areas of expertise include Polymer Concrete, Characterization and Performance Evaluation of Blended Concrete, Replacement of Conventional Cement Concrete, Performance and Emission Parameters Analysis of Engine etc. Again his fields of interests include other aspects like Air Pollution Modeling, Prediction Regression Model of Typical Traffic Volume etc. Presently he is working on the betterment of Geopolymer in connection with production and application.

Copyright © 2013 IJEIR, All right reserved