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EFFECT OF SILICA FUME ON STRENGTH AND DURABILITY PARAMETERS OF CONCRETE

N. K. Amudhavalli[1], Jeena Mathew[2]

[1]Asst. Professor (Senior Grade), Department of Civil Engg, Tamilnadu College of Engineering, Anna University, Coimbatore, India
nkamudhavalli@gmail.com

[2]*Asst Professor,* Department of Civil Engg, Sree Narayana Gurukulam College of Engineering, M.G. University, Ernakulam, India
jeenmathews@gmail.com

ABSTRACT

Portland cement is the most important ingredient of concrete and is a versatile and relatively high cost material. Large scale production of cement is causing environmental problems on one hand and depletion of natural resources on other hand. This threat to ecology has led to researchers to use industrial by products as supplementary cementations material in making concrete. The main parameter investigated in this study is M35 grade concrete with partial replacement of cement by silica fume by 0, 5, 10,15and by 20%. This paper presents a detailed experimental study on Compressive strength, split tensile strength, flexural strength at age of 7 and 28 day. Durability study on acid attack was also studied and percentage of weight loss is compared with normal concrete. Test results indicate that use of Silica fume in concrete has improved the performance of concrete in strength as well as in durability aspect.

KEYWORDS: *Silica fume, durability, Compressive strength, Split tensile strength, Flexural strength, Acid resistance*

I. INTRODUCTION

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). 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). Cement replacement up to 10% with silica fume leads to increase in compressive strength, for M30 grade of concrete. When pozzolanic materials are incorporated to concrete, the silica present in these materials react 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). In this paper 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.

II. EXPERIMENTAL INVESTIGATION

2.1. Materials

2.1.1. Cement

Ordinary Portland Cement of Ultratech brand of 53 grade confirming to IS: 12269-1987(9) was used in the present study. The properties of cement are shown in Table 1.

Table 1: Properties of Cement

Sl. No	Property	Result
1.	Normal Consistency	32%
2.	Initial Setting time	45 mins
3.	Specific Gravity	3.15
4.	Fineness of cement	5%

2.1.2. Fine Aggregate

Natural sand as per IS: 383-1987 was used. Locally available River sand having bulk density 1860 kg/m^3 was used The properties of fine aggregate are shown in Tab 2.

Table 2: Properties of fine aggregate

Sl. No	Property	Result
1.	Specific Gravity	2.57
2.	Fineness modulus	2.28
3.	Grading zone	II

2.1.3. Coarse Aggregate

Crushed aggregate confirming to IS: 383-1987 was used. Aggregates of size 20mm and 12.5 mm of specific gravity 2.74 and fineness modulus 7.20 were used.

2.1.4. Silica Fume (Grade 920 D)

Silica fume used was confirming to ASTM- C(1240-2000) and was supplied by "ELKEM INDUSTRIES" was named Elkem – micro silica 920 D. The Silica fume is used as a partial replacement of cement. The properties of fine aggregate are shown in Table 3.

Table 3: Properties of silica fume

Specific Gravity	2.2
Bulk Density	576, (Kg/m^3)
Size , (Micron)	0.1
Surface Area , (m^2/kg)	20,000
Si02	(90-96)%
Al_2O_3	(0.5 -0.8)%

*As per manufacturers manual

2.1.5. Super Plasticizer

In this investigation super plasticizer- CONPLAST-SP 430 in the form of sulphonated Naphthalene polymers complies with IS: 9103-1999 and ASTM 494 type F was used to improve the workability of concrete. The properties of super plasticizer are shown in Table 4.

Table 4: Properties of super plasticizer

Specific Gravity	1.220 – 1.225
Chloride content	NIL
Air entrainment	approximately 1% additional air is entrained

*As per manufacturers manual

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. M35 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/m^3)

Table 5: Mix Proportioning

Sl. No	Material	Quantity (Kg/m^3)
1.	Cement (OPC)	514
2.	Fine Aggregate	456.932
3.	Coarse Aggregate	1391.642
4.	Water	185.6

2.3. Test for Workability of Fresh Concrete

Workability is defined as the properties of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished. The workability was measured by conducting slump cone test and compaction factor test in accordance with IS: 1199-1959. The trials were carried out to improve the workability and cohesiveness of the fresh concrete by incorporating a super plasticizer.

Marsh cone test was conducted to select the better combination of water, cementitious materials and chemical admixtures. Mortar mixture was prepared and the saturated point was determined using a marsh cone with a nozzle having an opening of 5mm diameter and 50mm length. The time taken for the first 200ml of cement paste to flow through the cone was measured. This is called flow time. Three flow times were measured for each paste and mean value was used.

Super plasticizers can affect the concrete strength even at constant water cement ratio and the quantity of fines in a mixture influences the performance of super plasticizers (8). The strength of both cement paste and concrete can be affected by the dosage of SP. Thus, if the dosage of SP is varied with the silica fume replacement percentage, then the variations in the concrete strength will occur not only due to variations in the silica fume contents but also due to change in the dosage of super plasticizer. Hence the dosage of super plasticizer was also kept constant for all the mixes and thus the change in concrete properties at any constant water-binder ratio occurred primarily due to silica fume incorporation (8). Since the SP content of all the mixes was kept constant, to minimize variations in workability, the compaction energy was varied for obtaining proper compaction.

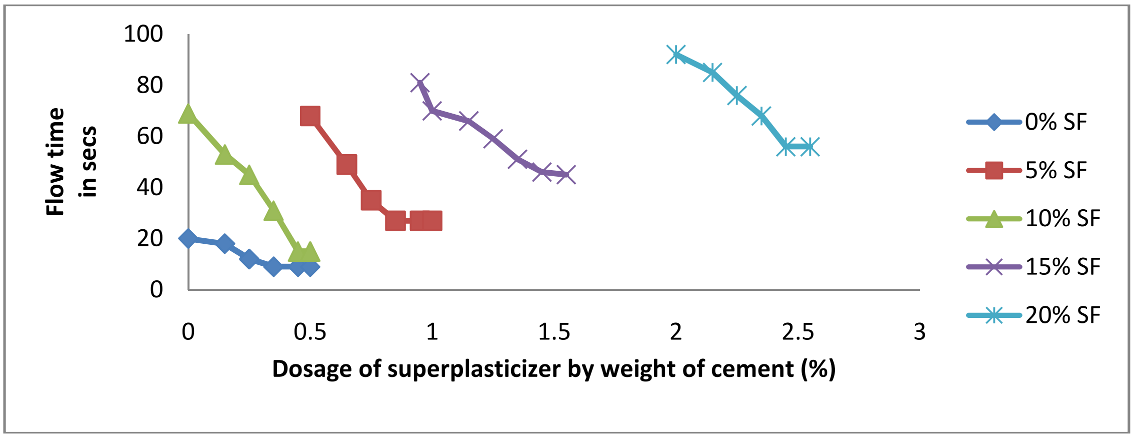

Fig. 1 Marsh cone time of cement paste with and without silica fume Vs dosages of super plasticizer in M35 grade concrete.

2.4. Experimental Procedure

The specimen of standard cube of (150mm x 150mm x 150mm) and standard cylinders of (300mm x 100mm) and Prisms of (150mm x150mm x 750mm) were used to determine the compressive strength, split Tensile strength and flexural strength of concrete. Three specimens were tested for 7 & 28 days with each proportion of silica fume replacement. Totally 30 cubes, 30 cylinders and 30 prisms were cast for the strength parameters and 15 cubes for acid attack test. The constituents were weighed and the materials were mixed by hand mixing. The water binder ratio (W/B) (Binder = Cement + Partial replacement of silica fume) adopted was 0.36 and weight of super plasticizer was estimated as 0.65% of weight of binder. The concrete was filled in different layers and each layer was compacted. The specimens were demoulded after 24 hrs, cured in water for 7 & 28 days, and then tested for its compressive, split tensile and flexural strength as per Indian Standards.

III. TEST RESULTS AND DISCUSSIONS

Results of fresh and hardened concrete with partial replacement of silcafume are discussed in comparison with those of normal concrete.

Table 6: Results Of Compressive Split Tensile And Flexural Strength

Mix	% of Silica SilicaFume added %	Compressive Strength(N/mm^2)		Split tensile Strength(N/mm^2)		Flexural Strength(N/mm^2)	
		7 days	28 days	7 days	28 days	7 days	28 days
M1	0	25.21	38.30	3.11	4.67	4.89	5.84
M2	5	29.33	41.29	3.65	4.802	6.9	7.07
M3	10	34.12	46.76	4.10	4.95	7.23	9.00
M4	15	38.3	47.3	3.83	4.63	7.75	9.38
M5	20	35.9	44.27	3.65	3.98	6.04	7.09

3.1. Compressive Strength

The results of compressive strength were presented in Table 6. The test was carried out conforming to IS 516-1959 to obtain compressive strength of concrete at the age of 7 and 28 days. The cubes were tested using Compression Testing Machine (CTM) of capacity 2000Kn. From Fig 3 the compressive strength is up to 38.3 N/mm^2 and 47.3 N/mm^2 at 7 and 28 days. The maximum compressive strength is observed at 15% replacement of silica fume.

There is a significant improvement in the compressive strength of concrete because of the high pozzolanic nature of the silica fume and its void filling ability(9).

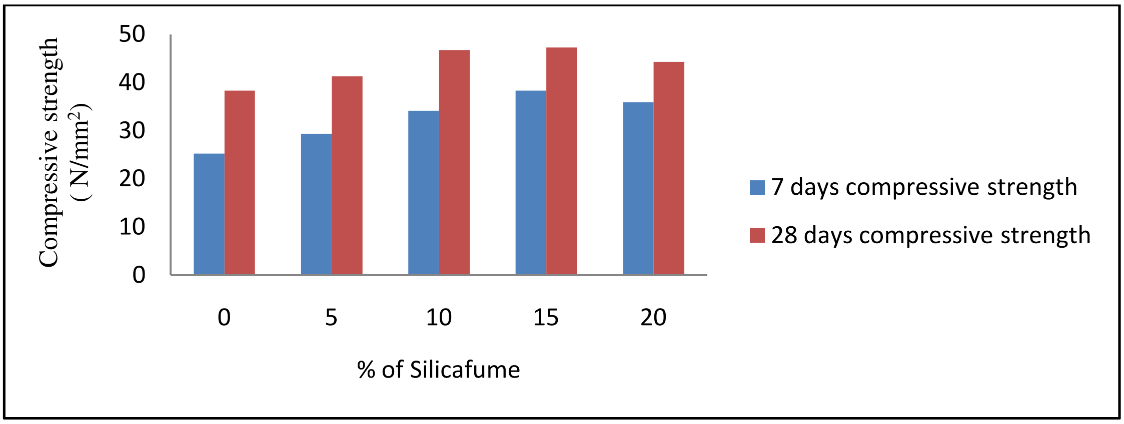

Fig 2. Effect of silica fume on compressive strength of concrete

3.2 Split Tensile Strength

The results of Split Tensile strength were presented in Table 6. The test was carried out conforming to IS 516-1959 to obtain Split tensile strength of concrete at the age of 7 and 28 days. The cylinders were tested using Compression Testing Machine (CTM) of capacity 2000Kn.From Fig 4 the increase in strength is 4.10N/mm^2 and 4.65N/mm^2 at 7 and 28 days. The maximum increase in split tensile strength is observed at 10% replacement of silica fume.

The optimum silica fume replacement percentages for tensile strengths have been found to be a function of w/cm ratio of the mix. The optimum 28-day split tensile strength has been obtained in the range of 5–10% silica fume replacement level, whereas the value for flexural strength ranged from 15% to 25%(10)

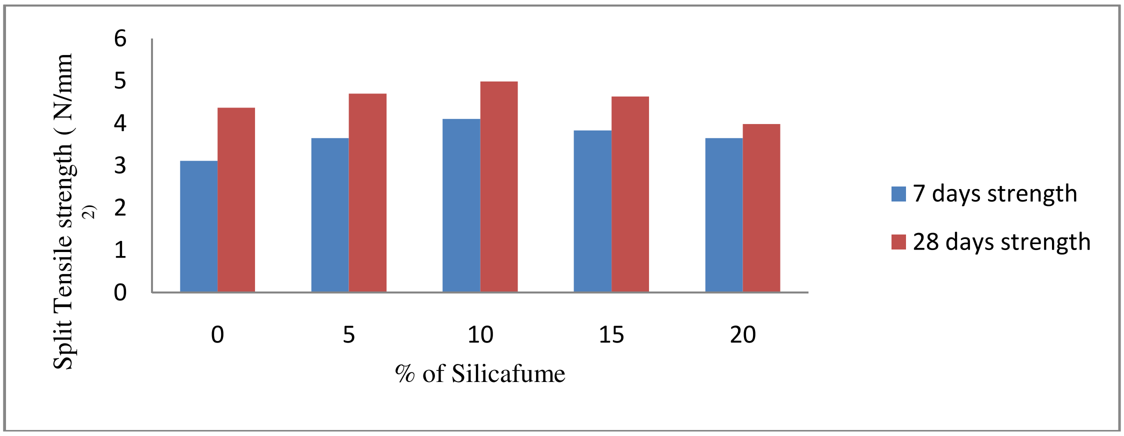

Fig 3 Effect of silica fume on split tensile strength of concrete

3.3 Flexural Strength

The results of flexural strength of normal concrete and silica fume replaced concrete were presented in Table 6. The test was carried out conforming to IS 516-1959 to obtain Flexural strength of concrete at the age of 7 and 28 days. The cubes were tested using Universal Testing Machine (UTM) of capacity 1000 tonnes.From Fig 5 the maximum increase in flexural strength is observed as 7.75 N/mm^2 and 9.38 N/mm^2 at 7 and 28 days when silica fume is replaced by 15%. to that of cement.

The flexure strength at the age of 28 days of silica fume concrete continuously increased with respect to conventional concrete and reached a maximum value of 12% replacement level for M40 grades of concrete (10).

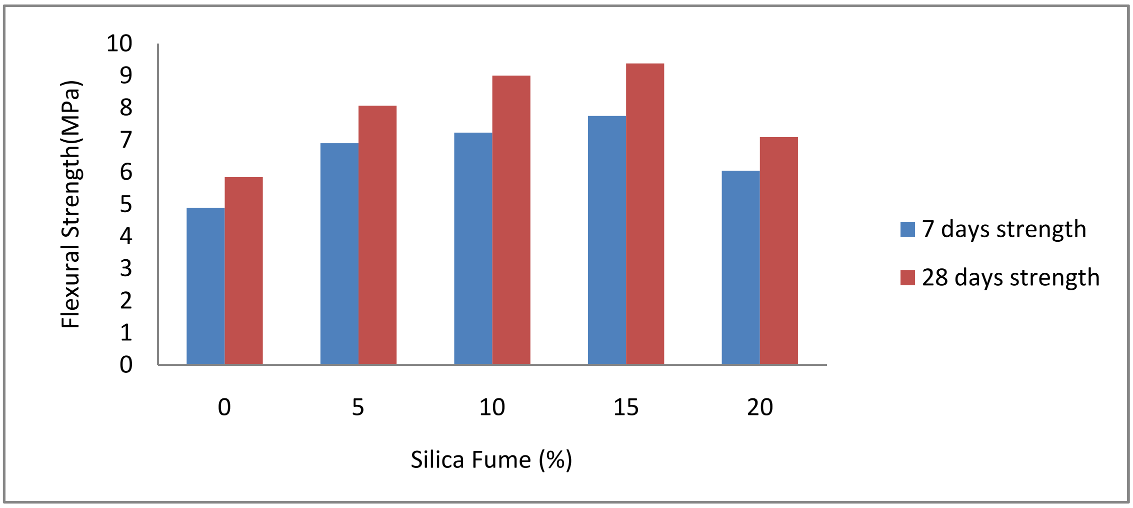

Fig 4 Effect of silica fume on flexural strength of concrete

3.4 Durability Test

3.4.1 Acid Resistance

Cubes of sizes 150mm were cast and cured for 28 days. After 28 days curing cubes were taken out and allowed for drying for 24 hours and weights were taken. For acid attack 5% dilute hydrochloric acid is used. The cubes were to be immersed in acid solution for a period of 30 days. The concentration is to be maintained throughout this period. After 30 days the specimens were taken from acid solution. The surface of specimen was cleaned and weights were measured. The specimen was tested in the compression testing machine under a uniform rate of loading 140Kg/cm^2 as per IS 516. The mass loss and strength of specimen due to acid attack was determined.

Acid attack

The action of acids on concrete is the conversion of calcium compounds into calcium salts of the attacking acid. These reactions destroy the concrete structure. The percentage of loss in compressive strength was 11.91%, 8.18%, respectively. Thus replacement of silica fume is found to have increased the durability against acid attack. This is due to the silica present in silica fume which combines with calcium hydroxide and reduces the amount susceptible to acid attack(6).

Table 7: Effect of Acid Attack On Weight And Compressive Strength Of Cubes

Sl. No	Silica fume %	Loss in Weight (%) At 30 Days	Loss in Compressive strength (%) At 30 days
1.	0	4.4	11.91
2.	5	2.81	8.18
3.	10	2.23	7.69
4.	15	2.76	8.02
5	20	2.90	8.35

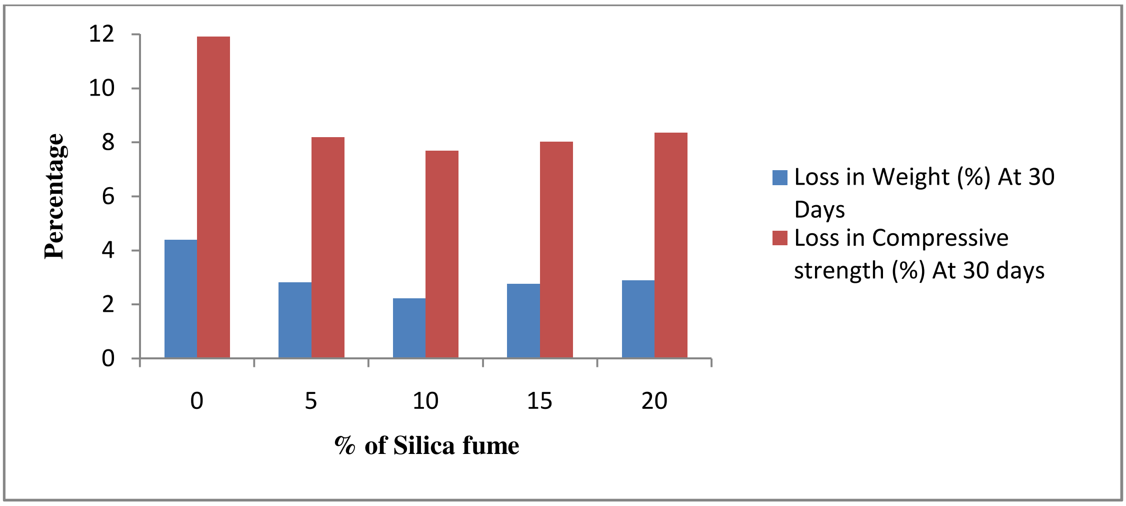

Fig 5 Effect of acid attack on weight and compressive strength of cubes

IV. CONCLUSIONS

Consistency of cement depends upon its fineness. Silica fume is having greater fineness than 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 increases from 0% to 20%. The optimum 7 and 28-day 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 gain in flexural tensile strength have occurred even up to 15 % replacements. Silica fume seems to have a more pronounced effect on the flexural strength than the split tensile strength. When compared to other mix the loss in weight and compressive strength percentage was found to be reduced by 2.23 and 7.69 when the cement was replaced by 10% of Silica fume.

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BIOGRAPHY

N. K. Amudhavalli, Assistant Professor (Senior Grade), Department of Civil Engineering, Tamilnadu College of Engineering, Coimbatore-59, India.She has obtained her Bachelor's degree in Civil Engineering, from Tamilnadu College of Engineering, Coimbatore, in the year 1989,Masters Degree in Structural Engineering from Government College of Technology, Coimbatore in the year 2009 and at present she is pursuing hers Doctorate Degree under the Anna University of Technology, Coimbatore, India. She has 9 years of teaching experience and has presented papers in National Seminars and Conferences and has attended International Conferences. She has guided many BE Civil Engineering projects, Eight PG projects and many seminars.

Jeena Mathew. Assistant professor, Department of Civil Engineering, Sree Narayana Gurukulam College of Engineering ,MG university, Ernakulum, India. She has obtained her Bachelor's Degree in Civil engineering from Karunya University in the year 2009. Masters degree in Structural Engineering from Tamilnadu College of Engineering ,Coimbatore in the year 2011.She has attended many seminars and conferences and presented papers.