

A Comparative Study of Concrete made with Portland Slag Cement, OPC and PPC Containing Silica fume

Niral H Varmora¹, Yogeshkumar V Akbari²

¹PG Student, Department of Civil Engineering, Darshan Institute of Engineering and Technology Rajkot, Gujarat & Gujarat Technological University,

²Professor, Department of Civil Engineering, Darshan Institute of Engineering and Technology Rajkot, Gujarat & Gujarat Technological University,

Abstract— Concrete is worldwide second most consumed materials after steel. The advantages of concrete are many but there are side effects leading to environment issues. As a solution of these issues, one way is a use of industrial by-products in higher value application and need for reduce clinker. This paper focuses on the compression of Physical properties, mechanical properties and evaluate the optimum percentage of silica fume concrete incorporating Portland Slag Cement, Ordinary Portland cement and Portland pozzolana cement with partial replacement by Silica Fume. Total eighty mixes of concrete were prepared including three control mixes, fifty mixes were various three types of cement replacement by Silica fume at 6 % to 14 % at two percent gap variation for Standard grade of concrete M 45. The physical properties investigated in current study include Compacting factor test and slump test. The mechanical properties investigated in current study include compressive strength, splitting tensile strength and flexural strength (modulus of rupture).

Keywords— Portland slag cement, Silica fume, Ground Granulated Blast Furnace Slag (GGBFS), Mechanical properties, Physical property of concrete

I. INTRODUCTION

Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space among the aggregate particles and glues them together. Cement is one of the world's most important industries for several reasons. First, cement is an essential part of concrete and concrete is the foundational material for any construction industry. Second, because of the importance of cement for assorted construction-related activities such as roads, residential and commercial buildings, tunnels and dams, production progression generally reflect economic activity

Cement production India stands next to china, which is the largest producer of cement in the world. 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 of greenhouse effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material. 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.

Silica fume and GGBFS are some of the pozzolanic materials which can be used in concrete as partial replacement of cement When pozzolanic materials are incorporated to concrete, the silica present in these materials are act with the calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C-S-H), which improve the mechanical properties of concrete.

II. MATERIALS AND METHODS

A. MATERIALS

- 1) **CEMENT:** The Ordinary Portland (OPC) 53 Grade conforming IS 269:2015, Portland Slag Cement (PSC) 53 grade conforming IS 455:1989 and Portland pozzolana cement conforming IS 1489:1991.
- 2) **SILICA FUME:** Silica fume is a byproduct in the reduce of high-purity quartz with coke in electric arc furnaces in the manufacture of silicon and ferrosilicon alloys. Micro silica consist of fine element with a surface area on the order of 20,000 m²/kg The densified Silica fume used in this study with 92.21 % silica contain conforming IS 15388 : 2003. The typical physical and chemical property shown in table no 1 & 2 respectively.

Table 1 - Physical Properties of Silica Fume

<u>Physical Properties</u>	<u>Result Obtained</u>
Density	1.89 Kg/m ³
Bulk Density	317 Kg/m ³
Specific Surface Area (BET)	16.44 M ² /gm
Moisture	1.17 %
Accelerated Pozzolanic Strength Activity Index with Portland Cement at 7 Days	>106.3 &

Table 2 - Chemical Property of Silica Fume

<u>Chemical Properties</u>	<u>Result Obtained</u>
Silica as SiO₂	92.21 %
Calcium Oxides as CaO	0.89 %
Magnesium as MgO	0.95 %
Iron as Fe₂O₃	2.34 %
Alumina as Al₂O₃	0.93 %
Sodium Oxide as Na₂O	0.13 %
Potassium Oxide as K₂O	0.28 %
Sulphur Trioxide as SO₃	0.73

- 3) COARSE AND FINE AGGREGATE: Coarse aggregate (CA) and Fine aggregate (FA) was used to work conforming IS 383:2016 from Natural source. FA fraction size was 4.75 mm to 150 μ , Specific gravity and water absorption was 2.69 and 1% respectively and CA fraction size was 20 mm to 4.75 mm, Specific gravity and water absorption was 2.87 and 0.5% respectively.
- 4) WATER AND CHEMICAL ADMIXTURE: The portable water used which pH value not less than 6 as per IS 456: 2000 and High range water reducer (HRWR) chemical admixture also used in this study.

III.METHODS

In this experimental investigation an attempt has been made to find out the strength of concrete produced by replacing the cement with Silica fume in various percentages ranging from 6% to 14% in increments of 2% [0%, 6%, 8%, 10%, 12%, and 14%] compression with OPC, PSC and PPC. Mix design carried out for M45 grade of concrete as per IS 10262:2009 yielded a mix proportion of 1:1.74:2.99 with water cement ratio of 0.41. Specimens were prepared according to the mix proportion and by replacing cement with Silica Fume in different proportion. An increasing trend in compressive strength and flexural strength was observed with increasing replacement of cement. To find out compressive strength, split tensile strength and flexural strength specimens of dimensions 150x150x150 mm, 150x300 mm and 100x100x500 mm were cast and tested as per IS 516: 2018. Details of mix content with various three types of cement with Silica fume, is shown in Table 3.

Table 3 - Various Mix Proportion

Mix – 1 PSC + Silica fume % (M 45)	Mix – 2 OPC + Silica fume % (M 45)	Mix – 3 PPC + Silica Fume % (M 45)
100% PSC + 0% SF	100% OPC + 0% SF	100% OPC + 0% SF
PSC + 6% SF	OPC + 6% SF	PPC + 6% SF
PSC + 8% SF	OPC + 8% SF	PPC + 8% SF
PSC + 10% SF	OPC + 10% SF	PPC + 10% SF
PSC + 12% SF	OPC + 12% SF	PPC + 12% SF
PSC + 14% SF	OPC + 14% SF	PPC + 14% SF

IV. RESULTS AND DISCUSSION

The All work is carried out in single stages, result of all stage is presented in graphical form. Tests are performed on cubes, beams & cylinders and their 7 days, 14 days & 28 days strengths have been determined. A comparison of strengths for 7 days, 14 days and 28 days are also formulated.

A. Workability of Concrete Mixes: The workability of concrete mixes was found out by slump test and compacting factor test Water cement ratio (W/C) was kept constant 0.41 for all the concrete mixes. The workability results of different concrete mixes were shown in Figure 1 & 2.

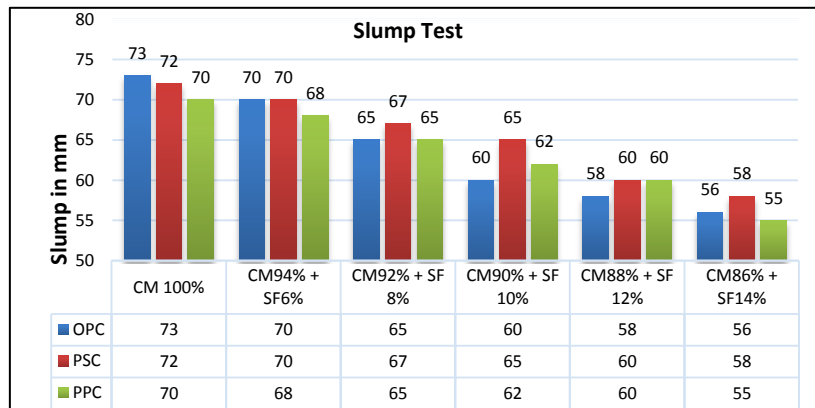


Figure 1 - Slump Test

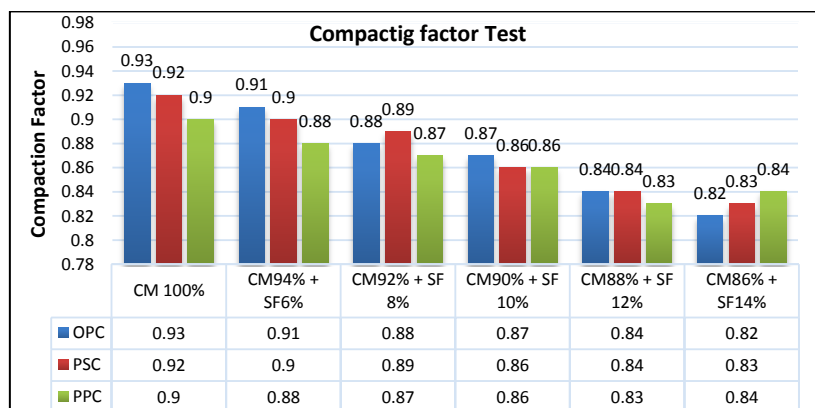


Figure 2 - Compacting Factor Test

B. Compressive Strength: The results of the compressive strength tests conducted on concrete specimens of different mixes cured at different ages are presented and discussed in this section. The compressive strength test were conducted at curing ages of 7 and 28 days. Variation of compressive strength of all the mixes are also shown in Graphs which shows the variation of compressive strength of concrete mixes w.r.t control mix (100% OPC + 0% SF) after 7 and 28 days respectively shown in figure 3 & 4.

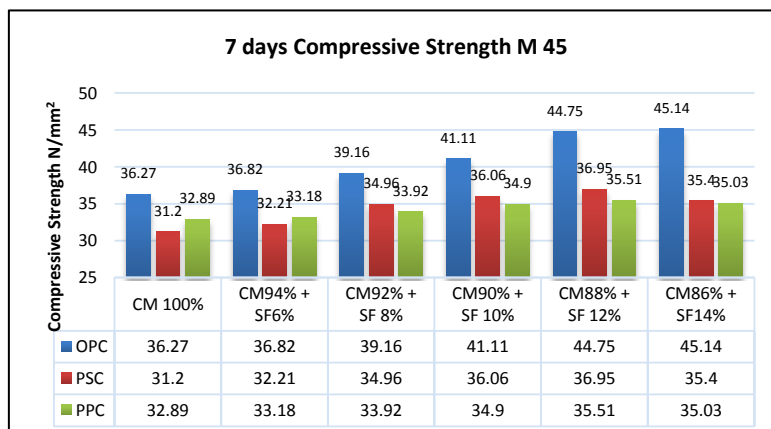


Figure 3 - 7 Days Compressive Strength

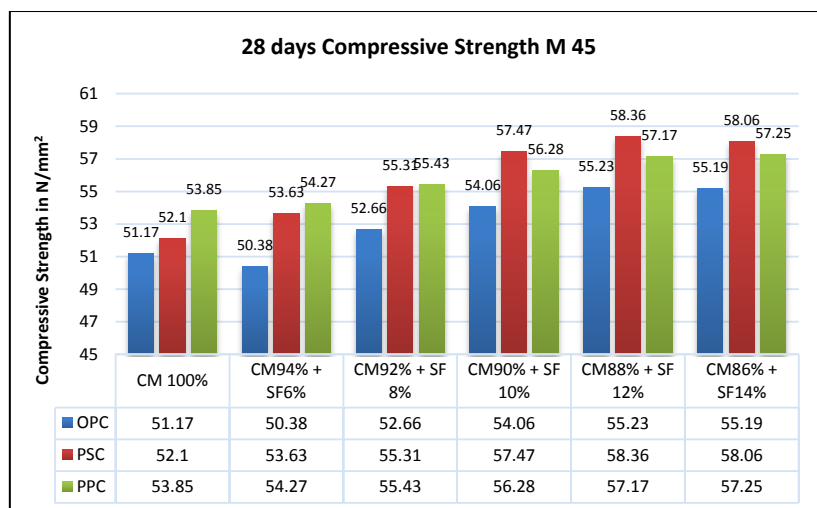


Figure 4 – 28 Days Compressive Strength

C. **Split Tensile Strength Test:** The results of the splitting tensile strength tests conducted on concrete specimens of different mixes. The splitting tensile strength test was conducted at curing ages of 28 days. Variation of splitting tensile strength of all the mixes shown in figure 5.

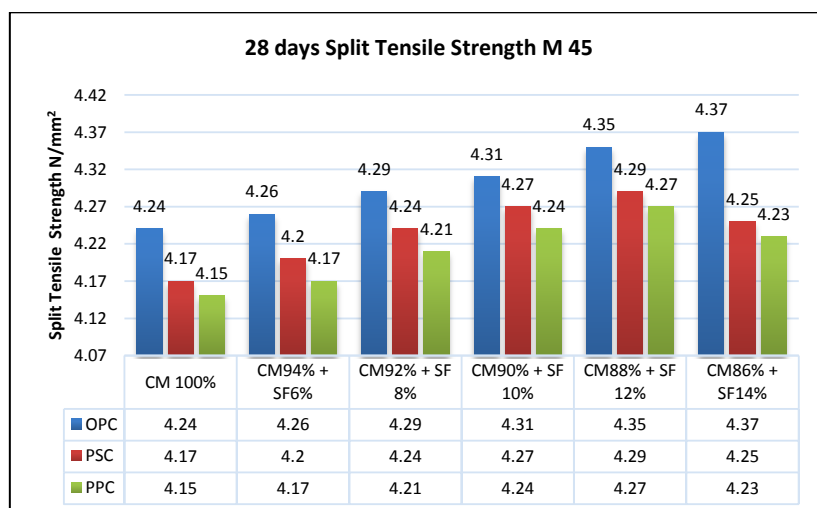


Figure 5 - 28 Days Split Tensile Strength M 45

D. **Flexural Strength Test:** The results of the flexural strength tests conducted on concrete specimens of different mixes. The flexural strength test results of all the mixes at 28 days curing ages shown in figure 6.

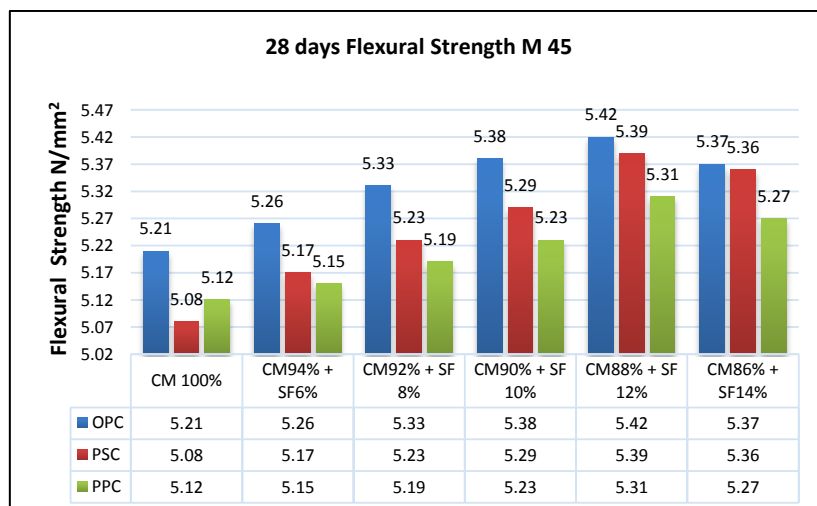


Figure 6 - 28 Days Flexural Strength M 45

V. CONCLUSION

The following conclusion is made from the detailed experimental investigations conducted on the behaviour of standard grade concrete. Compressive strength, Flexural strength, Split tensile strength of concrete Mixes made with and without silica fume has been determined at 7 & 28 days of curing. The strength gained has been determined of silica fume added concrete with addition of 6%, 8%, 10%, 12% & 14% for M 45 grade as a partial replacement of three types of cement (PSC, OPC and PPC) concrete. After performing all the tests and analysing their result, the following conclusions have been derived:

1. Workability of Mix – 1 (OPC) is decreases with increase percentage of silicafume. It is observed that the workability decrease by 4.29 to 30.36 % for 6 to 14 % replacement of silica fume.
2. Compressive strength increased by 0.41 % to 7.35% at the age of 28 days for 6 to 12 % replacement of Silica fume. Splitting Tensile strength also increased by 0.47 % to 2.55 % and Flexural Strength increased by 0.96 to 3.90 % for 6 to 12 % replacement of silica fume as compare with normal mix.
3. Workability of Mix – 2 (PSC) is decreases with increase percentage of silicafume. It is observed that the workability decreases by 2.86 to 24.14 % for 6 to 14 % replacement of silica fume but less decreases as OPC & PPC.
4. Compressive strength Mix – 2 (PSC) is increased by 2.85 % to 10.73 % at the age of 28 days for 6 to 12 % replacement of Silica fume but the Earlier strength (7 days) is less compare with OPC. Splitting Tensile strength also increased by 0.71 % to 2.80 % and Flexural Strength increased by 1.74 to 5.75 % for 6 to 12 % replacement of silica fume as compare with normal mix.
5. Workability of Mix – 3 (PPC) is decreases with increase percentage of silicafume. It is observed that the workability decreases by 2.94 to 27.27 % for 6 to 14 % replacement of silica fume but less decreases as OPC.
6. Compressive strength Mix – 2 (PSC) is increased by 0.77 % & 2.85 % at the age of 28 days for 6 & 8 % replacement of Silica fume but the Earlier strength (7 days) is less compare with OPC and PSC both. Splitting Tensile strength also increased by 0.48 % to 1.43 % and Flexural Strength increased by 0.58 to 1.35 % for 6 & 8 % replacement of silica fume as compare with normal mix.

VI. ACKNOWLEDGEMENT

I take this opportunity to thank my college Darshan Institute of Engineering and Technology for providing laboratory facility and financial support, Prof. Yogesh V. Akbri and all professors who have directly or indirectly helped in this research work. I pay my respects and love to my parents and friends for their love and encouragement throughout my career. Last but not the least I express to friends Jay, Gunjan and Abhi for their help me in my practical work and cooperation and support.

REFERENCES

- [1] Liu, Zhichao, Sherif El-tawil, Will Hansen, and Fazhou Wang. 2018. "Effect of Slag Cement on the Properties of Ultra-High Performance Concrete." *Construction and Building Materials* 190:830–37.
- [2] Patil, Hitesh. 2018. "Optimize Properties of Concrete with Silica Fume." (May 2017):2–6.
- [3] Suryavanshi, Akshay, Siddhartha Nigam, S. K. Mittal, Ram Bharosh, Lakshminarayan College, and M. P. Bhopal. 2018. "An Experimental Study on Partial Replacement of Cement in Concrete by Using Silica Fume."
- [4] Rostami, M. and K. Behfarnia. 2017. "The Effect of Silica Fume on Durability of Alkali Activated Slag Concrete." *Construction and Building Materials* 134:262–68.
- [5] Thomas, Robert and Sulapha Peethamparan. 2016. "Alkali-Activated Slag Cement Concrete." (January):32–39.
- [6] Erdemir, Mustafa and Halil Ibrahim. 2016. "Utilization and Efficiency of Ground Granulated Blast Furnace Slag on Concrete Properties – A Review." 105:423–34.
- [7] Srivastava, Vikas, Rakesh Kumar, V. C. Agarwal, and P. K. Mehta. 2015. "Effect of Silica Fume on Workability and Compressive Strength of OPC Concrete Effect of Silica Fume on Workability and Compressive Strength of OPC Concrete." (January):4–8.
- [8] Divsholi, Bahador Sabet, Tze Yang, Darren Lim, and Susanto Teng. 2014. "Durability Properties and Microstructure of Ground Granulated Blast Furnace Slag Cement Concrete." 8(2):157–64.
- [9] Mazloom, M. 2004. "Effect of Silica Fume on Mechanical Properties of High-Strength Concrete." 26:347–57.
- [10] Boddy, A. M., R. D. Hooton, and M. D. A. Thomas. 2003. "The Effect of the Silica Content of Silica Fume on Its Ability to Control Alkali – Silica Reaction." 33:1263–68.
- [11] BIS: 10262-2009. (2009). Indian concrete mix design guide lines. Bureau of Indian Standards, New Dehli.
- [12] BIS: 456-2000, R. 2005. (2005). Plain and Reinforced Concrete. Bureau of Indian Standards, New Dehli. <https://doi.org/624.1834 TAY>
- [13] BIS: 383-1970, Specification for fine and coarse aggregates from natural sources for concrete. Bureau of Indian Standards, New Delhi.
- [14] BIS: 15388-2003, silica fume - specification. Bureau of Indian Standards, New Delhi
- [15] BIS: 455 – 1989, Portland Slag Cement – Specification Bureau of Indian Standards, New Delhi

BIOGRAPHIES



Niral H. Varmora, postgraduate student at Civil Engineering Department ,Darshan Institute of Engineering and Technology, Rajkot-363650, Gujarat Technological University, Gujarat, India



Yogeshkumar V. Akbari, Professor at Civil Engineering Department, Darshan Institute of Engineering and Technology, Rajkot-363650, Gujarat Technological University, Gujarat, India