To Study the Influence of Nano Silica on the Strength & Durability of Self Compacting Concrete

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Abstract: Self-compacting concrete (SCC) 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.It is used to facilitate and ensure proper filling and good structural performance of heavily reinforced structural members. 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.
Degradation of concrete members exposed to aggressive sulphuric acid environments is a key durability issue that affects the life cycle performance and maintenance costs of vital civil infrastructure. Sulphuric acid in groundwater, chemical waste or generated from the oxidation of sulphur bearing compounds in backfill can attack substructure concrete members. Moreover, concrete structures in industrial zones are susceptible to deterioration due to acid rain of which sulphuric acid is a chief component. 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 twonano silica 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.

Key words: Cement, compressive strength, FLY ASH and fibers.

1. Introduction

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 has gained wide use for placement in congested reinforced concrete structures with difficult casting conditions. For such applications, the fresh concrete must possess high fluidity and good cohesiveness. 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. SCC is not affected by the skills of workers, the shape and amount of reinforcing bars or the arrangement of a structure and, due to its high-fluidity and resistance to segregation it can be pumped longer distances. The main advantage of SCC is to shorten construction period and to assure compaction in the structures especially in the confined zones where vibration and compaction is difficult. The other advantages of SCC are

1. It eliminates noise due to vibration.
2. It provides high stability during transport and placement.
3. It provides uniform surface quality and homogenous.
4. It provides greater freedom for design
5. It is useful for casting of underwater structures.

The concept of SCC was proposed in 1986 by Professor Hajime Okamura, but the prototype was first developed in 1988 in Japan, by Professor Ozawa at the University of Tokyo. SCC was developed at that time to improve the durability of concrete structures. Since then, various investigations have been carried out and SCC has been used in practical structures in Japan, mainly by large construction companies. Investigations for establishing a rational mix design method and Self-Compactability, testing methods have been carried out from the viewpoint of making it a standard concrete. SCC is cast so that no additional inner or outer vibration is necessary for the compaction. It flows like “honey” and has a very smooth surface level after placing. With regard to its composition, SCC consists of the same components as Conventional concrete, which are cement, aggregates, and water, with the addition of chemical and mineral admixtures in different proportions. Usually, these concretes have higher workability, superior mechanical properties and/or greater resistance to chemical attack as compared to traditional concrete.

2. Development of Self-compacting 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.2.1**). Studies to develop SCC, including a fundamental study on the workability of concrete, were carried out by researchers Ozawa and Maekawa at the University of Tokyo.

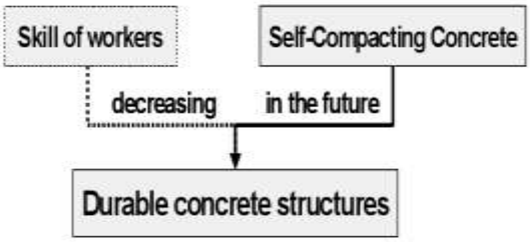

Figure:2.1Necessity of Self-compacting Concrete (SCC)

3. Mechanism for achieving 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 Ozawa have employed the following methods to achieve self-compactability (**Fig. 4.1 & 4.2**)

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

The frequency of collision and contact between aggregate particles can increase as the relative distance between the particles decreases and then internal stress can increase when concrete is deformed, particularly near obstacles. Research has found that the energy required for flowing is consumed by the increased internal stress, resulting in blockage of aggregate particles limiting the coarse aggregate content, whose energy consumption is particularly intense, to a level lower than normal is effective in avoiding this kind of blockage.

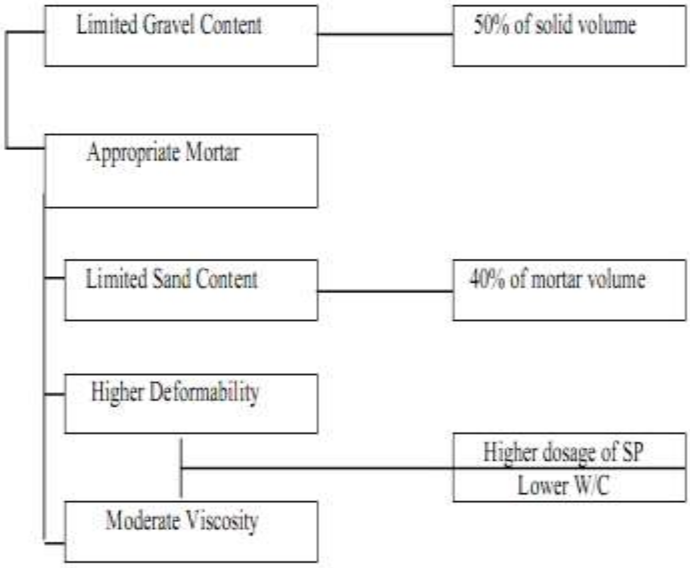

Figure 4.1 Methods for achieving self-compactability

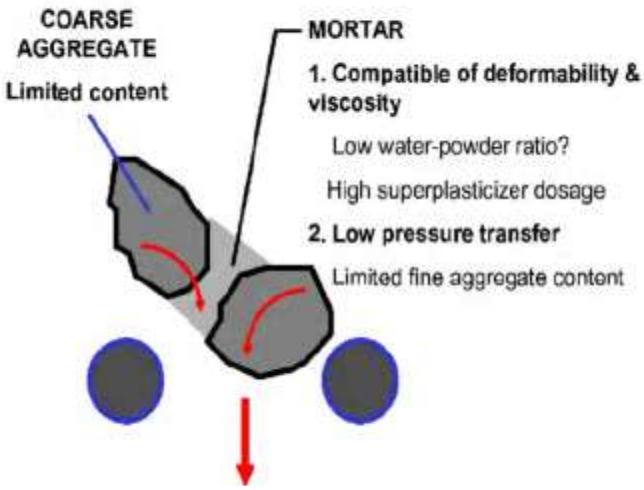

Figure 4.2 Mechanism for achieving self-compatibility

High deformability can be achieved only by the employment of a super plasticizer, keeping the water-powder ratio to a very low value.

Since the development of the prototype of SCC in 1988, the use of SCC in actual structures has gradually increased. The main reasons for the employment of SCC can be:

- To shorten construction period.
- To assure compaction in the structure; especially in confined zones where vibrating compaction is difficult.
- To eliminate noise due to vibration; effective especially at concrete production plants.

By employing SCC, the cost of chemical and mineral admixtures is compensated by the elimination of vibrating compaction and work done to level the surface of the normal concrete. . SCC can greatly improve construction systems previously based on conventional concrete requiring vibrating compaction. Vibrating compaction, which can easily cause segregation, has been an obstacle to the rationalization of construction work. Once this obstacle has been eliminated, concrete construction could be rationalized and a new construction system, including formwork, reinforcement, support and structural design, could be developed.

4. Materials used.

The different materials used in this investigation are

- 53 Grade Ordinary Portland cement
- Fine Aggregate
- Coarse Aggregate
- Super Plasticizer (CONPLAST SP430)
- Fly ash.
- Water
- Nano Silica (16% and 30% nano content)

A) 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.

B) 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. To obtain Zone-2 sand correctly, sand retained on each sieve is mixed in appropriate proportion according to the mix design and required quantity in which each size fraction is mixed.

C) 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.

D) WATER:

The least expensive but the most important ingredient of concrete is water. The water which is used for mixing concrete was clean and free from harmful impurities such as oil, alkali, acid etc. The portable water was used for mixing and curing work. The specific gravity of water is 1.

E) *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.

F) 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 superplasticisers 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.

G) 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 3.3.

Table 5.1 Properties of nano-sio2

Notation for NanoSilica Gel	***Active nanocontent (%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***

H) 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.

5. Experimental Tests

WORKABILITY

This test measures the ease of flow of the concrete; shorter flow times indicate greater flow ability. For SCC a flow time of 10 seconds is considered appropriate. The inverted cone shape restricts flow, and prolonged flow times may give some indication of the susceptibility of the mix to blocking. After 5 minutes of settling, segregation of concrete will show a less continuous flow with an increase in flow time.
Tests were conducted on 40Mpa Self Compating Concrete for the above explained methods for SCC. The details of the experimental results obtained as shown in **Table 3.4.**

Table 5 Fresh Properties of Self-Compacting Concrete

S. No	Method	Unit	Value	EFNARC Specification
1.	Slump flow by Abrams cone	mm	680	600-800
2.	T50cm Slump Flow	Sec	4.38	2-5
3.	V-funnel	Sec	8.38	6-12
4	V-funnel T5 min	sec	10.27	+3
5.	J-ring	mm	9	0-10

COMPRESSIVE STRENGTH:

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.,withoutnano silica, 3batches of nano silica(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 nansu 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 6.1.

Table 5.1 Details of specimens cast

S.No	Grade of Concrete	Type of Concrete	% of Nanosilica added by BWOC added	No. of cubes cast 150x150x150 mm
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

6. Mix Design proportions

Table : Mix 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/m^3)
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

7. RESULT AND DISCUSSION:

7.1. Effect of nano silica on Compressive Strength:

Fig. 7.1 and **Table 4.1** 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.

Grade	Compressive strength		%Increase in compressive	
	7days	28days	strength (Mpa)	
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

CONCLUSIONS

The present work deals with understanding the effect of nano silica inclusion on strength and durability properties of self-compacting concrete.

7.2. 5.1 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.

7.3. 5.2 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 weight are 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% HCl respectively 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.

7.4. 5.3 Effect of Nano Silica on Sorptivity:

- 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.
- There is no much comparison of coefficient of sorptivity between the various nanoadditons, but 2% Nano XTX addition has less coefficient of sorptivity when compared to the other types.
- 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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