

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 6, Issue 12, December 2017

A Study on Effect of Silica Fume and Steel Slag on Various Properties of Concrete

D.Sreehari Rao ¹, Yesupogu Chiranjeevi ²

Assistant Professor, Department of Civil Engineering, Sri Venkateswara University College of Engineering,
Tirupati, Andhra Pradesh, India. ¹

. PG Student, Department of Civil Engineering, Sri Venkateswara University College of Engineering, Tirupati,
Andhra Pradesh, India ²

ABSTRACT: Due to increase in industrial wastes and increase in scarcity of natural construction materials, there is need of some alternative replacement material. Steel slag is a by-product obtained during matte smelting and refining of steel. In this paper it is used as a partial sand replacement in concrete and Silica Fume is used as replacement of Cement.

This research work is concentrated on M25 Grade of Concrete with Steel Slag (10%, 20% & 30%) as replacement for Fine Aggregate and Silica Fume (5%, 10% & 15%) as replacement of Cement and Tests for Compressive strength, Splitting Tensile strength, Flexural Strength, Modulus of Elasticity, Acid Resistance were performed and tabulated.

Compressive strength of concrete with combined application of Steel Slag (10%) & Silica Fume (10%) shows 17.1% improved Compressive Strength compared to Controlled Concrete. Similar trend is observed in Split Tensile Strength, Flexural Strength and Modulus of Elasticity with improved percentages of 13.49%, 10.55% & 7.11% higher than Controlled Concrete. In Acid Resistance, Loss of Weight (%) is observed minimum for Silica Fume (10%) and Loss in Compressive Strength is minimum for Steel Slag (10%) and Silica Fume (10%).

KEYWORDS: Steel Slag, Silica Fume, Partial Replacement, Particle Packing and Strength of Concrete, Splitting Tensile strength, Flexural Strength, Modulus of Elasticity, Acid Resistance, Combination and Strength of Concrete.

I. INTRODUCTION

The Concrete innovation has made colossal walks in past decades. Cement is an extremely solid and flexible malleable development material or Concrete is a composite material that comprises basically of a binding medium inside which are implanted particles or pieces of aggregate. In hydraulic driven bond concrete, the fastener is shaped from a blend of hydraulic driven concrete and water. Steel slag, a by-product of steel making, is produced during the separation of the molten steel from impurities in steel-making furnaces. The slag occurs as a molten liquid melt and is a complex solution of silicates and oxides that solidifies upon cooling

II. OBJECTIVE

This project will present experimental investigation carried out to find the suitability of silica fume and Steel Slag combination in production of concrete. It deals with M 25 grade concrete by replacing cement with Silica Fume (5%,10%,15%) and sand with Steel Slag (10%,20%,30%). Comparison of the test results of Conventional Concrete and Silica Fume and Steel Slag Concrete. Comparison of the test results of Conventional Concrete with combined use of Silica Fume and Steel Slag Concrete

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III. EXPERIMENTAL INVESTIGATION

3.10 PROPERTIES OF MATERIALS

3.11 CEMENT

In the present investigation Ordinary Portland Cement (OPC) of 53 Grade confirming to IS specifications was used. The properties of cement are shown in Table.1.

Table 1. Properties of Cement

S. No	Characteristics	Test results	Requirements as per IS 12269 – 1987
1	Fineness (retained on 90- μ m sieve)	6%	<10%
2	Normal Consistency	33%	--
3	Initial setting time of cement	90 min's	30 minutes (minimum)
4	Final setting time of cement	340 min's	600 minutes (maximum)
5	Expansion in Le-chatelier's method	4 mm	10 mm (maximum)
6	Specific gravity	3.15	3.10 – 3.25

3.12 FINE AGGREGATE

Locally available river sand confirming to IS specifications was used as the fine aggregate in the concrete preparation. The properties of fine aggregate are shown in Table.2.

Table 2. Properties of Fine Aggregate

S.No	Property	Value
1	Specific Gravity	2.67
2	Fineness Modulus	3.05
3	Bulk Density (Loose)	14.50 kN/m ³
4	Grading of Sand	Zone – II

3.13 COARSE AGGREGATE

Crushed granite metal of nominal size 20 mm and 10 mm obtained from the local quarry and confirming to IS specifications were used. The properties of coarse aggregate are shown in Table.3. The coarse aggregate used for the preparation of concrete is a combination of 20 mm and 10 mm size aggregates in ratio 1.5: 1.0.

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Table3. Properties of Coarse Aggregate

S.No	Property	Result
1	Specific Gravity	2.78
2	Bulk Density (Loose)	14.80 kN/m ³
3	Water Absorption	1.2 %
4	Fineness Modulus	7.52

3.14 STEEL SLAG

Steel slag is obtained from Agni Steels Private Limited, Ingur Tamilnadu, India and its specific gravity in fine form was found to be 2.95 and in coarse form it is 3.1. The slag was collected from the open stocking yard of the industry where the slag was exposed to atmosphere over a period of more than 1.5 years. The predominant compounds are dicalcium silicate, tricalcium silicate-dicalcium ferrite, merwinite, calcium aluminate, calcium magnesium iron oxide and free lime and free magnesia (periclase). The relative proportion of all these compounds depends on the steel making process and the cooling rate. The properties of Steel slag are shown in Table 4.

Table 4. Physical Properties of Steel slag

Properties	Value
Specific gravity	Coarse form – 3.1 Fine form – 2.95
Water absorption (%)	0.9
Bulk density (kg/m ³)	1650
Aggregate impact value	13.2
Aggregate crushing value	26.70

3.15 SILICA FUME:

Silica Fume is highly pozzolanic mineral admixture, which is mainly utilized to improve concrete strength and durability of concrete. Silica Fume reacts with calcium hydroxide formed during hydration of cement results in the increase in strength and also the Silica Fume fills the voids between cement particles leads to increase in the durability. Silica Fume is procured from ASTRRA CHEMICALS, Thousand Lights and Chennai. The properties of Silica Fume are shown in Table 6 and Table 7.

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Table 6. Physical Properties of Silica Fume

S.No.	Physical Properties	Results
1	Physical State	Micronised Powder
2	Odour	Odourless
3	Appearance	White Colour Powder
4	Colour	White
5	Pack Density	0.76 gm/cc
6	PH of 5% SOLUTION	6.90
7	Specific Gravity	2.63
8	Moisture	.058%
9	Oil Absorption	55 ml / 100 gms

Table 7. Chemical Properties of Silica Fume

S.No.	Chemical Properties	Results
1	Silica (SiO ₂)	99.886%
2	Alumina (Al ₂ O ₃)	0.043%
3	Ferric Oxide (Fe ₂ O ₃)	0.040%
4	Titanium Oxide (TiO ₂)	0.001%
5	Calcium Oxide (CaO)	0.001%
6	Magnesium Oxide (MgO)	0.000%
7	Pottassium Oxide (K ₂ O)	0.001%
8	Sodium Oxide (Na ₂ O)	0.003%

3.16 WATER

Water used for casting and curing of concrete test specimens is free from impurities which when present can adversely influence the various properties of concrete.

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3.17 CONCRETE MIX PROPORTION

The concrete mix design was proposed by using Indian Standard for control concrete. The grade was M20. The mixture will be prepared with the cement content of 320 kg/m³ and water to cement ratio of 0.5. The mix proportion of materials is 1:2.15:3.66 as per IS 10262-2009.

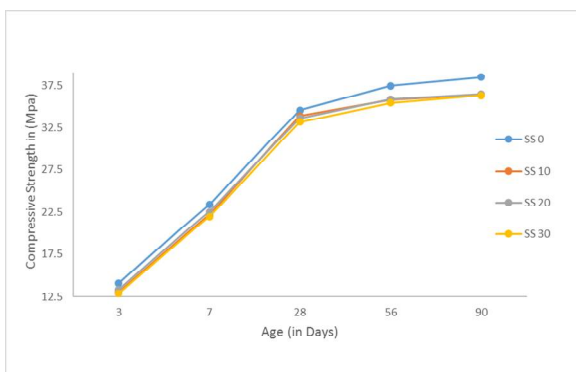
3.20 TEST SPECIMENS

Concrete test specimens consist of 150 mm × 150 mm × 150 mm cubes, cylinders of 150 mm diameter and 300 mm height and 100 mm × 100 mm × 500 mm prisms. Concrete cube specimens were tested at 3, 7, 28, 56 & 90 days of curing to obtain the compressive strength of concrete. Cylindrical specimens were tested at the age of 28 days to obtain the compressive strength, split tensile strength and Modulus of Elasticity of concrete. The prisms were tested at the age of 28 days to obtain the flexural strength of concrete. The rate of loading is as per the Indian Standard specifications. Acid attack test is also performed for durability

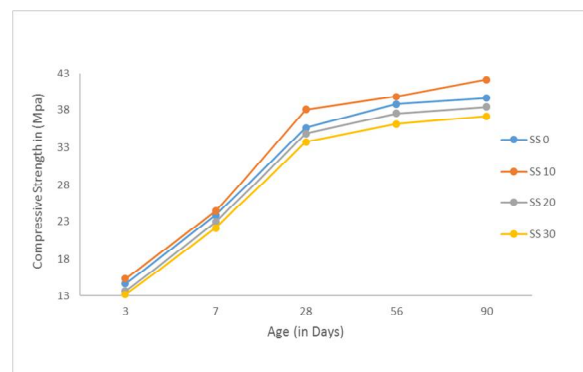
IV. RESULTS AND DISCUSSIONS

4.10 COMPRESSIVE STRENGTH

The variation of the cube compressive strength with the age of M25 grade concrete prepared using the various proportions of Silica Fume & Steel Slag is shown in Fig.1. The Cube Compressive Strength of Controlled Concrete is compared with various proportions of Steel Slag (10%, 20% & 30%) and Silica Fume (5%, 10% & 15%) is shown in Fig No. 1 (i), (ii) & (iii). It can be observed that the Concrete with Steel Slag (10%) & Silica Fume (10%) expresses higher Compressive Strength compared to other mixes.



(i) 5% Silica Fume



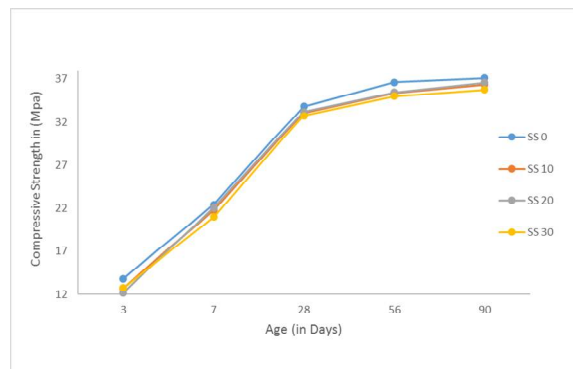
(ii) 10% Silica Fume

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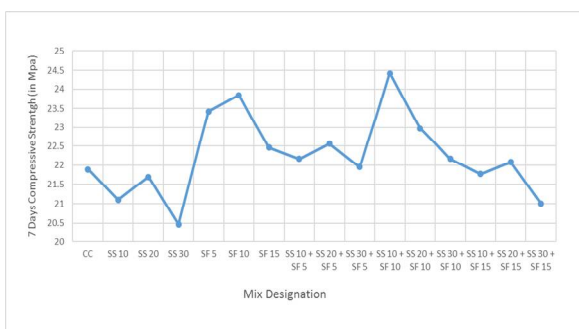
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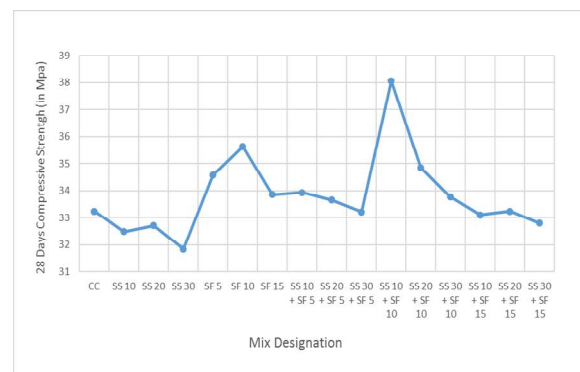
(iii) 15% Silica Fume

Fig. 1. Variation of the cube compressive strength with the age of M25 grade concrete prepared using the various proportions of Silica Fume & Steel Slag.

Fig 2 shows the variation of 7 – Days and 28 Days Compressive Strength of Concrete with various proportions of Steel Slag (10%, 20% & 30%) and Silica Fume (5%, 10% & 15%).



(i) 7 Days Compressive Strength



(ii) 28 Days Compressive Strength

Fig. 2. Variation of 7 – Days & 28 Days Cube Compressive Strength of M25 Grade Concrete for different percentages of Silica Fume & Steel Slag.

4.20 SPLIT TENSILE STRENGTH

The variation of the Split Tensile strength of M25 grade concrete prepared using the different percentages of Silica Fume & Steel Slag is shown in Fig.3. The Split tensile strength of Control concrete is 3.49 MPa. It is observed that all the replacements & admixtures exhibits improved Strength Characteristics compared to Control Concrete, But the Optimum mix of Steel Slag (10%) & Silica Fume (10%) resulted in significant improvement with 13.49 % more than Control Concrete

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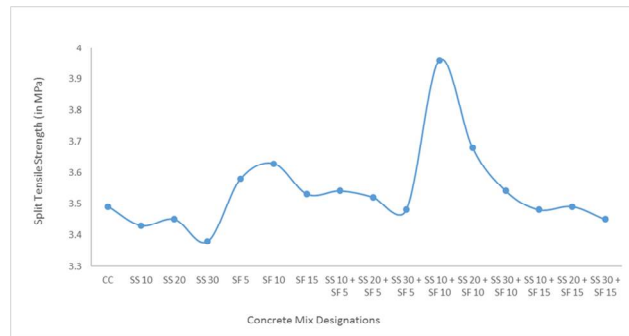


Fig. 3. Variation of Split Tensile strength of M25 grade concrete prepared using the different percentages of Silica Fume & Steel Slag.

4.30 FLEXURAL STRENGTH

The variation of the Flexural strength of M25 grade concrete prepared using the different percentages of Silica Fume & Steel Slag is shown in Fig.4. The Flexural strength of Control concrete is 5.4 MPa. It is observed that all the replacements & admixtures exhibits improved Strength Characteristics compared to Control Concrete, But the Optimum mix of Steel Slag (10%) & Silica Fume (10%) resulted in significant improvement with 10.55 % more than Control Concrete

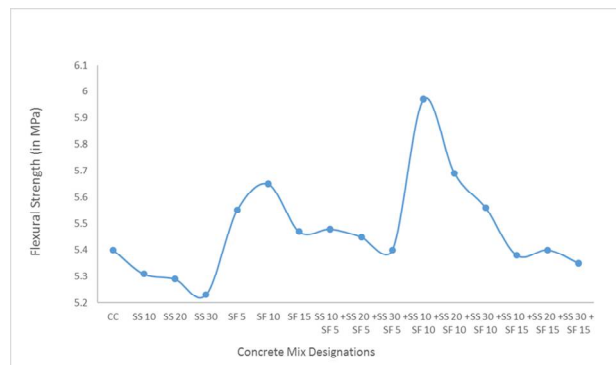


Fig. 4. Variation of Flexural strength of M25 grade concrete prepared using the different percentages of Silica Fume & Steel Slag.

4.40 MODULUS OF ELASTICITY

The variation of the Modulus of Elasticity of M25 grade concrete prepared using the different percentages of Silica Fume & Steel Slag is shown in Fig.5. The Modulus of Elasticity of Control concrete is 29.22 Gpa. It is observed that all the replacements & admixtures exhibits improved Strength Characteristics compared to Control Concrete, But the Optimum mix of Steel Slag (10%) & Silica Fume (10%) resulted in significant improvement with 7.11 % more than Control Concrete

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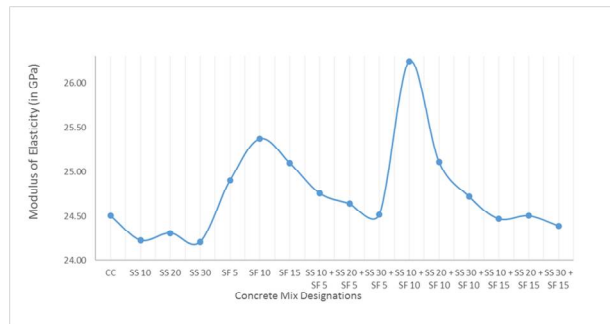
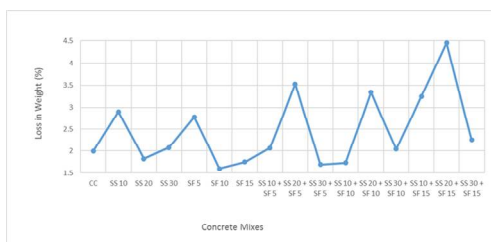


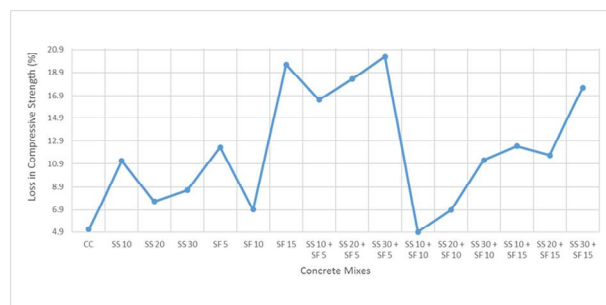
Fig. 5. Variation of Modulus of Elasticity of M25 grade concrete prepared using the different percentages of Silica Fume & Steel Slag

4.50 SULPHATE RESISTANCE

The variation of the Loss in Compressive Strength & Loss of Weight of M25 grade concrete prepared using the different percentages of Silica Fume & Steel Slag is shown in Fig.6. The Loss of Weight (%) is minimum for combined proportion of Silica Fume (10%) when compared to other proportions and Control Concrete. It can also be observed that only Concrete with Steel Slag (10%) and Silica Fume (10%) has lesser % Loss of Compressive Strength compared to other mixes.



(i) % Loss in Weight



(ii) % Loss in Compressive Strength

Fig. 6. Variation of Loss in Compressive Strength & Loss of Weight of M25 grade concrete prepared using the different percentages of Silica Fume & Steel Slag

V. CONCLUSIONS

It can be observed that the compressive strength of concrete with Combined application of Steel Slag (10%) & Silica Fume (10%) shows 17.1% improved Compressive Strength compared to Controlled Concrete. Similar trend can be observed in the case of Split Tensile Strength, There is 13.49 % increase in Split Tensile strength in Concrete (SS10% &SF10%) when compared to Control Concrete. Same trend followed in the case of Flexural Strength, There is 10.55 % increase in Flexural strength in Concrete (SS10% &SF10%) when compared to Control Concrete. The Modulus of Elasticity of Control concrete is 29.22 Gpa. It is observed that all the replacements & admixtures exhibits improved Strength Characteristics compared to Control Concrete, But the Optimum mix of Steel Slag (10%) & Silica Fume (10%) resulted in significant improvement with 7.11 % more than Control Concrete. The Loss of Weight (%) is minimum for combined proportion of Silica Fume (10%) when compared to other proportions and Control Concrete. It

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