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EFFECT OF NANO SILICA INCLUSION ON STRENGTH AND DURABILITY PROPERTIES OF SELF COMPACTING CONCRETE

Syed Irfanullah Hussaini[*1] & Gulam Samdani[2]
[*1&2]Department of Civil Engineering, Aurora Inst. Of Technological Sciences, Warangal, India

ABSTRACT

This paper presents a study Self-compacting concrete (SCC) which is also considered as a concrete which can be placed and compacted under its own weight with little or no vibration without segregation or bleeding. The use of SCC with its improving productions techniques is increasing every day in concrete production. Recently, nano particles have been gaining increasing attention and have been applied in many fields to fabricate new materials with novel functions due to their unique physical and chemical properties.
In this work 40Mpa self-compacting concrete is developed using modified Nan-Su method of mix design.Slump flow, J-Ring, V-funnel tests are conducted to justify the fresh properties of SCC and are checked against EFNARC (2005) specifications. Specimens of dimensions 150x150x150mm were cast without nano silica and with two different grades of nano silica which is in colloidal state with 16% and 30% nano content are added in different percentages(1%, 1.5% and 2% by weight of cement) to SCC. To justify the compressive strength for 7and28days, specimens are tested under axial compression. Durability propertieswere also studied by immersing the specimensin5% HCl and5% H_2SO_4. Sorptivity test has also been conducted.Test results indicate that use of Nano Silica in concrete has improved the performance of concrete in strength as well as in durability aspect

Keywords: magnetic water, mortar, compressive strength, mineral admixtures and curing period

I. INTRODUCTION

Now-a-days the most suitable and widely used construction material is concrete. This building material, until these days, went through lots of developments. Self-Compacting Concrete (SCC) is a new generation of concrete, which has generated tremendous interest since its initial development in Japan by Okamura in the late 1980's in order to reach durable concrete structures. SCC is considered as a concrete which can be placed and compacted under its self-weight with little or no vibration effort, and which is at the same time, cohesive enough to be handled without segregation or bleeding. It is used to facilitate and ensure proper filling and good structural performance of heavily reinforced structural members. SCC development is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete The main motive for development of SCC was the social problem on durability of concrete structures that arose around 1983 in Japan. Due to a gradual reduction in the number of skilled workers in Japan's construction industry, a similar reduction in the quality of construction work took place. As a result of this fact, one solution for the achievement of durable concrete structures independent of the quality of construction work was the employment of SCC, which could be compacted into every corner of a formwork, purely by means of its own weight (**Fig.1.1**). Studies to develop SCC, including a fundamental study on the workability of concrete, were carried out by researchers Ozawa and Maekawaat the University of Tokyo.

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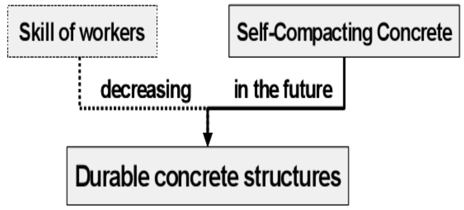

*Figure II.1**Necessity of Self Compacting Concrete (SCC)***

The method for achieving SCC involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregate and mortar when concrete flows through the confined zones of reinforcing bars. Okamura and Ozawahave employed the following methods to achieve self-compactability (Fig. 1.2 & 1.3)

(1) Limited aggregate content.
(2) Low water-powder ratio.
(3) Use of super plasticizer.

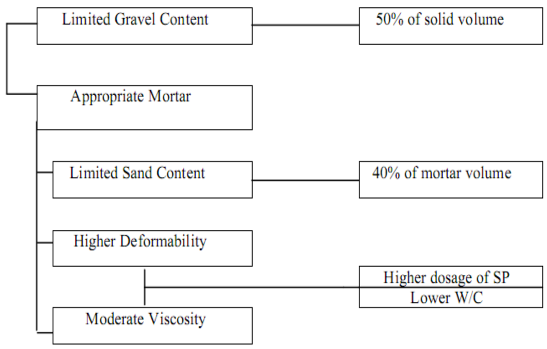

*Figure II.2**Methods for achieving self-compactability***

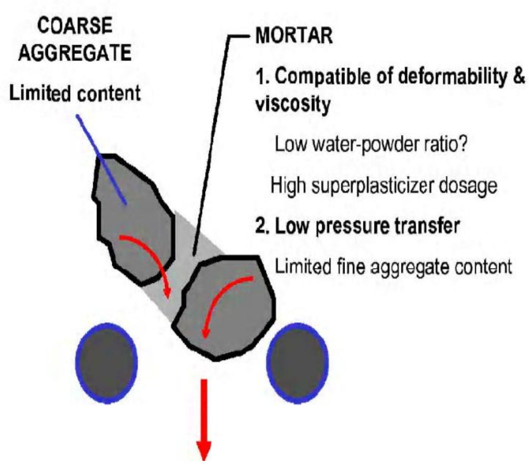

*Figure II.3 **Mechanism for achieving self-compactability***

Nano Technology

"Nanotechnology is the art and science of manipulating matter at the nano scale". Nanotechnology is the creation of materials and devices by controlling of matter at the levels of atoms, molecules, and supra molecular (nano scale) structures. In other words, it is the use of very small particles of materials to create new large scale materials.

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Nano materials

The particle packing in concrete can be improved by using Nano-silica which leads to densi- fying of the micro and nanostructure resulting in improved mechanical properties. Nano-silica addition to cement based materials can also control the degradation of the fundamental C-S-H (calcium-silicate-hydrate) reaction of concrete caused by calcium leaching in water as well as block water penetration and therefore lead to improvements in durability.

Nano-Silica (NS) is the first nano product that replaced the micro silica. It has a specific surface area near to 1, 00,000 m^2/kg (micro silica has only 20,000 m^2/kg) and a particle size of 5 nm to 250 nm. Nano Silica (NS) can contribute to efficient 'Particle Packing' in concretes by densifying the micro and nanostructure leading to improved mechanical and durability properties.

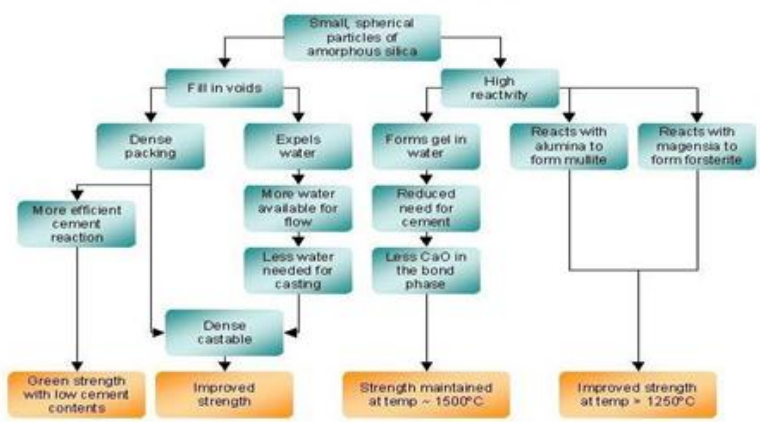

Figure II.*4*Nano Silica Properties

The main objective of this project is to study the strength and durability effects of Nano silica inclusions in Self Compacting Concrete with various percentage additions.

II. LITERATURE REVIEW

*In 1997 Hajime okamura [1]:*A new type of concrete, which can be compacted into every corner of a formwork purely by means of its own weight, was proposed by Okamurain 1986, he started a research project on the flowing ability and workability of this special type of concrete, later called self-compacting concrete. The Self-Compactability of this concrete can be largely affected by the characteristics of materials and the mix proportions. In his study, Okamura has fixed the coarse aggregate content to 50% of the solid volume and the fine aggregate content to 40% of the mortar volume, so that self compactability could be achieved easily by adjusting the water to cement ratio and super plasticizer dosage only.

In 1988 Kazumasa ozawa [2] Ozawa completed the first prototype of self compacting concrete using materials already in the market. By using different types of super plasticizers, he studied the workability of concrete and developed a concrete which was very workable. It was suitable for rapid placement and had very good permeability. The viscosity of the concrete was measured using the v-funnel test. Other experiments carried out by Ozawa focused on the influence of mineral admixtures, like fly ash and blast furnace slag, on the flowing ability and segregation resistance of SCC. He found out that the flowing ability of the concrete improved remarkably when Portland cement was partially replaced with fly ash and blast furnace slag. After trying different proportions of admixtures, he concluded that 10-20% of fly ash and 25-45% of slag cement, by mass, showed the best flowing ability and strength characteristics.

In 1999 Domone et al [3] has done their research on the effect on fresh properties of mortar phase of SCC of four different types of super plasticizer and various combinations of powder, including Portland cement, GGBS, fly ash, micro silica and lime stone powder. He concluded that many of important parameters that influence the performance SCC can be assessed by testing on mortars. This include the comparison of the performance of different super plasticizer of the effects of the time of addition of the super plasticizer during mixing process and the work ability and workability retention characteristics of mixes containing binary and ternary blends of powders.

S. Venkateswara Rao, M.V. Seshagiri Rao, P. Rathish Kumar [4] developed standard and high strength Self Compacting Concrete (SCC) with different sizes of aggregate based on Nan-su's mix design procedure. The results indicated that SCC can be developed with all sizes of graded aggregate satisfying the SCC characteristics. The mechanical properties viz., compressive strength, flexural strength and split tensile strengths were studied at the end of 3, 7 and 28days for standard and high strength SCC with different sizes of aggregate. It was noted that with 10mm size aggregate and 52% fly ash in total powder the mechanical properties were superior in standard SCC, while 16mm size aggregate with a 31% fly ash in total powder improved the properties of high strength SCC.

S Venkateswara Rao, M V Seshagiri Rao,
*D Ramaseshu[12]*Their research proposes a rational mix design procedure for Self Compacting Concrete (SCC). From the strength and workability studies conducted on SCC, it was noted that there is a significant change in the mix proportions with respect to packing factor, effective size of aggregate, fine aggregate – total aggregate ratio, fly ash content, cement content and water content. It was hence felt that these parameters, which were otherwise assumed, are of reasonable importance. Hence, a rational mix design methodology modifying the existing Nan Su method has been proposed. This rational mix design procedure can be adopted to design any grade of self compacting concrete. A simplified and direct mix design methodology for SCC is proposed based on experimental observations.

III. RESEARCH SIGNIFICANCE

From the detailed literature review it was noted that the literature on nano silica is scarce and hence there is a need to develop a systematic experimental to study the influence of nano silica in Self Compacting Concrete. The main objective of this project is to study the strength and durability effects of Nano silica inclusions in Self Compacting Concrete with various percentage additions.

IV. EXPERIMENTAL PROGRAM

The experimental study consists of arriving at suitable mix proportions that satisfied the fresh properties of self compacting concrete as per EFNARC specifications. Standard cube moulds of 150mm x 150mm x 150mm made of cast iron were used for casting standard cubes. The standard moulds were fitted such that there are no gaps between the plates of the moulds. If there are any small gaps they were filled with plaster of paris. The moulds were then oiled and kept ready for casting. After 24hrs of casting, specimens were demoulded and transferred to curing tank where in they were immersed in water for the desired period of curing.

The program consists of casting and testing of 40Mpa Self Compacting Concrete with additions of nano silica and without nano silica. A total of 7batches were made, out of which 1batch is of normal SCC i.e.,without nano silica, 3batches of nanosilica(16% nano content) with additions of 1%, 1.5% and 2% bwoc and 3batches of nano silica(30% nano content) with additions of 1%, 1.5% and 2% bwoc. The mix proportion for 40Mpa Self compacting concrete was designed by using modified nan su method. Water reducing admixtures are added into mixes on requirement, till the desired properties are exhibited by them.15cubes were casted in each batch, out of which 6cubes of each batch are tested for compressive strength for 7days and 28days, 3cubes of each batch are tested for 5% H_2SO_4 (sulphuric acid), 5% HCl (Hydrochloric acid) and Sorptivity test for durability aspects. The details of the specimen's cast are shown in Table 4.1

Table 1: Details of specimens cast

S.No	Grade of Concrete	Type of Concrete	% of Nanosilica added by BWOC added	No. of cubes cast 150x150x150mm
1.	40Mpa	SCC without Nano silica	-	15
		SCC with Nano silica (16% nano content)	1%	15
			1.5 %	15
			2 %	15
		SCC with Nano silica (30% nano content)	1%	15
			1.5 %	15
			2 %	15
Total Specimens				105

Materials used in the present investigation were

Cement
Cement used in the investigation was 53 Grade Ordinary Portland cement confirming to IS 12269.The cement was obtained from a single consignment and of the same grade and same source. Procuring the cement it was stored properly. The Specific gravity of the cement is found to be 3.10.

Fine Aggregate
The Fine aggregate conforming to Zone-2 according to IS 383 was used. The fine aggregate used was obtained from a nearby river source. The bulk density, specific gravity, and fineness modulus of the sand used were 1.41g/cc, 2.68, and 2.90.The sand obtained was sieved as per IS sieves (i.e. 2.36, 1.18, 0.6, 0.3, and 0.15mm). Sand retained on each sieve was filled in different bags and stacked separately for use.

Coarse Aggregate
Crushed granite Aggregate was used as coarse aggregate. The coarse aggregate was obtained from a local crushing unit having 20mm MSA, 20mm 16mm, and 10mm well graded aggregate according to IS: 383 is used in this investigation. The bulk density, specific gravity of the coarse aggregate sand used was 1.41g/cc, 2.65.

Fly ash
Fly ash confirming to IS3812:1981 is used as mineral admixture. Mineral admixtures are used to improve the fresh and hardened properties of concrete and at the same time reduce the cost of concrete materials. In order to achieve the necessary viscosity to avoid segregation, additional fine materials are used.

Super plasticizer
High range water the reducing admixtures known as super plasticizers are used for improving or workability for decreased water-cement ratio without decreasing the compressive strength. These admixtures when they disperse in cement agglomerates significantly decrease a viscosity of the paste by forming a thin film around the cement particles. In the present work water-reducing admixture Conplast SP430 is differentiated from conventional super

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plasticizers in that it is based on a unique carboxylic ether polymer with long lateral chains. This greatly improves cement dispersion. At the start of the mixing process an electrostatic dispersion occurs but the cement particle's capacity to separate and disperse. This mechanism considerably reduces the water demand in flowable concrete. Conplast SP430 combines the properties of water reduction and workability retention. It allows the production of high performance concrete and/or concrete with high workability.

Water

Potable water was used in the experimental work for both mixing and curing.

Properties of nano-sio$_2$

In this study, two different types of suspended nano silica gel containing different percentages of active nano silica with 99.99% pure $SiO_2$is used. The nomenclature followed for different nano silica gel is given in Table 3.3. Specific gravity of each material varies from 1.08 to 1.32. Particle size of nano Silica varies between 5-40 nm. The pH of the solutions is between 9.3 and 10.4. The properties of different nano silica provided by the manufacturer are given in Table 4.2.

Table 4.2: Properties of nano-sio2

Notation for NanoSilica Gel	*Active nano content (%wt/wt)*	*pH*	*Specific gravity*
XLP	16.0	9.3-9.6	1.08-1.11
XTX	30.0	9.0-10.0	1.20-1.22

Basic Properties of SCC

Fresh SCC must possess at required levels the following key properties

(a) **Filling ability:** This is the ability of the SCC to flow into all spaces within the formwork under its own weight.

(b) **Passing ability:** This is the ability of the SCC to flow through tight openings such as spaces between steel reinforcing bars under its own weight.

(c) **Resistance to segregation:** The SCC must meet the required levels of properties (a) & (b) while its composition remains uniform throughout the process of transport and placing. Many tests have been used in successful applications of SCC. However, in all the projects the SCC was produced and placed by an experienced contractor whose staff has been trained and acquired experience with interpretation of a different group of tests. In other cases, the construction was preceded by full-scale trials in which a number, often excessive, of specific tests was used (Ouchi et al., 1996). The same tests were later used on the site itself.

Mix Design proportions

Table IV.1Mix Proportions of mixes 40Mpa SCC based on rational mix design

Mix	*Cement (kg/m^3)*	*Fly ash (kg/m^3)*	*F.A (kg/m^3)*	*C.A (kg/m^3)*	*SP 430 (lit/m^3)*	*Water (lit/m^3)*	*Nano-silica*

							(colloidal) (kg/m³)
Normal SCC	468.00	353.05	946.72	794.48	19.70	244.71	-
NS.XLP (1%)	468.00	353.05	946.72	794.48	19.70	220.14	29.25
NS.XLP (1.5%)	468.00	353.05	946.72	794.48	19.70	207.855	43.875
NS.XLP (2%)	468.00	353.05	946.72	794.48	19.70	195.6	58.5
NS.XTX (1%)	468.00	353.05	946.72	794.48	19.70	229.11	15.6
NS.XTX(1.5%)	468.00	353.05	946.72	794.48	19.70	233.79	23.4
NS.XTX (2%)	468.00	353.05	946.72	794.48	19.70	222.87	31.2

Moulds and Equipment Cubes:
Standard cube moulds of 150X150X150mm are made of cast iron were used for obtaining compressive strength and durability properties.

Casting
The standards moulds were fitted such that there are no gaps between the plates of the moulds. If there are small gaps they were filled with plaster of Paris. The moulds then oiled and kept ready for casting. A pan mixer of having 100kg capacity was used for mixing concrete and the super plasticizer was used for workability purpose as per the specifications and calculations. This was dispersed in water in required proportion before mixing the water with the ingredients coarse, fine aggregates, cement and fly ash. Water and super plasticizer were added subsequently. Nano silica is added after thorough mixing. Nano silica is in colloidal state, so the amount of water content present in nano silica is deducted from actual water content. At the end of casting the top surface of cube was made plane using trowel and a hacksaw blade to ensure atop uniform surface. After 24hrs of a casting the moulds were kept for wet curing for the required number of days before testing.

Figure 4.1 Cubes demoulded after 24hrs of casting

Curing
After the completion of casting all the specimens were kept to maintain the ambient conditions viz. temperature of 27±2 C and 90% relative humidity for 24hours. The specimens were removed from the mould and submerged in

clean fresh water until just prior to testing. The temperature of water in which the cubes were submerged was maintained at 27± 2 C. The specimens were cured for 7 and 28 days.

Figure 42 Specimen kept for curing in curing tank

V. TESTS FOR HARDENED PROPERTIES OF SCC

At the end of the required number of days of curing i.e. 7 days and 28days, the specimens were taken out and tested under 2000kN Compression Testing Machine. After 28days curing the specimens are immersed in 5%H2SO4, 5% HCl and tested again after 3days, 7days and 28days under CTM.

Compressive Strength

The cube specimens were tested on compression testing machine of capacity 2000kN.The bearing surface of the machine was wiped off clean and any loose sand or other material removed from the surface of the specimen .The specimen was placed in the machine in such a manner that the load was applied to opposite sides of the cubes as caste that is, not top and bottom. The axis of the specimen was carefully aligned at the center of the loading frame. The load applied was increased continuously at a constant rate until the resistance of the specimen to the increasing load breaks down and no longer can be sustained. The maximum load applied on the specimen was recorded. The details of compressive strength results for specimens without and with nano silica were compared. The cube specimen under compressive test is shown in fig 4.3.

Figure 5.1 CTM where cubes are tested for compressive strength

Acid attack study

The chemical resistance of the concrete was studied through chemical attack by immersing them in an acid solution. After 28days curing period of the specimens of each batch were removed from curing tank and their surfaces were cleaned with a soft nylon brush to remove weak reaction products and loose materials from the specimen. The initial mass, body diagonal dimensions value were measured. 3specimens of each batch of concrete were immersed in 5% H_2SO_4 and 5% HCl.

5.2.1 Preparation of 5% H_2SO_4:

Volume of H_2SO_4taken = 100 ml, Density of H_2SO_4 =1.83 g/cc
Mass of H_2SO_4(98% purity)= 100 x 1.835=183.5 grams
Actual mass of H_2SO_4 = 98/100 x 183.5 = 179.83 grams
5% H_2SO_4= actual mass H_2SO_4 / (mass H_2SO_4+ mass water)
5/100 = 179.83/(183.5+x)
X =3413 ml of water.
i.e., for 100ml of 98% H_2SO_4, 3413ml volume of water is added to make 5% H_2SO_4 solution.

Figure 5.2 cubes immersed in 5% H_2SO_4 and 5% HCl

Preparation of 5% HCl:

Volume of HCl= 100 ml
Mass of HCl (36.5% purity)= 100 x 1.18=118 grams
Actual mass of HCl = 36.5/100 x 118= 42.07 grams
5% HCl= actual mass HCl / (mass HCl+ mass water)
5/100 = 42.07/(118+x)
X =731 ml of water.
i.e., for 100ml of 36.5% HCl, 731ml volume of water is added to make 5% HCl solution.

The mass, diagonal dimensions values are measured at 3, 7, 14, 21, 28 days of immersion. Compressive strength is measured at 3days, 7days and 28days of immersion. Normality of the solutions is maintained constant throughout the durability test. Normality of solution is checked for every after 10days, if any decrease in normality the amount of acid consumption is measured and replaced with that amount. Normality of the acid is determined by titrating the acid with 1N NaOH (base) solution as shown in Fig.3.10.Before testing, each specimen is removed from the baths, brushed with a soft nylon brush and rinsed in tap water. This process removes loose surface material from the specimens.Mass change, reduction in compressive strengths values and diagonal dimensions are observed.

Figure 5.3 Titration of acid solution with 1N NaOH base solution

For determining the resistance of concrete specimens to aggressive environment such as acid attack, the durability factors as proposed by the philosophy of ASTM (666-1997). In the present investigation, the "Acid Durability

Factors" are derived directly in terms of relative strengths. The relative strengths are always compared with respect to the 28 days value (i.e. at the start of the test)

The "Acid Durability Factors" (ADF) can be calculated as follows.
ADF = Sr N / M ---------------------- Eq(3.2)
Where, Sr - Relative Strength at N days, (%)
N - Number of days at which the durability factor is needed.
M - Number of days at which the exposure is to be terminated.
So M is 28 in this case.

The extent of deterioration at each corner of the struck face and the opposite face is measured in terms of the acid diagonals (in mm) for each of two cubes and the "Acid Attack Factor" (AAF) per face is calculated as follows.
AAF = (Loss in mm on eight corners of each of 2 cubes)/4. ----------------------Eq(3.3)

Figure 5.4 Measurement of diagonals to determine Acid Attack Factor

Sorptivity study

The sorptivity tests were carried out on all batches of SCC with size of 15x15 x15cm, after drying in oven, at a temperature of 100 ± 10 ºC. The samples were stored until the weight loss was negligible. The preparation of samples also included water impermeability of their lateral faces, reducing the effect of water evaporation. The test started with the registration of samples weight and afterwards they were placed in a recipient in contact with a level of water capable to submerge them about 5 mm as shown in Fig 3.12. After a predefined period of time, the samples were removed from the recipient to proceed to weight registration. Before weighing, the samples superficial water was removed with a wet cloth. Immediately after weighting, the samples were replaced in the recipient till reach the following measuring time. The procedure was repeated, consecutively, at various times such as15 min, 30 min, 1 h, 2 hrs, 4 hrs, 6 hrs, 24 hrs, 48 hrs,72 hrs, 7days, 14days and 28days.

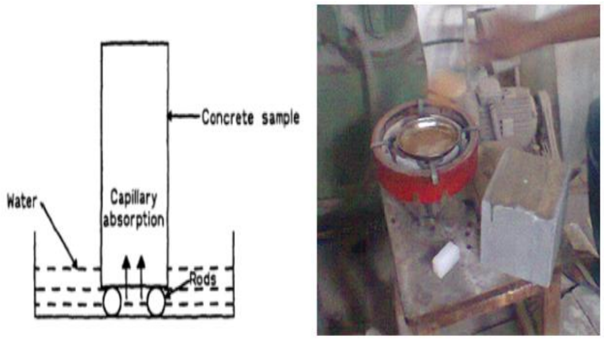

Figure 5.4 Sorptivity test, applying wax on the sides of the cube specimen

Because of a small initial surface tension and buoyancy effects, the relationship between cumulative water absorption (kg/m^2) and square root of exposure time ($t^{0.5}$)shows deviation from linearity during first few minutes. Thus, for the calculation of sorptivity coefficient,only the section of the curves for exposure period from15 min to 72 hrs, where the curves were consistently linear, was used.

The sorptivity coefficient (k) was obtained by using the following expression:

$$\frac{W}{A} = k\sqrt{t} \text{ ----------------------Eq(3.4)}$$

Where$W$ = the amount of water adsorbed in (kg);
A = thecross-section of specimen that was in contact with water(m^2);
t = time (min);
k = the sorptivity coefficient of the specimen (kg/m^2/min$^{0.5}$).
The details of the experimental program conducted are discussed in the next chapter.

VI. RESULTS AND DISCUSSIONS

General

The results of the various strength and durability tests as described in chapter 3 are presented and discussed in this chapter. A flowchart showing the details of experimental program is shown in **Fig. 6.1**.

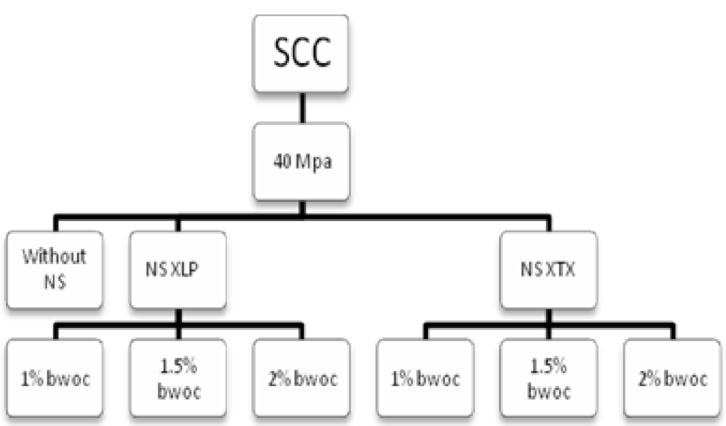

Figure 6.1Flow Chart showing the details of Experimental program

Effect of nano silica on Compressive Strength

Fig. 6.2and **Table 6.1**are the details of Compressive Strength of SCC without nano silica and with nano silica. It is very much evident from the figure that there is only a steep increase in the compressive strength of nano silica concrete. It can also be said that nano silica with 1.5% is optimum in both the grades of nano silica. Compressive strength of NANO SILICA-XLP of 1.5% bwoc added in SCC is more compared to NANO SILICA-XTX of 1.5% bwoc.

Table 6.1 Average Compressive Strength of SCC with and without nano silica

	Compressive strength (Mpa)		**%Increase in compressive strength (Mpa)**	
Grade	**7 days**	**28days**	**7days**	**28days**
Normal SCC	30.51	42.3	0	0
NS.XLP (1%)	41.19	51.86	34.99	22.60
NS.XLP (1.5%)	47.05	61.74	54.21	45.96
NS.XLP (2%)	39.93	52.98	30.88	25.25
NS.XTX (1%)	42.31	55.48	38.66	31.16
NS.XTX (1.5%)	47.11	59.7	54.40	41.13
NS.XTX (2%)	43.62	58.12	42.96	37.40

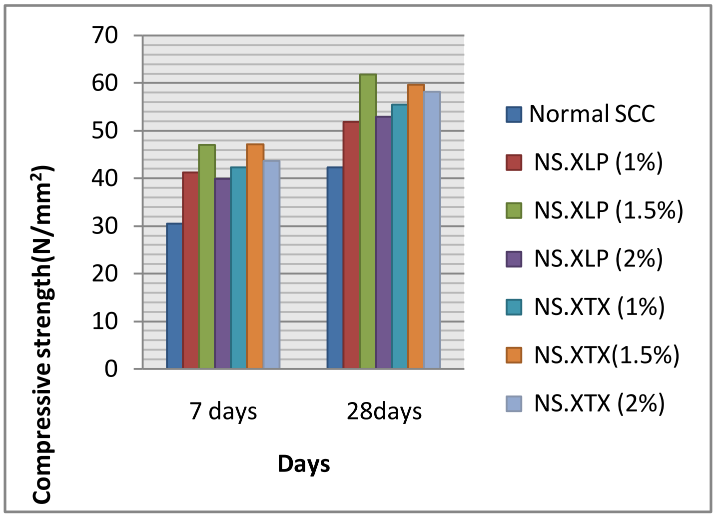

Figure 6.2Average compressive strength of SCC without and with nano silica

Acid attack

In acid attack studies on SCC, the effect of 5% H_2SO_4 and 5% HCl acid were studied. The various observations made are explained below.

Visual observation

In the first stage of the test the change in the physical state of the specimens after 3, 7, 14, 21, 28 days of immersion is observed. After 28 days of immersion the cement mortar from the surface was badly eaten up and aggregates are clearly visible as shown in figure 6.3. The specimens in 5% H_2SO_4 solution even after 7days immersion of time only efflorescence was observed.For the specimens immersed in 5% HCl, cracks were observed on the surface and edges were lost after 28days.

Figure 6.3Specimen of normal SCC immersed in 5% H_2SO_4

Loss of Weight

The change in the mass of the specimens were observed and plotted against the number of days of immersion in acids as shown in the following Table 6.2, 6.3and Figures 6.4, 6.5.

Table 6.2 Percentage mass losses when immersed in 5% Sulphuric acid solution

	Cubes immersed in 5% H2so4					
	GRADE	***DAYS***				
		0	**7**	**14**	**21**	**28**
%MASS LOSS	Normal	0	1.14	1.58	1.95	2.32
	NS-XLP-1%	0	0.20	0.61	0.79	1.09
	NS-XLP-1.5%	0	0.31	0.62	0.76	1.06
	NS-XLP-2%	0	0.44	0.73	1.23	1.63
	NS-XTX-1%	0	0.33	0.69	1.21	1.81
	NS-XTX-1.5%	0	0.43	0.63	0.99	1.38
	NS-XTX-2%	0	0.25	0.62	0.97	1.30

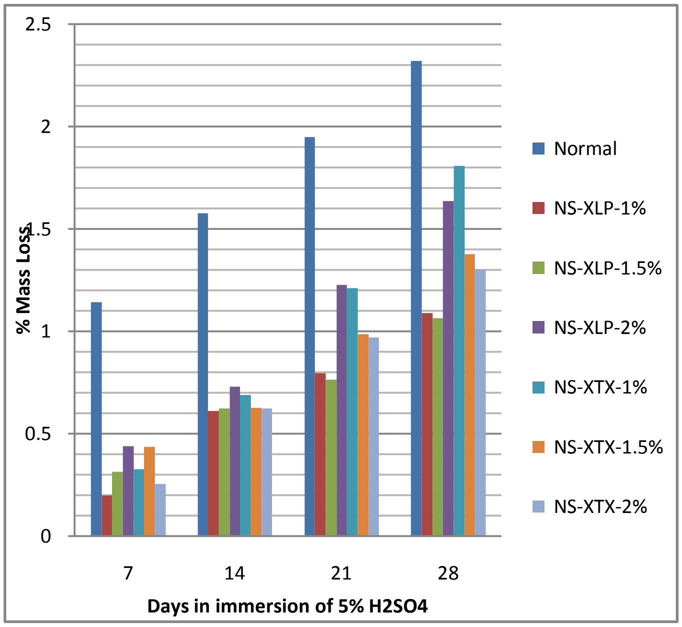

Figure 6.4Percentage mass losses when immersed in 5% Sulphuric acid solution

Table 6.3Percentage mass losses when immersed in 5% Hydrochloric acid solution

	Cubes immersed in 5% HCl						
	GRADE	***DAYS***					
		0	***3***	***7***	***14***	***21***	***28***
%MASS LOSS	Normal	0	2.45	3.03	3.22	3.66	3.85
	NS-XLP-1%	0	1.28	1.72	1.87	2.08	2.17
	NS-XLP-1.5%	0	1.47	2.02	2.11	2.35	2.37
	NS-XLP-2%	0	1.30	1.71	1.73	2.11	2.28
	NS-XTX-1%	0	1.16	1.19	1.37	1.57	1.95
	NS-XTX-1.5%	0	0.74	1.10	1.26	1.45	1.89
	NS-XTX-2%	0	0.83	1.18	1.35	1.55	1.81

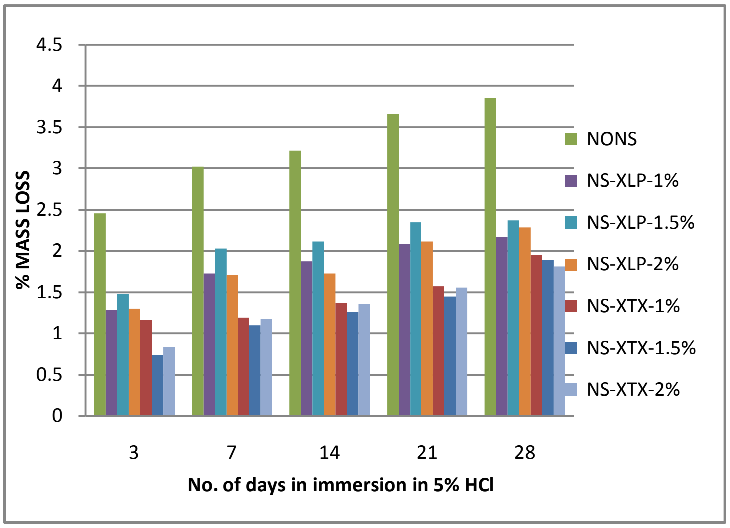

Figure 6.5 Percentage mass loss when immersed in 5% Hydrochloric acid solution

From the above graphs it can be observed that the mass loss in normal SCC is more when compared to various percentages of nano silica addition. After 28 days of immersion Nano Silica- XLP 1% and 1.5% additions has less percentage of mass loss in sulphuric acid and Nano silica-XTX 2% has less percentage of mass loss in Hydrochloric acid.

Acid Durability Factor

The % loss of Compressive Strength and Acid Durability Factor (ADF) of the specimens were observed and plotted against the number of immersion days in acids as shown in the following Table 6.4, 6.5 and Figures 6.6, 6.7 and 6.8, 6.9.

Table 6.4 :% loss of Compressive Strength and Acid Durablity Factors for 5% H_2SO_4

Grade	***% loss of Compressive Strength and Acid Durablity Factors***								
	3days			***7days***			***28days***		
	% loss of Comp. Strengt	***relative strength (Sr.)***	***ADF***	***% loss of Comp. Strengt***	***relative strength (Sr.)***	***ADF***	***%loss of Comp. Strength***	***relative strength (Sr.)***	***ADF***

	h			***h***					
Normal	11.51	88.49	9.48	18.78	81.22	20.31	49.09	50.91	50.91
NS-XLP-1%	9.57	90.43	9.69	15.95	84.05	21.01	41.23	58.77	58.77
NS-XLP-1.5%	7.65	92.35	9.89	19.38	80.62	20.16	56.02	43.98	43.98
NS-XLP-2%	11.51	88.49	9.48	16.36	83.64	20.91	45.23	54.77	54.77
NS-XTX-1%	10.21	89.79	9.62	16.45	83.55	20.89	44.25	55.75	55.75
NS-XTX-1.5%	9.68	90.32	9.68	14.23	85.77	21.44	49.63	50.37	50.37
NS-XTX-2%	8.78	91.22	9.77	15.27	84.73	21.18	52.03	47.97	47.97

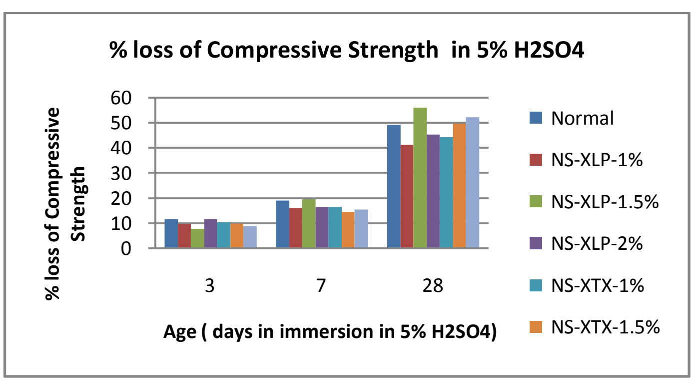

Figure 6.6: % loss of Compressive Strength for cubes immersed in 5%H_2SO_4

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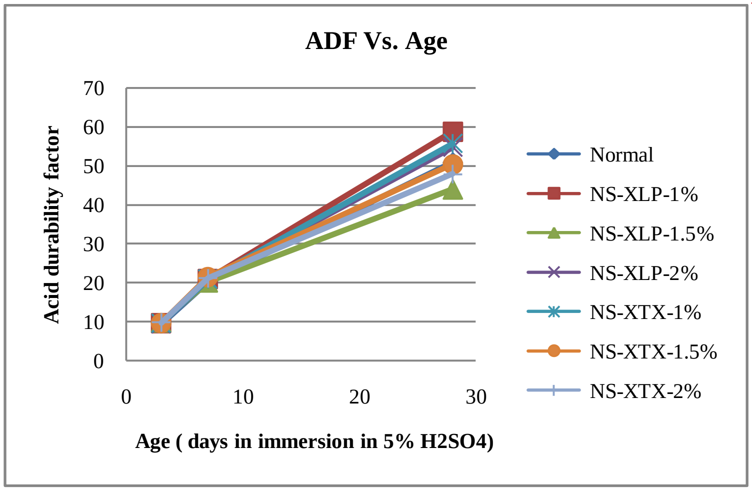

Figure 6.7:Graph between Acid Durability Factor and No. of days in immersion in 5% H_2SO_4

Table 6.5:% loss of Compressive Strength and Acid Durablity Factors for 5% HCl

Grade	*% loss of Compressive Strength and Acid Durablity Factors for 5% HCl*								
	3days			*7days*			*28days*		
	%loss of Comp. Strength	*relative strength (Sr.)*	*ADF*	*%loss of Comp. Strength*	*relative strength (Sr.)*	*ADF*	*%loss of Comp. Strength*	*relative strength (Sr.)*	*ADF*
Normal	5.94	94.06	10.08	7.98	92.02	23.01	14.93	85.07	85.07
NS-XLP-1%	3.45	96.55	10.34	4.23	95.77	23.94	12.32	87.68	87.68
NS-XLP-1.5%	2.34	97.66	10.46	4.65	95.35	23.84	18.74	81.26	81.26

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NS-XLP-2%	3.78	96.22	10.31	7.12	92.88	23.22	12.67	87.33	87.33
NS-XTX-1%	2.15	97.86	10.48	4.43	95.57	23.89	11.21	88.79	88.79
NS-XTX-1.5%	1.18	98.82	10.59	3.34	96.67	24.17	12.57	87.43	87.43
NS-XTX-2%	1.67	98.33	10.54	3.99	96.01	24.00	10.91	89.09	89.09

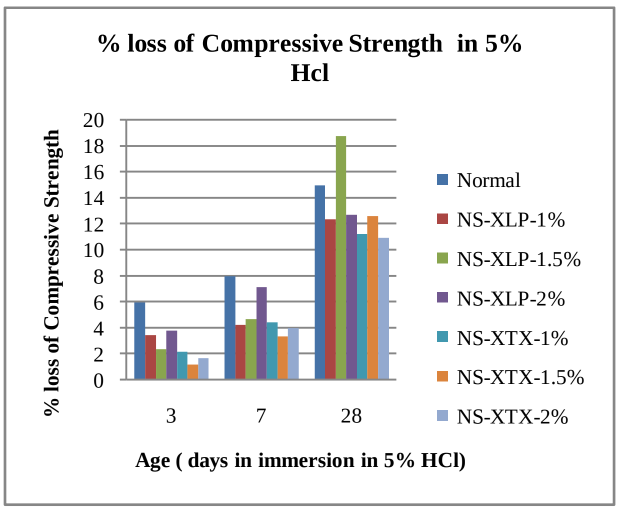

Figure 6.8:% loss of Compressive Strength cubes immersed in 5% HCl

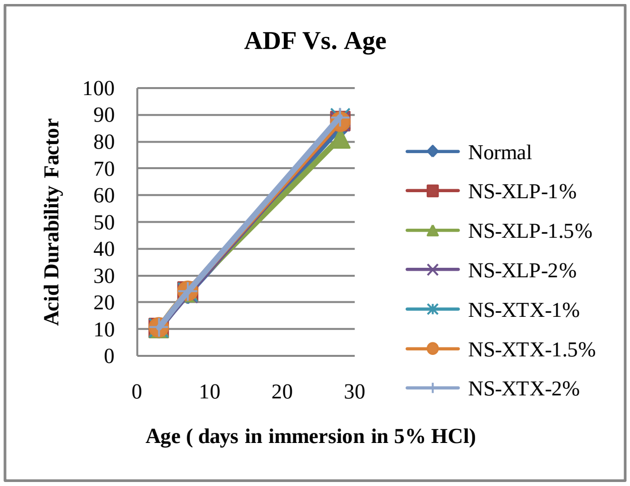

Figure 6.9 Acid Durablity FactorsVs. No. of days in immersion in 5% HCl

From the figures, the following observation are made

- After 28 days of immersion in both the acid solutions percentage loss of compressive strength of 1.5 % Nano-XLP SCC is more when compared due to normal SCC.
- Acid durability factor for cube immersed in 5% sulphuric acid is more for 1% Nano silica SCC of two grades. This implies that 1% addition is more durable when compared to other.
- Acid durability factor for cube immersed in 5% Hydrochloric acid is almost same for all the specimens and but it is more for 2% Nano silica -XTX grade, also for 1% Nano silica SCC of two grades . This implies that 2% Nano silica SCC of XTX grade,1% addition of both grades of nano silica is more durable in hydrochloric acid when compared to other.
- It is observed that the percentage loss of compressive strength is more in sulphuric acid is more when compared to hydrochloric acid.

Acid Attack Factor

The Acid Attack Factor (AAF) of the specimens were observed and plotted against the number of immersion days in acids as shown in the following Table 6.6, 6.7 and Figures 6.10, 6.11, 6.12, 6.13.

Table 6.6:Acid Attack Factor for cubes immersed in 5% H_2SO_4

Grade	Acid Attack Factor									
	3days		7days		14days		21days		28days	
	total loss in 8 corners	AAF	total loss in 8 corners	AAF	total loss in 8 corners	AAF	total loss in 8 corners	AAF	total loss in 8 corners	AAF

	(mm		**(mm**		**(mm**		**(mm**		**(mm**	
Normal	2	0.063	6	0.188	10	0.313	12	0.375	14	0.438
NS-XLP-1%	2	0.063	3	0.094	7	0.219	9	0.281	11	0.344
NS-XLP-1.5%	1	0.031	3	0.094	6	0.188	9	0.281	11	0.344
NS-XLP-2%	2	0.063	6	0.188	9	0.281	11	0.344	13	0.406
NS-XTX-1%	1	0.031	5	0.156	8	0.250	9	0.281	12	0.375
NS-XTX-1.5%	1	0.031	5	0.156	7	0.219	9	0.281	12	0.375
NS-XTX-2%	2	0.063	5	0.156	7	0.219	9	0.281	12	0.375

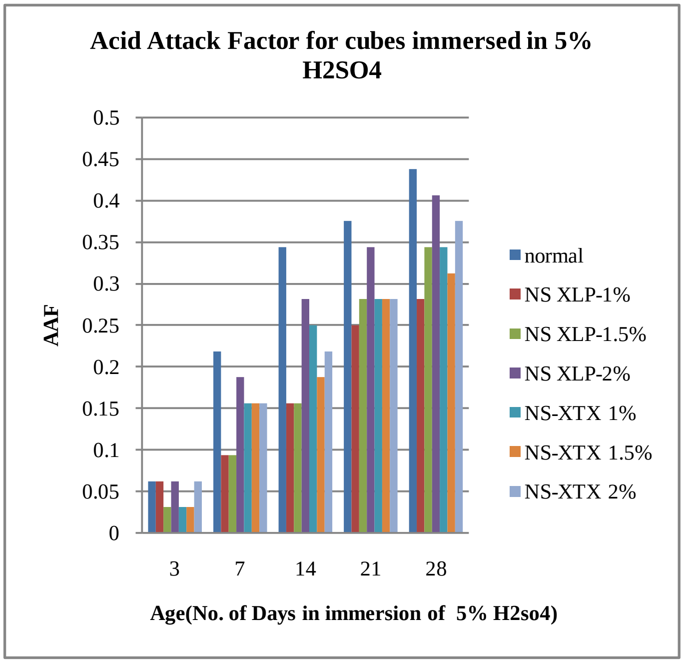

Figure 6.10: Bar chart showing Acid Attack Factor of cubes immersed in 5% H_2SO_4

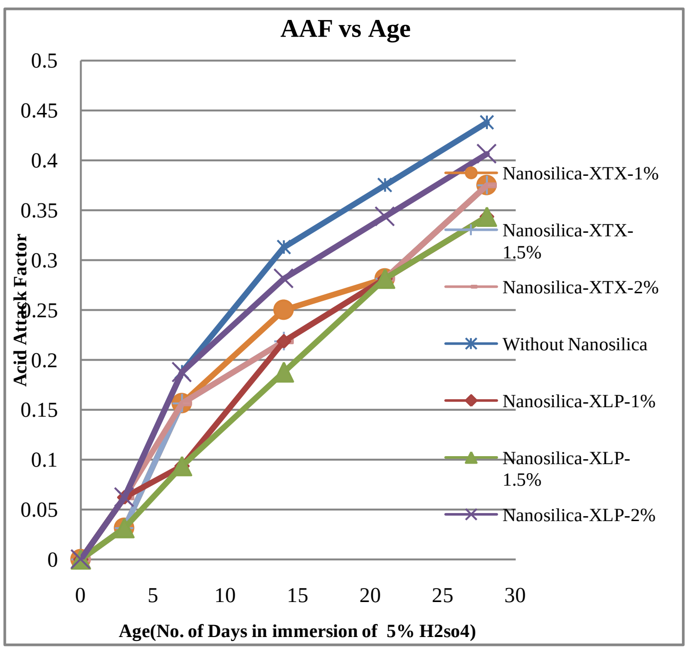

Figure 6.11:Acid Attack Factor for cubes immersed in 5% H_2SO_4

Table 6.7:Acid Attack Factor for cubes immersed in 5% HCl

Grade	3days		7days		14days		28days	
	total loss in 8 corners (mm)	AAF	total loss in 8 corners (mm)	AAF	total loss in 8 corners (mm)	AAF	total loss in 8 corners (mm)	AAF
Normal	1	0.031	2	0.063	5	0.156	6	0.188
NS-XLP-1%	1	0.031	2	0.063	4	0.125	6	0.188
NS-XLP-1.5%	0	0	2	0.063	3	0.094	5	0.156
NS-XLP-2%	0	0	2	0.063	4	0.125	6	0.188
NS-XTX-1%	1	0.031	3	0.094	4	0.125	6	0.188
NS-XTX-1.5%	0	0	2	0.063	4	0.125	6	0.188
NS-XTX-2%	0	0	1	0.031	3	0.094	5	0.156

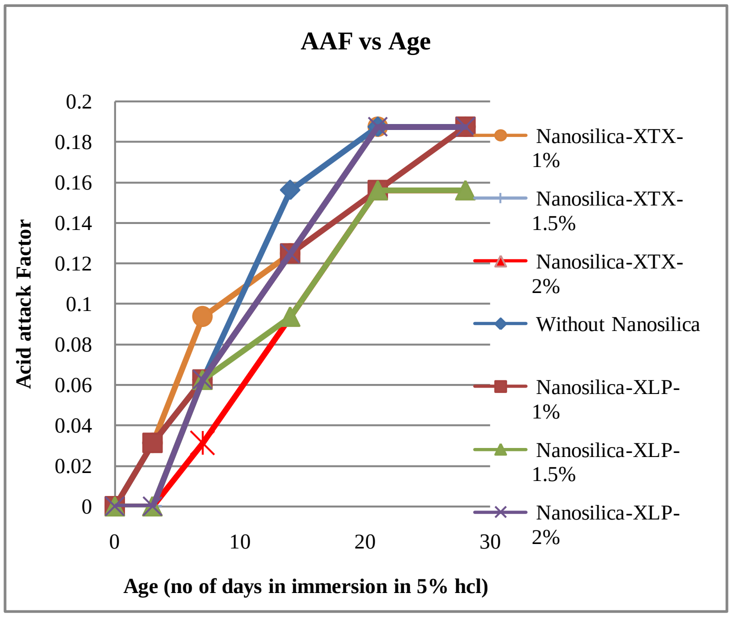

Figure 6.12Acid Attack Factor for cubes immersed in 5% HCl

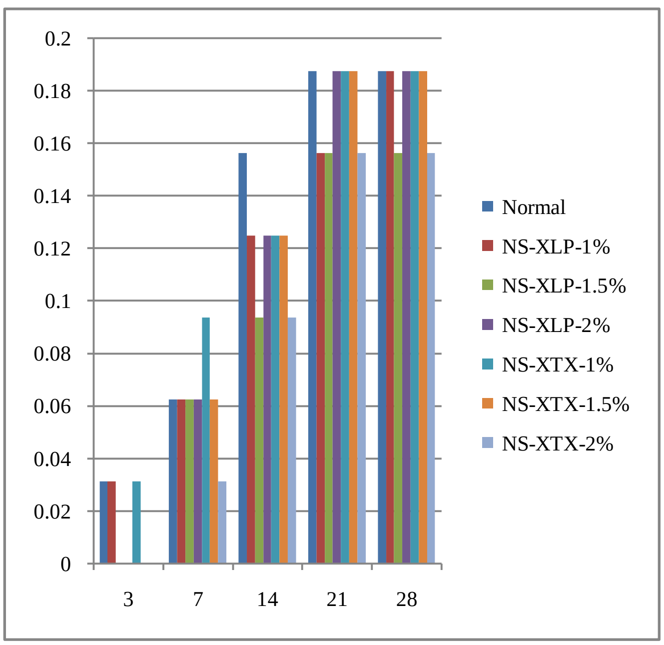

Figure 6.13:Bar chart showing Acid Attack Factor for cubes immersed in 5% HCl

From the figures, the following observation are made

- In sulphuric acid solution after 28 daysimmersion the loss of diagonals lengths is morein normal SCC when compared tonano additions.

- After 28days of immersion sulphuric acid, 1% and 1.5% Nano silica- XLP is less attacked when compared to other nano percentages and normal SCC in terms of Acid attack factor.
- Acid Attack factor for cube immersed in 5% sulphuric acid is more when compared with solutions of 5% Hydrochloric acid.
- Nano silica additions are less attacked and said to be more durable when compared with normal SCC in terms of Acid attack factor.
- AAF values are almost same for the cubes immersed in 5% HCl after 28days.

Sorptivity

The water absorption and Sorptivity coefficient of the specimens were observed and plotted against the in square root of time in minutes as shown in the following Table 6.8 and 6.9and Figures 6.14 and 6.15

Table 6.8: water absorption of the cubes immersed up to 5mm in water.

Time^0.5 (min)	***0***	***3.873***	***5.4772***	***7.746***	***18.974***	***37.9473***	***65.7267***	***141.99***	***200.798***
Grade	**water absorption (W/A) in cm**								
Normal SCS	0	0.006	0.0059	0.0074	0.0089	0.01778	0.02222	0.0222	0.01778
Nanosilica-XLP-1%	0	0.001	0.003	0.003	0.0044	0.00593	0.00889	0.0119	0.01185
Nanosilica-XLP-1.5%	0	0.001	0.0015	0.0015	0.003	0.00444	0.00741	0.0089	0.00741
Nanosilica-XLP-2%	0	0.003	0.003	0.0044	0.0074	0.00889	0.01185	0.0119	0.01185
Nanosilica-XTX-1%	0	0.003	0.0044	0.0044	0.0089	0.01185	0.01481	0.0178	0.01481
Nanosilica-XTX-1.5%	0	0	0.0015	0.0015	0.0015	0.00444	0.00593	0.0089	0.00889
Nanosilica-XTX-2%	0	0	0.0015	0.0015	0.003	0.00444	0.00593	0.0089	0.00593

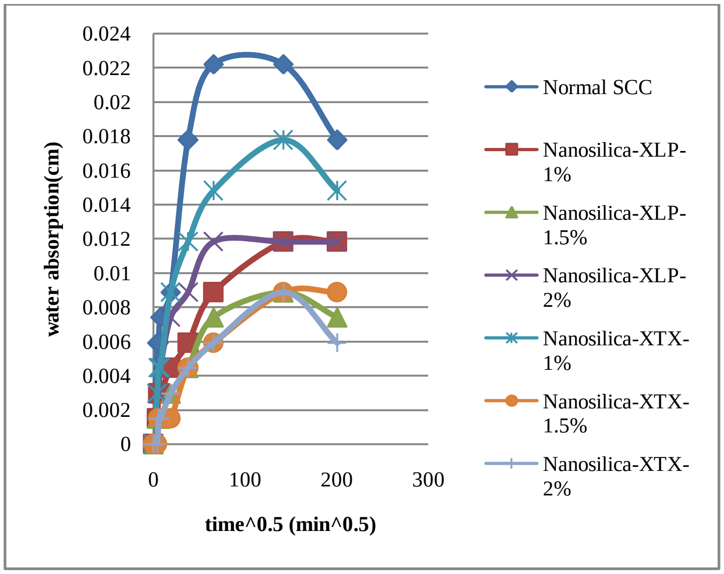

Figure 6.14 Graph between Water absorption and time$^{0.5}$

Table 6.9: Sorpitivity coefficient(cm/min ^0.5) of the cubes immersed up to 5mm in water

time^0.5	3.873	5.477	7.746	18.974	37.947	65.7267	141.986	200.8
Grade	**Sorpitivity coefficient(cm/min ^0.5)**							
Without Nanosilica	0.002	0.001	0.001	0.0005	0.0005	0.00034	0.00016	9E-05
Nanosilica-XLP-1%	4E-04	5E-04	0.0004	0.0002	0.0002	0.00014	8.3E-05	6E-05
Nanosilica-XLP-1.5%	4E-04	3E-04	0.0002	0.0002	0.0001	0.00011	6.3E-05	4E-05
Nanosilica-XLP-2%	8E-04	5E-04	0.0006	0.0004	0.0002	0.00018	8.3E-05	6E-05
Nanosilica-XTX-1%	8E-04	8E-04	0.0006	0.0005	0.0003	0.00023	0.00013	7E-05
Nanosilica-XTX-1.5%	0	3E-04	0.0002	8E-05	0.0001	9E-05	6.3E-05	4E-05
Nanosilica-XTX-2%	0	3E-04	0.0002	0.0002	0.0001	9E-05	6.3E-05	3E-05

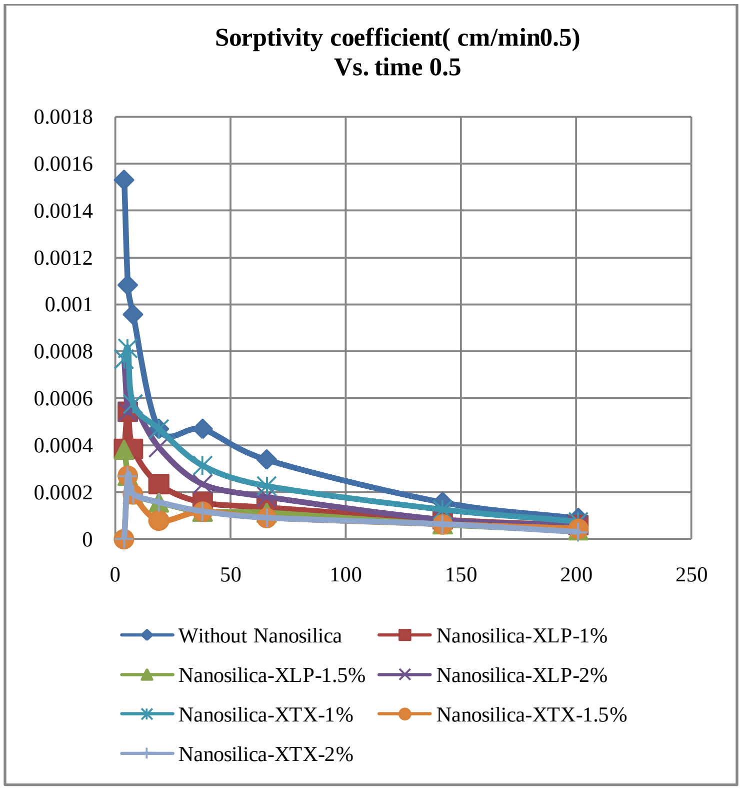

Figure 6.15 Graph between Sorptivity Coefficient and time$^{0.5}$

From the graphs it is observed that

- Initially there is little bit increase in water absorption in all the batches but after 14 days it is observed that there is decrease.
- Out of three specimens in all the batches only one or two specimens are showing a marginal increase in weight.
- Nano additions in SCC are almost impermeable, as there is no capillary suction. This is might be due to fill of nano materials into the pores.
- There is no much comparison of coefficient of sorptivity between the various nano additons, but 2% Nano XTX addition has less coefficient of sorptivity when compared to the other types.

VII. CONCLUSION

Effect of Nano Silica on Compressive Strength

1. In the present study 40Mpa SCC was developed based on modified nansu method and nano silica additions are made in that.
2. There is a steep increase in the compressive strength at 28days of about 45.2% and 41.13% with the addition of 1.5% Nano silica of XLP grade and XTX grade respectively. Hence 1.5% addition of nano silica is said to optimum.
3. The addition of nano silica improves the hydrated structure of concrete.

Effect of Nano Silica on Durability

1. The surface of the specimens was badly damaged and cement mortar was completely eaten up in 5% $H_2SO_4$and it was not found in 5% HCl.
2. The percentage mass loss with 5% $H_2SO_4$and 5% HCl revealed that nano additions have less percentage of mass loss than normal SCC.
3. After 28 days, the percentage mass loss for Nano Silica XLP with 1.5% addition is 1.06% in 5% sulphuric acid, which is said to less when compared to other percentage of nano silica.
4. After 28 days, the percentage mass loss for Nano Silica XTX with 2% addition is 1.81% in 5% hydrochloric acid, which is said to less when compared to other percentage of nano silica.
5. The percentage loss of both compressive strength and weightare increasing with the time of exposure to acid attack.
6. The percentage compressive strength loss is more for 1.5% Nano Silica-XLP and is about 56.02 % and 18.74% with 5% H_2SO_4 and 5% HClrespectively after 28 days of immersion. This may be due to higher pozzalonic content.
7. At 28 days, the loss of compressive strength is less for XLP- Nano-Silica of 1% addition which is about 41.23% and has more Acid Durability factor of about 58.77, hence it is said to be more durable when compared to others.
8. The deterioration effect of 5% sulphuric acid is more severe when compared to 5% Hydrochloric acid.
9. Acid durability factor for cubes immersed in 5% Hydrochloric acid are almost same but after 28 days ADF is more for 2% Nano silica SCC of XTX grade, and also for 1% Nano silica SCC of two grades. This implies that 2% Nano silica SCC of XTX grade, 1% addition is more durable in hydrochloric acid when compared to other in terms of Acid durability factor.
10. Nano silica additions are less attacked and said to be more durable when compared with normal SCC in terms of Acid attack factor.
11. At 28days 1% and 1.5% Nano silica- XLP has an acid attack factor of about 0.344 when immersed in 5% sulphuric acid, hence it is said to be less attacked in terms of Acid Attack Factor.
12. Acid Attack Factor values are almost same for the cubes immersed in 5% HCl after 28 days.

Effect of Nano Silica on Sorptivity

1. Initially there is little bit increase in water absorption in all the batches but after 14 days it is observed that there is decrease.
2. Out of three specimens in all the batches only one or two specimens are showing a marginal increase in weight.
3. There is no much comparison of coefficient of sorptivity between the various nano additons, but 2% Nano XTX addition has less coefficient of sorptivity when compared to the other types.

1\. Nano additions in SCC are almost impermeable, as there is no capillary suction. This is might be due to fill of nano materials into the pores

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