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EXPERIMENTAL REPORT ON STEEL SLAG CONCRETE WITH POZZOLANAS

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ABSTRACT

Concrete is the most versatile construction material because it can be designed to withstand the harshest environments while taking on the most inspirational forms. Engineers are continually pushing the limits to improve its performance with the help of innovative chemical admixtures and supplementary cementitious materials. Nowadays, most concrete mixture contains supplementary cementitious material which forms part of the cementitious component. These materials are majority byproducts from other processes. The main benefits of SCMs are their ability to replace certain amount of cement and still able to display cementitious property, thus reducing the cost of using Portland cement. The fast growth in instralisation has resulted in tons and tons of byproduct or waste materials, which can be used as SCMs such as fly ash, silica fume, ground granulated blast furnace slag, steel slag etc. The use of these byproducts not only helps to utilize these waste materials but also enhances the properties of concrete in fresh and hydrated states. Slag cement and fly ash are the two most common SCMs used in concrete. Perhaps the most successful SCM is silica fume because it improves both strength and durability of concrete to such extent that modern design rules call for the addition of silica fume for design of high strength concrete. To design high strength concrete good quality aggregates is also required. Steel slag is an industrial byproduct obtained from the steel manufacturing industry. This can be used as aggregate in concrete. It 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 byproduct more wisely as a replacement for both fine and coarse aggregates in a conventional concrete mixture. Replacing all or some portion of natural aggregates with steel slag would lead to considerable environmental benefits. Steel slag aggregate generally exhibit a propensity to expand because of the presence of free lime and magnesium oxides hence steel slag aggregates are not used in concrete making. Proper weathering treatment and use of pozzolanic materials like silica fume with steel slag is reported to reduce the expansion of the concrete.

However, all these materials have certain shortfalls but a proper combination of them can compensate each other's drawbacks matrix product with enhance overall quality. In the present work a series of tests were carried out to make comparative studies of various mechanical properties of concrete mixes prepared by using ACC brand Slag cement , Fly ash cement and their blend (in 1:1 proportion). These binder mixes are modified by 10% and 20% of silica fume in replacement. The fine aggregate used is natural sand comply to zone II as per IS 383-1982.The coarse aggregate used is steel making slag of 20 mm down size. The ingredients are mixed in 1: 1.5: 3 proportions. The properties studied are 7days, 28days and 56 days compressive strengths, flexural strength, porosity, capillary absorption.

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The main conclusions drawn are inclusion of silica fume increases the water requirement of binder mixes to make paste of normal consistency. Water requirement increase with increasing dose of silica fume. Water requirement is more with fly ash cement than slag cement. The same trend is obtained for water binder ratio while making concrete to achieve a target slump of 50-70 mm. Comparatively higher early strength gain (7-days) is obtained with fly ash cement while later age strength (28 days) gain is obtained with slag cement. Their blended mix shows comparatively moderate strength gain at both early and later ages. Mixing of silica fume had made concrete sticky ie more plastic specifically with fly ash cement. The porosity and capillary absorption tests conducted on mortar mixes show decrease in capillary absorption and porosity with increase in silica fume percentage with both types of cements. The decrease is more with fly ash cement than slag cement. But the reverse pattern is obtained for concrete i.e. the results show decrease in 7days,28 days and 56 days compressive strength of concrete due to inclusion of silica fume in the matrix. The increasing dose of silica fume show further decrease in strength at every stage. Almost same trend is obtained for flexural strength also. The specimens without silica fume had fine cracks which are more visible in concrete made with slag cement than fly ash cement.
Keywords: Cementitious Material, Steel Slag, Slag Cement, Silica Fume, Fly Ash Cement.

I.INTRODUCTION

Concrete is a mixture of cement, sand, coarse aggregate and water. Its success lies in its versatility as can be designed to withstand harshest environments while taking on the most inspirational forms. Engineers and scientists are further trying to increase its limits with the help of innovative chemical admixtures and various supplementary cementations materials SCMs.

II. SUPPLEMENTARY CEMENTITIOUS MATERIAL

More recently, strict environmental –pollution controls and regulations have produced an increase in the industrial wastes and sub graded byproducts which can be used as SCMs such as fly ash, silica fume, ground granulated blast furnace slag etc. The use of SCMs in concrete constructions not only prevent these materials to check the pollution but also to enhance the properties of concrete in fresh and hydrated states.

The SCMs can be divided in two categories based on their type of reaction : hydraulic and pozzolanic. Hydraulic materials react directly with water to form cementitious compound like GGBS. Pozzolanic materials do not have any cementitious property but when used with cement or lime react with calcium hydroxide to form products possessing cementitious prosperities.

1.2.Ground granulated blast furnace Slag: It is hydraulic type of SCM

Ground granulated blast furnace slag (GGBS or GGBFS) is obtained by quenching molten iron slag ,a by-product of iron and steel making from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder.

Ground granulated blast furnace slag (GGBFS) has been utilized for many years as an additional cementitious material in Portland cement concretes, either as a mineral admixture or as a component of blended cement. Granulated blast furnace slag typically replaces 35–65% Portland cement in concrete. The use of GGBFS as a

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partial replacement of ordinary Portland cement improves strength and durability of concrete by creating a denser matrix and thereby increasing the service life of concrete structures. It has a higher proportion of the strength-enhancing calcium silicate hydrates (CSH) than concrete made with Portland cement only, and a reduced content of free lime, which does not contribute to concrete strength.

1.2.Fly ash: It is pozzolanic SC material.

Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally capturedfrom the chimneys of coal-fired power plants, and is one of two types of ash that jointly are known as **coal ash**; the other, bottom ash, is removed from the bottom of coal furnaces. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO). Fly ash is classified as Class F and Class C types.

1.3.Silica Fume: It is also a type of pozzolanic material.

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.

1.4.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.

II. MATERIALS & PROPERTIES

2.1.Physical Properties of silica fume.

The properties of silica fume were determined in laboratory. Specific gravity analysis is given below.

Materials	**Specific gravity**
Silica fume	2.27

2.2 Chemical Analysis of silica fume

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The chemical analysis of silica fume is given below in Table. It is also compared with ASTM

Silica fume	ASTM-C-1240	Actual Analysis
SiO_2	85% min	86.7%
LOI	6% Max	2.5%
Moisture	3%	0.7%
Pozz Activity Index	105% min	129%
Sp Surface Area	>15 m2/gm	22 m2/gm
Bulk Density	550 to 700	600
+45	10% max	0.7%

2.3. Sieve Analysis of Steel slag

Sieve Analysis of steel slag in done to know the grade of the aggregate. This is given in Table

Sieve size	Wt Retain	Cum WtRet^n	% Cu wtRet^n	% Passing
20 mm	270 gm	0.270 kg	5.4	94.6
12.5 mm	3522 gm	3.792 kg	75.84	21.16
10 mm	790 gm	4.582 kg	91.64	8.36
4.75 mm	334 gm	4.916 kg	98.62	1.68
Total	5000 gm			

No gradation was found from the above test.

2.4. Physical properties of Steel slag.

The different physical properties of steel slag are given below in Table

Material	Specific gravity	Water absorption in %
Steel slag	1.634	3.8%

2.5. XRD Analysis of Steel slag.

From XRD Analysis of steel slag we can find what type Alkalis present. These are tabulated in Table

Chemical Compound	Visible	Ref-Code	Score
Na_2O	Yes	03-1074	10
K_2O	Yes	77-2176	10

2.6. Physical Properties of Slag cement.

Before proceeding to experimental work , the physical properties of slag cement is determined. Consistency is the main properties of cement for determining water content for mortar. Vicats apparatus is used to determine consistency, initial setting time and final setting time. Specific gravity of cement was determined The properties of slag by cement Lechatel is given in Table

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Cement	Consistency in %	Specific gravity	Initial setting time	Final setting time
Slag cement	32	2.95	2 hour	4 hour
SC10	35			
SC20	40.5			

SC 10 - Slag cement with 10% silica fume Replacement.

SC20 - Slag cement with 20% silica fume Replacement.

III. RESULTS AND DISCUSSIONS

3.1 EXPERIMENTAL STUDY ON MORTAR.

3.1.1 Normal Consistency for Mortar:

Normal consistency of different binder mixes were tabulated below in Table

Mix	Description	Cement (grams)	Silica fume (gms)	Consistency
SC0	SC	300	00	31.5
SC10	SC with 10% SF	270	30	35
SC20	SC with 20% SF	240	60	40.5
FC0	FC	300	00	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	00	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

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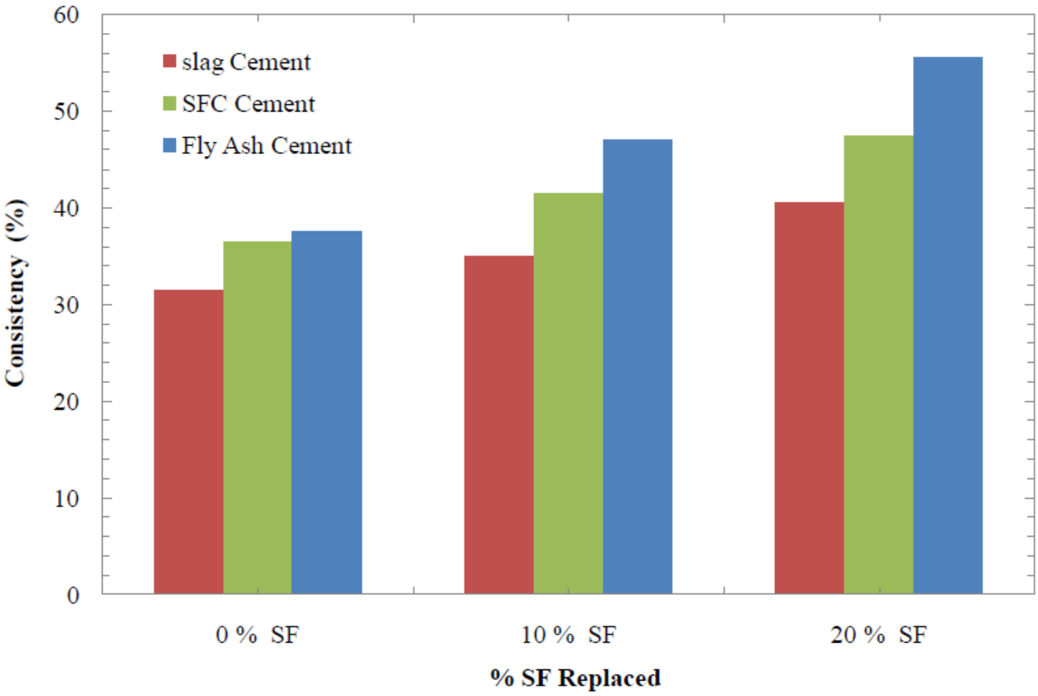

Figure.5.1 Consistency of Mortar.

3.1.2 Compressive Strength of Mortar.

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

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

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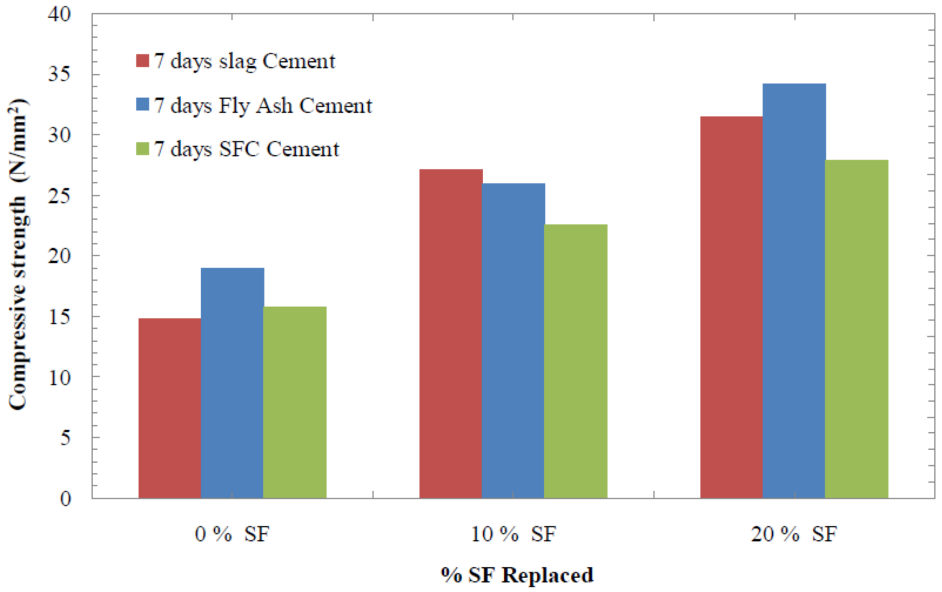
Figure.5.2



Compressive strength for mortar for 7 days

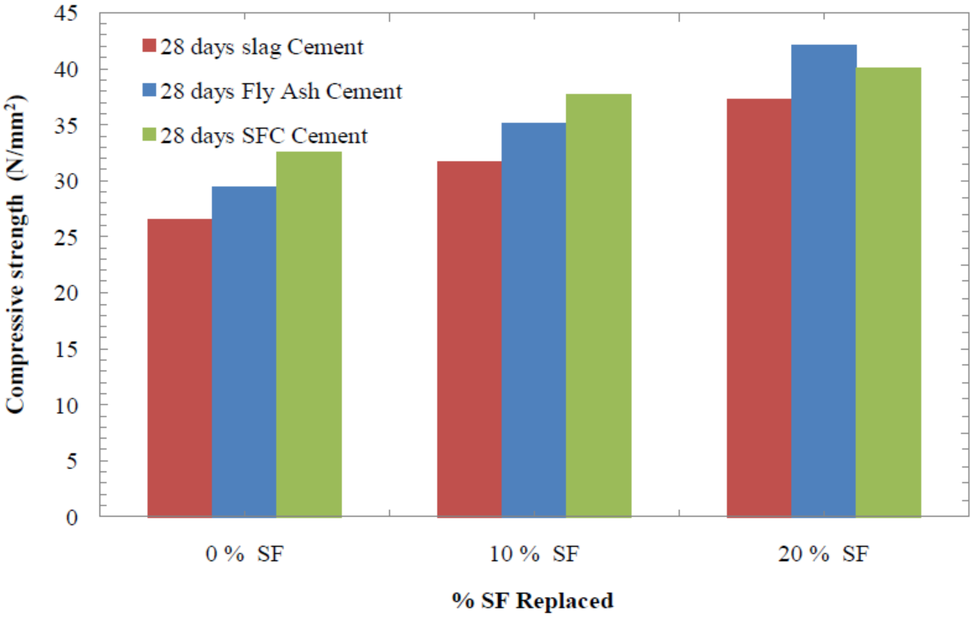


Figure.4.3 compressive strength for mortar for 28 day

3.2.3 Compressive Strength by Compression Testing Machine:

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

Type of cement	% of SF replaced	7days	28days	56 days
Fly ash cement	0	10.88	31.33	42.1
	10	10	23.33	28.44
	20	9.55	19.55	25
Slag cement	0	19.33	28.66	30.44
	10	21.33	27.55	27.55

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	20	22.22	27.11	25.1
Slag and fly ash cement blend (1:1)	0	26.88	43.11	44.11
	10	21.77	37.11	39.77
	20	20	35.77	38.88

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. which is shown by SEM (Scanning Electron Microscope) Analysis, which are given below

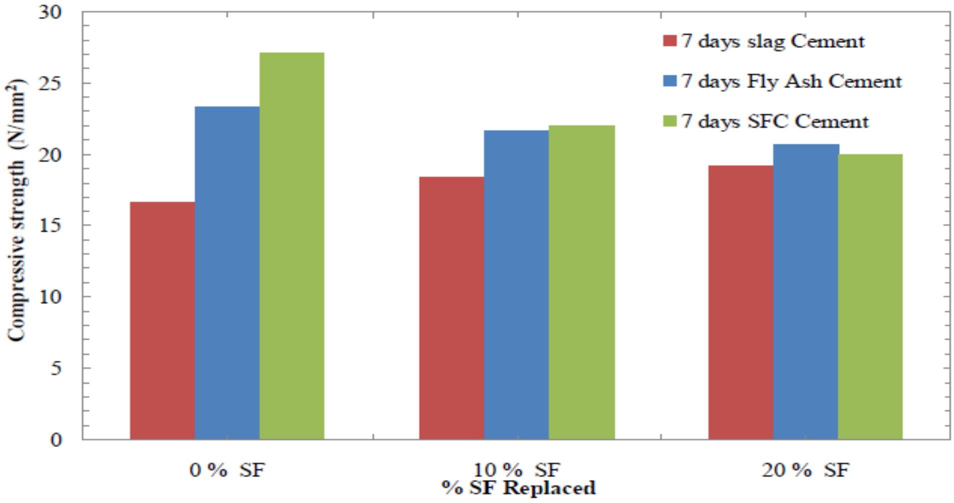

Figure.5.9 Compressive strength of concrete for 7 days

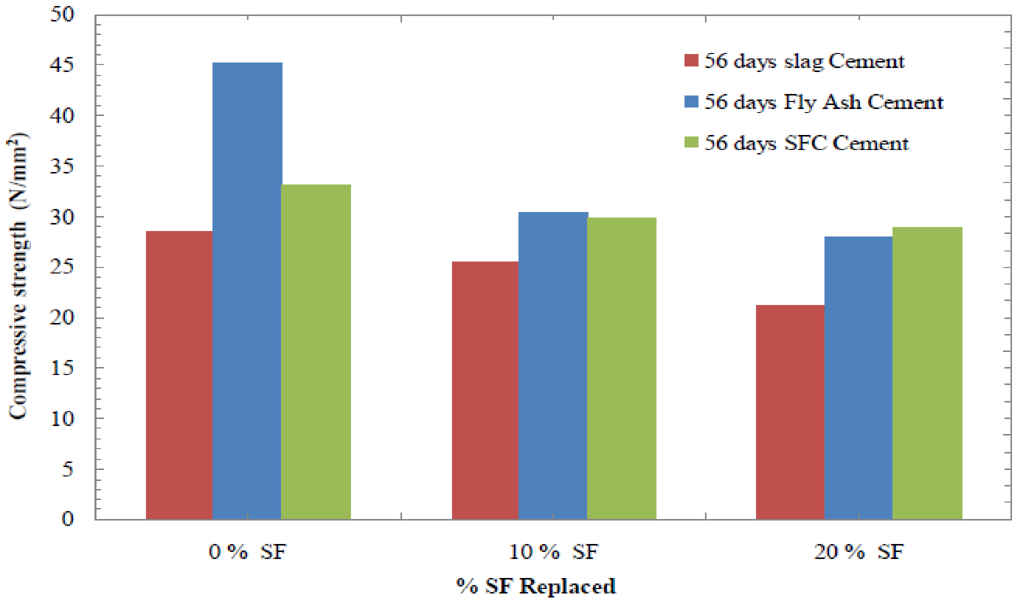

Figure.5.10 Compressive strength of concrete for 28 days

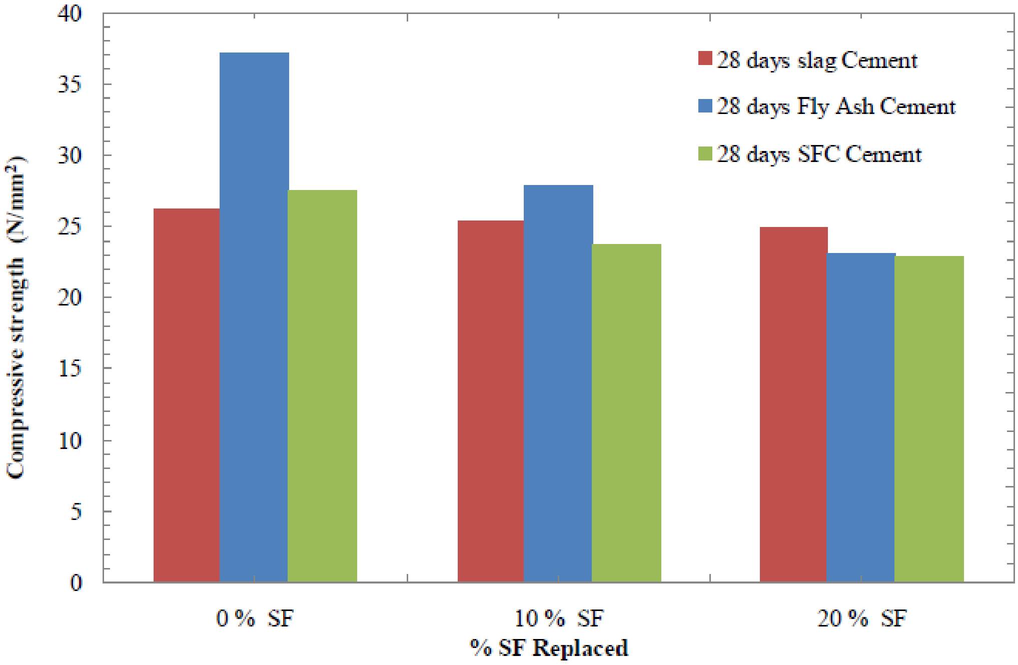

Figure.5.11 Compressive strength of concrete for 56 days

3.2.5 Flexural Test.

The flexural strength of steel slag concrete at 28 days and 56 days is given below.

Type of cement	% of SF replaced	28 days(N/mm^2)	56 days (N/mm^2)
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.

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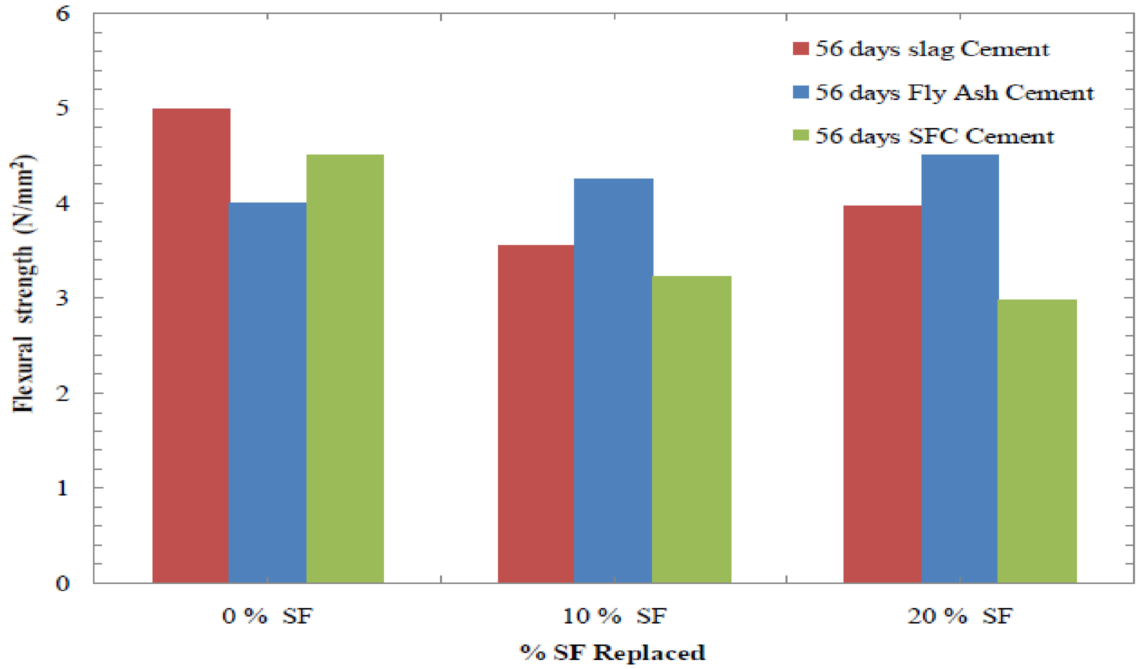

Figure.5.19 Flexural strength of concrete for 56 days

3.2.6 Porosity Test.

The 28 days and 56 days porosity test is given below

Type of cement	% of SF replaced	28 days (%)	56 days (%)
Fly ash cement (FC)	0	6.1	4.8
	10	8.3	6.7
	20	9.1	7.4
Slag cement (SC)	0	9.3	7.3
	10	16	11.11
	20	18	13.23
Slag and fly ash cement blend (1:1) (SFC)	0	5.7	3.79
	10	7.1	5.21
	20	12	9.83

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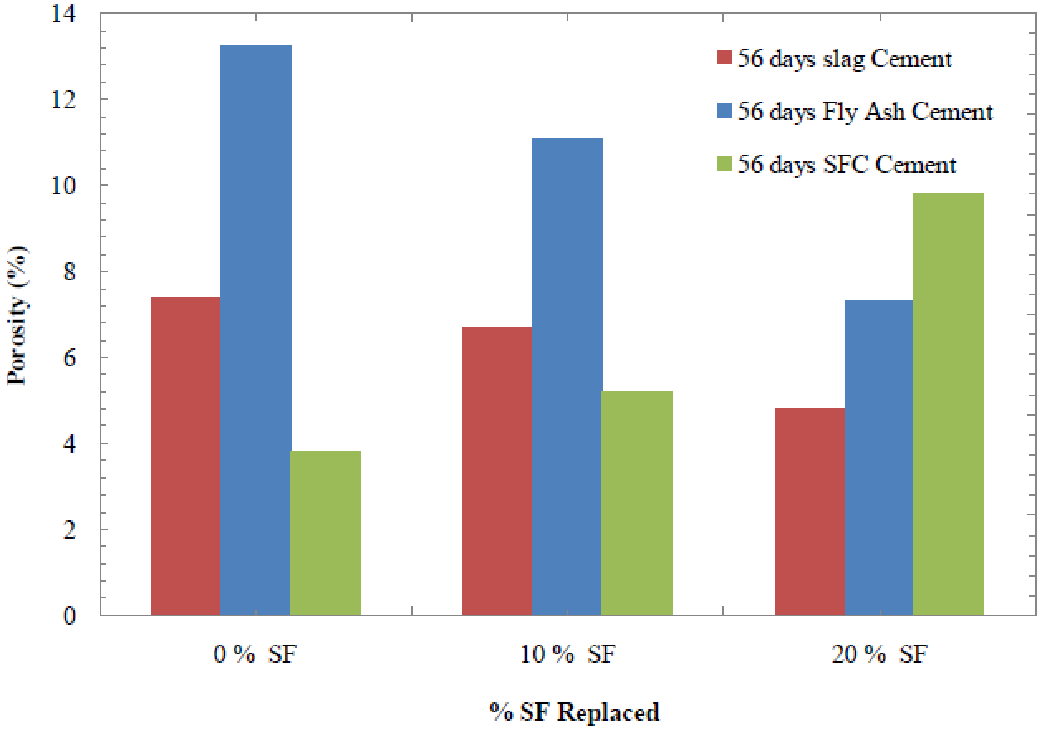

Figure.5.21 Porosity of concrete for 56 days

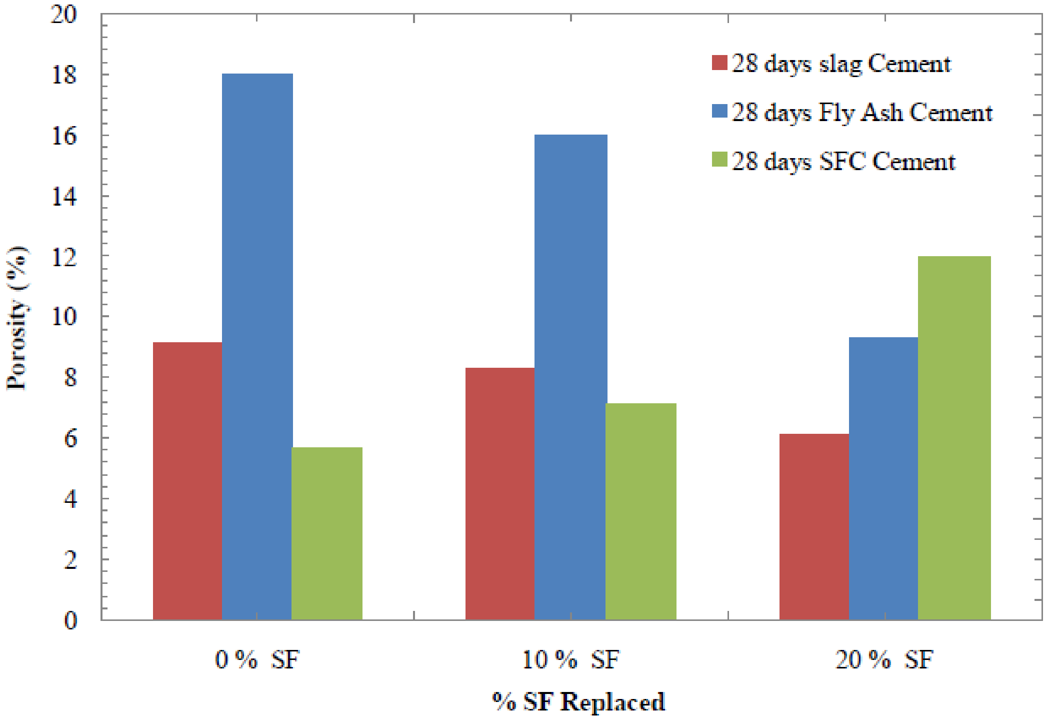

Figure.5.22 Porosity of concrete for 28 days

IV. CONCLUSION

From the present study the following conclusions are drawn:

1. Inclusion of silica fume improves the strength of different types of binder mix by making them more denser.
2. Addition of silica fume improves the early strength gain of fly ash cement whereas it increases the later age strength of slag cement.
3. The equal blend of slag and fly ash cements improves overall strength development at any stage.
4. Addition of silica fume to any binder mix reduces capillary absorption and porosity because fine particles of silica fume reacts with lime present in cement and form hydrates dancer and crystalline in composition.
5. The capillary absorption and porosity decreases with increase dose up to 20% replacement of silica fume for mortar.

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