Performance of Concrete by using Silica Fume - An Experimental Study

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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, 10, 20, 25, 30, 35, and by 40%. This paper presents a detailed experimental study on Compressive strength, split tensile strength, flexural strength at age of 7 and 28 day. Test results indicate that use of Silica fume in concrete has improved the performance of concrete in strength.

Key words: Silica Fume Durability, Compressive Strength, Split Tensile Strength, Flexural Strength

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.

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 greenhouse 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. 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 25 to 30 %.

II. Literature Survey

Sasikumar & Tamilvanam (2016) [1] performed an experiment investigation on properties of silica fume as a partial replacement of cement main parameter investigated in this study is M30 grade concrete with partial replacement of cement by silica fume 0%,5%,10%,20%,25%.the optimum 7 and 28 days compressive strength has been obtained in the 25% silica fume replacement level.

Alok (2016) [2] write a research paper on partial replacement of cement im M30 concrete from silica fume were 0%,2.5%,and 7%,.water cement ratio was kept 0.43 in all the cases 43.1 n/mm^{2}was the maximum compressive strength

Kumar & Dhaka (2016) [3] write a review paper on partial replacement of cement with silica fume and its effect on concrete properties the main parameter investigated in this study M35 concrete with partial replacement of silica fume with varying 0,5,10,15,20,25% by weight of cement. the paper presents a detailed study on compressive strength ,flexural strength and split tensile strength for 7 days and 28 days respectively.

Jain & pawade (2015) [4] studied the characteristics of silica fume concrete. The physical properties of high strength silica fume concrete and their sensitivity of curing procedures were reference Portland cement concrete having their the same concrete content as the silica fume concrete

Sharma & Seema (2012) [5] examined the effect of partial replacement of cement with silica fume on compressive strength of concrete with w/c ratio as 0.5 and percentage replacement was 0%,10%,15%,20%,25%,. The optimum compressive strength is obtained at 20% cement replacement by a silica fume at all levels.

Fig. 1: Measurement of admixture

III. Experimental Investigation

A. Materials

Ordinary Portland Cement (OPC) of 43 grade J.K. Cement was used throughout the course of investigation. Specific gravity of this cement is 3.15.

Sl. No	Property	Result
1.	Normal Consistency	32%
2.	Initial Setting time	30 mins
3.	Specific Gravity	3.15
4.	Fineness of cement	95%

Table 2: Properties of Cement

B. Fine Aggregate

Natural sand used Specific gravity was 2.50, sieve analysis = III zone 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.

Sl. No	Property	Result
1.	Specific Gravity	2.50
2.	Fineness modulus	2.28
3.	Grading zone	III

Table 3: Properties of fine aggregate

C. Coarse Aggregate

Natural coarse aggregates were obtained from Gunawata (Rajasthan). Specific gravity of these aggregates were 2.8.

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.

D. Silica Fume

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.

Specific Gravity	2.2
Bulk Density	576, (Kg/m^3)
Size, (Micron)	0.1
Surface Area, (m^2/kg)	20,000
SiO_2	(90-96)%
Al_2O_3	(0.5 -0.8)%

Table 4: Properties of silica fume
*As per manufacturers manual

E. Super Plasticizer

There are different type of chemical admixture which are being used in construction and they may be retarding admixture accelerating admixture, water reducing admixture, air-entraining admixture, Super plasticizing admixture and retarding super plasticizing admixture but because of higher grade of concrete water reducing super plasticizer (workability aid) has been used here in this thesis work i.e. naphtha based as per IS 9103:1999.The super plasticizer which is used for the experimental performance is KavassuPlast SP-431/ Shaliplast SP-431.

It was advised by the manufacturer to shakeit well before use.

- Brand of Admixure: Shalimar and Kavassu Brand
- Product Description: ShaliplastSP-431/KavassuPlast SP-431
- Product Form: Black Brown liquid

KavassuPlast SP-431/Shaliplast SP-431 is a chloride free super-plasticizer & water reducing agent for concrete. It has high workability to flow for concrete mixes so that the voids can be filled by the concrete slurry even with very less amount of compaction. The properties of super plasticizer are shown in Table 4.

Specific Gravity	1.20 – 1.5
Chloride content	NIL
Air entrainment	approximately 1% additional air is entrained

Table 4: Properties of super plasticizer

*As per manufacturers manual

F. 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 5 shows mix proportion of concrete (Kg)

Sl. No	Material	Quantity(kg) (Kg/m^3)
1.	Cement (OPC)	405
2.	Fine Aggregate	660
3.	Coarse Aggregate	1122
4.	water	162

Table 5: Mix Proportioning

G. 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.

IV. EXPERIMENTAL PROCEDURE

The specimen of standard cube of (150mm x 150mm x 150mm) and standard cylinders of (300mm x 150mm) 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 54 cubes, 30 cylinders and 30 prisms were cast for the strength parameters and. 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 0.40 and weight of super plasticizer was estimated as 0.50% of weight of cement. 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.

A. Test Results and Discussions

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

Mix	% of Silica Silica	Compressive Strength (N/ mm^2)	Split tensile Strength (N/ mm^2)	Flexural Strength (N/ mm^2)

	Fume added %	7 days	28 days	7 days	28 days	7 days	28 days
M35	0%	29.40	39.80	3.10	4.68	4.92	6.40
M35	10%	29.80	41.20	3.23	4.89	5.24	6.45
M35	20%	32.10	42.27	3.38	4.97	5.32	6.53
M35	25%	33.40	43.01	3.73	5.12	5.67	6.62
M35	30%	36.30	43.50	4.17	5.47	5.94	6.67
M35	35%	35.10	42.15	3.76	4.67	5.42	6.48
M35	40%	34.60	41.70	2.90	4.21	5.36	6.30

Table 6: Results of Compressive Split Tensile and Flexural Strength

B. *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 36.30 N/ mm^2 and 43.50 N/ mm^2 at 7 and 28 days. The maximum compressive strength is observed at 30% replacement of silica fume.

Fig. 2: Mixing of concrete and concrete cubes

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.

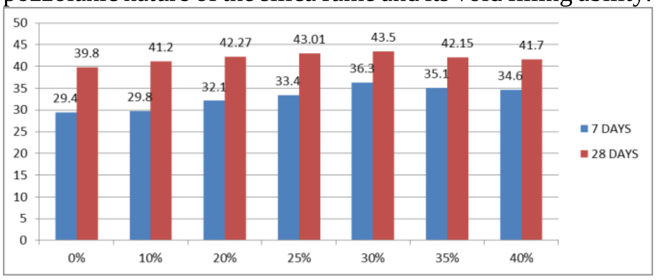

Fig. 3: Effect of silica fume on compressive strength of concrete

C. *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 3 the increase in strength is 4.17N/ mm^2 and 5.47N/ mm^2 at 7 and 28 days. The maximum increase in split tensile strength is observed at 30% 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 25–30% silica fume replacement level, whereas the value for flexural strength ranged from 25% to 30%

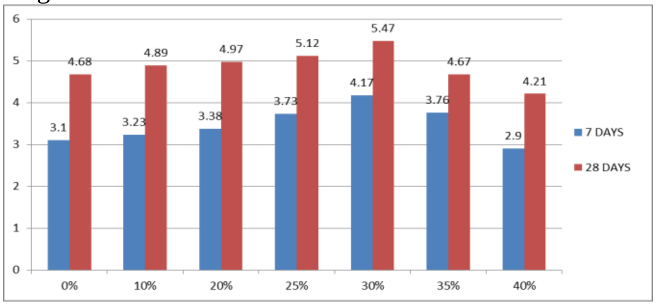

Fig. 4: Effect of silica fume on split tensile strength of concrete

D. *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 tones. The maximum increase in flexural strength is observed as 5.94 N/mm^2 and 6.67 N/ mm^2 at 7 and 28 days when silica fume is replaced by 30% to that of cement.

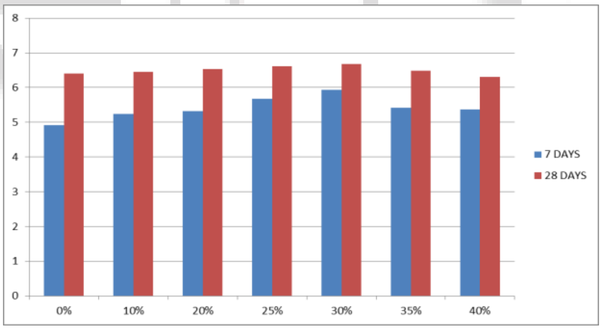

Fig. 5: Effect of silica fume on flexural strength of concrete

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 30% replacement level for M35 grades of concrete

V. CONCLUSIONS

By Using Silica Fume with partial replacement of cement it's possible to achieve desire strength and durability properties through the use of waste material

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 40%. The optimum 7 and 28-day compressive strength and flexural strength have been obtained in the range of 25-30 % 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 30 % replacements. Silica fume seems to have a more pronounced effect on the flexural strength than the split tensile strength.

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