Advances in Concrete Construction, *Vol. 6, No. 2 (2018) 145-157*
DOI: https://doi.org/10.12989/acc.2018.6.2.145

Review study towards effect of Silica Fume on the fresh and hardened properties of concrete

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(Received November 9, 2017, Revised February 22, 2018, Accepted March 5, 2018)

Abstract. This paper presents a review on the use of Silica Fume (SF) as a mineral admixture in the concrete. Distinctive outcome from several researches have been demonstrated here, particularly emphasizing on the fresh and hardened properties of concrete when blended with Silica Fume (Micro-silica or Nano-silica). The results showed a substantial enhancement in the mechanical properties of concrete when replaced with SF. The review also presented a brief idea of percentage replacement of SF in case of normal and high-strength concrete. A decreasing trend in workability (slump value) has been identified when there is a increase in percentage replacement of SF. It can be concluded that the optimize percentage of replacement with SF lies in the range of 8-10% particularly for compressive strength. However the variation of blending goes up to 12-15% in case of split tensile and flexure strength of concrete. The study also demonstrates the effect of silica fume on durability parameters like water absorption, permeability, sulphate attack and chloride attack.

Keywords: Silica Fume; workability; compressive strength; split tensile strength; flexure strength

1. Introduction

1.1 Background

Silica Fume possess a high reactive pozzolanic property, while it is used in concrete because of its fine particles, large surface area and high SiO_2 content. Silica fume is much fined separated silica obtained as a by-product in industry. It is used as an admixture in the concrete mix and it has significant effects on the properties of the resulting material (Panjehpour *et al*. 2011).

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. It is extremely fine with particles size less than 1 micron and with an average diameter of about 0.1 microns, about 100 times smaller than average cement particles. Its behaviour is related to the high content of amorphous silica (>90%). The reduction of high-purity quartz to silicon at temperatures up to 2,000℃ produces SiO_2 vapours, which oxidizes and condense in the low temperature zone to tiny particles consisting of non-crystalline silica (Singh *et al*. 2016).

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http://www.techno-press.org/?journal=acc&subpage=7 ISSN: 2287-5301 (Print), 2287-531X (Online)

Silica Fume was firstly obtained in Norway (Oslo) in 1947, during filtration of the exhaust gases from furnaces as fumes. The large portion of these fumes contained very fine powder of high percentage of silicon dioxide. Since the 1970s, filtration of gases has started at large scale and, in 1976, first standard NS 3050 was granted to use silica fume in factory-produced cement Newman and Choo (2003). It is a high quality material used in the cement and concrete industry. It has been reported that if a typical dosage of silica fume of 8-10% by weight of cement is added in concrete, then its effect is between 50,000 and 100,000 microspheres percent particle; that is, concrete mix will be denser and cohesive due to fine particles of silica fume (Tomas *et al*. 2012).

Silica Fume can be utilised as material for supplementary cementations to increase the strength and durability conforming to AASHTO M 307 or ASTM C 1240. According to the Florida Department of Transportation (2004), the quantity of cement replacement with silica fume should be between 7% and 9% by mass of cementation materials (Bhanja and Sengupta 2005).

Now a days, the use of high performance concrete is in great demand in the construction industry. For improved strength and durability, the use of silica fume as the replacement of cement has been found to be an appropriate admixture. The mechanical property especially compressive strength of the concrete has been investigated with an objective to find an optimum dose of silica fume replacement. Different researchers have arrived at different optimum value.

1.2 Production and form of silica fume

Silica fume (SF) is a by-product of the smelting process in the silicon and ferrosilicon industry. The reduction of high-purity quartz to silicon at temperatures up to 2,000℃ produces SiO_2 vapours, which oxidizes and condense in the low temperature zone to tiny particles consisting of non-crystalline silica. By-products of the production of silicon metal and the ferrosilicon alloys having silicon contents of 75% or more contain 85-95% non-crystalline silica. The by-product of the production of ferrosilicon alloy having 50% silicon has much lower silica content and is less pozzolanic. Therefore, SiO_2 content of the silica fume is related to the type of alloy being produced. Silica fume is also known as micro silica, condensed silica fume, volatized silica or silica dust. The American concrete institute (ACI) defines silica fume as a “very fine non-crystalline silica produced in electric arc furnaces as a by product of production of elemental silicon or alloys containing silicon”. It is usually a grey colour powder, somewhat similar to Portland cement or some fly ashes. It can exhibit both pozzolanic and cementitious properties. Silica fume has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties to a great extent. The physical composition of silica fume Diameter is about 0.1 micron to 0.2 microns; Surface area about 30,000 m^2/kg and Density varies from 150 to 700 kg/m^3. Fig. 1 shows the schematic diagram of silica fume production. The silica fume is collected in very large filters in the bag house and then made available for use in concrete (Siddique and Khan 2011).

1.3 Physical properties of silica fume

The property of silica fume depends on the type of production as well as the process used for its manufacturing. It is in powder form whose particle size is 100 times smaller than that of Portland cement. Silica Fume can be obtained in three forms i.e., powder, condensed and slurry. The colour of SF varies from light to dark grey or white which is because of the different manufacturing process and is influenced by some of the parameters like wood chip composition, furnace

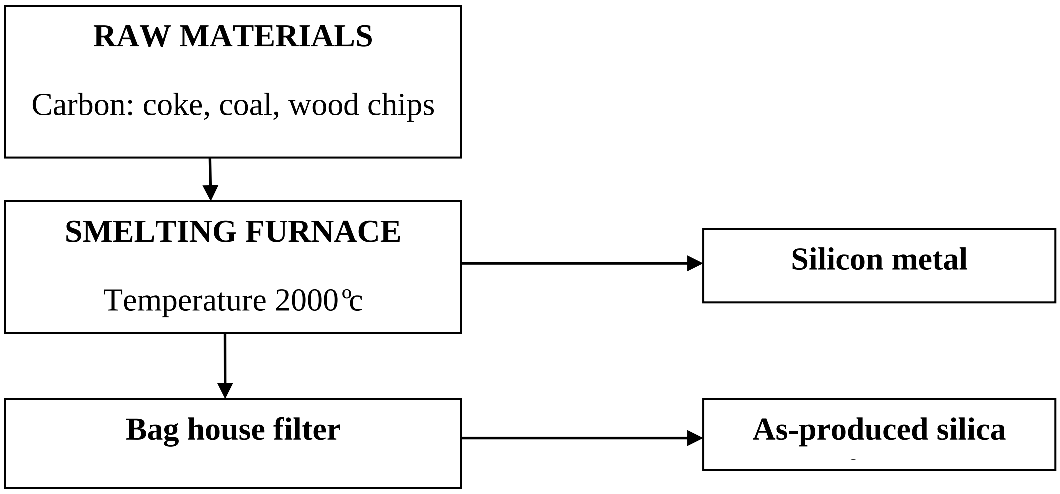

Fig. 1 Schematic diagram of silica fume production (Siddique and Khan 2011)

Table 1 Typical physical properties of silica fume

Properties / Authors	Particle size	Bulk density (kg/m^3)	Specific gravity	Surface area (BET) (m^2/kg)
Toutanji and Bayasi (1999)	0.14 mm	225	2.3	20,000
Kumar *et al*. (2014)	-	240	2.34	20,000
Detwiler and Mehta (1989)	0.1µ	-	2.2	20,000
Mohyiddeen and Maya (2015)	1µ	576	2.2	20,000

temperature, ratio of wood chip to the coal used, exhaust temperature, and type of metal produced. Table 1 shows a brief detail of the physical properties of SF adopted by several authors.

1.4 Chemical properties of silica fume

Silica fume is produced during a high-temperature reduction of quartz in an electric arc furnace when the main product is silicon or ferrosilicon. Due to the large amount of electricity needed, theses arc furnaces are located in countries with well-provided electrical capacity including Scandinavia, Europe, Canada, USA, South Africa, and Australia. The chemical process is complex and it depends on the temperature of the producing. The SiC formed, initially plays important intermediate roles. At temperatures >1520℃, the reaction follows as ($SiO_2+3C=SiC+2CO$) but at temperatures >1800℃, the reaction mechanism changes as ($3SiO_3+2SiC=Si+4SiO+2CO$). The unstable gas diffuses in the furnace where it reacts with oxygen to give the silicon dioxide as ($4SiO+2O_2=4SiO_2$) (Panjehpour *et al*. 2011). Below Table 2 demonstrates a variation of several chemical compositions of SF adopted by several authors.

1.5 Experimental variations adopted by several authors

Past researchers have performed several experimental setups for the replacement of cement by silica fume with varying replacement level. In this paper, parametric variations adopted by

Table 2 Chemical composition of silica fume samples

Authors \ Oxides	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	K_2O (%)	Na_2O (%)	SO_3 (%)	LOI (%)
Sandvik and Gjorv (1992)	92.1	0.5	1.4	0.5	0.3	0.7	0.3	-	2.8
Hooton and Titherington (2004)	96.65	0.23	0.07	0.31	0.04	0.56	0.15	0.17	2.27
Fuat *et al*. (2008)	81.35	4.48	1.42	0.80	1.47	-	-	1.34	3.4
Detwiler and Mehta (1989)	96.0	0.1	0.6	0.1	0.2	0.4	0.1	-	1.7
Kumar *et al*. (2014)	90-96	0.5-3.0	0.2-0.8	0.1-0.5	0.5-1.5	0.04-0.1	0.2-0.7	0.1-2.5	0.7-2.5
Koksal *et al*. (2015)	85.35	1.42	2.39	0.80	1.47	-	-	1.34	3.4
Turkel and Altuntas (2009)	92.26	0.89	1.97	0.49	0.96	1.31	0.42	0.33	2.05
Khan *et al*. (2014)	91.4	0.09	0.04	0.93	0.78	2.41	0.39	0.01	2.0
Behnood and Ziari (2008)	91.7	1	0.9	1.68	1.8	-	0.10	0.87	2
Khater (2013)	94.92	0,02	1.28	0.03	0.01	0.15	0.28	0.02	3.28

Table 3 Experimental variations adopted by several authors

Authors	Material used	Super plasticizers type	Replacement level	w/c ratios	Concrete grade
Ajileye (2012)	OPC by QNCC, silica fume		0, 5, 10, 15, 20 25%	0.38	M30
Amudhavalli and Mathew (2012)	OPC 53 grade, silica fume (grade 920D)	CONPLAST-SP 430	0, 5, 10, 15, 20%	0.36	M35
Amarkhail (2015)	OPC, silica fume		0, 5, 10,15%	0.3	M40
Rathore and Walia (2016)	OPC 43 grade, silica fume	Shaliplast SP-431	0, 2.5, 5. 7.5, 10%	-	M55 & M60
Singh *et al*. (2016)	OPC 43, silica fume	-	0, 5, 10, 15%	-	M30
Sundararaman and Azhagarsamy (2015)	OPC 53, rice husk ash & silica fume	-	0, 5, 10, 15, 20, 25%	0.40	M20
Pradhan and Dutta (2013)	OPC 43, silica fume (grade 920D)	CONPLAST- SP 430	0, 5, 10, 15, 20%	0.50	-
Roy and Sil (2012)	OPC 53, silica fume (grade 920D)	-	0, 2.5, 5, 7.5, 10%	0.45	M20
Kumar *et al*. (2014)	OPC 53, fly ash grade C, silica fume	CONPLAST- SP 430	0, 10, 20, 30%	0.33, 0.34, 0.35, 0.36	M60
Mohyiddeen and Maya (2015)	Portland Pozzolana cement, silica fume	CONPLAST- SP 430	0, 4, 8, 12%	0.45	M30

different researchers for carrying out their experiment to ascertain the properties of concrete by the addition of SF have also been included. Table 3 shows a brief description of the experimental variations adopted by several authors:

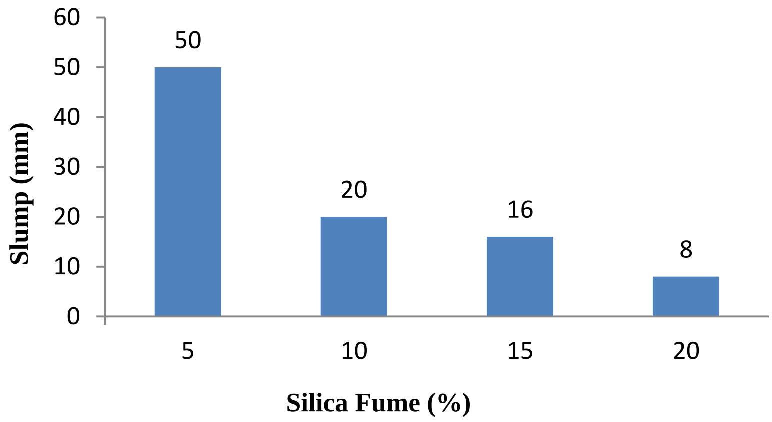

Fig. 2 Slump values for different replacement levels of silica fume (Amarkhail 2015)

2. Properties of fresh concrete

2.1 Effect of silica fume on workability of concrete

Lot more study has been carried out to assess the properties of fresh concrete with different level of replacements of silica fume. This property of fresh concrete has been checked by several authors and some of the findings are explained here in this study. Kadri and Dual (1998) identified an increasing trend in workability within a range of 5-6% when cement was partially replaced by 10% of silica fume whereas Khayat *et al*. (1997) found a loss of 15 to 20 mm slump when cement was replaced with 7.5% of silica fume. His findings were further supported by Yogendran *et al*. (1987) who in his research have also substantiated a decreasing trend in workability when the replacement level of silica fume is increased. Moreover the researchers like Ramkrishnan and Shriniwasan (1982), Nader (2007), Srivastava (2012) have performed the experiment on replacement of cement by silica fume and they reported that the workability of fresh concrete decreases with the increasing percentage of silica fume and in some rare cases it improves the workability as well as Mohyiddeen and Maya (2015) obtained an increasing trend in the workability of concrete when the percentage of copper slag increases and workability of concrete decreases when the percentage of silica fume increases. It can be concluded that the decrease in the workability with silica fume is due to high specific surface of silica fume whereas increase in workability with copper slag is due to low water absorption.

Amarkhail (2015) found that the overall workability of the fresh concrete was low because of low water/cement ratio (w/c=0.3). He observed that up to 10% cement may be replaced by silica fume without harming the concrete workability. Fig. 2 depicts the variation in slump values with the varying replacement percentage of SF.

Wong and Razak (2005) studied the fresh properties of blended concrete by adopting three different w/c ratios of 0.27, 0.30 and 0.33. At each w/c ratio, cement was replaced with 0, 5, 10, and 15% silica fume. Table 3 shows a variation of Slump with different degrees of replacement at specific w/c ratio. It is concluded in the study that the large variation of workability across mixtures was due to the constant super plasticizer dosage used for mixtures with the same w/c ratio.

Table 3 Slump values for different w/c ratios and silica fume replacement Wong and Razak (2005)

Mixture	W/C ratios	Slump (mm)	W/C ratio	Slump (mm)	W/C ratio	Slump (mm)
Control	0.27	165	0.30	225	0.33	240
SF 5%		100		215		180
SF10%		50		117		100
SF 15%		35		30		35

3. Properties of hardened concrete

3.1 Effect of silica fume on compressive strength

Several researches have been carried out for the enhancement of compressive strength of concrete with different percentage variation of silica fume blending. Perumal and Sundararajan (2004) examined the effect of silica fume on the high performance concrete or high strength concrete and performed the test for M60, M70 and M110 concrete grades for mixes and investigated to arrive at the maximum levels of replacement of cement with Silica fume. Compressive strengths of these grades of concrete have been fond at 28 days curing and an optimum replacement level of silica fume was found to be 10%. Moreover, Hanumesh *et al*. (2015) investigated the mechanical properties of concrete incorporating silica fume as partial replacement of cement (5, 10, 15 and 20%) for M 20 grade of concrete. The result shows that the maximum compressive strength of concrete gained at 10% silica fume blending which can be said as the optimum dose. But a decreasing trend in compressive strength is observed when the replacement level exceeds 10%. From 10% there is a decrease in compressive strength. On the hand, Katkhuda *et al*. (2009) investigated on the influence of silica fume addition on high strength light weight concrete. They replaced silica fume by 5, 10, 15, 20 and 25% with w/c ratio varying in the range of 0.26 to 0.42. They reported the maximum compressive strength for different w/c ratios as for 0.26, 0.30 & 0.34, 0.38 and 0.42 are 61.75 N/mm^2 at 15% SF replacement and 56.23 & 52 N/mm^2 at 20% SF replacement and 46.15 & 40.95 N/mm^2 at 25% SF replacement respectively. In addition to this, Ismeik (2009) performed the effect of mineral admixtures on mechanical properties of high strength concrete made with locally available materials. He adopted different replacement levels of SF as 5, 7.5, 10, 12.5, and 15% for three different w/c ratios (0.30, 0.35 & 0.40). He observed that the maximum value of compressive strength was obtained as 50 N/mm^2 at 28 days for which the optimum replacement of silica fume was 10% at 0.30 w/c ratio where as the minimum compressive strength was found as 37 N/mm^2 at 0.40 w/c ratio. Similarly, Amudhavalli and Mathew (2012) also investigated the effect of silica fume on strength of the concrete with a constant w/c ratio of 0.36 and the replacement level of silica fume taken as 5, 10, 15, and 20%. The maximum compressive strength for 7 days and 28 days are 38.3 & 47.3 Mpa respectively and the optimum percentage replacement of silica fume was observed at 15%.

Kumar and Dhaka (2016) worked on partial replacement of cement with silica fume and its effects on concrete properties for M35 concrete mix with varying percentage level of silica fume is 5, 9, 12, and 15% by weight of cement. The optimum percentage replacement of SF was found to be 12% for which the maximum compressive strength was obtained. The maximum compressive strength for 7 days and 28 days was found as 30.95 N/mm^2 & 46.14 N/mm^2 respectively. Moreover, Ajileye (2012) also investigated the effect of SF on the properties of concrete by

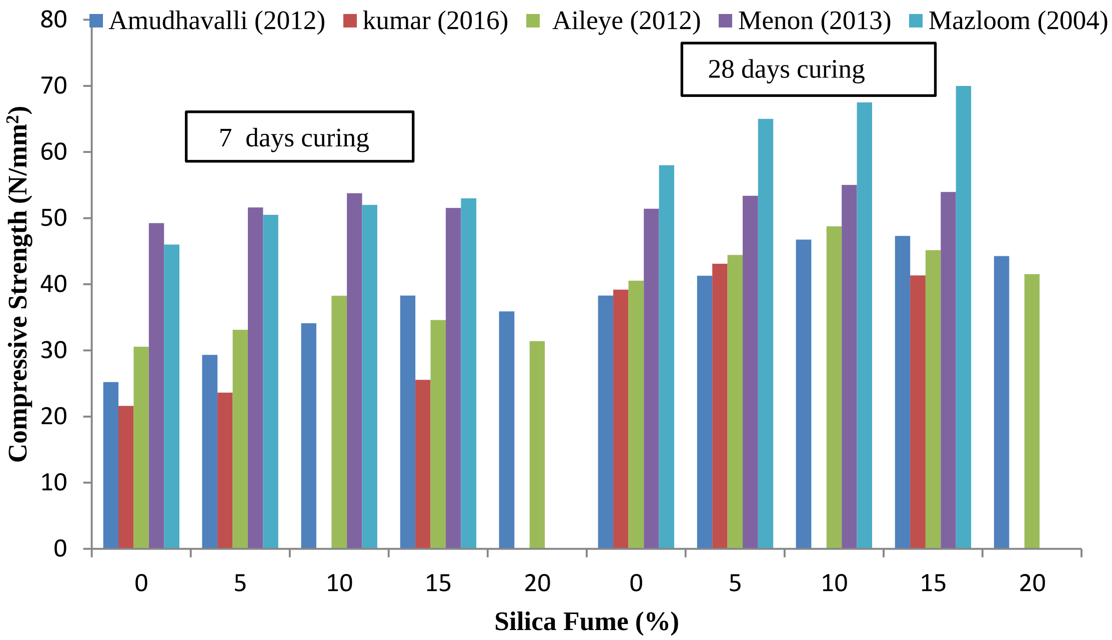

Fig. 3 Variation of compressive strength at different level of silica fume for 7 and 28 days curing

adopting a replacement level of 5, 10, 15, 20, and 25% at 0.38 w/c ratio for M30 mixes. He also demonstrated an increasing trend in compressive strength up to 10% of SF variation. On the hand, a clear statement is reported by ACI Committee 226 (1987) that the main contribution of silica fume to concrete strength development at normal curing temperature takes place from about 3 to 28 days. It is also reported that the admixture appears to be more efficient pozzolan than fly ash. Furthermore, several researches have also been carried out to assess the effect of SF blending on the mechanical properties of concrete by Mohyiddeen and Maya (2015), Menon *et al*. (2013) and Mazloom *et al*. (2004). Fig. 3 depicts a combined result of different researchers for compressive strength of concrete at different level of SF replacement for 7 and 28 days of curing age.

3.2 Effect of silica fume on split tensile strength

Several researches have been carried out to assess the performance of concrete in terms of split tensile strength at different percentage variation of silica fume replacement. Hanumesh *et al*. (2015) identified the mechanical properties of concrete by incorporating Silica Fume as Partial Replacement of Cement (5, 10, 15 and 20%). They affirmed an increasing trend in split tensile strength by the use of silica fume up to 10% replacement of cement above which the split tensile strength tends to decrease. The optimum percentage of replacement of cement by silica fume was found as 10% for M20 grade of concrete. However, Sasikumar and Tamilvanan (2016) performed an experimental investigation by adopting a variation level of SF up to 50% for M 30 grade of concrete. They found an optimum percentage of silica fumes at 25% for maximum split tensile strength for 7 and 28 days age of curing. Moreover, Katkhuda *et al*. (2009) investigated on the influence of silica fume on high strength light weight concrete by replacing 5, 10, 15, 20 and 25% of SF with w/c ratio varying from 0.26 to 0.42. They reported an optimum percentage to be 15%

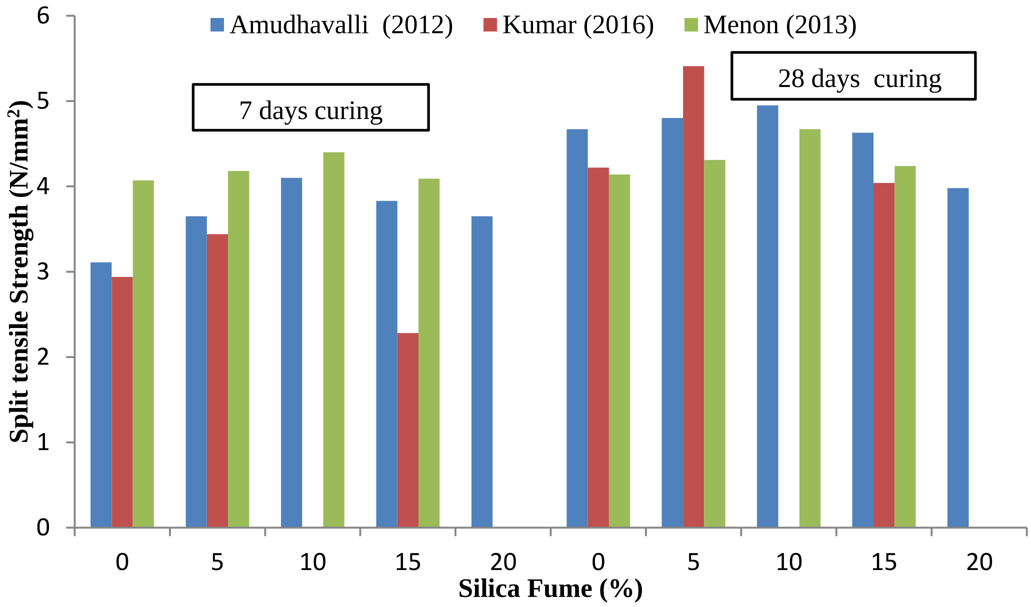

Fig. 4 Variation of split tensile strength at different level of silica fume for 7 and 28 days curing

for 0.26 and 0.30 w/c ratios where as 20% optimum replacement was found at 0.34, 0.38 and 0.42 w/c ratios.

Menon *et al*. (2013) investigated on the effect of silica fume on the fresh and hardened properties of fly ash-based self-compacting geopolymer concrete (SCGC). They focused on the concrete mixes with a fixed water-to-geopolymer solid (W/Gs) ratio of 0.33 by mass and a constant total binder content of 400 kg/m^3. The mass fractions of silica fume that replaced fly ash in this research were 5, 10, and 15%. They found the maximum split tensile strength to be 4.40 & 4.67 N/mm^2 at 7 and 28 days of curing respectively at optimum dosage of 10% silica fume replacement. Several more researches have been carried out by Amudhavalli and Mathew (2012) and Kumar and Dhaka (2016) to assess the effect of SF replacement on split tensile strength by adopting varying parameters in their experimental studies like w/c ratios, age of curing, percentage of SF variation as well as for different grades of concrete. Fig. 4 depicts a combined result of different researchers for split tensile strength of concrete at different level of SF replacement for 7 and 28 days of curing age.

3.3 Effect of silica fume on flexure strength

The past researches demonstrate a clear estimate of the dose of silica fume towards the enhancement of flexural strength of concrete. Some of the findings on flexure strength improvement are illustrated in this study to substantiate the above statement.

Katkhuda *et al*. (2009) replaced SF by 5, 10, 15, 20 and 25% with w/c ratio varying from 0.26 to 0.42 for 28 days of curing. The optimum percentage for maximum flexural strength was found as 15% for w/c 0.26, 20% for w/c 0.30 & 0.34 and 25% for w/c 0.38 & 0.42. Similarly, Ismeik (2009) also investigated the effect of mineral admixtures SF (by varying 5, 7.5, 10, 12.5, and 15%) on mechanical properties of high strength concrete for different w/c ratios (0.30, 0.35 & 0.40). He

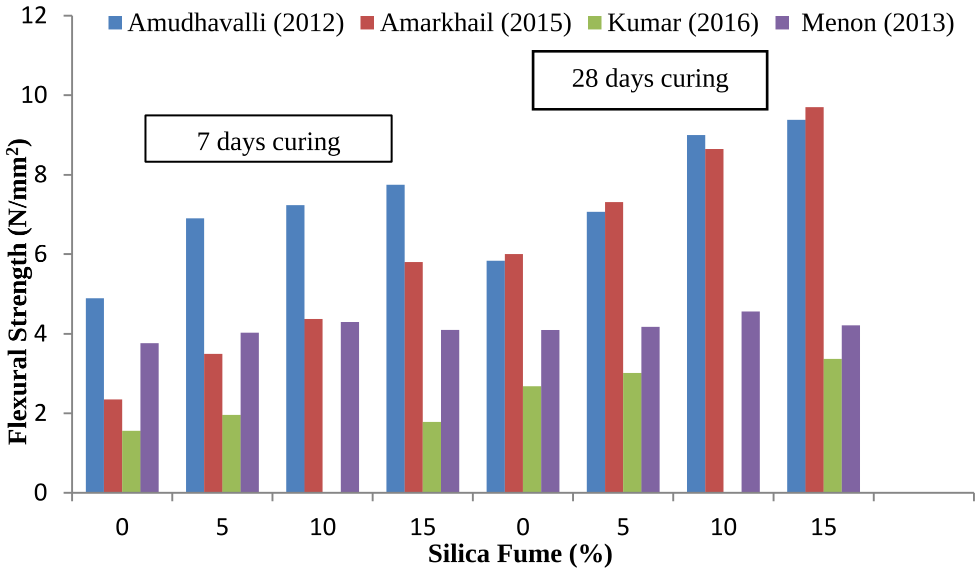

Fig. 5 Variation of flexure strength at different level of silica fume for 7 and 28 days curing

found the maximum value of flexural strength to be 10 N/mm^2 at 28 days for which the optimum replacement of silica fume was 15% for 0.30 w/c ratio whereas the minimum flexural strength was found as 6.6 N/mm^2 at 0.40 w/c ratio. He also concluded that the flexure strength tends to increase with decrease in w/c ratios for each percentage variation of silica fume.

Amudhavalli and Mathew (2012), Amarkhail (2015) adopted a similar variation in replacement level of SF i.e., 5, 10, 15, 20% for 7 and 28 days of curing period at different w/c ratios as 0.36 and 0.30 respectively. Both have found increasing flexure strength for 15% of optimum replacement of Silica Fume.

On the other hand, Roy and Sil (2012) studied the effect of partial replacement of cement by silica fume on hardened concrete and observed that the flexure strength in increased by approximately 39% and 21% to those of the normal concrete when 10% of cement is replaced by SF. Similarly, Kumar and Dhaka (2016) also investigated the partial replacement of cement with silica fume by 5, 9, 12 and 15% by weight of cement for 7 and 28 days curing. Maximum flexural strength was found at 12% replacement of silica fume.

Furthermore, Mohyiddeen and Maya (2015) also worked on the effect of silica fume on concrete containing copper slag as fine aggregate for M30 grade of concrete with the silica variation of silica fume of 4, 8 and 12% and fine aggregate replacement with copper slag at 20, 40 and 60%. They tested flexural strength for different concrete mixes at 28 days found the maximum value of flexural strength as 7.5 N/mm^2 at optimum replacement level of 8% silica fume and 40% copper slag. In addition to this, Menon *et al*. (2013) investigated the effect of silica fume on the fresh and hardened properties of fly ash-based self-compacting geopolymer concrete (SCGC). They found an increase in flexural strength up to 4.29 and 4.56 N/mm^2 for 7 and 28 days respectively at 10 % replacement level of silica fume as an optimum percentage. Fig. 5 depicts a combined result of different researchers for flexural strength of concrete at different level of SF replacement for 7 and 28 days of curing age.

3.4 Effect of silica fume on durability parameters

Distinctive research have been carried out to assess the durability aspects of concrete when blended with Silica Fume. This section deals with an overview of research outcomes obtained for the durability parameters of Silica Fume concrete. On the same line, authors like Ramakrishnan and Srinivasan (1982), Song *et al*. (2010) reported about the significance of Silica Fume blending in concrete with respect to its absorption co-efficient which was found to be less than the normal concrete (i.e., OPC). This revealed that the silica fume concrete becomes less prone to permeability which in turn making the concrete to be more impermeable as by adding silica fume with cement, makes the microstructure of concrete denser. It has also been found that the permeability of concrete is dramatically reduced as silica fume replacement ratio goes beyond 8 to 12%. However, if this replacement exceeds 12%, the permeability is quite marginal and in some cases it increases for increased water to binder ratio. They also observed a reduction in permeability with increase in fineness of Silica Fume. Similarly, Diaz and Delvasta (2005) and Shekarchi *et al*. (2009) reported that the incorporation of silica fume improves water absorption properties of the Portland cement based composites owing to a reduction of permeable voids. It is noted that the coefficient of capillary absorption was lowered when a pozzolanic material was added to a cementitous matrix. The effect is very pronounced in the case of silica fume. It is also reported that addition of silica fume retarded the action of chloride ions which cause breakdown of passive protective film surrounding the steel reinforced bars placed in mortars. Shekarchi *et al*. (2009) concluded that the addition of 7.5% silica fume resulted in a significant reduction in chloride diffusion in concrete. However, an increase of silica fumes content from 7.5 to 12.5%, exhibited little effect on the reduction in permeability.

On a similar note, Gjorve (1995) reported that condensed silica fume substantially increase the resistance to chloride penetration. Replacement up to 9% of silica fume in high grade concrete may reduce the chloride diffusivity by a factor of about five. He concluded that if properly dispersed condensed silica fume is combined with a low water cement ratio, it appears that concrete structures with an excel performance can be constructed even in the most aggressive and hostile environment. Moreover, Khayat *et al*. (1997) reported that the rapid chloride ion permeability of concrete made with blended silica fume cement was four to five times lower than the referral OPC concrete. Similarly, Chung *et al*. (2010), Elahi *et al*. (2010) also accounted about the increased efficiency of blended concrete resistance towards chloride ion diffusion because of adsorption of chloride ion to C-S-H layers and the improved microstructure by the pozzolanic reaction. It was reported by ACI Committee-234, (2000) that the use of silica fume will produce a much less permeable concrete, however the concrete will be of lesser mass per unit volume. It is also trusted by the committee that the low permeability characteristics of silica fume concrete and the corresponding improvements in long term durability will provide the single most significant improvement to the concrete construction industry. On the other hand, Lee *et al*. (2005) observed the use of silica fume with beneficial effect in terms of controlling the strength loss of OPC matrix due to its pozzolanic reaction and the consequent reduction of calcium hydroxide, when employed in the sodium sulphate environment. The silica fume matrix does not easily permit the permeation and diffusion of sulphate ions originating from the sodium sulphate solution.

4. Conclusions

Based on the review, it is quite clear that mineral admixture like Silica Fume has proved to be the most promising blending material to provide a good quality concrete. The following generalized conclusions can be drawn on the properties of fresh and hardened concrete.

I. Silica Fume is considered as a highly reactive pozzolanic material which provides an increased cohesiveness in concrete due to its high fineness modulus which consequently results into a high amount of water requirement to maintain the desired workability. However, the requirement of water may be offset by adding plasticizer.

II. The workability of concrete with Silica Fume greatly depends on the particle size, specific surface area, particle shape, and replacement level. In general, smaller the particle size and higher the specific surface of mineral admixture increases the water demands of concrete. The workability of fresh concrete decreases with the increasing in the percentage of silica fume.

III. The compressive strength of concrete increases with the increase in replacement level of Silica Fume in a range of 8-12% below which no significant change in compressive strength can be expected. Rather, a decreasing trend in compressive strength is anticipated if the replacement level is going beyond 12%. Also, It is found that the compressive strength decrease with increasing w/c ratio followed by an increase in Silica Fume replacement.

IV. The split tensile strength of concrete shows an increasing tendency up to a limit of 10-15%. It can be said that the split tensile strength decreases with increasing w/c ratio followed by an increase in Silica Fume replacement. However, a similar trend is observed in case of flexure strength in a replacement range of 10-15%.

V. Durability parameters like water absorption, permeability, sulphate attack and chloride penetration resistance are higher in case of concrete blended with silica fume as compared to normal OPC concrete.

Acknowledgements

The authors would like to acknowledge the support of Sam Higginbottom University of Agriculture Technology and Sciences (SHUATS), Allahabad for providing the resources used in the conducting this review work.

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