Influence of Nano-Silica on the Strength and Durability of Self Compacting Concrete

Sanga Kranthi Kumar
Post Graduation, Structural Engineering, Prasad Engineering College, Telangana, India

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 production 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 7 and 28 days, specimens are tested under axial compression. Durability properties were also studied by immersing the specimens in 5% HCl and 5% H2SO4. 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.

Key Words: Nano Particles, Sorptivity test, J-Ring, and V-funnel tests etc...

1. Introduction of Self Compacting Concrete

From the foregoing discussion, it is clear that the main aim of the work is developing a SCC and understands the behavior 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.

1.1 Self-Compacting Concrete (SCC)

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.

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.

Eg1: 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 [1].

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 Ozawahave employed the following methods to achieve self-compactability.

(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.

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.

**Carbon nanotubes** (CNTs) when used as a proxy for polymeric chemical admixtures can remarkably improve mechanical durability by gluing concrete mixtures, that is, cementitious agents and concrete aggregates, and prevent crack propagation. Incorporation of CNTs as crack bridging agents into non-decorative ceramics can enhance their mechanical strength and reduce their fragility, as well as improve their thermal properties.

**SiO₂ and Fe₂O₃ nanoparticles** (NPs) can be used as filling agents to pack the pores and reinforce concrete to prevent the penetration of CaCl₂ and MgCl₂ into nano- or micropores that concrete develops due to cement hydration, reacting with concrete constituents to weaken the structure.

Addition of **magnetic nickel nano-particles** during concrete formation increases the compressive strength by over 15% as the magnetic interaction enhances the mechanical properties of cement mortars.

**Copper nano-particles** mitigate the surface roughness of steel to promote the weldability and render the steel surface corrosion-resistant.

One of the principal structural units in nanotechnology is quantum dot or nanoparticle, which can be represented as a cluster of tens to thousands of atoms of 1-100 nm in
The key is the size of particles because the properties of materials are dramatically affected under a scale of the nanometer (nm), 10^-9 meter (m).

- Low maintenance coating
- Improving pipe joining materials and techniques.
- Better properties of cementitious materials
- Reducing the thermal transfer rate of fire retardant and insulation
- Increasing the sound absorption of acoustic absorber

2. EXPERIMENTAL INVESTIGATION

2.1 Introduction

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(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. 15 cubes were casted in each batch, out of which 6 cubes of each batch are tested for compressive strength for 7 days and 28 days, 3 cubes of each batch are tested for 5% H_2SO_4 (sulphuric acid), 5% HCl (Hydrochloric acid) and Sorptivity test for durability aspects.

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. 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.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Grade of Concrete</th>
<th>Type of Concrete</th>
<th>% of Nanosilica added by BWOC added</th>
<th>No. of cubes cast</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SCC with Nano silica (16% nano content)</td>
<td>1%</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SCC with Nano silica (16% nano content)</td>
<td>1.5%</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SCC with Nano silica (16% nano content)</td>
<td>2%</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SCC with Nano silica (30% nano content)</td>
<td>1%</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SCC with Nano silica (30% nano content)</td>
<td>1.5%</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SCC with Nano silica (30% nano content)</td>
<td>2%</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>SCC with Nano silica (30% nano content)</td>
<td>105</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Details of specimens cast

MATERIALS USED

The different materials used in this investigation are

- 53 Grade Ordinary Portland cement
- Fine Aggregate
- Coarse Aggregate
- Super Plasticizer (CONPLAST SP430)
- Flyash
- Water
- Nano Silica (16% and 30% nano content)
Fig -3: Abrams Slump flow Equipment

Fig -4: J-Ring equipment

Fig -5: V-Funnel equipment

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

Table -2: Average Compressive Strength of SCC with and without nano silica

Chart -3: Flow Chart showing the details of Experimental program

Chart -4: Average compressive strength of SCC without and with nano silica

Chart -5: Graph between Sorptivity Coefficient and time
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 additions, but 2% Nano XTX addition has less coefficient of sorptivity when compared to the other types.

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

Effect of Nano Silica on Compressive Strength:
1. In the present study 40Mpa SCC was developed based on modified nan su 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% H₂SO₄ and it was not found in 5% HCl.
2. The percentage mass loss with 5% H₂SO₄ 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% H₂SO₄ 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.

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 nano additions, 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.

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

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.

The addition of nano silica improves the hydrated structure of concrete. The percentage compressive strength loss is more for 1.5% Nano Silica-XLP and is about 56.02% and 18.74% with 5% H₂SO₄ and 5% HCl respectively after 28 days of immersion. This may be due to higher pozzalonic content.
REFERENCES


