An Experimental Study on The Strength Characteristics of Flyash, Steel Slag Concrete Under the Influence of Nano Silica

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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. 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 Nano silica 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. The main conclusions drawn are inclusion of Nano silica increases the water requirement of binder mixes to make paste of normal consistency. Water requirement increase with increasing dose of Nano silica. 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. The mortar strength (1:3) increases with increasing percentage of Nano silica. 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 Nano silica 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 Nano silica 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 Nano silica in the matrix. The increasing dose of Nano silica show further decrease in strength at every stage. Almost same trend is obtained for flexural strength also. The specimens without Nano silica had fine cracks which are more visible in concrete made with slag cement than flyash 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 cementitious materials SCMs

Early SCMs consisted of natural, readily available materials like volcanic ash or diatomaceous earth. The engineering marvels like Roman aqueducts, the Coliseum are examples of this technique used by Greeks and Romans. Nowadays, most concrete mixture contains SCMs which are mainly byproducts or waste materials from other industrial processes

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, Nano silica, 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

II. REVIEW OF LITERATURE

Many works have been done to explore the benefits of using pozzolanic materials in making and enhancing the properties of concrete. M.D.A. Thomas, M.H.Shehata1 et al. have studied the ternary cementitious blends of Portland cement, Nano silica, and fly ash offer significant advantages over binary blends and even greater enhancements over plain Portland cement. Sandor Popovics2 have studied the Portland cement-fly ash – Nano silica systems in concrete and concluded several beneficial effects of addition of Nano silica to the fly ash cement mortar in terms of strength, workability and ultra sonic velocity test results. Jan Bijen3 have studied the benefits of slag and fly ash added to concrete made with OPC in terms of alkali-silica reaction, sulphate attack. L. Lam, Y.L. Wong, and C.S. Poon4 in their studied entitled Effect of fly ash and Nano silica on compressive and fracture behaviors of concrete had concluded enhancement in strength properties of concrete by adding different percentage of fly ash and Nano silica. Tahir Gonen and Salih Yazicioglu5 studied the influence of binary and ternary blend of mineral admixtures on the short and long term performances of concrete and concluded many improved concrete properties in fresh and hardened states. Mateusz Radlinski, Jan Olek and Tommy Nantung6 in their experimental work entitled Effect of mixture composition and Initial curing conditions on the scaling resistance of ternary concrete have find out effect of different proportions of ingredients of ternary blend of binder mix on scaling resistance of concrete in low temperatures. S.A. Barbhuiya, J.K. Gbagbo, M.I. Russeli, P.A.M. Basheer7 studied the properties of fly ash concrete modified with hydrated lime and Nano silica concluded that addition of lime and Nano silica improve the early days compressive strength and long term strength development and durability of concrete. Susan Bernal, Ruby De Gutierrez, Silvio Delvasto8, Erich Rodriguez carried out Research work in Performance of an alkali-activated slag concrete reinforced with steel fibers. Their conclusion is that The developed AASC present higher compressive strengths than the OPC reference concretes. Splitting tensile strengths increase in both OPCC and the AASC concretes with the incorporation of fibers at 28 curing days. Hisham Qasrawi , Faisal Shalabi, Ibrahim Asi 9 carried out Research work in Use of low CaO unprocessed steel slag in concrete as fine aggregate.Their conclusion is That Regarding the compressive and tensile strengths of concrete steel slag is more advantageous for concretes of lower strengths. O. Boukendakdji, S. Kenai, E.H. Kadri, F. Rouis 10 carried out Research work in Effect of slag on the rheology of fresh self-compacted concrete. Their conclusion is that slag can produce good self- compacting concrete. Shaopeng Wu, Yongjie Xue, Qunshan Ye, Yongchun Chen11 carried out Research work in Utilization of steel slag as aggregates for stone mastic asphalt (SMA) mixtures. Their conclusion is that The test roads shows excellent performances after 2-years service, with abrasion and friction coefficient of 55BPN and surface texture depth of 0.8 mm M. Ibrahim and M.S Barry12 carried out experimental work on comparison of properties of steel slag and crushed limestone aggregate concretes, finally concluded that durability characteristics of steel slag cement concrete were better than those of crushed limestones aggregate concrete. Some of physical properties were better than of crushed lime stones concrete. J. G. Cabrera and P. A. Claisse13 carried out experimental work on Oxygen and water vapour transport in cement pastes, hence concluded that the flow of oxygen is described by the Darcy equation, but the flow of water vapour is not. The different mechanisms of transmission cause the transmission rates for oxygen to be spread over a far greater range than those for water vapour with some of the SF samples almost impermeable to oxygen. Houssam A. Toutanji and Tahar El-Korchi14 carried out experimental work on Oxygen and water vapour transport in cement pastes, hence concluded that the increase in compressive strength of mortar containing Nano silica as a partial replacement for cement, greatly contributes to strengthening the bond between the cement paste and aggregate. It was also demonstrated that super plasticizer in combination with Nano silica plays a more effective role in mortar mixes than in paste mixes. This can be attributed to a more efficient utilization of super plasticizer in the mortar mixes due to the better dispersion of the Nano silica.

III. METHODOLOGY

Nano silica-Nano silica is a byproduct in the reduction of high-purity quartz with coke in electric arc furnaces in the production of silicon and ferrosilicon alloys. Nano silica 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, Nano silica is a very effective pozzolanic material particle. The weakest area in concrete is the interface between the cement matrix and the aggregate. Adding an appropriate amount of nano-SiO2 to the concrete can enhance the interface strength and refine the pores, which can effectively reduce the water permeability of concrete. Nano-silica can also optimize the microstructure of recycled concrete. Silica particles promoted the hydration reaction to produce more dense gel materials, which can improve the interface strength between waste concrete and cement slurry compared the improvement effect of colloidal nano-SiO2 and powdered nano- SiO2 on the mechanical properties of concrete, and found that powdered nano-SiO2 promoted the generation of more C-S-H in mortar. Therefore, nano-SiO2 powder is more effective to improve the mechanical properties of concrete.

Fig :-Nano silica

The pore volume of cement slurry prepared by replacing part of cement with nano-SiO2 can be reduced by 13.4%, and it does not adversely affect for the porosity and permeability of cement slurryNano silica 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 Nano silica and free calcium hydroxide in the paste. Addition of Nano silica 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 Nano silica is incorporated, the rate of cement hydration increases at the early hours due to the release of OH ÿ ions and alkalis into the pore fluid. The increased rate of hydration may be attributable to the ability of Nano silica to provide nucleating sites to precipitating hydration products like lime, C±S±H, and ettringite. It has been reported that the pozzolanic reaction of Nano silica is very significant and the non- evaporable water content decreases between 90 and 550 days at low water /binder ratios with the addition of Nano silica.***Physical Properties of Nano silica*** -The properties of Nano silica were determined in laboratory. Specific gravity analysis is given below.

Chemical Analysis of Nano silica:

Table No. 3. 1

Nano silica	ASTM-C-1240	Actual Analysis
SiO2	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%

Steel Slag **:-** Steel slag is the residue of steel production process and composed of silicates and oxides of unwanted elements in steel chemical composition. Fifty million tons per year of LD slag were produced as a residue from Basic Oxygen Process (BOP) in the world.In order to use these slags in cement, its hydraulic properties should be known. Chemical composition is one of the important parameters determining the hydraulic properties of the slags. In general, it is assumed that the higher the alkalinity, the higher the hydraulic properties. If alkalinity is> 1.8, it should be considered as cementitious material Investigations were carried out also on the usability of steel slag as construction material under laboratory and practical conditions. For this application, the required properties are high compression strength, wear strength and resistance to climatic conditions. The most important criterion is volume stability, in which free CaO and MgO contents of the slag play an important role. Both oxides can go into reaction with water. Hydration causes volume expansion and affects stability of volume. This is one reason why steel slag aggregate are not suitable for use in Portland cement concrete b. But at the moment, most steel slag being used as unbound aggregate for ashphalt concrete pavement in many countries. Sieve Analysis of steel slag in done to know the grade of the aggregate. This is given in Table 3.2

Table No. 3.2

Sieve size	Wt Retain	Cum Wt Retn	% Cu wt Retn	% 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.

XRD Analysis of Steel slag:- From XRD Analysis of steel slag we can find what type Alkalis present. These are tabulated in Table No 3.5

Table No 3.3

Chemical Compound	Visible	Ref-Code	score
Na2O	Yes	03-1074	10
K2O	Yes	77-2176	10

From above table we can conclude that some amount of Alkalis present in steel slag

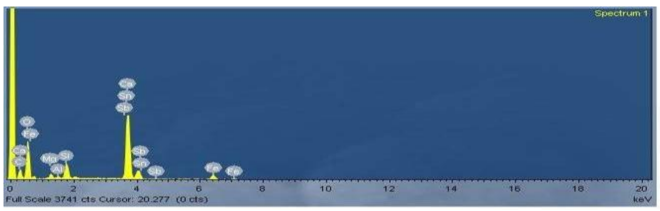


Figure 3.1 XRD Analysis of Steel Slag

***Flyash*:-**Fly ash, which is largely made up of silicon dioxide and calcium oxide, can be used as a substitute for Portland cement, or as a supplement to it. The materials which make up fly ash are pozzolanic, meaning that they can be used to bind cement materials together. Pozzolanic materials, including fly ash cement, add durability and strength to concreteFly ash cement is also known as green concrete. It binds the toxic chemicals that are present in the fly ash in a way that should prevent them from contaminating natural resources. Using fly ash cement in place of or in addition to Portland cement uses less energy, requires less invasive mining, and reduces both resource consumption and CO2 emissions

Table No. 3.4

cement	Consistency in %	Specific gravity	Initial setting time	Final setting time
Fly ash cement	37.5	3	3 hour 50 min	11 hour 35 min
FC10	47			
FC20	55.5			

Xrd Analysis of Fly ash cement:- By XRD (X ray diffraction) Analysis we can know what type of chemical composition present in cement. This analysis were done in metallurgical dept. of NIT Rourkela. The chemical compound found in this analysis was listed below

Table No. 3.5

Chemical Compound	Visible	Reference Code	Score
Ca54MgAl2Si16O90	Yes	13-0272	59
CaAl2O4	Yes	34-0440	17
CaCO3	Yes	72-1937	20
(MgO) 0.593(FeO).41	Yes	77-2367	14
Mg(CO3)	Yes	80-0042	16

Chemical Analysis of Fly ash cement:- The chemical analysis of cement is done to know the amount of chemical composition present in cement. Its procedure is accordingly Vogel‟s Inorganic Quantitative Analysis. This experiment was done in our institute chemistry laboratory. Here our aim is to determined actual chemical composition of the specimen provided by the company. The chemical analysis of fly ash cement is listed in

Table 3.6

Chemical Compound	Fly Ash Cement in (%)
Sio_2	6
Cao	49
MgO	0.66
Fe_2O_3	15
Al_2O_3	16

***Slag Cement*:-**Slag cement has been used in concrete projects in the United States for over a century. Earlier usage of slag cement in Europe and elsewhere demonstrates that long-term concrete performance is enhanced in many ways. Based on these early experiences, modern designers have found that these improved durability characteristics help further reduce life-cycle costs, lower maintenance costs and makes concrete more sustainable. For more information on how slag cement is manufactured and it enhances the durability and sustainability of concrete.

XRD Analysis of Slag cementBy XRD (X ray diffraction) Analysis we can know what type of chemical composition present in cement.This analysis were done in metallurgical department of NIT Rourkela. The chemical compound found in this analysis was listed below in

Table No 3.7

Chemical Compound	Visible	Reference Code	Score
Ca54MgAl2Si16O19	Yes	13-0272	68
MgAl2O4	Yes	84-0377	19
SiO2	Yes	43-0596	36

Chemical Analysis of Slag cement:- The chemical analysis of cement is done to know the amount of chemical composition present in cement. Its procedure is accordingly Vogel"s Inorganic Quantitative Analysis. This experiment was done in our institute chemistry laboratory. Here our aim is to determine actual chemical composition of the specimen provided by the company. The chemical analysis of slag cement is listed in Table No. 3.8

Chemical Compound	Slag Cement in (%)
Sio_2	12
Cao	43
MgO	0.37
Fe_2O_3	12
Al_2O_3	26

Sand:-Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The most common constituent of sand, in inland continental settings and non-tropical coastal settings, is silica(silicon dioxide, or SiO2), usually in the form of quartz which, because of its chemical inertness and considerable hardness, is the most common mineral resistant to weathering.It is used as fine aggregate in concrete ***Sieve Analysis of sand***:-The Sieve Analysis of sand is carried out to know the zone of the sand. The results of sieve analysis is given in **Table No. 3.9**

Sieve size	Weight Retained in gm	% passing
4.75 mm	16 gm	98.4
2.36 mm	11 gm	97.3
1.18 mm	65 gm	90.8
600 micron	391 gm	51.6
300 micron	420 gm	9.4
150 micron	82 gm	1.2
Total	1000 gm	-

From the sieve analysis result, Sand falls under Zone II

Test Procedure:-The Experimental programme was carried out in two stages

Stage 1: Experimental work were conducted on mortar mixes by using different binder mix modified with different percentages of Nano silica

Stage2: Experimental works were conducted on steel slag concrete mixes by using different binder mix modified with different percentages of Nano silica

Stage 1: This experimental investigation was carried out for three different combinations of slag cement and fly ash cement. In each combination three different proportion of Nano silica had been added along with the controlled mix without Nano silica

Binders being used were different combinations of slag cement, fly ash cement in the proportions 1:0, 0:1 and 1:1 hence total three combinations. Further in each type of combination of binder mix 0%,10 % and 20 % percentage of Nano silica had been added. Hence total 12 sets of mortar of 1:3 proportion were prepared by mixing one part of binder mix and three parts of naturally available sand

Stage2: Here concrete is prepared with three different types of binder mix with Nano silica **A**: Determination Of Strength Of Concrete Of 1:1.5:3 Mix Proportion By Using Fly Ash Cement + Nano silica As Binder Mix ,Sand As Fine Aggregate And Steel Slag As Coarse Aggregate. In this phase concrete of mix proportion 1 : 1.5 : 3 will be prepared by using fly ash cement + Nano silica as binder mix with different proportion of Nano silica, sand as fine aggregate and steel slag as coarse aggregate. The different proportion of Nano silica in the concrete mix will vary from 0%, 10%, and 20%. The concrete mixes will be tested for following strengths

B: Determination Of Strength Of Concrete Of 1:1.5:3 Mix Proportion Byusing Slag Cement+Nano silica As Binder,Sand As Fine Aggregate And Steel Slag As Coarse Aggregate.

In this phase concrete of mix proportion 1 : 1.5 : 3 will be prepared by using slag cement + Nano silica as binder mix with different proportion of Nano silica ,sand as fine aggregate and steel slag as coarse aggregate. The proportion of Nano silica in the concrete mix will vary from 0% , 10% and 20 % of the blend. The concrete mixes will be tested for following strengths

IV. RESULTS AND DISCUSSIONS

Experimental Study On Mortar :-Here we prepared mortar with ratio 1:3 from different types of cement + Nano silica 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

Normal Consistency for Mortar.

Normal consistency of different binder mixes was determined using the following procedure referring to IS 4031: part 4 (1988) Normal consistency of different binder mixes were tabulated below in Table No. **4.1**

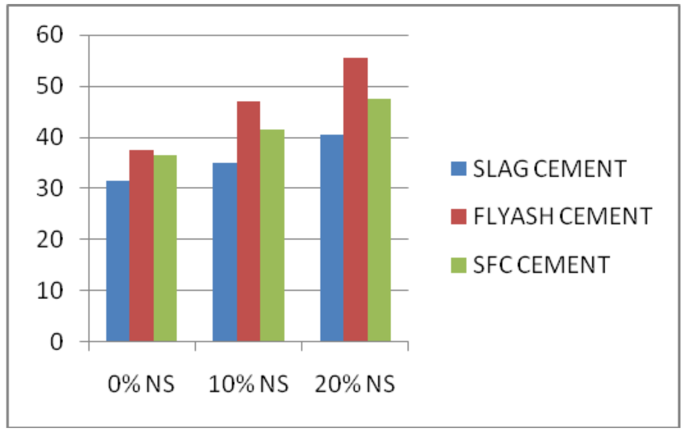
Table No.4.1

Mix	Description	Cement(grams)	Nano silica (grams)	Consistency (%)
SC 0	SC	300	00	31.5
SC 10	SC with 10% NS	270	30	35
SC 20	SC with 20% NS	240	60	40.5
FC 0	FC	300	00	37.5
FC 10	FC with 10% NS	270	30	47
FC 20	FC with 20% NS	240	60	55.5
SFC0	SC:FC (1:1)	150 each	00	36.5
SFC 10	SC:FC (1:1) with 10% NS	135 each	30	41.5
SFC 20	SC:FC (1:1) with 20% NS	120 each	60	47.5

Where, SC = slag cement FC = fly ash cement NS = Nano silica SFC = slag and fly ash cement

SC0 = Slag cement with 0% Nano silica replacement SC10 = Slag cement with 10% Nano silica replacement From the above table we can conclude that water requirement increases with increase in percentage of replacement by Nano silica 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 Nano silica replacement.

Water requirement in case of fly ash cement binder mix is more because it is finer when compared to slag cement.



% NS **Replaced**

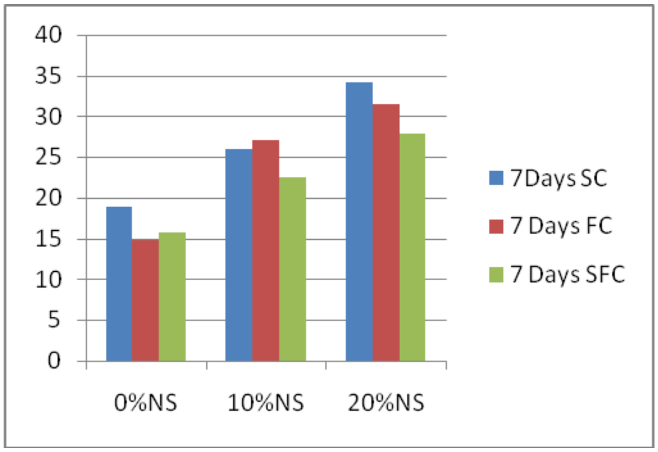
From the above graph we can conclude that water requirement increases with increase in percentage of replacement by Nano silica and fly ash cement consumes more water due to its fineness. Water requirement or normal consistency of a binder mix increases with increment in percentage of Nano silica replacement.

Water requirement in case of fly ash cement binder mix is more because it is finer when compared to slag cement

Compressive Strength of Mortar Compressive Strength of different mortars after 7 days and 28 days are tabulated in table 4.2

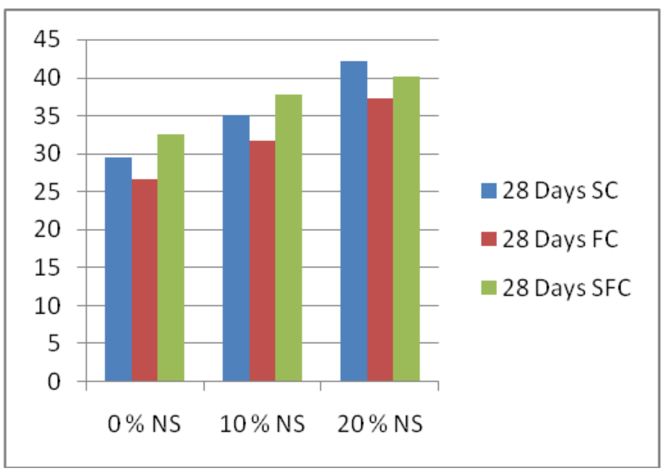
Type of cement	% of NS replaced	7 days	28 days
Slag cement (SC)	0	18.91	29.43
	10	25.97	35.09
	20	34.13	42.12
Fly ash cement (FC)	0	14.82	26.57
	10	27.07	31.74
	20	31.43	37.23
Slag and fly ash cement blend (1:1) (SFC)	0	15.73	32.57
	10	22.58	37.69
	20	27.89	40.12

From the above table, we can conclude that capillary absorption decreases with increase in percentage of replacement by Nano silica. The reason could be the inclusion of Nano silica to the different cements actually forms denser matrices thereby improve resistance of the matrices against water ingress which is one of the most important reasons that increases the deterioration of concrete. All binder mixes shows that up to 20% replacement of cement with Nano silica the durability in terms of capillary absorption coefficients decreases with increasing dose of Nano silica. Capillary absorption coefficient decreases with increasing % of Nano silica up to 20% replacement. This indicates that inclusion of Nano silica to the different cements actually forms denser matrices thereby improve resistance of the matrices against water ingress which is one of the most important reasons that increases the deterioration of concrete. Decrease in capillary absorption coefficient between 7day to 28 day of curing is about 16% observed in slag cement with 15% Nano silica and is about 3% observed in fly ash cement with 20% Nano silica and is about 6% observed in blended binder mix with 20% Nano silica



% NS Replaced

Figure.4.2 Compressive strength for mortar for 7 days



% NS Replaced

Figure.4.3 Compressive strength for mortar for 28 days

Capillary Absorption Coefficients of capillary absorption of different mortars after 7 days and 28 days of curing were tabulated in Table No. 4.4

Types of cement	% Nano silica replace	28 days(k*10-3 cm/s)	56 days(k*10-3 cm/s)
Slag cement	0	1.232	1.093
	10	0.811	0.783
	20	0.624	0.518
Fly ash cement	0	0.886	0.795
	10	0.637	0.598
	20	0.538	0.485
Slag and fly ash cement blend (1:1)	0	0.982	0.871
	10	0.842	0.638
	20	0.593	0.541

b

From the above table, we can conclude that capillary absorption decreases with increase in percentage of replacement by Nano silica. The reason could be the inclusion of Nano silica to the different cements actually forms denser matrices thereby improve resistance of the matrices against water ingress which is one of the most important reasons that increases the deterioration of concrete. All binder mixes shows that up to 20% replacement of cement with Nano silica the durability in terms of capillary absorption coefficients decreases with increasing dose of Nano silica. Capillary absorption coefficient decreases with increasing % of Nano silica up to 20% replacement. This indicates that inclusion of Nano silica to the different cements actually forms denser matrices thereby improve resistance of the matrices against water ingress which is one of the most important reasons that increases the deterioration of concrete. Decrease in capillary absorption coefficient between 7day to 28 day of curing is about 16% observed in slag cement with 15% Nano silica and is about 3% observed in fly ash cement with 20% Nano silica and is about 6% observed in blended binder mix with 20% Nano silica

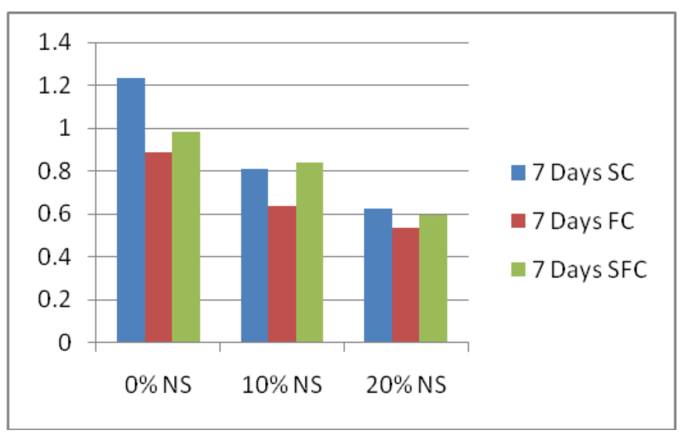
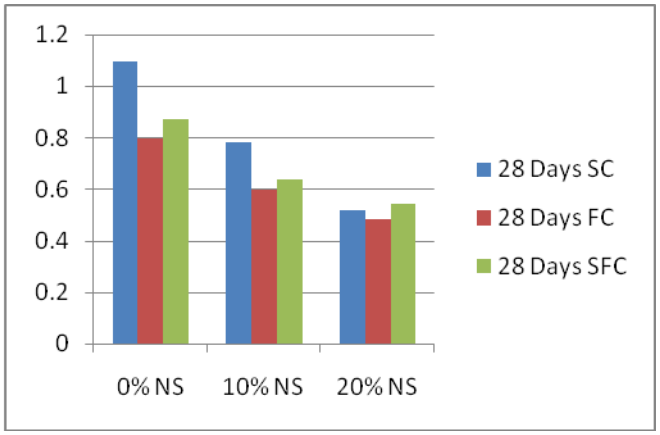


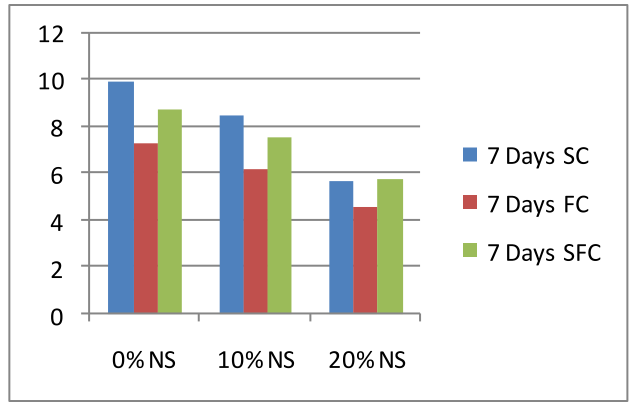
Figure.4.4Capillary Absorption for mortar for 7 days

% NS Replaced



% NS Replaced

Figure.4.5 Capillary Absorption for mortar for 28 days



%

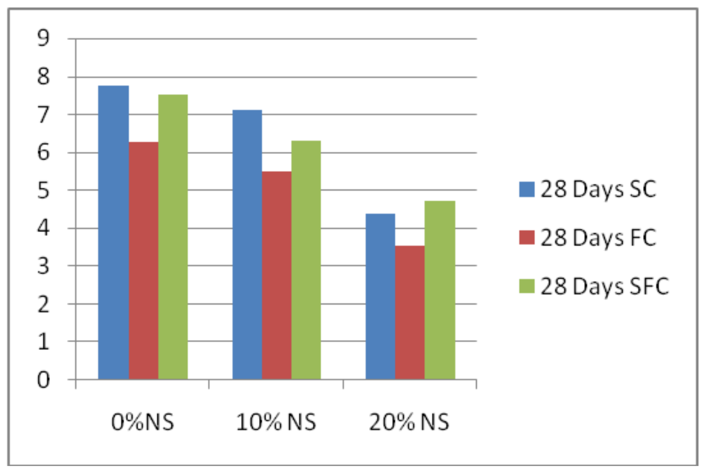
NS Replaced

Figure.4.6 Porosity of mortar for 7 days

Porosity Test of Mortar. Porosity of different mortar after 7 days and 28 days of curing were tabulated in Table No.4.5

Type of cement	% of NS replaced	7 days (%)	28 days (%)
Slag cement	0	9.92	7.76
	10	8.47	7.12
	20	5.73	4.38
Fly ash cement	0	7.35	6.27
	10	6.18	5.48
	20	4.58	3.53
Slag and fly ash cement blend(1:1)	0	8.76	7.52
	10	7.54	6.32
	20	5.82	4.71

From the above table, we can conclude that porosity decreases with increase in percentage of replacement by Nano silica. The reason could be the inclusion of Nano silica to the different cements actually forms denser matrices thereby improve resistance of the matrices against water ingress which is one of the most important reasons that increases the deterioration of concrete. All binder mixes shows that up to 20% replacement of cement with Nano silica the durability in terms of decreases with increasing dose of Nano silica. Porosity decreases to about 16 % in slag cement, about 17 % in Fly ash cement and about 17% in blended binder mix with 20% addition of Nano silica between 7days to 28 days of curing



% NS Replaced

Figure.4.7 Porosity of mortar for 28 days

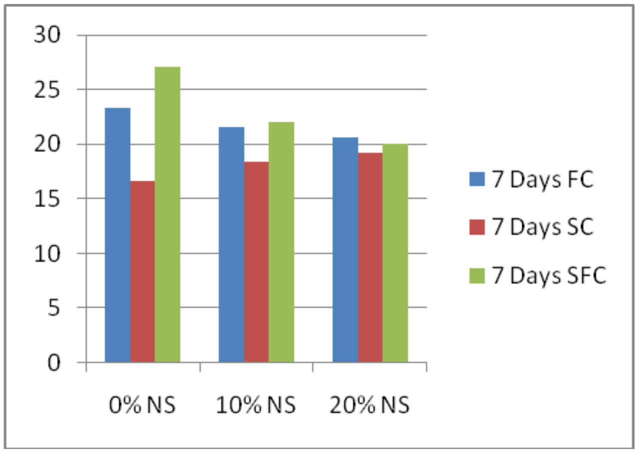
Compressive Strength by Rebound Hammer Method Compressive Strength of different concrete cubes after 7 days, 28 days and 56 days were tabulated in Table No. 4.7

Type of cement	% of NS 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 Nano silica

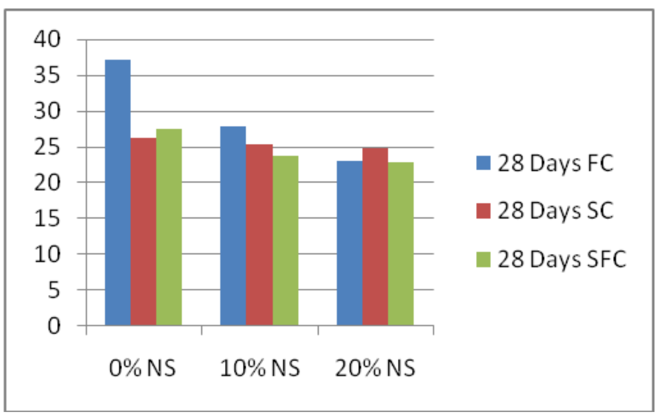
Compressive Strength by Compression *Testing Machine* Compressive Strength of different mortars after 7days ,28days and 56 days were tabulated in Table No. 4.8

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 Nano silica. This is due to the weak bond formation between cement paste and steel slag. There are lots of voids present in concrete, which is shown by SEM (Scanning Electron Microscope) Analysis, which are given below



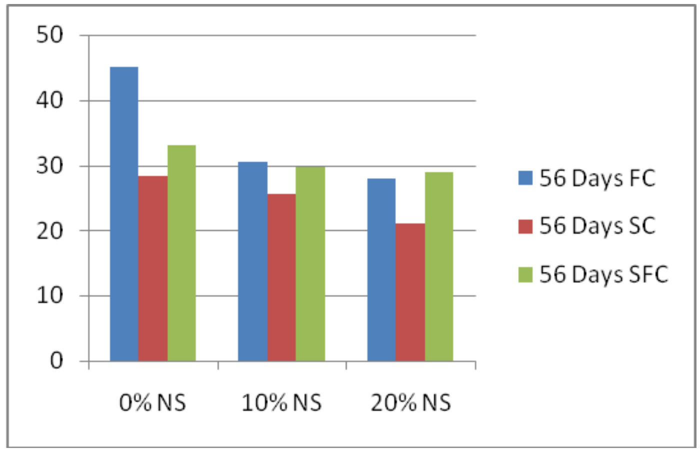
% NS Replaced

Figure.4.9 Compressive strength of concrete for 7 days



% NS Replaced

Figure.4.10 Compressive strength of concrete for 28 days



% NS Replaced

Figure.4.11 Compressive strength of concrete for 56 days

Wet and Dry Test Table No.4.12 shows 28 days and 56 days wet and dry test of concrete cube

Type of cement	% of NS replaced	28 days (N/mm2)	56 days (N/mm2)
Fly ash cement(FC)	0	36.5	36.0
	10	30.7	30.66
	20	26.8	28.44
Slag cement (SC)	0	23.8	27.55
	10	26.8	24.88
	20	25.3	20.88
Slag and fly ash cement blend (1:1) (SFC)	0	20.7	38.22
	10	36.5	24
	20	30.1	30.66

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

Type of cement	% of NS 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

Porosity Test The 28 days and 56 days porosity test is given below

Type of cement	% of NS replaced	28days (%)	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

From the above table, we can conclude that porosity increases with increase in percentage of replacement by Nano silica. The reason could be the inclusion of Nano silica to the different cements actually forms denser matrices thereby improve resistance of the matrices against water ingress which is one of the most important reasons that increases the deterioration of concrete

Capillary Absorption Test The capillary coefficients for different types of steel slag is given below

Type of cement	% of NS replaced	28 days (k*10-3 cm/s)	56 days (k*10-3 cm/s)
Fly ash cement	0	2.09	1.83
	10	1.142.30	0.95
	20	0.838	0.621
Slag cement	0	2.30	1.92
	10	1.46	1.02
	20	1.04	0.81
Slag and fly ash cement blend (1:1)	0	2.01	1.63
	10	1.21	0.98
	20	0.85	0.671

From the above table, we can conclude that capillary absorption decreases with increase in percentage of replacement by Nano silica. The reason could be the inclusion of Nano silica to the different cements actually forms denser matrices thereby improve resistance of the matrices against water ingress which is one of the most important reasons that increases the deterioration of concrete

V. CONCLUSIONS

From the present study the following conclusions are drawn Inclusion of Nano silica improves the strength of different types of binder mix by making them more denser

1. Addition of Nano silica improves the early strength gain of fly ash cement whereas it increases the later age strength of slag cement
2. The equal blend of slag and fly ash cements improves overall strength development at any stage
3. Addition of Nano silica to any binder mix reduces capillary absorption and porosity because fine particles of Nano silica reacts with lime present in cement and form hydrates dancer and crystalline in composition
4. The capillary absorption and porosity decreases with increase dose up to 20% replacement of Nano silica for mortar
5. Addition of Nano silica to the concrete containing steel slag as coarse aggregate reduces the strength of concrete at any age
6. This is due to the formation of voids during mixing and compacting the concrete mix in vibration table because Nano silica make the mixture sticky or more cohesive which do not allow the entrapped air to escape. The use of needle vibrator may help to minimize this problem
7. The most important reason of reduction in strength is due to alkali aggregate reaction between binder matrix and the steel slag used as coarse aggregate. By nature cement paste is alkaline. The presence of alkalis Na2O, K2O in the steel slag make the concrete more alkaline. When Nano silica is added to the concrete, silica present in the Nano silica react with the alkalis and lime and form a gel which harm the bond between aggregate and the binder matrix. This decrease is more prominent with higher dose of Nano silica
8. Combination of fly ash cement and Nano silica makes the concrete more cohesive or sticky than the concrete containing slag cement and Nano silica causing formation of more voids with fly ash cement. Therefore the concrete mixes containing fly ash and Nano silica show higher capillary absorption and porosity than concrete mixes containing slag cement and Nano silica
9. The total replacement of natural coarse aggregate by steel slag is not recommended in concrete. A partial replacement with fly ash cement may help to produce high strength concrete with properly treated steel slag
10. The steel slag should be properly treated by stock piling it in open for at least one year to allow the free CaO & MgO to hydrate and thereby to reduce the expansion in later age
11. A thorough chemical analysis of the steel slag is recommended to find out the presence of alkalis which may adversely affect to the bond between binder matrix and the aggregate

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