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An experimental study on partial replacement of cement by silica fume and steel slag

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ABSTRACT

In this industrious world due to pollution, the amount of emission of co_2 has to be reduced. And so the amount of CO_2 which is being used as main binding materials in construction industry can be replaced by its alternative material. One of the materials is steel slag and silica fume which are by-products from steel industry. In this experimental study, we are partially replacing cement by silica fume and again cement by st**eel slag with 2.5%, 5%, 7.5%&10%.** Mechanical properties are being studied to select which material is best and suited for cement in construction industry. The concrete blocks were prepared and tested and the results were discussed.

Keywords: Cement, Fine aggregate, Coarse aggregate, Steel slag, Silica fume

INTRODUCTION

The steel slag in industrial is large and increases with time. In each country the steel slag composition is different, since it is affected by socioeconomic characteristics, consumption patterns and waste management programs, but generally the level of steel slag in waste composition is high. The largest component of the steel slag smelting. The large volume of materials required for construction is potentially a major area for the reuse of waste materials. Recycling in concrete has advantages since it is widely used and has a long service life, which means that the waste is being removed from the waste stream for a long period. Because the amount of mineral aggregates required in concrete is large, the environmental benefits are not only related to the safe disposal of bulk waste, but also to the reduction of environmental impacts arising from the extraction of fine aggregates. In the recent past, there have been considerable attempts for improving the properties of concrete with respect to strength and durability, especially in aggressive environments. High performance concrete appears to be better choice for a strong and durable structure. A large amount of by-product or wastes such as fly-ash, copper slag, silica fume etc. are generated by industries, which causes environmental as well as health problems due to dumping and disposal. Proper introduction of silica fume in concrete improves both the mechanical and durability characteristics of the concrete. This paper present literature review on replacement of Cement by Silica Fume and steel slag [1-5].

Definition of silica fume

Silica fume is also known as micro silica or condensed silica fume, is used as an artificial pozzolanic admixture. It is a material resulting from reduction of quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. Chemical composition of silica fume contains more than 90 percent silicon dioxide Other constituents are carbon, Sulphur and oxides of

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aluminum, iron, calcium, magnesium, sodium and potassium. The physical composition of silica fume diameter is about 0.1micron to 0.2 microns; Surface area about 30,000 m^2/kg and Density varies from 150 to 700 kg/m^3.

Definition of steel slag

Steel slag is a by-product of the conversion of iron to steel, Process and it presents differences depending on the raw materials and process. Fifty million tons per year of steel slag are produced as a residue in the world. In Europe every year nearly 12 million tons of steel slags are produced. Owing to the intensive research work during the last 30 years, today about 65% of the produced steel slags are used on qualified fields of application. But the remaining 35% of these slags are still dumped. Because the chemical composition of steel slags is highly variable, the mineral composition of steel slag alsovaries. Olivine, merwinite, C3S, C2S, C4AF, C2F, RO phase (CaO–FeO–MnO–MgO solid solution) and free-CaO are common minerals in steel slag.

LITERATURE REVIEW

Md.shams fabrex ansai, ajay swarur, dhananjay Yadav et al., (2018)

This experimental study investigates partially replacement of cement with silica fumes. The M30 grade of concrete is used. The main objective of this study is to determine of directly replacement of admixture in a high % of cement. The following tests are carried out such as compressive strength. Split tensile strength and flexure strength.

K.Thangaselvi (2015)

This experimental study investigates strength and durability of concrete using steel slag as a partial replacement. In this study, the replacement was done with coarse aggregate by steel slag for different proportions of 0%,20%,40%,60%,80% and M40 grade of concrete are used.The tests which are done are compressive strength, split tensile strength and flexural strength.

Faseyemi victor ajileye (2012)

This experimental study investigation on microsilica (silica fume) as partial cement replacement in concrete. Repla cement are done @ ratio of 0 to 25% and curing are undertaken about 7, 14 and 28 days respectively the compressive strength of M30 grade are determined.

Huang yi, guopingxu, huinguo cheng, et al., (2012)

The current utilization rate of steel slag is only 22% in china, far behind the developed countries. At present, the amount of slag deposited in storage yard adds up to 30Mt, leading to the occupation of farm land and serious pollution to the environment. Improving the slag utilization is an important way to resolve these problems. The physical and chemical characteristics of steel slag were analyzed and then the research progress of steel slag utilization at home and abroad as recycled raw material in steel enterprise interior, aggregate of road and hydraulic construction, cement additive and concrete admixture, materials for waste water or gas treatment, construction materials and fertilizer in agriculture production were introduced respectively. At last, the important routes and critical problems for large-scale utilization of steel slag were proposed.

MATERIAL

Cement

Ordinary Portland cement of 53-grade was used as it satisfied the requirements of IS: 269- 1969 and results have been tabulated in table

Table – 1 Cement properties

CEMENT PROPERTIES	
Initial Setting Time	37 mins
Final Setting Time	578 mins

Consistency	26%
Fineness modulus	90 microns

Coarse Aggregate

Coarse aggregate shall comply with the requirement of IS 383 as for as possible crushed Aggregate shall be used for ensuring adequate durability. The aggregate used for concrete the nominal maxi size of coarse aggregate used in Production of shall be 20 mm.

Table – 2 Material requirement

As per design M40 Grade Material Requirement for 1 m^3	
Material	**Quantity in kgs**
Cement	450 kg
Sand	862 kg
Aggregate	1097 kg
Water	197 litres

Fine aggregate: Fine aggregate shall conform to requirement.

Table – 3 Properties of aggregate

Types of Tests	Types of Aggregate		
	CA	**FA**	**Steel slag**
Specific Gravity	2.9	2.88	3.51
Water Absorption	0.5%	3.5%	Nil
Moisture content	Nil	Nil	Nil

Steel slag

Steel slag is a by-product of the conversion of iron to steel process and it present differences depending upon the raw materials and process. 15 million tons of steel slag is produced. Owing to the intensive research work during the last 30 years, today about 65% of the produced steel slag are used on qualified fields on applications. But the remaining 35% of steel slag are still dumped.

Silica Fume

Silica Fume, also known as micro silica, is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. it is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consist of spherical particles with an average particle diameter of 150mm.The main field of application is as pozzolanic material for high performance concrete.

Water

The water used for mixing concrete mix should be potable drinking water having pH range of 6 to 8.

Design Mix

The HSC is defined as higher concrete whose characteristic strength ranges from 50 and above. Hence for my work I'm considering M40 grade concrete. The mix design for M40 grade concrete is carried out using the Indian standard code 10262:2009. For which the water cement ratio is kept as the least value of 0.45 for the slump value is assumed as 100mm, the fine aggregate of Zone I, coarse aggregate of 20mm size and below.

- Cement = 450 kg/m3
- Water = 197 litres
- Fine Aggregate = 862 kg/m^3
- Coarse Aggregate = 1097 kg/m^3
- Admixture = 2% of conplast

The proportion for the mix is 1:2.69:3.42

Experimental investigation

The fresh property test that is considered is the slump cone test. The result obtained for the slump cone test is

Table – 4 Slump Values of different mixes

Slump Values of different mixes	
Concrete Mix	Slump Value (mm)
0%	95
2.5%	96
5%	92
7.5%	103
10%	98

The cubes casted are of 150 x 150 x 150mm in dimension. The cylinders are of 150mm in diameter and 300mm in length. The prisms are of 100m x 100mm x 500mm. The cubes, cylinders and prisms are kept for curing for the duration of 7, 14 and 28 days in water.

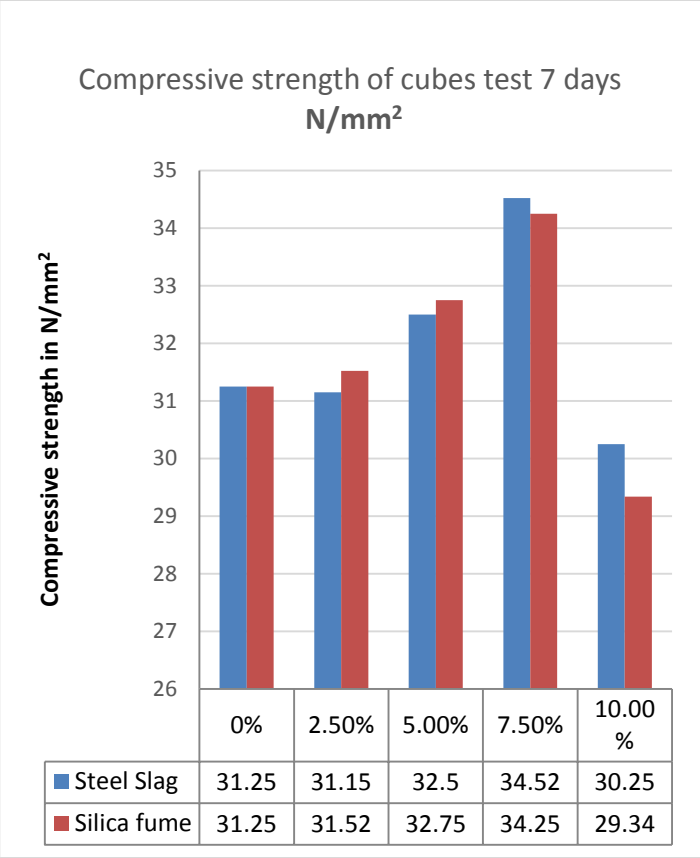
EXPERIMENTAL RESULTS

The strength test that are considered for are Compressive strength, split tensile and the flexural strength test.

Compressive Strength Test

Table – 5.1 COMPRESSIVE STRENGTH OF CUBES 7 DAYS

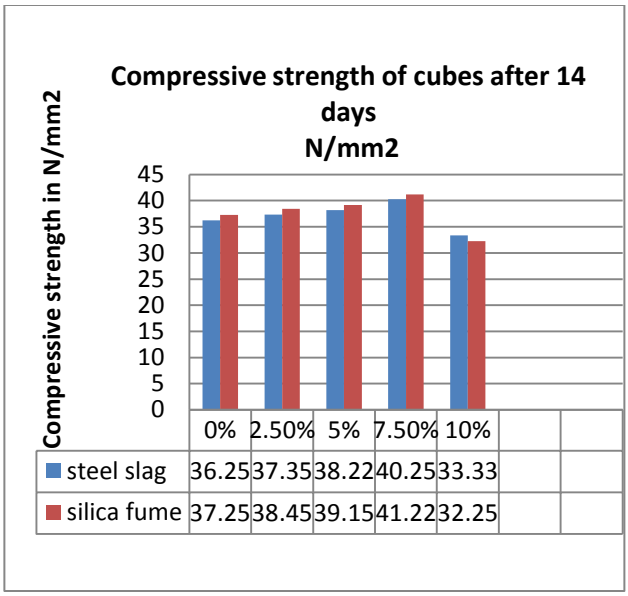
COMPRESSIVE STRENGTH OF CUBES 7 DAYS N/mm^2			
% replacement of Steel Slag	Strength (N/mm^2)	% replacement of Silica fume	Strength (N/mm^2)
0%	31.25	0%	31.25
2.5%	31.15	2.5%	31.52
5%	32.50	5%	32.75
7.5%	34.52	7.5%	34.25
10%	30.25	10%	29.34



Graph -1 Compressive strength of cubes test 7 days

Table 5.2 Compressive strength of cubes 14 days

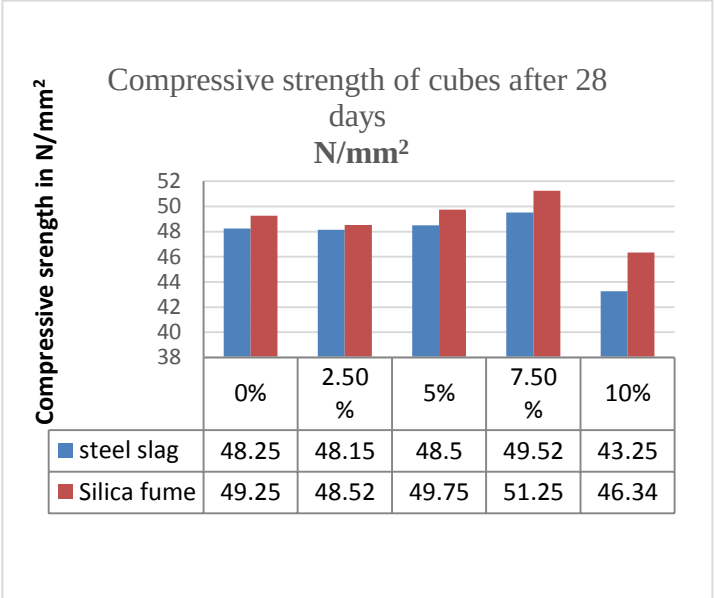
COMPRESSIVE STRENGTH OF CUBES 14 DAYS N/mm²			
% replacement of Steel Slag	Strength (N/mm²)	% replacement of Silica fume	Strength (N/mm²)
0%	36.25	0%	37.25
2.5%	37.35	2.5%	38.45
5%	38.22	5%	39.15
7.5%	40.25	7.5%	41.22
10%	33.33	10%	32.25



Graph – 2 COMPRESSIVE STRENGTH OF CUBES 14 DAYS

Table.5.3 Compressive strength of cubes 28 days

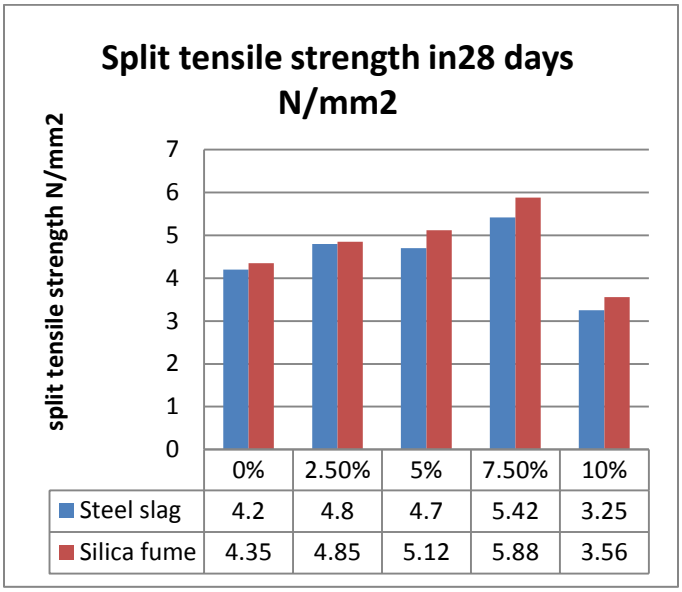
COMPRESSIVE STRENGTH OF CUBES 28 DAYS N/mm^2			
% replacement of Steel Slag	Strength (N/mm^2)	% replacement of Silica fume	Strength (N/mm^2)
0%	48.25	0%	49.25
2.5%	48.15	2.5%	48.52
5%	48.50	5%	49.75
7.5%	49.52	7.5%	51.25
10%	43.25	10%	46.34



Graph – 3 Compressive strength of cubes 28 days

Table.5.4 – Split Tensile Strength Test

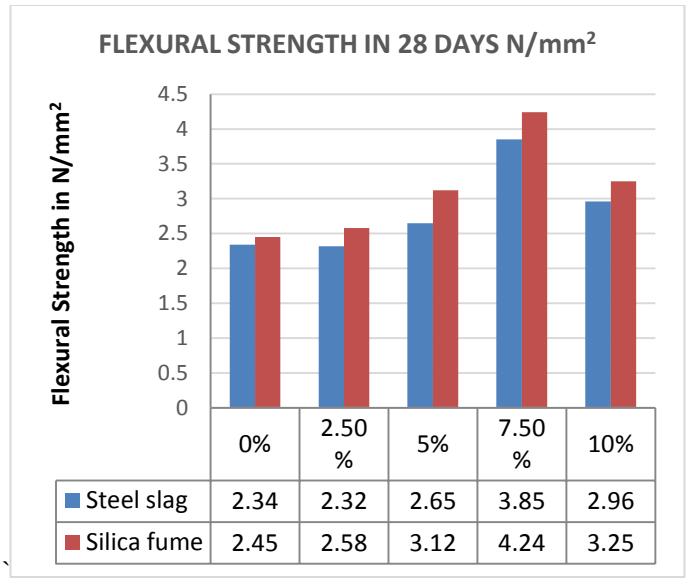
	SPLIT TENSILE STRENGTH OF CYLINDER 28 DAYS N/mm^2		
% replacement of Steel Slag	Strength (N/mm^2)	% replacement of Silica fume	Strength (N/mm^2)
0%	4.2	0%	4.35
2.5%	4.8	2.5%	4.85
5%	4.7	5%	5.12
7.5%	5.42	7.5%	5.88
10%	3.25	10%	3.56



Graph – 4 Split tensile strength of cylinder 28 days

Table – 5.5 Flexural Strength of Prism at 28 Days

FLEXURAL STRENGTH OF PRISM 28 DAYS N/mm^2			
% replacement of Steel Slag	Strength (N/mm^2)	% replacement of Silica fume	Strength (N/mm^2)
0%	2.34	0%	2.45
2.5%	2.32	2.5%	2.58
5%	2.65	5%	3.12
7.5%	3.85	7.5%	4.24
10%	2.96	10%	3.25



Graph – 5 Flexural strength of prism at 28 days

CONCLUSION

From the result and discussions, the following conclusions were made.

- The replacement of fine aggregate using steel slag in concrete there by increases the self-weight of the concrete
- The workability of concrete increased with the increase in steel slag content of fine aggregate replacements at same water-cement ratio.
- Form the results of compressive strength, split tensile strength and flexural strength, the concrete shown higher value at 7.5% replacement of cement using steel slag. So it is recommended that 7.5% of cement can be replaced by copper slag and in the case of Silica Fume it is noted that the replacement by 7.5% gives the maximum strength.
- The construction industry is the only area for safe use of waste materials, which reduces cost of construction

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