EXPERIMENTAL INVESTIGATION ON THE PROPERTIES OF NANO-SILICA CONCRETE

Dr. D. V. Prasada Rao¹, K. Jayalakshmi²

¹(Associate Professor, Department of Civil Engineering, Sri Venkateswara University College of Engineering, Tirupati-517 502, Andhra Pradesh, India)
²(PG Student, Department of Civil Engineering, Sri Venkateswara University College of Engineering, Tirupati-517 502, Andhra Pradesh, India)

ABSTRACT

This paper presents the strength and durability properties of M20 and M25 grades of concrete prepared using Nano-Silica. The influence of Nano-Silica on various properties of concrete is obtained by replacing the cement with various percentages of Nano-Silica, i.e., 3%, 4.5% and 6% respectively. Compressive strength, tensile strength, flexural strength, modulus of elasticity and rapid chloride permeability tests were conducted on specimens prepared using Nano-Silica concrete. The tested results indicate that the replacement of cement with Nano-Silica influences the strength and permeability properties of concrete. The replacement of cement with 3% Nano-Silica results in higher strength and reduction in the permeability than the controlled concrete. The replacement of cement with Nano-Silica more than 3% results in the reduction of various properties of Nano-Silica concrete.

Keywords: Nano-Silica, Cement Replacement, Controlled Concrete, Compressive Strength, Flexural Strength and Permeability.

1. INTRODUCTION

Concrete is the most common material used in the construction. Concrete is a composite material made up of cement, sand, water and sometimes admixtures. Cement is the most active component of concrete usually has the greatest unit cost, its selection and proper use are important in obtaining economical concrete and also concrete of desired properties. The use of large quantities of cement results in increasing CO₂ emissions and as a consequence of the green house effect. One of
the methods to reduce the cement content in concrete mixes is the use of nano materials. The properties of concrete in hardened state such as strength and durability are affected by the mix proportions and grading which results in particle packing.

At present Nano Technology is a dynamic research field that covers a large number of disciplines including construction industry. The application of Nano materials in cement composites is steadily growing. Nano materials are very reactive because of the particle’s small size and large surface area and have great potential in improving concrete properties and the incorporation of nano particles can fill the voids more effectively to enhance the overall strength and durability.

This research is directed to evaluate the use of Nano materials in concrete preparation. The properties of Nano concrete are compared with the controlled concrete. The various properties of concrete prepared with the addition of Nano-Silica as cement partial replacement was studied. Compressive strength, tensile strength, flexural strength, modulus of elasticity and permeability of concrete with addition of Nano-Silica were determined and the results were compared with the controlled concrete.

2. EXPERIMENTAL PROGRAMME

2.1 Materials

2.11 Cement

In the present investigation Ordinary Portland cement (OPC) of 43 Grade confirming to IS specifications was used. The specific gravity of the cement is 3.15.

2.12 Fine aggregate

Locally available river sand (Zone - II) confirming to IS specifications with fineness modulus of 2.86 and specific gravity of 2.6 was used as the fine aggregate in the concrete mix.

2.13 Coarse Aggregate

Machine crushed aggregate confirming to IS 383-1970 obtained from the local quarry was used in this study. The nominal sizes of coarse aggregate adopted in the present investigation were 20 mm and 12.5 mm. Fineness modulus and specific gravity of coarse aggregate used in this study were 7.52 and 2.67 respectively.

2.14 Nano-Silica

Nano-silica is new pozzolanic material. Nano-Silica used in this research is in the form of water emulsion of colloidal silica type with 40% suspension produced by BEE CHEMS. Nano-Silica has extremely large specific area. The properties of Nano-Silica used in the present investigation are shown in the Table. 1

<table>
<thead>
<tr>
<th>S.No</th>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nano Solids</td>
<td>39.5-41%</td>
</tr>
<tr>
<td>2</td>
<td>PH</td>
<td>9-10</td>
</tr>
<tr>
<td>3</td>
<td>Specific Gravity</td>
<td>1.29-1.31</td>
</tr>
<tr>
<td>4</td>
<td>Texture</td>
<td>White Milky Liquid</td>
</tr>
<tr>
<td>5</td>
<td>Dispersion</td>
<td>Water</td>
</tr>
</tbody>
</table>
2.15 Water

The water used for casting and curing of concrete test specimens was free from acids, organic matter, suspended solids and impurities which when present can adversely affect the strength of concrete.

2.16 Water Reducing Admixture (Super plasticizer)

Super plasticizer by trade name Glenium B-233, BASF Constructions Pvt. Ltd., Hyderabad was used to achieve the required workability. It is available in brown color in liquid form instantly dispensable in water.

2.2 Concrete Mix Proportions

The purpose of the experimental investigation is to obtain the compressive strength, tensile strength, flexural strength, modulus of elasticity and permeability of M20 and M25 grades of concrete by partial replacement of cement with Nano-Silica. Concrete specimens were prepared with Nano-Silica content of 3%, 4.5% and 6%.

M20 and M25 grades of concrete were designed based on Indian Standard Specifications. In the concrete mix, 12.5 mm and 20 mm coarse aggregate were used in the ratio of 1:1.5. Super plasticizer was used in the concrete mixes containing Nano-Silica to achieve desired workability. The mix proportions by weight of M20 and M25 grades of concrete are shown in Table 2.

<table>
<thead>
<tr>
<th>Grade of Concrete</th>
<th>Cement (kg/m³)</th>
<th>Fine Aggregate</th>
<th>Coarse Aggregate</th>
<th>Water-Cement Ratio</th>
<th>Cement (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 20</td>
<td>1</td>
<td>1.97</td>
<td>3.79</td>
<td>0.55</td>
<td>320</td>
</tr>
<tr>
<td>M 25</td>
<td>1</td>
<td>1.71</td>
<td>3.62</td>
<td>0.50</td>
<td>340</td>
</tr>
</tbody>
</table>

2.3 Preparation of Concrete Test Specimens

For each grade of concrete three types concrete mixes were prepared by varying the Nano-Silica at 3%, 4.5% and 6% by weight as replacement of cement. For each concrete mix three sets of cubes of size 150 mm×150 mm×150 mm, 2 sets of cylinders of size 150 mm× 300 mm, one set of prism of size 100 mm×100 mm×500 mm and one cylinder of size 100 mm × 200 mm were prepared.

2.4 Testing

To obtain the compressive strength of Nano-Silica concrete, cubes were tested at the age of three, seven and 28 days and also cylinders were tested for 28 days. The split tensile strength is determined by conducting test on cylinders at the age of twenty-eight day. Flexural strength is found by using three prisms at the age of twenty-eight day. At the age of twenty-eight days three cylinders were used to find modulus of elasticity of concrete. Cylinders of size 100 mm × 200mm were used to conduct the rapid chloride permeability test at the age of 28 days.

3. RESULTS AND DISCUSSION

3.1 Compressive Strength

Fig 1 shows the compressive strength of M20 and M25 grades Nano-Silica concrete at 3, 7 and 28 days. It can be observed that the compressive strength of concrete with 3% Nano-Silica is more than the controlled concrete. But, further increase in the percentage of Nano-Silica the strength of the concrete is reduced. This can be attributed to the fact that as the quantity of Nano-Silica is increased the surface area of the particles increases which demands more water content. Then the
required workability of Nano-Silica concrete can be achieved by using super plasticizers. But, excessive quantity of super plasticizers is prohibited as it leads to various problems like delayed setting. IS code limit the maximum water-cement ratio, the use of more cement content is not a viable solution. Because of the insufficient CSH gel in concrete of high Nano-Silica content leads to reduction of concrete strength. Similar trend can be observed in the M20 and M25 grades of concrete.

(i) M20 Grade Concrete

(ii) M25 Grade Concrete

**Fig. 1:** Variation of Cube compressive strength of M20 and M25 grades of concrete with age
Fig. 2 shows the reduction in strength of concrete with increase in the percentage of Nano-Silica content from 3% to 6%. For any grade of concrete and at any period of curing, it can be observed that the increase in the content of Nano-Silica, the strength of concrete is decreased. It can
also be observed that the cement replacement by 3% Nano-Silica content results in more compressive strength compared to the controlled concrete of M20 and M25 grades of concrete. It can be concluded that the large quantity of Nano-Silica in concrete mixture leads to agglomerate effect which results in decrease in the compressive strength of concrete.

### 3.2 Split Tensile Strength

Fig. 3 shows the split tensile strength of M20 and M25 grades. It can be observed that as the percentage of Nano-silica is increased, split tensile strength of concrete is also decreased. The split tensile strength of M20 grade controlled concrete is 3.24 N/mm$^2$ but with 3% of Nano-Silica content the split tensile strength is marginally increased to 3.47 N/mm$^2$.

![Fig.3: Variation of Split Tensile strength of M20 and M25 Grades of concrete with different percentages of Nano-Silica](image)

### 3.3 Flexural Strength

The variation of flexural strength of M20 and M25 grades of concrete with increase in the Nano-Silica content from 3% to 6% is presented in Fig 4. It can be observed that for both M20 and M25 grades of concrete the flexural strength is decreased with increase in the Nano-Silica content. The results indicate that when Nano-Silica particles are added in small quantities, the flexural strength of concrete can be increased. Flexural strength of M20 and M25 grades of controlled concrete are 3.28 N/mm$^2$ and 4.96 N/mm$^2$ respectively.
3.4 Modulus of Elasticity

Fig. 5 shows the variation of modulus of elasticity of concrete with and without Nano-silica. It can be observed that the modulus of elasticity of concrete attained maximum value with 3% Nano-Silica and then the modulus of elasticity of concrete decreases with increase in the Nano-Silica content. The Modulus of elasticity of M20 and M25 grades of Controlled concrete is 22.00 kN/mm$^2$ and 25.3 kN/mm$^2$. 

**Fig.4:** Variation of Flexural strength of M20 and M25 Grades of concrete with different percentages of Nano-Silica

**Fig.5:** Variation of Modulus of Elasticity of M20 and M25 grades of concrete with different percentages of Nano-Silica
3.5 Rapid Chloride Permeability Test

This test determines concrete’s chloride permeability by measuring the charge passed through the specimen. AASHTO standard provided the relation between the charge passed in coulombs in 6 hours for concrete specimen and the level of chloride permeability is shown in the Table 3.

<table>
<thead>
<tr>
<th>Charge passed (Coulombs)</th>
<th>Chloride Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 4000</td>
<td>High</td>
</tr>
<tr>
<td>2000 -4000</td>
<td>Moderate</td>
</tr>
<tr>
<td>1000-2000</td>
<td>Low</td>
</tr>
<tr>
<td>100-1000</td>
<td>Very low</td>
</tr>
<tr>
<td>&lt; 100</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

Fig.6 shows the results of rapid chloride permeability test. Rapid chloride permeability test was conducted at the age of 28 days on concrete specimens with and without Nano-Silica. It can be observed that the tested concrete specimens shows moderate permeability in the range of 2000 – 4000 Coloumbs at the age of 28 days. Concrete with 3% of Nano-silica has better permeability resistance than controlled concrete.

![Rapid Chloride Permeability Test Results of M20 and M25 grades of concrete with different percentages of Nano-Silica](image-url)
4. CONCLUSIONS

On the basis of experimental investigation, it can be concluded that compressive strength of concrete initially increased up to 3% of Nano-Silica and with further increase in the Nano-Silica content the compressive strength of concrete decreases. Concrete containing lower percentages (≤ 3%) of Nano-Silica possess higher values of compressive strength than that of controlled concrete.

A considerable increase in flexural strength, split tensile strength and modulus of elasticity of Nano-Silica concrete was observed compared to controlled concrete and the maximum value is corresponding to the concrete which contain 3% of Nano-Silica.

Based on the experimental results, use of Nano-Silica as partial replacement of cement in small quantities is advantageous on the performance of concrete. Nano-Silica added in small quantities can improve the strength and permeability resistance. It can also be concluded that the permeability of concrete decreases with the increase in the percentage of Nano-Silica up to 3% due to the effect of Nano-Silica filling the voids in concrete.

REFERENCES

1. Paramita Mondal, Surendra P. Shah, Laurence D. Marks, and Juan J. Gaitero, “Comparative Study of the Effects of Microsilica and Nanosilica in Concrete”.
8. IS : 456 – 2000 – Code of practice for Plain and Reinforced Concrete. BIS, New Delhi
9. IS : 10262 – 1983 – Recommended Guidelines for Concrete Mix Design. BIS, New Delhi