EXPERIMENTAL INVESTIGATION OF STRENGTH IN CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH SILICA FUME

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ABSTACT: The increased environmental awareness and its potential hazardous effects, utilization of industrial byproducts has become an attractive alternative to disposal. Silica fume(SF), which is byproduct of the melting process in the silicon and ferrosilicon industry. Silica fume is very effective in the design and development of high performance concrete. This paper presents the results of an experimental investigations carried out to find the suitability of silica fume in concrete. The water binder ratio (W/B) adopted was 0.43. The main parameter investigated in this study is M30 grade concrete by partial replacement of cement with silica fume by 2, 4, 6,8 sand by 10%. .Specimens such as cubes and cylinders were cast for various mix proportions and tested at the age of 14and 28 days. The investigation revealed that the partial replacement of cement by silica fume will develop compressive strength and split tensile strength sufficient for construction purposes The optimum dosage of silica fume found to be 8% (by weight), when used as partial replacement of ordinary Portland cement .Its use will lead to a reduction in cement quantity required for construction purposes and hence sustainability in the construction industry as well as economic construction.

KEY WORDS: Compressive strength, Silica fume,Split Tensile strength

I. INTRODUCTION

Mineral admixture are widely used in concrete for various reasons especially for reducing the amount of cement required for making concrete which shows to a reduction in construction cost. Moreover most pozzolanic materials are byproduct materials. The use of these materials shows the reduction in waste, freeing up valuable land, save in energy consumption to produce cement and save the environment. Durability of portland cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, fire or another process of deterioration. In other words, cement concrete will be termed durable, when it keeps its form and shape within the allowable limits, while exposed to different environmental conditions. Durability of concrete has been a major concern of civil engineering professionals. Also, it has been of considerable scientific and technological interest over the last few decades . The American concrete institute (ACI) defines silica fume as a ‘‘very fine non crystalline silica produced in electric arc furnaces as a byproduct of production of elemental silicon or alloys containing silicon’’. Silica fume is also known as micro silica, condensed silica fume, volatized silica or silica dust. It is usually a grey colored 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. Addition of silica fume to concrete improves the durability of concrete and also in protecting the embedded steel from corrosion. When fine pozzolana particles are dispersed in the paste, they generate a large number of nucleation sites for the precipitation of the hydration products. Therefore, this mechanism makes the paste more homogeneous and dense as for the distribution of the fine pores. This is due to the reaction between the amorphous silica of the pozzolanic and the calcium hydroxide produced by the cement hydration reactions [3].Silica fume is a byproduct and it is the most beneficial uses in concrete. Because of its chemical and physical properties, it is a very reactive pozzolana. Concrete containing silica fume can have very high strength and can be very durable. In this paper the advantages of using silica fume in concrete in partial replacement of cement are found. The present experimentation has been carried out to determine the mechanical properties of conventional concrete and concrete using silica fume. Suitability of silica fume has been discussed by replacing cement with silica fume at varying percentage and the strength parameters were compared with conventional concrete.

material that has many uses. Often, additives (such as pozzolans or superplasticizers) are included in the mixture to improve the physical properties of the wet mix or the finished material. Most concrete is poured with reinforcing materials (such as rebar) embedded to provide tensile strength, yielding reinforced concrete.

II. EXPERIMENTAL INVESTIGATION

2.1. MATERIALS AND PROPERTIES

2.1.1. SILICA FUME

Silica fume is a byproduct in the reduction of high-purity quartz with coke in electric arc furnaces in the production of silicon and ferrosilicon alloys. Silica fume consists of fine particles with a surface area on the order of 215,280 ft²/lb (20,000 m²/kg) when measured by nitrogen adsorption techniques, with particles approximately one hundredth the size of the average cement Because of its extreme fineness and high silica content, silica fume is a very effective pozzolanic material particle.

Silica fume is added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength, and abrasion resistance. These improvements stems from both the mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolanic reactions between the silica fume and free calcium hydroxide in the paste. Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions .When silica fume is incorporated, the rate of cement hydration increases at the early hours due to the release of OH ÿ ions and alkalis into the pore fluid. The increased rate of hydration may be attributable to the ability of silica fume to provide nucleating sites to precipitating hydration products like lime, C±S±H, and ettringite. It has been reported that the pozzolanic reaction of silica fume is very significant and the nonevaporable water content decreases between 90 and 550 days at low water /binder ratios with the addition of silica fume

Table No. 1 Physical Properties of silica fume

Materials	Silica fume
Specific gravity	2.27

Table 2 Chemical properties of silica fume

Silicon dioxide (SiO_2)	96.0
Aluminium oxide (Al_2O_3)	0.1
Iron oxide (Fe_2O_3)	0.6
Calcium oxide (CaO)	0.1
Magnesium oxide (MgO)	0.2
Sodium oxide (Na_2O)	0.1
Potassium oxide (K_2O)	0.4
Loss on ignition	1.7

2.1.2. CEMENT

Cement is a binding material which possesses very good and cohesive properties which make it possible to bond with other materials .Ordinary Portland Cement is the most commonly used cement for general engineering works. The specific gravity of all grades namely 33, 43 and 53 grades. In this project Ordinary Portland Cement of 53 grades is used for experimental work. of Ultratech to IS: 12269-1987(9) was used in the present study.

Table 3 Properties of Cement

Normal Consistency	32%
Initial Setting time	45 mins
Specific Gravity	3.15
Fineness of cement	5%

2.1.3. FINE AGGREGATE

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The most common constituent of sand, in inland continental settings and non-tropical coastal settings, is silica(silicon dioxide, or SiO_2), usually in the form of quartz which, because of its chemical inertness and considerable hardness, is the most common mineral resistant to weathering.It is used as fine aggregate in concrete.

Table No 8 Physical properties of fine aggregate

properties	Result
Specific gravity	2.65
Water absorption in %	1.08

2.1.4. COARSE AGGREGATE

Coarse aggregate are the important constituents in concrete .Coarse aggregate are particles greater than 4.75 mm, but generally range between 9.5mm to 37.5mm in diameter. They can either be from primary, secondary or recycled sources. Primary, or 'virgin', aggregates are either land or marine-won. Gravel is a coarse marine-won aggregate; land-won coarse aggregate include gravel and crushed rock. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder .Secondary aggregates are materials which are the by-products of extracting operations and are derived from a very wide range of materials.

Table No 8 Physical properties of coarse aggregate

Property	Result
Specific gravity	2.66
Fineness modulus	4.32
Aggregate impact value	2.43
Water absorption	0.90

The specific gravity, fineness modulus, water absorption and bulk density of the coarse aggregate were tested. Hard granite broken stones of less than 20mm size were used as coarse aggregate. The specific gravity, fineness modulus, water absorption and impact value of the coarse aggregate were tested. **C**rushed aggregate confirming to IS: 383-1970 was used. Aggregates of size 12.5 mm of specific gravity 2.83 and fineness modulus 6.28 were used.

2.2 MIX PROPORTIONING

Concrete mix design in this experiment was designed as per the guidelines specified in ACI234R – 96 "Guide for the use of silica fume in concrete" by ACI committee 234(7).All the samples were prepared using design mix. M30 grade of concrete was used for the present investigation. Mix design was done based on I.S 10262-1982. The Table 6 shows mix proportion of concrete (Kg/m3)

Table 12 Mix design result

Material	Quantity (Kg/m3)
Cement (OPC)	450
Fine Aggregate	665.62
Coarse Aggregate	1090.12
Water	0.43

The mix ratio for M30 grade of concrete = 1:1.47:2.42

For this study, M 30 grade of concrete and water cement ratios are used on 0.43, the quantities of materials used for w/cm ratio are worked out. Two types of concrete mix are prepared, the first one (type I) was conventional concrete (0% Silica Fume) with w/cm ratio 0.43, the second (type II) was combination of Portland cement and various % of silica fume (2%, 4%,6%, 8% and 10%) with w/cm ratio 0.43.

2.3. CASTING OF TEST SPECIMENS

The following mould for casting the specimen were used

The specimen of standard cubes of (150 mm x 150 mm x 150 mm) was used to determine the compressive strength.

The specimen of standard cylinders of (300 mm x 150 mm) were used to determine split tensile strength.

Total 12 Cubes & 12 cylinders were casted for the strength parameters. The constituents were waved and the material were mixed by hand mixing. The concrete was filled in different layer and each layer was compacted. The specimens were demoulded after 24 hours cured in water for 14 & 28 days. Thus tested for its compressive and split tensile as per Indian standard

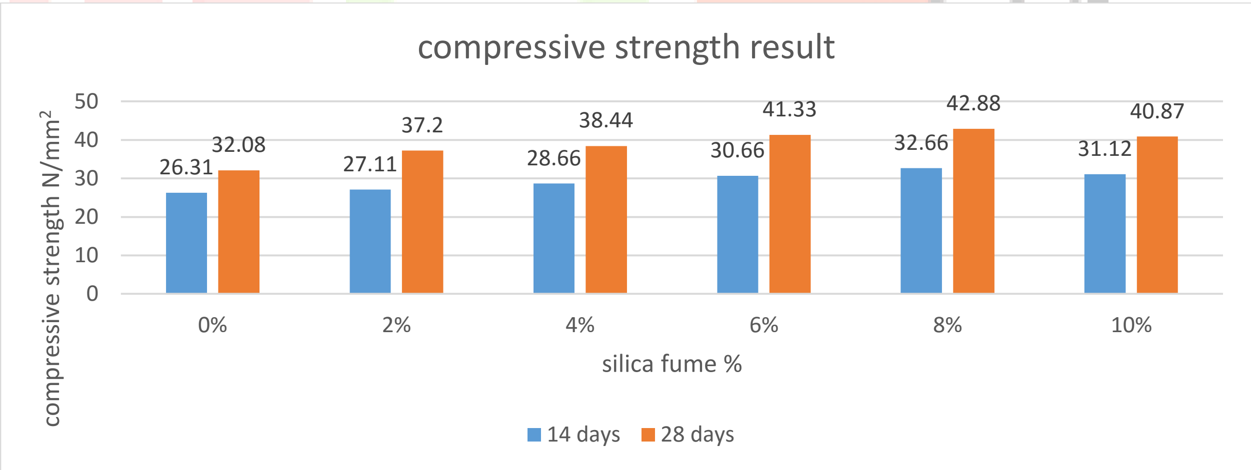
III. RESULTS AND DISCUSSION

3.1. COMPRESSIVE STRENGTH TEST

The test was carried out conforming to IS 516-1959 to obtain compressive strength at the age of 14 and 28 days . The cubes were tested using Compression Testing Machine (CTM) of capacity 2000 KN. the results are shown below:-

Table 13 Compressive strength of cube

w/c ratio	Silica fume %	Load (KN)		Compressive Strength N/mm^2	
		14 days	28 days	14 days	28 days
0.43	0	592	722	26.31	32.08
	2	610	837	27.11	37.20
	4	645	865	28.66	38.44
	6	690	930	30.66	41.33
	8	735	965	32.66	42.88
	10	700	920	31.12	40.87



The compressive strength as shown in above parameter upto 32.66 N/mm2 & 42.88 N/mm .at 14 and 28 days. There is a significant improvement in the compressive strength of concrete. The compressive strength with partial replacement of cement by silica fume increased 8 % and then decreased . The optimum percentage of replacement of cement by silica fume is 8%.

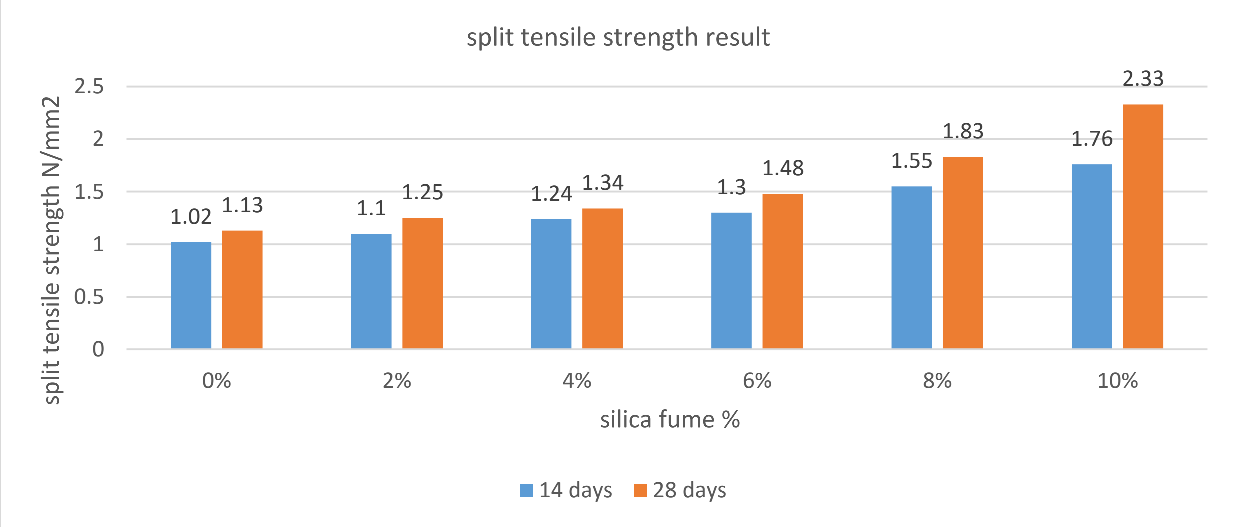
3.2. SPLIT TENSILE STRENGTH TEST

The test was carried out conforming to IS 516-1959 to obtain Split Tensile Strength of Concrete strength at the age of 7 and 28 days . The cylinders were tested using Compression testing machine (CTM) of capacity 1000 Kn. The results are shown below

Table 14 Split tensile strength of cylinder

w/c ratio	Silica fume %	Load (KN)	Spilt tensile Strength N/mm^2

		14 days	28 days	14 days	28 days
0.43	0	75	80	1.02	1.13
	2	78	90	1.10	1.25
	4	88	95	1.24	1.34
	6	92	105	1.30	1.48
	8	110	130	1.55	1.83
	10	125	165	1.76	2.33



Split Tensile Strength of Concrete increases with the increase of percentage of silica fume as shown above parameter. The partial replacement 10 %Silica fume is found to be suitable optimum. Thus at the age of 28 days with the partial replacement of high performance concrete obtained.

IV. CONCLUSION

- concrete produced from cement replacement upto 8 silica fume leads to increase in compressive strength of concrete. Beyond 8%there is a decrease in compressive strength of concrete.
- The cement replacement upto 10% silica fume leads to increase in split tensile strength of concrete .
- The compressive strength mainly depends on the percentage of silica fume because of its high pozzolanic nature.
- Concrete with silica fume can be effectively used in high rise buildings since high early strength is required, and the construction period can be reduced.
- The percentage of increase in the compressive strength is 30% at the age of 28 days by replacing 8% of cement by silica fume.The optimum percentage of replacement of cement by silica fume is 8%.

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