A REVIEW ON SILICA FUME - AN ADDITIVE IN CONCRETE

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ABSTRACT

Concrete is the most versatile, durable and reliable construction material in the world. And which required large quantities of Portland cement. Ordinary Portland cement production is second only to the automobile as the major generator of carbon dioxide, which degrades the environment. In addition, large amount of energy is also consumed for the cement production. On an average, approximately 1 ton of cement is being produced each year for every human being in the world. Hence, in order to protect the environment, the main concern of minimizing CO_2 emission can be realized by reducing the percentage of cement used in making concrete. Therefore, it has been suggested to deploy new technology materials like geopolymers. Geopolymer concrete is an new technology which is produced by the chemical action of inorganic molecules. Geopolymer technology is a generic term coined by Joseph Davidovits in the 1970s and describes all alkali activated materials. These alkali-activated materials are produced through the reaction of an aluminosilicate material rich in (Si + Al) but has low CaO content which is normally supplied in powder form as an industrial by-product or other inexpensive material with an alkaline activator which is usually in the form of a concentrated aqueous solution of alkali hydroxide, silicate, carbonate or sulphate. Supplementary cementitious materials like Fly Ash, GGBS, silica fume etc. are available worldwide in plenty. There are number of studies based on the utilization of micro silica in ordinary Portland cement concrete (OPC) as well as geopolymer concrete (GPC). Portland cement is nowadays partially replaced by silica fume, a by-product from silicon alloy factories. Silica fume is a non-metallic and non-hazardous material having very large surface area which is suitable for concrete mix. Previous study shows that the use of silica fume in concrete has improved the performance of concrete in strength as well as in durability aspect. Hence silica fume is a suitable material for concrete as a replacement of cement. This paper reviews the effect of silica fume on ordinary Portland cement (OPC) and geopolymer concrete (GPC) based on the work done by other researchers.

Keyword – *Silica fume, Ordinary Portland Cement (OPC), Geopolymer concrete (GPC), Compressive strength, Split tensile strength, Flexural strength.*

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1. INTRODUCTION

The cement industry is the second largest producer of the greenhouse gas. On an average, approximately 1 ton of cement is being produced each year for every human being in the world. Hence, in order to protect the environment, the main concern of minimizing CO_2 emission can be realized by reducing the percentage of cement used in making concrete. Hence it is necessary either to search for another material or partly replace it by some other material. The alternative material will lead to global sustainable development and lowest possible environmental impact. Due to substantial energy and cost savings industrial by products are used as a partial replacement of cement. Some of the pozzolanic materials like fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, high reactive Metakaolin, silica fume (SF) that can be used in concrete as partial replacement of cement. Addition of silica fume to concrete has many advantages like high strength and durability.

Silica fume is known in different names such as micro silica, silica dust, and condensed silica fume[16]. When SF is used as an additive in cement concrete, a heat of hydration is observed resulting in the formation of pozzolanic material and calcium hydroxide. Due to large surface area silica fume gets densely packed in the paste of cement and aggregate reducing the wall effect in the transition zone between the paste and aggregate. Silica fume shows improvement in both strength and durability properties of concrete. The main physical effect of silica fume in concrete is that it act as a filler and because of its fineness, silica fume fit in to the space between the cement grains just as sand fill the space between particles of coarse aggregate or cement grains fill the space between the sand grains [17]. Realizing the pozzolanic nature of the materials, this has been used successfully as an admixture in producing concrete. For the improvement of strength and durability of the concrete, the use of silica fume as a replacement of cement has been tried with success in concrete. The use of silica fume in concrete mix has engineering potential and economic advantage. The use of silica fume will not affect the weight of concrete. Silica fume will produce a much less permeable and high strength concrete [2].

Geopolymer technology is a generic term coined by Joseph Davidovits in the 1970s and describes all alkali activated materials. These alkali-activated materials are produced through the reaction of an aluminosilicate material rich in (Si + Al) but has low CaO content which is normally supplied in powder form as an industrial by-product or other inexpensive material with an alkaline activator which is usually in the form of a concentrated aqueous solution of alkali hydroxide, silicate, carbonate or sulphate. The chemical reaction involves polymerization process which involves reaction between silica and alumina along with alkaline solution produces three dimensional polymeric ring structures, an N–A–S–H or alkaline silicoaluminate hydrate gel. The presence of calcium in source material in larger amount disturbs the polymerization process and also the microstructure of concrete. The source material with alkaline liquid subjecter to thermal curing at temperature 60º to 90ºC increases the compressive strength. The compressive strength value based on the chemical reaction and concentration of sodium hydroxide (NaOH) solution. Mainly, Sodium-based activators were chosen than Potassium-based activators, because they are cheaper than Potassium-based activators. The sodium hydroxide is usually used, in flake or pellet form. Based on the concentration of the solution, the mass of NaOH solids in a solution varied, which is expressed in terms of molarity, M. The concentration of sodium hydroxide solution can vary in the range between 8 M and 16 M. The compressive strength and workability of geopolymer concrete are based on the proportions and properties of the constituent materials in the geopolymer paste.

2. SILICA FUME

Silica fume is also known as micro silica and it is a very fine pozzolanic material and composed of amorphous silica produced by electric arc furnaces as a by- product of the production of elemental silicon or ferrosilicon alloys and also consists of spherical particles. The main field of application of silica fume is as pozzolanic material for high performance concrete. Silica fume can also be used in a variety of products such as grouts, and mortars. The range of properties of silica fume generally used in the studies as reported by Amudhavalli N. K and Jeena Mathew [2] is shown below.

Table -1 Properties of silica fume.

Specific Gravity	2.2-2.3
Bulk Density(Kg/m^3)	150 to 700
Size , (Micron)	0.1-0.2
Surface Area , (m^2/kg)	20,000-30,000
SiO_2	(90-96)%
Al_2O_3	(0.5 -0.8)%

3. COMPRESSIVE STRENGTH

N. K. Amudhavalli and Jeena Mathew [2] concluded that the optimum 7 and 28-day compressive strength have been obtained for replacement of cement with silica fume in the range of 10-15% for normal concrete in the range of 10-15 % silica fume replacement level. Vishal S. Ghutke and Pranita S.Bhandari [18] concluded from their result that silica fume was a better alternative for cement. The strength of concrete with silica fume was high when compared to concrete with cement only. They performed various tests by varying the water-cement ratio from 0.5 to 0.6 and analyzed their results and concluded that as the water-cement ratio increases, the strength of concrete decreases. The target value of compressive strength can be achieved at 10% replacement of silica fume. The strength of 15% replacement of cement by silica fume was greater than the normal concrete. Therefore the optimum silica fume replacement percentage varies from 10% to 15%. Compressive strength decreases when the cement replacement was above 15% silica fume. Figure 1, 2, 3 shows the compressive strength of 3,7,28 days respectively as reported by Vishal S. Ghutke and Pranita S. Bhandari [18].

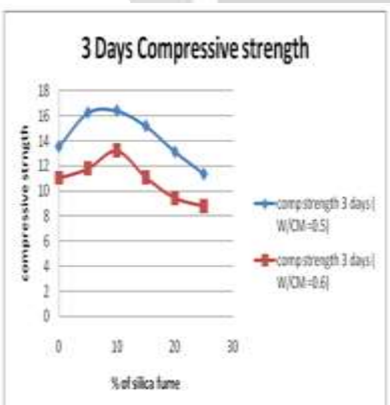

Fig. 1- 3 Days compressive test result

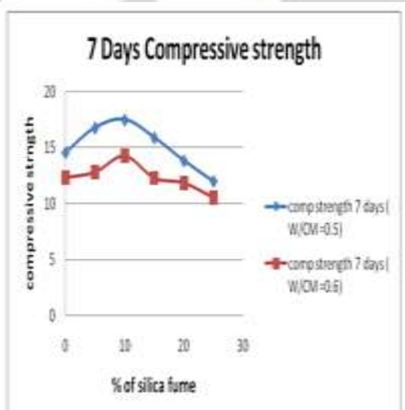

Fig. 2- 7 Days compressive test result

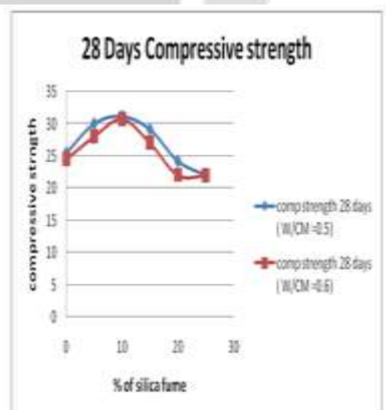

Fig. 3- 28 Days compressive test result

And also Anusha Priya.B and Vamsi Mohan U [3] studied M20 grade concrete with partial replacement of cement by silica fume by 0, 10 and 15% and Quarry dust by 20, 30 and 40% by weight of sand respectively. Based on their test results, it was found that by replacement of 15% silica fume with cement and 30% Quarry Dust with sand, the compressive strength for cubes increases by 9.93%, 14.30%, 22.55%, 27.28% and 30.97% for 7days, 14days, 28 days, 56 days and 90 days respectively. Pardhasaradhi .K and Giri Prasad .G [9] also conclude that the silica fume is a better replacement of cement. The maximum value of compressive strength was obtained at 15% replacement level of cement by weight of silica fume in conjunction with 1% superplasticizer and was found to be 46.66N/mm^2. Sudarsana Rao et.al [14] concluded that as the silica fume content increases the compressive strength increases up to 15% and then decreases for High performance concrete (HPC). Hence the optimum replacement is 15%. The 7 days and 28 days cube compressive strength ratio of HPC is 0.84 to 0.9. As the percentage replacement of cement by silica fume increases, the workability decreases. Karthi.R and Dr. P. Chandrasekaran [6] found that compressive strength of the silica fume concrete with polypropylene fibers increased by 10.63%, than conventional concrete and compressive strength of the geopolymer concrete with fibers has increased by 10.70%, than conventional concrete. Manjunath S. Sontakki and Swapnil B. Cholekar [7] concluded that the compressive strength increases with increase in the silica fume content and decrease with increase in fluid/binder ratio for all ages of curing. It was observed that the strength development of geopolymer concrete is slow under ambient conditions. Early strength gain was observed with oven curing. Vikas Srivastava, Rakesh Kumar, V. C. Agarwal and P. K. Mehta[19] concluded that the optimum replacement level of cement by silica fume is found to be 5% by weight and there is a significant improvement in the compressive strength of concrete using silica fume at both 7 and 28 days as compared to the referral concrete.

Some researchers have investigated the properties of geopolymer concrete with silica fume. Hisham M Khater [5] concluded that Silica fume addition up to 7% greatly enhances the geopolymerization process with the formation of a well-refined and compact matrix, while further increase of SF content leads to the decrease in the mechanical characteristics of the reaction product. Ahmed Mohmed Ahmed [1] found that the compressive strength of geopolymer concrete made of GGBS in 7-14 days was 3 MPa and that in 14-28 days 12 MPa. SF incorporation in geopolymer concrete results in finer pore structure which leads to low permeability concrete. Mijarsh. M.J.A., M.A. Megat Johari, Zainal Arifin Ahmad[8] studied the geopolymer concrete prepared by using mixtures of treated palm oil fuel ash (TPOFA) and mineral additives like $Ca(OH)_2$, $Al(OH)_3$ and silica fume (SF). From the study, it was found that the mechanical properties of TPOFA-based geopolymer mortar was enhanced by 75.21% at 28 days when TPOFA was substituted with $Ca(OH)_2$ and modified with two other additives ($Al(OH)_3$ and SF). It was observed that the type of gel formed (N–A–S–H and/or C–S–H) is directly dependent on the initial chemical compositions of the mixture.

4. SPLIT TENSILE STRENGTH

Amudhavalli N.K and Jeena Mathew.N. K [2] concluded that with increase in fineness of cement consistency increases. Silica fume is having higher fineness than cement and higher surface area and so, the consistency increases greatly, when silica fume percentage increases. When silica fume percentage increases from 0% to 20%, the normal consistency is increases about 40%. Increase in split tensile strength beyond 10% silica fume replacement was almost unsatisfactory. Anusha Priya.B and Vamsi Mohan.U [3] studied M20 grade concrete and it was found that maximum split tensile strength of 3.02 N/mm^2 was obtained for 15% replacement of silica fume with cement and 30% Quarry Dust with sand. The percentage increase in tensile strength was 23.26%. Pardhasaradhi .K and Giri Prasad .G[9] concluded that maximum value of split tensile strength 6.00 N/mm^2 was obtained at 15% replacement level of cement by silica fume in conjunction with 1% superplasticizer. Karthi.R and

Dr. P. Chandrasekaran [6] concluded that Split tensile strength of the geopolymer concrete without fibers have increased by 11.58%, when compared with conventional concrete and split tensile strength of geopolymer concrete with fibers has increased by 13.62%, when compared with conventional concrete. Figure 4 shows the 7 days and 28 days split tensile strength test result with optimum SF replacement as reported by K.G.Raveendran, V. Rameshkumar [13].

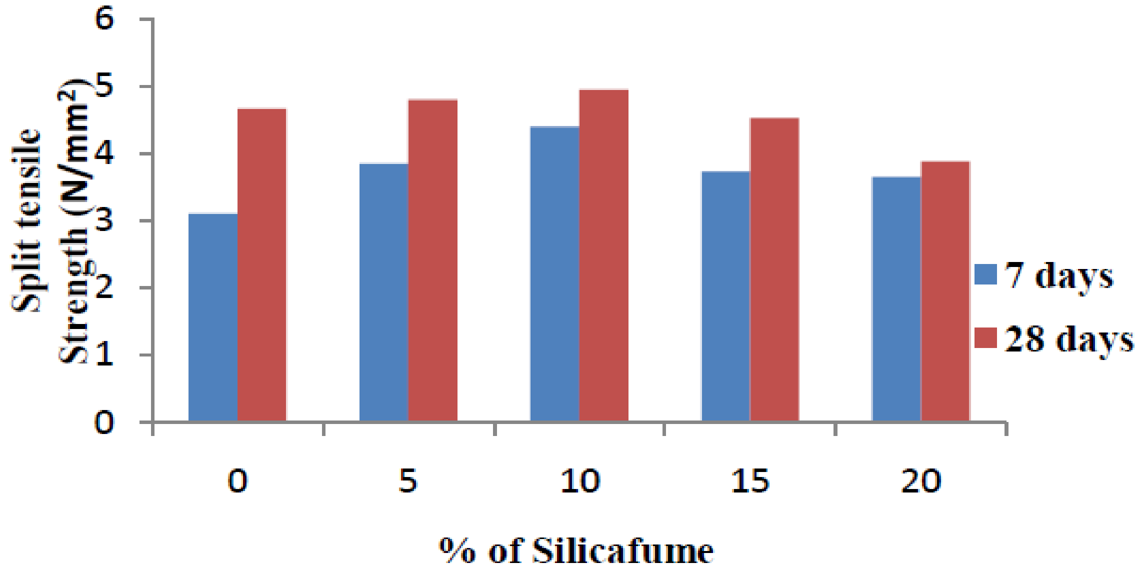

Figure 4: 7 days, 28 days split tensile strength test result with optimum SF replacement

5. FLEXURAL STRENGTH

Amudhavalli N. K, Jeena Mathew [2] found that the optimum 7day and 28-day flexural strength was obtained in the range of 10-15 % silica fume replacement level for normal concrete. Increase in flexural strength occurred up to 15% replacement of cement with silica fume. Silica fumes to have a more satisfactory effect on the flexural strength as compared to tensile strength. Pardhasaradhi .K and Giri Prasad .G[9] concluded that the maximum value of flexural strength 4.102 N/mm^2 was obtained at 15% replacement of cement by silica fume in conjunction with 1% superplasticizer. Raveendran. K.G, Rameshkumar.V, M. Saravanan, P.Kanmani and S.Sudhakar [11] concluded that the optimum 7 and 28-day compressive strength and flexural strength have been obtained in the range of 10-15 % silica fume replacement level. Gains in flexural tensile strength have occurred up to 15 % replacements of cement by silica fume. Eroshkina.N et.al [4] found that flexural strength to a greater extent, than compressive strength depends on the time of hardening in the early age, because number of defects depends up on the flexural strength. Figure 5 shows the 7 days and 28 days flexural strength test result with silica fume replacement as reported by K.G.Raveendran, V. Rameshkumar [13].

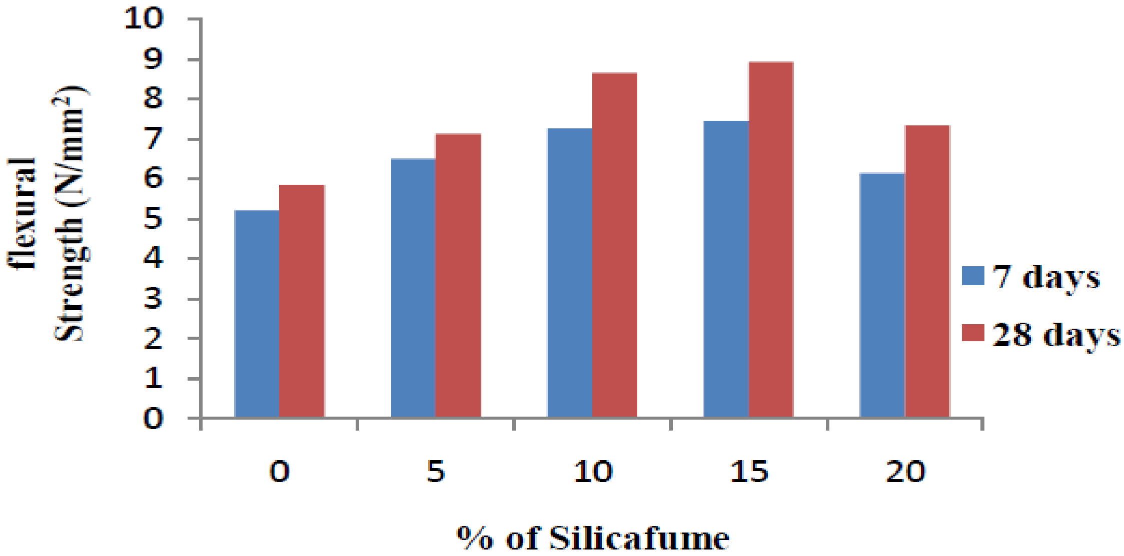

Figure 5. 7 days and 28 days flexural strength test result with silica fume replacement

6. CONCLUSIONS

Cement is the most widely used building material which suit the modern era with reference to its strength and durability performance. But manufacture of cement consumes large amount of energy and cause emission of CO_2 which degrades environment. The possibility of using silica fume as an alternative for cement was discussed based on the investigation done by other researchers. Silica fume which is a by-product of silicon and ferrosilicon industry can be effectively used in construction industry along with other supplementary cementitious material. From the literature reviews it can be concluded that the optimum percentage of cement replacement by silica fume is 10-15% for achieving maximum compressive, split tensile and flexural strength. The compressive strength increases with increase in the silica fume content and decrease with increase in fluid/binder ratio. Early gain in compressive strength was obtained for geopolymer concrete with silica fume when oven curing was done. Based on the studies conducted on concrete with silica fume and fibres, maximum percentage increase was obtained for flexural strength. Hence, silica fume is a good choice for replacing cement in conventional concrete, geopolymer concrete and other building material.

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