INFLUENCE OF SILICA FUME ON STEEL SLAG CONCRETE

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Abstract - *Concrete is the most adaptable construction material since it very well may be intended to withstand the harshest conditions while taking on the most uplifting structures. Designers are ceaselessly stretching the boundaries to improve its exhibition with the assistance of creative compound admixtures and advantageous cementitious materials. These days, most solid combination contains strengthening cementitious material which structures part of the cementitious segment. These materials are dominant part side-effects from different cycles. The primary advantages of supplementary cementitious materials (SCM) are their capacity to supplant certain measure of concrete and still ready to show cementitious property, subsequently decreasing the expense of utilizing Portland concrete. The utilization of these results assists with using these waste materials as well as improves the properties of cement in new and hydrated states. In the current work various tests were done to make similar investigations of different mechanical properties of cement mixed Slag concrete , Fly ash concrete and their mix (in 1:1 extent). These binder mixes are altered by 10% and 20% of silica fumes in substitution. The fine aggregates utilized is normal sand agree to zone II according to IS 383-1982.The coarse aggregates utilized is steel making slag of 20 mm size. The elements are added in 1: 1.5: 3 ranges. The properties examined are 7days, 28 days and 56 days compressive strength, flexural strength, and other properties.*

Key Words: Compressive strength, Flexural strength, Silica fumes, Fly ash, Coarse aggregates

1. INTRODUCTION

Concrete is a combination of concrete, sand, coarse aggregates and water. Its prosperity lies in its flexibility as can be intended to withstand harshest conditions while taking on the most uplifting structures. Architects and researchers are further attempting to build its cutoff points with the assistance of inventive substance admixtures and different SCMs. Early SCMs comprised of normal, promptly accessible materials like volcanic ash or diatomaceous earth. The designing wonders like Roman reservoir conduits, the Coliseum are instances of this procedure utilized by Greeks and Romans. These days, most solid mix contains SCMs which are fundamentally results or waste materials from other mechanical cycles. The SCMs can be isolated in two classes dependent on their sort of response : water driven and pozzolanic. Pressure driven materials respond straightforwardly with water to shape cementitious compound like GGBS. Pozzolanic materials don't have any cementitious property however when utilized with concrete or lime respond with calcium hydroxide to shape items having cementitious successes

1.1 Silica Fume

Silica fume is a byproduct in the reduction of high-purity quartz with coke in electric arc furnaces in the production of silicon and ferrosilicon alloys. Silica fume consists of fine particles with a surface area on the order of 215,280 ft^2/lb (20,000 m^2/kg) when measured by nitrogen adsorption techniques, with particles approximately one hundredth the size of the average cement because of its extreme fineness and high silica content, silica fume is a very effective pozzolanic material particle. Silica fume is added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength, and abrasion resistance. These improvements stems from both the mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolanic reactions between the silica fume and free calcium hydroxide in the paste. Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions .When silica fume is incorporated, the rate of cement hydration increases at the early hours .The increased rate of hydration may be attributable to the ability of silica fume to provide nucleating sites to precipitating hydration products. It has been reported that the pozzolanic reaction of silica fume is very significant and the non- evaporable water content decreases between 90 and 550 days at low water /cement ratios with the addition of silica fume. During the last decade, considerable attention has been given to the use of silica fume as a partial replacement of cement to produce high-strength concrete.

1.2 Steel Slag

The Steel slag, a byproduct of steel making, is produced during the separation of molten steel from impurities in steel making furnaces. This can be used as aggregate in concrete. Steel slag aggregate generally exhibit a propensity to expand because of the presence of free lime and magnesium oxides that have not reacted with the silicate structure and that can hydrated and expand in humid environments. This potentially expansive nature (volume changes up to 10 percent or more attributable to the hydration of calcium and magnesium oxides) could cause difficulties with products containing steel slag, and is one reason why steel slag aggregate are not used in concrete construction. Steel slag is currently used as aggregate in hot mix asphalt surface applications, but there is a need for some additional work to determine the feasibility of utilizing this industrial by-product more wisely as a replacement for both fine and coarse aggregates in a conventional concrete mixture. Most of the volume of concrete is aggregates. Replacing all or some portion of natural aggregates with steel slag would lead to considerable environmental benefits. Steel slag has high specific gravity, high abrasion value than naturally available aggregate apart from the drawbacks like more water absorption, high alkalis. Therefore with proper treatments it can be used as coarse aggregate in concrete. The production of a HSC may be hampered if the aggregates are weak. Weak and marginal aggregates are widespread in many parts of the world and there is a concern as to the production of HSC in those regions. Incorporation of silica fume is one of the methods of enhancing the strength of concrete, particularly when the aggregates are of low quality.

2. EXPERIMENTAL METHODOLOGY

2.1. Silica Fume

Silica fume is a side-effect in the decrease of high-virtue quartz with coke in electric curve heaters in the creation of silicon and ferrosilicon composites. Silica rage comprises of fine particles with a surface zone on the request for 215,280 ft^2/lb (20,000 m^2/kg) when estimated by nitrogen adsorption methods, with particles roughly 100th the size of the average concrete Because of its outrageous fineness and high silica content, silica fume is an extremely powerful pozzolanic material molecule.

Silica fume is added to Portland concrete cement to improve its properties, specifically its compressive strength, bond strength, and scraped area obstruction. These upgrades originates from both the mechanical enhancements coming about because of expansion of a fine powder to the concrete glue blend just as from the pozzolanic responses between the silica smoke and free calcium hydroxide in the glue. Expansion of silica seethe additionally diminishes the porousness of cement to chloride particles, which shields the building up steel of cement from consumption, particularly in chloride-rich conditions like beach front areas .When silica rage is consolidated, the pace of concrete hydration increments at the early hours The expanded pace of hydration might be owing to the capacity of silica fume to give nucleating locales to accelerating hydration items. It has been accounted for that the pozzolanic response of silica fume is extremely critical and the non-evaporable water content reductions somewhere in the range of 90 and 550 days at low water/cement proportions with the expansion of silica fume.

2.2 Physical and chemical Properties of silica fume

The properties of silica fume were determined in laboratory. Specific gravity of silica flume is 2.27.The chemical analysis of silica fume is given below in Table 1. It is also compared with ASTM

Table 1 chemical Properties of silica fume

Silica fume	ASTM-C-1240	Actual Analysis
SiO2	85% min	86.70%
LOI	6% max	2.50%
Moisture	3%	0.70%
Bulk Density	550 to 700	600

2.3 Steel Slag

Steel slag is the residue of steel production process and composed of silicates and oxides of unwanted components in steel. Fifty million tons each time of LD slag were created as a buildup from Basic Oxygen Process (BOP) on the planet. To utilize these slags in concrete, its water driven properties ought to be known. Substance creation is one of the significant boundaries deciding the pressure driven properties of the slags. By and large, it is expected that the higher the alkalinity, the higher the water driven properties. On the off chance that alkalinity is more prominent than 1.8, it ought to be considered as cementitious material.

3. EXPERIMENTAL STUDY ON MORTAR

Here we prepared mortar with ratio 1:3 from different types of cement plus silica fume replacement as binder mix and sand as fine aggregate. Then its physical properties like capillary absorption consistency, compressive strength and porosity was predicted. These test results both in tabular form and graphical presentation are given below.

3.1 Normal Consistency for Mortar

Normal consistency of different binder mixes was determined using the following procedure referring to IS 4031: part 4 (1988):300 gm. of sample coarser than 150 micron sieve is taken. Approximate percentage of water was added to the sample and was mixed thoroughly for 2-3 minutes. Paste was placed in the Vicat's mould and was kept under the needle of Vicat's apparatus. Needle was released quickly after making it touch the surface of the sample. Check was made whether the reading was coming in between 5-7 mm or not and same process was repeated if not. The percentage of water with which the above condition is satisfied is called normal consistency. Normal consistency of different binder mixes were tabulated below in Table 2.

Table 2 Normal consistency of different binder mixes

Mix	Description	Cement (grams)	Silica fume (grams)	Consistency (%)
SC0	SC	300	0	31.5
SC10	SC with 10% SF	270	30	35
SC20	SC with 20% SF	240	60	40.5
FC0	FC	300	0	37.5
FC10	FC with 10% SF	270	30	47
FC20	FC with 20% SF	240	60	55.5
SFC0	SC:FC (1:1)	150 each	0	36.5
SFC10	SC:FC (1:1) with 10% SF	135 each	30	41.5
SFC20	SC:FC (1:1) with 20% SF	120 each	60	47.5

Where, SC = slag cement FC = fly ash cement
SF = silica fume
SFC = slag and fly ash cement
SC0 = Slag cement with 0% silica fume replacement.
SC10 = Slag cement with 10% silica fume replacement.

From the above table we can conclude that water requirement increases with increase in percentage of replacement by silica fume and fly ash cement consumes more water due to its fineness. Water requirement or normal consistency of a binder mix increases with increment in percentage of silica fume replacement.
Water requirement in case of fly ash cement binder mix is more because it is finer when compared to slag cement.

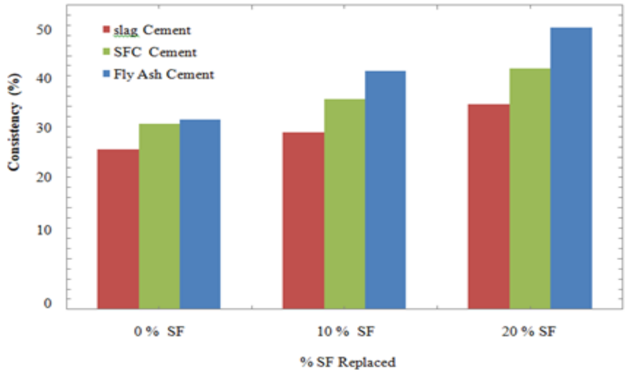

Fig-1 Consistency of Mortar

From the above graph we can conclude that water requirement increases with increase in percentage of replacement by silica fume and fly ash cement consumes more water due to its fineness. Water requirement or normal consistency of a binder mix increases with increment in percentage of silica fume replacement.
Water requirement in case of fly ash cement binder mix is more because it is finer when compared to slag cement.

3.2 Compressive Strength of Mortar

Compressive Strength of different mortars after 7 days and 28 days are tabulated in table 3.

Table 3 Compressive Strength of different mortars after 7 days and 28 days

Type of cement	% of SF replaced	7 days	28 days
Slag cement (SC)	0	18.91	29.43
	10	25.97	35.09
	20	34.13	42.12
Fly ash cement (FC)	0	14.82	26.57
	10	27.07	31.74
	20	31.43	37.23
Slag and fly ash cement blend (1:1) (SFC)	0	15.73	32.57
	10	22.58	37.69
	20	27.89	40.12

From the above table, we can reason that early or 7 days strength and 28 days strength increments with increment in level of substitution by silica rage. Early addition of solidarity is more in the event of fly ash concrete and gain of solidarity at later stages is more if there should be an occurrence of slag concrete. the explanation behind early addition of solidarity in fly ash concrete could be quick response between fly ash and silica rage particles because of fine nature. as slag particles are coarser than fly ash, response rate is moderately sluggish and thus gain of early strength isn't excessively a lot yet at later stages gain of solidarity is more. All fastener blends shows that up to 20% supplanting of concrete with silica seethe the Compressive strength increments with expanding portion of silica Fume. Early strength taking all things together folio blends increments in with 5% substitution by silica fume. The equivalent is seen if there should arise an occurrence of 10% substitution. Be that as it may, among three sorts of fasteners, acquire in fly ash concrete is more. The strength increments amazingly by supplanting any kind of concrete by silica fume up to 15%.

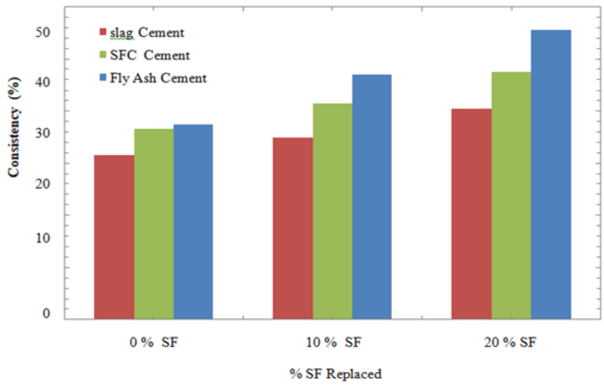

Fig- 2 Compressive strength for mortar for 7 days

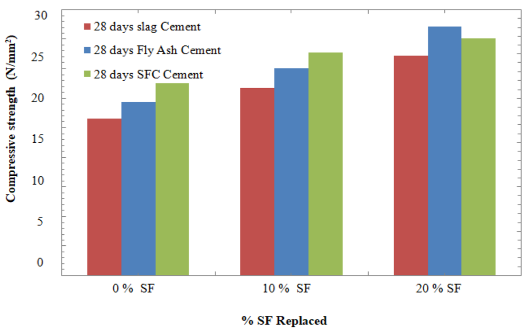

Fig- 2 Compressive strength for mortar for 28 day

4 RESULTS AND DISCUSSIONS

4.1 Experimental Study on Concrete Cube

Here we prepared concrete with ratio 1:1.5:3 from different types of cement + silica fume replacement as binder mix sand as fine aggregate and steel slag as coarse aggregate. Then its physical properties like capillary absorption, water/cement ratio, compressive strength, porosity, flexural strength, and wet-dry test was predicted.

4.2 Water /Cement Ratio and Slump

The water cement ratio and slump of steel slag concrete with different binder mix with silica fume replacement is given below.

Table 4 the water cement ratio and slump of steel slag concrete with different binder mix

Type of cement	% of SF replaced	W/C Ratio	Slump in (mm)
Fly ash cement	0	0.51	52
	10	0.58	52
	20	0.591	58
Slag cement	0	0.47	63
	10	0.518	50
	20	0.581	55
Slag and fly ash cement blend (1:1)	0	0.489	60
	10	0.543	53
	20	0.544	52

From the above table we concluded that W/C ratio increases with increase in silica fume replacement. Because silica fume consumes more water.

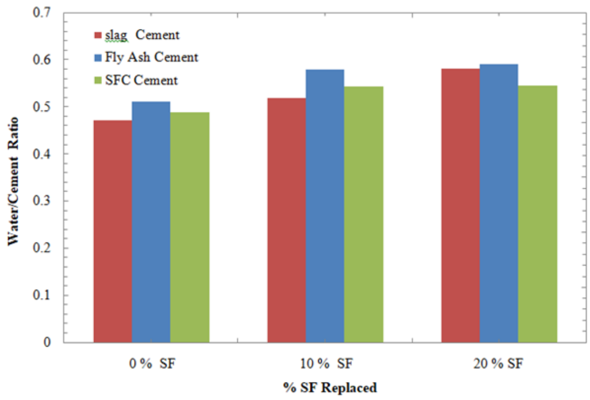

Fig-4: Water Cement Ratio for steel slag concrete

4.2 Compressive Strength by Rebound Hammer Method

Compressive Strength of different concrete cubes after 7 days, 28 days and 56 days were tabulated in Table 5.

Table 5 Compressive Strength of different concrete cubes after 7 days, 28 days and 56 days

Type of cement	% of SF replaced	7 days	28 days	56 days
Fly ash cement	0	24.54	29.55	36.4
	10	21	25,7	25.94
	20	21.4	22.9	29.2
Slag cement	0	18.2	22.3	26.35
	10	18.6	22.3	27.4
	20	18.3	21.4	27.5
Slag and fly ash cement blend (1:1)	0	20.9	25.4	31.45
	10	21.8	23	27.44
	20	21.4	20.9	28.23

From the above table, we can conclude that early or 7 days strength, 28 days and 56 days strength decreases with increase in percentage of replacement by silica fume.

4.3 Compressive Strength by Compression Testing Machine

Compressive Strength of different mortars after 7days, 28days and 56 days were tabulated in Table 6

Table 6 Compressive Strength of different mortars after 7days, 28days and 56 days

Type of cement	% of SF replaced	7days	28days	56 days
Fly ash cement	0	23.33	37.1	45.1
	10	21.61	27.77	30.44
	20	20.66	23.1	28
Slag cement	0	16.6	26.21	28.44
	10	18.44	25.33	25.55
	20	19.2	24.89	21.1
Slag and fly ash cement blend (1:1)	0	27.05	27.55	33.11
	10	22	23.77	29.77
	20	20	22.88	28.88

From the above table, we can conclude that early or 7 days strength, 28 days and 56 days strength decreases with increase in percentage of replacement by silica fume. This is due to the weak bond formation between cement paste and steel slag.

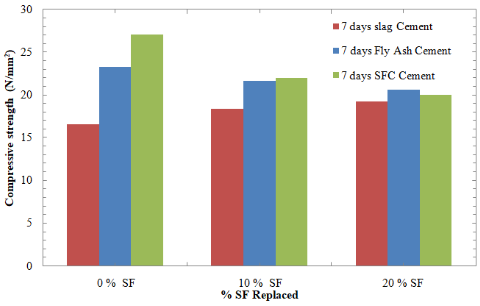

Fig-5: Compressive strength of concrete for 7 days

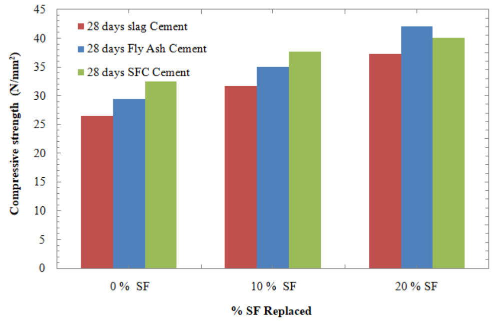

Fig-6: Compressive strength of concrete for 28 days

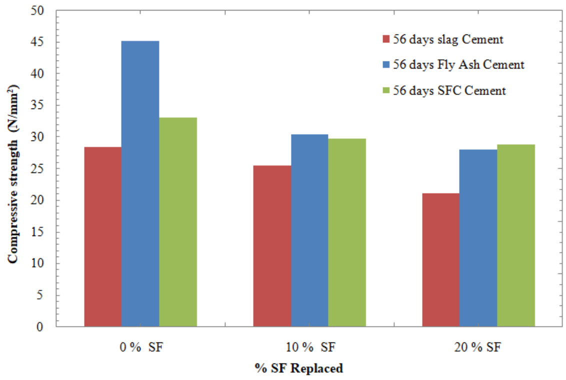

Fig-7: Compressive strength of concrete for 56 days

From the above graph, we can conclude that early or 7 days strength, 28 days and 56 days strength decreases with increase in percentage of replacement by silica fume. This is due to the weak bond formation between cement paste and steel slag.

4.4 Flexural Test

The flexural strength of steel slag concrete at 28 days and 56 days is given in table 7.

Table 7 the flexural strength of steel slag concrete at 28 days and 56 days

Type of cement	% of SF replaced	28 days(N/mm²)	56 days (N/mm²)
Fly ash cement (FC)	0	6.875	4
	10	7	4.25
	20	6.875	4.5
Slag cement (SC)	0	7	5
	10	6.5	3.55
	20	6.125	3.975
Slag and fly ash cement blend (1:1) (SFC)	0	7	4.5
	10	6.725	3.23
	20	4.75	2.975

From above table we see that flexural strength of steel slag concrete is decreased from 28 days to 56 days.

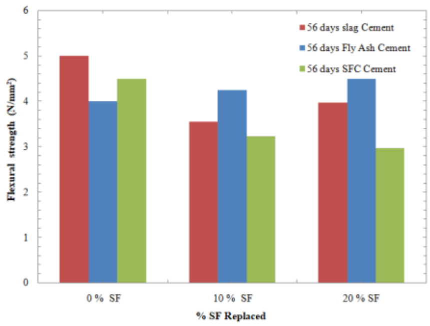

Fig-8: Flexural strength of concrete for 56 days

5. CONCLUSIONS

Combination of fly ash concrete and silica flume makes the solid more strong or tacky than the solid containing slag concrete and silica seethe causing arrangement of more voids with fly ash concrete. In this manner the solid blends containing fly ash and silica fumes show higher slender ingestion and porosity than concrete blends containing slag concrete and silica fume. The absolute substitution of common coarse aggregates by steel slag isn't suggested in concrete. A fractional supplanting with fly ash concrete may assist with creating high strength concrete with appropriately treated steel slag. The steel slag ought to be appropriately treated by storing it in open for in any event one year to permit the free CaO and MgO to hydrate and along these lines to decrease the extension in later age.

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