

Performance of Silica Fume on Strength and Durability of Concrete

K.G.Raveendran¹, V. Rameshkumar², M. Saravanan³, P.Kanmani⁴, S.Sudhakar⁵U.G. Student, Department of Civil Engineering, Prist University, Thanjavur, Tamil Nadu, India^{1,2,3,4,5}

ABSTRACT: In this study, effects of mineral admixtures on the water permeability and compressive strength of concretes containing silica fume (SF) were experimentally investigated. The main parameter investigated in this study is M20 grade concrete with partial replacement of cement by silica fume. They were incorporated into concrete at the levels of 0%, 5%, 10%, 15% and 20%. This paper presents a detailed experimental study on compressive strength, split tensile strength and flexural strength at an age of 7 and 28 days. Test results indicate that use of silica fume in concrete has improved the performance of concrete in strength at a particular percentage replacement. Although the highest compressive strengths of concretes observed was 10% silica fume mix for ordinary Portland cement and were reduced as the increase in the replacement ratios.

KEYWORDS: Silica fume, Compressive strength, Split tensile strength, Flexural strength,

I. INTRODUCTION

Concrete is a most widely used building material for various types of structures due to its structural stability and strength. The process of selecting suitable ingredients of concrete and determining their relative amount with the objective of producing a concrete of the required strength durability and workability as economically as possible is termed the concrete mix design. The compressive strength of hardened concrete is generally considered to be an index of its other properties depends upon many factors. 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 material¹. 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 cement². 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 %^{3,4}. As strength of 15% replacement of cement by silica fume is more than normal concrete. 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 concrete⁵. 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. MATERIALS AND METHODS

Silica fume, also known as micro silica, is an amorphous (non- crystalline) polymorph of silicon dioxide. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm⁶. The main field of application is as pozzolanic material for high performance concrete. Silica fume is an ultrafine airborne material with spherical particles less than 1 μm in diameter, the average being about 0.1 μm. This makes it approximately 100 times smaller than the average cement particle. The unit weight, or bulk density, of silica fume depends on the metal from which it is produced. Its unit weight usually varies from 130 to 430 kg/m. The specific gravity of silica fume is generally in the range of 2.20 to 2.5. In order to measure the specific surface area of silica fume a specialized test called the “BET method” or nitrogen adsorption

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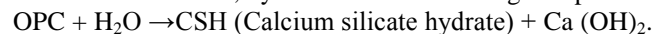
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method must be used. Based on this test the specific surface of silica fume typically ranges from 15,000 to 30,000 m²/kg.

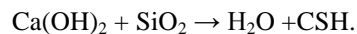
Cement: Cement is made by heating limestone (calcium carbonate) with small quantities of other materials (such as clay) to 1450°C in a kiln, in a process known as calcinations, where by a molecule of carbon dioxide is liberated from the calcium carbonate to form calcium oxide, or quicklime, which is then blended with the other materials that have been included in the mix. The resulting hard substance, called 'clinker', is then ground with a small amount of gypsum into a powder to make 'ordinary Portland cement', the most commonly used type of cement (often referred to as OPC)⁷. Portland cement is a basic ingredient of concrete, mortar and most non-specialty grout. The most common use for portland cement is in the production of concrete. Concrete is a composite material consisting of aggregate (gravel and sand), cement, and water. As a construction material, concrete can be cast in almost any shape desired, and once hardened, can become a structural (load bearing) element.

Mechanism: Silica fume improves concrete through two mechanisms:

Pozzolonic effect: When water is added to cement, hydration occurs forming two products, as shown below:



In the presence of SF, the silicon dioxide from the ORISIL SF will react with the calcium hydroxide to produce more aggregate binding CSH as follows:



The reaction reduces the amount of calcium hydroxide in the concrete. The weaker calcium hydroxide does not contribute to strength. When combined with carbon dioxide, it forms a soluble salt, which will leach through the concrete causing efflorescence, a familiar architectural problem. Concrete is also more vulnerable to sulphate attack, chemical attack and adverse alkali-aggregate reactions when high amounts of calcium hydroxide are present in concrete. **Micro filler effect:** Silica Fume is an extremely fine material, with an average diameter 100 times finer than cement. At a typical dosage of 8% by weight of cement, approximately 100,000 particles for each grain of cement will fill the water spaces in fresh concrete. This eliminates bleed and the weak transition zone between aggregate and paste found in normal concrete. This micro filler effect greatly reduces permeability and improves paste-to aggregate bond in SF concrete compared to conventional concrete⁸. The silica fume react rapidly providing high early strength and durability. The efficiency of silica fume is 3-5 times that of OPC and consequently concrete performance can be improved drastically⁹. Addition of silica fume reduces capillary¹⁰.

The specimen of standard cube of (150mm x 150mm x 150mm) and standard cylinders of (300mm x 100mm) and Prisms of (150mm x 150mm x 750mm) were used to determine the compressive strength, split tensile strength and flexural strength of concrete with different partial replacement of silica fumes. 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. 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 0.4 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 silica fume are discussed in comparison with those of normal concrete.

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Table 1: Results of Compressive Split Tensile and Flexural Strength

Mix	%ofSilicaFume added	CompressiveStrength (N/mm ²)		Splittensile Strength(N/mm ²)		Flexural Strength(N/mm ²)	
		7 days	28 days	7 days	28 days	7 days	28 days
		M1	0	25.27	37.80	3.11	4.67
M2	5	28.43	40.29	3.85	4.8	6.5	7.12
M3	10	33.92	45.66	4.40	4.95	7.25	8.65
M4	15	32.35	43.34	3.73	4.53	7.45	8.92
M5	20	30.58	42.27	3.65	3.88	6.14	7.33

The results of compressive strength were presented in Table 1. 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 Universal Testing Machine (UTM) of capacity 2000Kn. From Fig 3 the compressivestrength is up to 38.3 N/mm² and 47.3 N/mm² at 7 and 28 days. The maximum compressive strength is observed at 10% 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 ability¹¹.

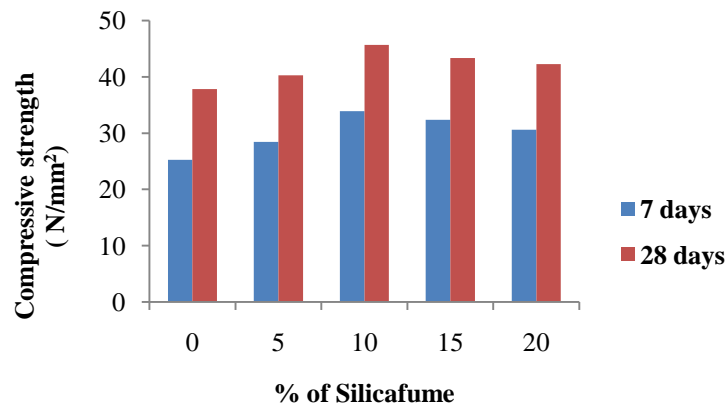


Figure 1: Effect of silica fume on compressive strength of concrete

The results of Split Tensile strength were presented in Table 1. 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/mm² and 4.65N/mm² 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 water cement 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 from15% to 25% .

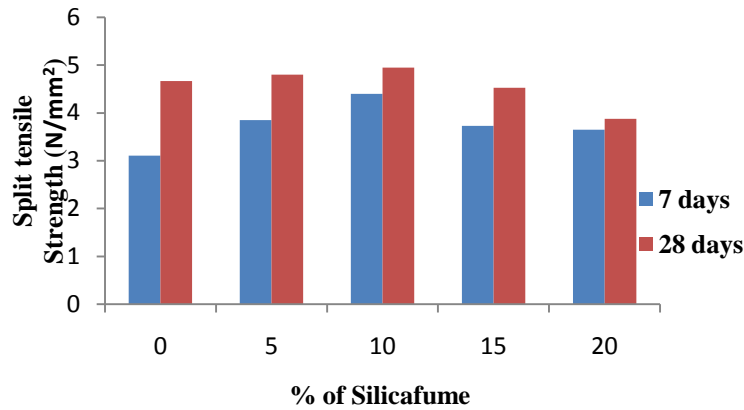


Figure2 Effect of silica fume on split tensile strength of concrete

The results of flexural strength of normal concrete and silica fume replaced concrete were presented in Table 1. 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. From Fig 5 the maximum increase in flexural strength is observed as 7.75N/mm² and 9.38 N/mm² 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 15% replacement level for M40 grades of concrete.

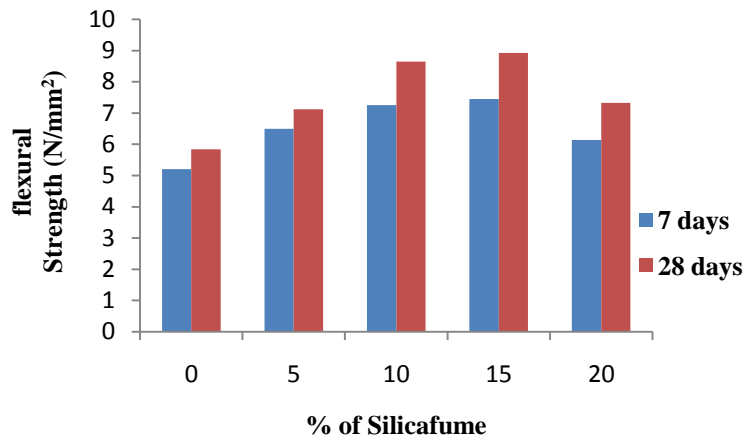


Fig 3 Effect of silica fume on flexural strength of concrete

IV. CONCLUSION

Silica fume increases the strength of concrete more 25%. Silica fume is much cheaper than cement therefore it very important from economical point of view. Silica fume also decrease the voids in concrete. Consistency of cement depends upon its fineness. Silica fume is having greater fineness than cement. When silica fume percentage increases consistency increases greatly. 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.

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REFERENCES

- [1] Bayasi, Zing, Zhou, Jing, "Properties of Silica Fume Concrete and Mortar", ACI Materials Journal, vol. 90 , no.4, pp.349 – 356, 1993.
- [2] DL. VenkateshBabu, SC. Nateshan, Investigations on silica fume concrete, The Indian concrete Journal, September, pp. 57-60, 2004.
- [3] S.A.Khedr, M.N.Abou - Zeid, "Characteristics of Silica-Fume Concrete", Journal of Materials in Civil Engineering, vol.6, no.3, pp.357 – 375, 1994.
- [4] BhanjaSantanu, and Sengupta, Bratish, "Optimum Silica Fume Content and its Mode of Action on Concrete," ACI Materials Journal, vol.100, no.5, pp. 407-412, 2003.
- [5] GR Sensualle, "Strength development of concrete with rice husk ash", Cement and Concrete Composites, 2006.
- [6] Silica fume manual by Oriental TreximPvt. Ltd. (2003).
- [7] M.S. Shetty, Concrete Technology, S. Chand and Company Pvt Ltd. New Delhi, India, 1999.
- [8] Ha-Won Song, Seung-Woo Pack, Sang-Hyeok Nam, Jong- Chul Jang and VeluSaraswathy, Estimation of the permeability of silica fume cement concrete, Construction and building material, vol.24, pp.315-321,2010.
- [9] A.Abdullah,Almusallam, HamoudBeshr, Mohammed Maslehuddin and Omar S.B. Al-Amoudi, Effect of silica fume on the mechanical properties of low quality coarse aggregate concrete, Cement and Concrete Composites, vol.26, pp.891–90 , 2004.
- [10] S.Bhanjaa and B.Sengupta, Influence of silica fume on the tensile strength of concrete, Cement and Concrete Research, vol.35, pp.743– 747, 2005.
- [11] Papayianni , G. Tsohos, N. Oikonomou, P. Mavria, "Influence of superplasticizer type and mix design parameters on the performance of them in concrete mixtures", Cement & Concrete Composite, vol.27, pp.217-222, 2005.
- [12] V.Bhikshma, K.Nitturkarand Y.Venkatesham, "Investigations on mechanical properties of high strength silica fume concrete." Asian journal of civil engineering (building and housing), vol. 10, no. 3, pp.335-346, 2009.
- [13] N.P.Rajamane, J.A. Peter, M.Neelamegam, J. K. Dattatreya and S. Gopalkrishnan, "Studies on compressive strength and porosity of high performance concrete containing silica fume", 22 -23 may, Madras, pp TS1-TS10, (conference proceedings).
- [14] S.VishalGhutke, Prof. PranitaBhandari, Influence of silica fume on concrete, iosr journal of mechanical and civil engineering, pp 44-47, 2014.