Effect of Silica Fume on Compressive Strength and Split Tensile Strength of Concrete

Deepak Yadav, Dr. D.P.Gupta, Dr. Arvind Dewangan, Er. Bhavana Arora

Abstract— **The present work aims at a deeper insight into the effect of cement replacement by silica fume in concrete over a wide range of water-cementitious material ratios and silica fume replacement percentages. Concrete is a widely used construction material for various types of structures due to its structural stability and strength. The usage, behaviour as well as the durability of concrete structures, built during the last first half of the century with ordinary portland cement (opc) and plain round bars of mild steel, the ease of procuring the constituent materials (whatever may be their qualities) of concrete and the knowledge that almost any combination of the constituents leads to a mass of concrete have bred contempt. Strength was stressed without a thought on the durability of structures. As a consequence of the liberties taken, the durability of concrete and concrete structures is on a southward journey; a journey that seems to have gained momentum on its path to self– destruction [1]. The ordinary portland cement (opc) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for green house effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material [2]. There are many important parameters which need to be studied in detail. The isolated effect of silica fume in concrete and the optimum silica fume replacement percentage causes the detailed investigations to ensure the maximum utilization of silica fume in concrete [8].**

Key words :Silica fume, Cement, Compressive strength and Split tensile strength .
Sub Area : Construction Technology & Management
Broad Area :Civil Engineering

I. INTRODUCTION

The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. Substantial energy and cost savings can result when industrial by products are used as a partial replacement of cement. Fly ash, ground granulated blast furnace slag, rice husk ash, high reactive met kaolin, silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement [3].

A number of studies are going on in India as well as abroad to study the impact of use of these pozzolanic materials as cement replacements and the results are encouraging. Addition of silica fume to concrete has many advantages like high strength, durability and reduction in cement production. The optimum silica fume replacement percentage for obtaining maximum 28- days strength of concrete ranged from 10% to 20% [4] [5]. When pozzolanic materials are incorporated to concrete, the Silica present in these materials reacts with the calcium hydroxide released during the hydration of Cement and forms additional calcium silicate hydrate (c – s – h), which improve durability and the Mechanical properties of concrete [6].

1.2 Silica fume

Silica fume is also known as micro silica or condensed silica fume, is a by product material that is used as a pozzolan by product is a result of the reduction of high-purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. Silica fume rises as an oxidized vapour from the 2000°C (3630°F) furnaces. When it cools it condenses and is collected in huge cloth bags. The condensed silica fume is then processed to remove impurities and to control particle size. Condensed silica fume is essentially silicon dioxide (usually more than 85%) in non-crystalline (amorphorous) form. Since it is an airborne material like fly ash, it has a spherical shape. It is extremely fine with particles less than 1µm in diameter and with an average diameter of about 0.1µm, about 100 times smaller than average cement particles. Condensed silica fume has a surface area of about 20,000 m^2/kg (nitrogen adsorption method). For comparison, tobacco smoke's surface area is about 10,000 m^2/ kg. Type I and Type III cements have surface areas of about 300 to 400 m^2/kg and 500 to 600 m^2/kg(Blaine) respectively. The relative density of silica fume is generally in the range of 2.20 to 2.5. Portland cement has a relative density of about 3.15. The bulk density (uncompacted unit weight) of silica fume varies from 130 to 430 kg/m^3 (8 to 27 lb/ft3). Silica fume is sold in powder form but is more commonly available in a liquid. Silica fume is used in amounts between 5% and 10% by mass of the total cementitious material. It is used in applications where a high degree of impermeability is needed and in high strength concrete. Silica fume must meet ASTM C 1240. ACI 234 (1994) and SFA (2000) provide an extensive review of silica fume .

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Compressive Strength Test (IS: 516 – 1959)

In order to study the effect on compressive strength, the cubes containing different proportion of silica fume were prepared and kept for curing for 7 and 28 days. The test was conducted on compression testing machine of capacity 2000 KN. The 7 days and 28 days compressive strength is listed in table 4.1 and 4.2 respectively, it is obtained that 28 days strength of all the mixes is invariably high. This is due to continuous hydration of Cement with concrete. The water-binder was kept constant at 0.36. The test results indicated that, when 5 to 15 percent by weight replacement of silica fume for cement is done, compressive strength increases. When 20% replacement of cement is done by silica fume, strength starts decreasing. Highest strength of 48.0.1 N/mm^2 was observed for 15% silica fume concrete mix at 28 days.

Figure 5.2 Compressive strength tests in progress

Compressive Strength after 7 Days:

Table 7 days compressive strength test result

Mix Designation	Percentage of Silica fume	Load (KN)	Compressive Strength (N/mm^2)	Average Compressive strength (N/mm^2)
M0	0	575 580 600	25.57 25.67 26.88	26.04
M1	5	610 650 675	27.01 28.65 30.02	28.56
M2	10	765 780 745	33.98 34.56 33.13	33.89
M3	15	890 880 865	39.57 38.98 38.48	39.01
M4	20	820 810 800	36.43 36.06 35.63	36.04

Compressive Strength after 28 Days:

Table : 28 days compressive strength test result

Mix Designation	Percentage of Silica fume	Load (KN)	Compressive Strength (N/mm^2)	Average Compressive strength (N/mm^2)

M0	0	830 840 860	37.05 37.45 38.18	37.56
M1	5	900 900 905	39.98 40.02 40.27	40.08
M2	10	1015 1025 1055	45.07 45.65 46.95	45.89
M3	15	1080 1095 1065	47.98 48.65 47.40	48.01
M4	20	990 970 995	39.12 40.02 36.48	43.76

7 and 28 days compressive strength are graphically represented as a belew

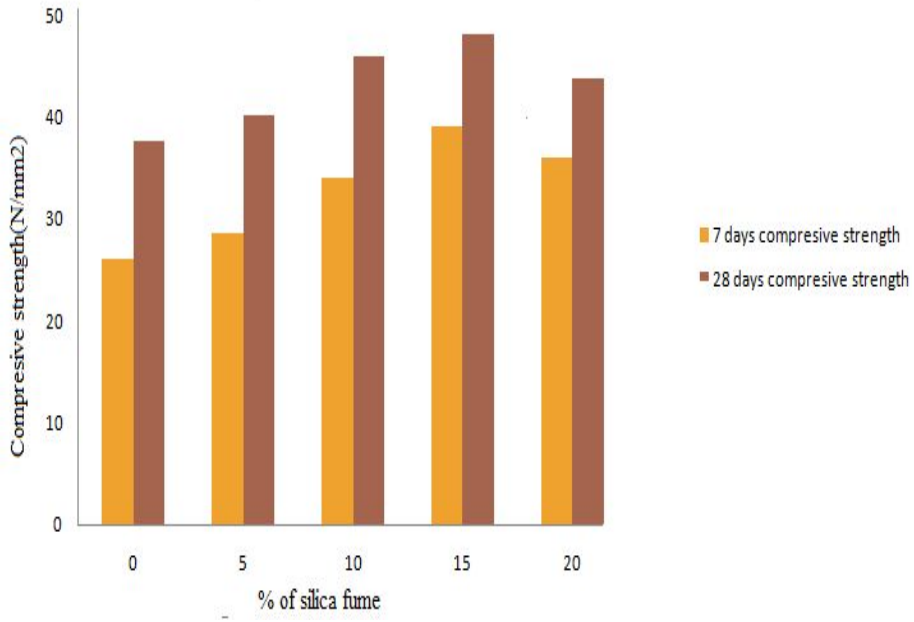

Figure : Compressive strength with silica fume replacement

Split Tensile Strength Test

Splitting Tensile strength studies were carried out at the age of 7 and 28 days. The results are shown in Table 4.3 and fig. 4.4The percentage of silica fume replaced by cement is 5%, 10% and 15% and the water binder ratio is kept at 0..36. The test results indicated that 10 to 15% by mass replacement of silica fume for cement provided the highest strength. When we increased the replacement of silica fume by 15% the tensile strength decreased. Highest Splitting tensile strength value of 5.06 N/mm^2 was obtained in the 15% replacement of silica at 28 days strength.

Results are represented graphically.

Figure : Testing for cylinder

Split Tensile Strength after 7 Days:

Table : 7 days split tensile strength test result

Mix Designation	Percentage of silica fume	Split Tensile Strength KN	Split Tensile Strength (N/mm^2)	Average strength (N/mm^2)
M0	0	220 255 190	3.15 3.65 2.71	3.17
M1	5	245 220 290	3.45 3.15 4.08	3.56
M2	10	320 280 275	4.57 3.96 3.92	4.15
M3	15	225 240 330	3.20 3.40 4.68	3.76
M4	20	245 265 255	3.50 3.80 3.65	3.65

Split Tensile Strength after 28 Day

Table : split tensile strength

Mix Designation	Percentage of silica fume	Split Tensile Strength (KN)	Split Tensile Strength (N/mm^2)	Average strength (N/mm^2)
M0	0	265 315	2.86 3.06	3.06

		430	3.26	
M1	5	340 285 400	4.80 4.02 5.67	4.83
M2	10	350 315 370	4.98 4.50 5.25	4.91
M3	15	293 350 355	4.15 4.98	4.73
M4	20	280 270 235	4.00 3.80 3.30	3.72

7 and 28 days tensile strength are graphically represented as a belew:

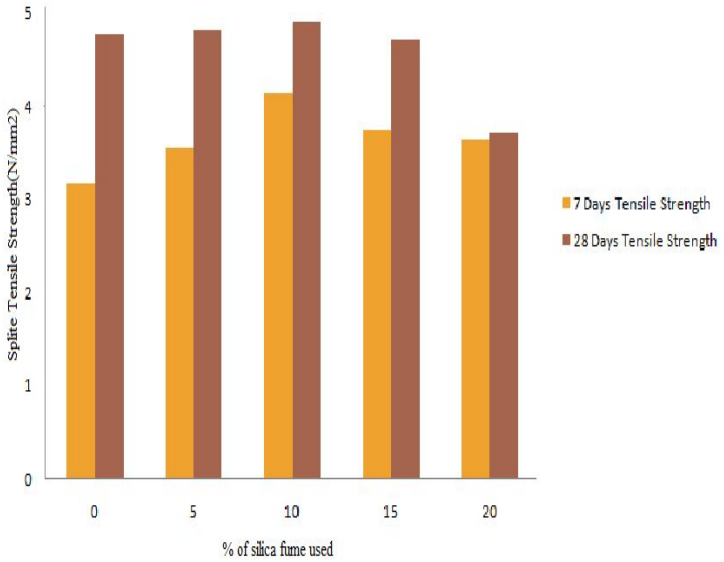

Figure : Tensile strength with silica fume replacement

CONCLUSION

Based on the results obtained in the present investigation, the following conclusion can be drawn:

A. The results obtained in the present study indicates that it is feasible to replace the cement by silica fume for improving the strength characteristics of concrete, thus the silica fume can be used as an alternative material for the production of concrete to address the waste disposal problems and to minimize the cost of construction with usages of silica fume which is most freely available.

B. Consistency of cement depends upon its fineness .silica fume is having greater fineness then cement and greater surface area so the consistency increases greatly when silica fume percentage increases. The normal consistency increases about 40% when silica fume percentage from 0% to 20%.

C. The optimum 7 and 28- day's compressive strength and flexural strength have been obtained in the range of 10-15% silica fume replacement level. Increase in split tensile strength beyond 10% silica fume replacement is almost insignificant whereas gains in flexural tensile strength have occurred even up to 15% replacement.

D. The maximum compressive strength obtained at 15% replacement of silica fume is 48.01N/mm^2 at 28 days. The maximum tensile strength obtained at 10% replacement of silica fume is 4.91N/mm^2 at 28 days. The maximum flexural strength obtained at 15% replacement of silica fume is 9.20N/mm^2 at 28 days.

E. There is a significant improvement in the compressive strength of concrete because pozzolanic nature of the silica fume and its void filling ability.

F. Silica fume seems to have a pronounced effect on the flexural strength than the split tensile strength.

G. When compared to other mix the less in weight and compressive strength percentage was found to be reduced by 2.23 and 7.69 when cement was replaced by 10% of silica fume.

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