Indian J.Sci.Res. 17(2): 142-147, 2018
ISSN: 0976-2876 (Print)
ISSN: 2250-0138(Online)

TO STUDY THE INFLUENCE OF NANO SILICA ON THE STRENGTH AND DURABILITY OF SELF COMPACTING CONCRETE

[1]R.Sujatha, [2]D Bharath Naik, [3]Gulam Dastagir Rizwani, [4]William Paul
[1] I & CAD Department, Nizamabad
[2]Department of Civil Engineering, College, Methodist College of Engineering, Hyderabad
[3] Department of Civil Engineering, College- Deccan College of Engineering and Technology, Hyderabad
[4]DRDO, Ministry of Defence, Govt of India, Hyderabad

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 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. 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 cubes were cast without nano silica with 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 properties were also studied by immersing the specimensin5% HCl and5% H_2SO_4.

Keywords- self compacting concrete, HCL, durability, 4

I. Introduction

To 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. Studies to develop SCC, including a fundamental study on the workability of concrete.

II. Materials of SCC:

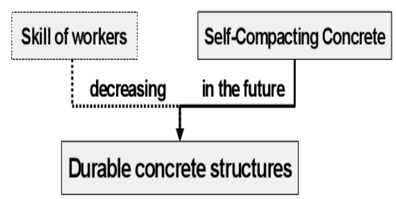
Additions : Stone Powder, Mineral Filler, Fly ash, Silica Fume, nano particles, Ground Blast furnace Slag (GGBS), Other additions (i.e Metakaolin, Natural Pozzolana, ground glass etc.,)

Aggregate : Coarse & Fine Aggregate

Admixture : Super Plasticiser/ High range water reducing admixtures (HRWR), Viscosity modifying admixtures (VMA), Air Entainingad Mixturess

Fibres : Metallic and polymer fibres.

The particle packing in concrete can be improved by using **Nano-silica** which leads to densifying 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.



Self-compacting Concrete

From the foregoing discussion, it is clear that the main aim of the work is developing a SCC and understands the behaviour of such a SCC under various loading action. In the early 1990's there was only a limited public knowledge about the use of self-compacting concrete, and if available that was mainly in Japanese. The first paper on self compaction concrete was presented by Ozawa at the second East-Asia and pacific conference on structural engineering and construction in January 1989. After that self compaction concrete became a point of interest for researchers and engineers around the world who are interested in the durability of concrete and in rational construction systems. In January 1997, RILEM's committee on self compaction concrete was formed and the first international workshop was held in Kochi, Japan in August 1998. As the investigation is aimed at developing and studying the properties of self-compacting concrete a good amount of literature review is done in this direction as detailed below.

III. Literature Review

[1]Corresponding Author

Self-compacting concrete extends the possibility of use of various mineral by-products in its manufacturing and with the densification of the matrix, mechanical behaviour, as measured by compressive, tensile and shear strength, is increased. On the other hand, the use of super plasticizers or high range water reducers, improves the stiffening, unwanted air entrainment, and flowing ability of the concrete. Practically, all types of structural constructions are possible with this concrete. The use of SCC not only shortens the construction period but also ensures quality and durability of concrete. This non-vibrated concrete allows faster placement and less finishing time, leading to improved productivity. In the following paragraph, a summary of the articles and papers found in the literature, about the self-compacting concrete and some of the research work carried out with this type of concrete, are presented.

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 Okamura in 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 (1997) 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.

A model formwork, comprised of two vertical sections (towers) at each end of a horizontal trough, was used by professor Okamura to observe how well self-compacting concrete could flow through obstacles. The concrete was placed into a right-hand tower, flowed through the obstacles, and rose in the left-hand tower. The concrete in the left-hand tower rose to almost the same level as in the right-hand tower. Similar experiments of this type were carried out over a period of about one year and the applicability of self-compacting concrete for practical structures was verified. With a super plasticizer the paste can be made more flowable with little concomitant decrease in viscosity.

The water-cement ratio was taken between 0.4 and 0.6 depending on the properties of the cement. The super plasticizer dosage and the final water-cement ratio were determined so, as to ensure the self-compactability, evaluated subsequently by using the U-type test, after Okamura began his research in 1986, other researchers in Japan have started to investigate self-compacting concrete, looking to improve its characteristics. One of those was Ozawa who has done some research independently from Okamura, and in the summer of 1988.

Kazumasa ozawa (1988) [2] he succeeded in developing SCC for the first time. The year after that, an open experiment on the new type of concrete was held at the University of Tokyo, in front of more than 100researchers and engineers. As a result, intensive research has begun in many places, especially in the research institutes of large construction companies and the University of Tokyo.

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.

Domone et al (1999)[3] has done their research on the effect on fresh properties of mortar phase of SCC of four different types of superplasticizer 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.

Nan su et al [4], proposed a simple mix design method for SCC. The amount of aggregates required is determined, and the paste of binders is then filled into the voids of aggregates to ensure that the concrete thus obtained has flow ability, self-compacting ability and other desired SCC properties. The amount of aggregates, binder, and mixing water, as well as type and dosage of super plasticizer (SP) to be used are the major factors influencing the properties of SCC. Slump flow, V-funnel, L-flow, U-box and compressive strength tests were carried out to examine the performance of SCC, and the results indicate that the proposed method could produce successfully SCC of high quality. The method involved determines Aggregate Packing Factor (PF) and influence on the strength, flow ability and self-compatibility ability.

H.J.H. Brouwers, H.J. Radix [5]: In their research, addresses experiments and theories on SCC. First, the features of ''Japanese and Chinese Methods'' are discussed, in which the packing of sand and gravel plays a major role. Here, the grading and packing of all solids in the concrete mix serves as a basis for the development of new concrete mixes. Mixes, consisting of slag blended cement, gravel (4–16mm), three types of sand (0–1, 0–2 and 0–4mm) and a poly carboxylic ether type super plasticizer, were developed. These mixes are extensively tested, both in fresh and hardened states, and meet all practical and technical requirements such as medium strength and low cost. It follows that the particle size distribution of all solids in the mix should follow the grading line as presented by Andreasen and Andersen. Furthermore, the packing behaviour of the powders (cement, fly ash, stone powder) and aggregates (three sands and gravel) used are analyzed in detail. It follows that their loosely piled void fraction are reduced to the same extent (23%) upon vibration (aggregates) or mixing with water (powders). Finally, the paste lines of the powders are used to derive a linear relation between the deformation coefficient and the product of Blaine value and particle density.

Efnarc specifications [6]: In designing the mix it is most useful to consider the relative proportions of the key components by volume rather than by mass. Indicative typical ranges of proportions and quantities in order to obtain self-compactability are given below. Further modifications will be necessary to meet strength and other performance requirements.

- Water/powder ratio by volume of 0.80 to 1.10
- Total powder content - 160 to 240 liters (400-600 kg) per cubic meter.
- Coarse aggregate content normally 28 to 35 per cent by volume of the mix.
- Water/cement ratio is selected based on requirements in EN 206. Typically water content does not exceed 200 liter/m3
- The sand content balances the volume of the other constituents

Generally, it is advisable to design conservatively to ensure that the concrete is capable of maintaining its specified fresh properties despite anticipated variations in raw material quality. Some variation in aggregate moisture content should also be expected and allowed for at mix design stage. Normally, viscosity-modifying admixtures are a useful tool for compensating for the fluctuations **Khayat's et al. [8]** the objective of his research was to evaluate the uniformity of in situ mechanical properties of self-consolidating concrete used to cast experimental wall elements. Eight optimized SCC mixtures with slump flow values greater than 630mm and a conventional concrete with a slump of 165mm were investigated. The SCC mixtures incorporated various combinations of cementitious materials and chemical admixtures. The water-cementitious materials ratio's ranged from 0.37 to 0.42. Experimental walls measuring 95cm in length, 20cm in width, and 150cm in height were cast. After casting, no consolidation was used for the SCC mixtures, while the medium fluidity conventional concrete received thorough internal vibration. Several cores were obtained in order to evaluate the uniformity of compressive strength and modulus of elasticity along the height of each wall. Khayat et al. found out that all cores from both types of concrete exhibited little variation in compressive strength and modulus of elasticity in relation to height of the wall, indicating a high degree of strength uniformity. However, compressive strength and modulus of elasticity were greater for SCC samples than those obtained from the medium fluidity conventional concrete

IV. Objective of the Study

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

V. Experimental Study

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.,with out nano 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 3.1.

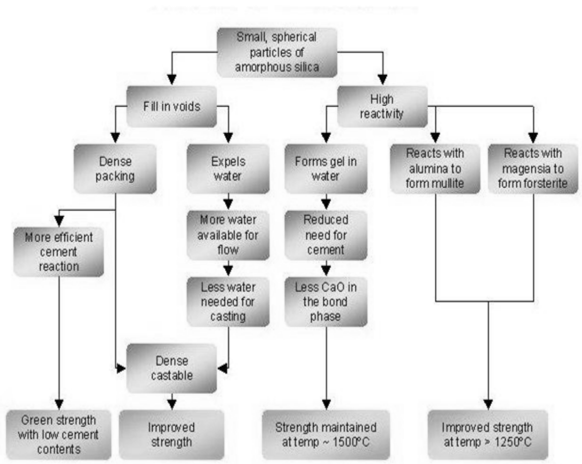
Nano Technology

Nanotechnology is the creation of materials and devices by controlling of matter at the levels of atoms, molecules, and supramolecular (nanoscale) structures

Nano materials

The Nano materials can improve vital characteristics of construction materials such as strength, durability, and lightness, endow useful properties (e.g., heat-insulating, self-cleaning, and antifogging), and function as key sensing components to monitor construction safety and structural health.

nano silica (nano sio2)



Nano Silica Properties

Materials used

- 53 Grade Ordinary Portland cement
- Fine Aggregate
- Coarse Aggregate
- Super Plasticizer (CONPLAST SP430)
- Fly ash.
- Water
- Nano Silica
- **Tests for Fresh Properties of Self-Compacting Concrete**

1. SLUMP FLOW
2. J RING
3. V- FUNNEL

VI. Experimental Results Of Tests

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

VII. Mix design proportions

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.XL (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.XL(2%)	468.00	353.05	946.72	794.48	19.70	195.6	58.5
NS.XT(1%)	468.00	353.05	946.72	794.48	19.70	229.11	15.6
NS.XT(1.5%)	468.00	353.05	946.72	794.48	19.70	233.79	23.4
NS.XT(2%)	468.00	353.05	946.72	794.48	19.70	222.87	31.2

Moulds –

Cubes:

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

Mixing

- First Mix all dry materials in the pan mixer.
- Add the liquid component of the mixture at the end of dry mixing, and continue the wet mixing for another four minutes

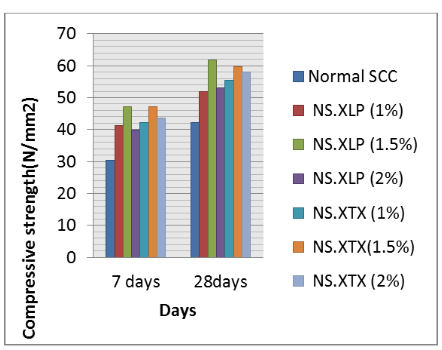
VIII. Results

Effect of Nano silica on Compressive Strength:

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. Compressive strength of NANO SILICA-XLP of 1.5% bwoc added in SCC is more compared to NANO SILICA-XT of 1.5% bwoc

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.XL (1%)	41.19	51.86	34.99	22.6
NS.XL (1.5%)	47.05	61.74	54.21	45.96
NS.XL (2%)	39.93	52.98	30.88	25.25
NS.XT (1%)	42.31	55.48	38.66	31.16
NS.XT(1.5%)	47.11	59.7	54.4	41.13
NS.XT (2%)	43.62	58.12	42.96	37.4



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.

		0	7	28
%MASS LOSS	Normal	0	1.14	2.32
	NS-XL-1%	0	0.20	1.09
	NS-XL-1.5%	0	0.31	1.06
	NS-XL-2%	0	0.44	1.63
	NS-XT-1%	0	0.33	1.81
	NS-XT-1.5%	0	0.43	1.38
	NS-XT-2%	0	0.25	1.30

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

Acid Attack Factor for cubes immersed in 5% H2SO4

Grade	Acid Attack Factor			
	7days		28days	
	total loss in 8 corners (mm)	AAF	total loss in 8 corners (mm)	AAF
Normal	6	0.188	14	0.438
NS-XL-1%	3	0.094	11	0.344
NS-XL-1.5%	3	0.094	11	0.344
NS-XL-2%	6	0.188	13	0.406
NS-XT-1%	5	0.156	12	0.375
NS-XT-1.5%	5	0.156	12	0.375
NS-XT-2%	5	0.156	12	0.375

Acid Attack Factor for cubes immersed in 5% HCl

Grade	Acid Attack Factor			
	7days		28days	
	total loss in 8 corners (mm)	AAF	total loss in 8 corners (mm)	AAF
Normal	2	0.063	6	0.188
NS-XL-1%	2	0.063	6	0.188
NS-XL1.5%	2	0.063	5	0.156
NS-XL-2%	2	0.063	6	0.188
NS-XT-1%	3	0.094	6	0.188
NS-XT1.5%	2	0.063	6	0.188
NS-XT-2%	1	0.031	5	0.156

IX. Conclusion

1. The present work deals with understanding the effect of nano silica inclusion on strength and durability properties of self-compacting concrete.
2. In the present study 40Mpa SCC was developed based on modified nansu method and nano silica additions are made in that.
3. 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 XL grade and XT grade respectively. Hence 1.5% addition of nano silica is said to optimum.
4. The addition of nano silica improves the hydrated structure of concrete.
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-XL 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

References

[1] "Specifications and guidelines for self-compacting concrete." published by EFNARC in February 2005.

[2] Nan Su, Kung-Chung Hsu, His-Wen Chai, "A simple mix design method for self-compacting concrete", Cement and Concrete Research, 6 June 2001, pp1799-1807.

[3] S. VenkateswaraRao, M.V. SeshagiriRao, P. Rathish Kumar "Effect of Size of Aggregate and Fines on Standard And High Strength Self compacting Concrete", Journal of Applied Sciences Research, 6(5): 433-442, 2010.

[4] M.R.Arefi, M.R. Jahaveri, E. Mollaahmadi,(2011) Silica nanoparticle size effect on mechanical properties and microstructure of cement motar, Journal of American science.

[5] A.A. Magsoudi, M.Magsoudi , and M. Noori, "Effect of Nanoparticles on SCC", second international conference on sustainable construction materials and technologies.June 28, 2010.

[6] G.Quercia& H.J.H. Brouwers ; "Application of Nano-Silica (nS) in Concrete Mixes", 8th fib OhD symposium in Kgs. Lyngby, Denmark June 20-23, 2010.

[7] CelikOzyildirim& Caroline Zegetosky ; Research Report on " Laboratory investigation of Nanomaterials to Improve the strength and permeability of Concrete".