# An Experimental Investigation on the Effect of Nano- Silica Particles on the Properties of Concrete

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**Abstract -** *Concrete is the one of the powerful ingredient for construction field, this concrete can improved by adding some extra additives like nano powders which helps to increases the strength in the concrete, but nano powder of silica is very advantageous in reducing temperature effects and high hardness property, so it used in highly temperature condition as a coatings and paints, the requirement of journals by using nano silica powder in concrete is minimum. Improving concrete properties by addition of Nano particles have shown significant improvement than conventional concrete. Adding Nano materials in ordinary concrete can improve the performance of concrete including strength, toughness, durability, permeability, fire resistance and other properties. The application of Nano silica in concrete not only save the resources and energy but also protect the environment from the pollution with the reduction of waste material and reduction of CO2 emission. The influence of Nano-silica on various properties of concrete is obtained by replacing the cement with various percentages of Nano silica.*

*In this present work nano silica used as a partial replacement for cement in the range of 0.5%, 1%, 1.5%, 2% weight of cement for M30 mix. Concrete cubes and cylinders have been casted. Laboratory tests are conducted to determine the Compressive Strength, Split Tensile Strength of Nano-silica concrete at the age of 7 and 28 days.*

***Key Words*: Strength, Nano Technology, Nano-Silica Powder, Nano Silica Concrete, Compressive Strength, Split Tensile Strength.**

## 1. INTRODUCTION

Concrete remains the choice of engineers in construction materials owing to its remarkable features like mold-ability to various shapes, easily available ingredients, high strength and low cost in spite of its environmental concern. Approximately 20 billion metric ton of concrete is being produced every year [1]. The production of cement for concrete is contributing nearly 8% of global carbon dioxide emission [2] and thus, a matter of concern for environmentalist. It is a composite material with wide range of length scales from millimeter to nanometer. Usually concrete is taken as one material by considering its bulk strength and other engineering properties, but at micro and nanoscale, it is having different type of compositions with complex characteristics. There has been always a relationship between the microstructure and bulk properties and researchers are making efforts to establish this relationship in concrete. The contemporary building sector is working for the development of advanced and new cementitious materials. Performance enhancement of cementitious system consists of judicious utilization of materials, developing more durable and sustainable concrete to reduce the maintenance and life cycle cost. There are two approaches for the performance enhancement of cement based materials, one is to find out suitable alternative materials to replace cementitious materials such as Geopolymer and another approach is tuning the performance of cement by admixtures. Nanotechnology is an emerging avenue of research having a potential impact on every domain of science and technology [3]. There are number of definitions for nanotechnology given by many researchers. Drexler et al. [4] defined as "the control of the structure of matter based on molecule-by-molecule control of products and by-products". Some researchers defined as "the understanding, control and manufacturing of matter on the order of nanometers (lesser than 100 nm) to create materials with fundamentally new properties and functions [5]. For construction sector, nanotechnology can be defined as science of controlling the properties at nanometer scale which can make revolutionary changes in bulk material properties. The aim of the application of ultra-fine additives like nanosilica in cementitious systems is to improve the characteristics of the plastic and hardened material. Micro and nano-scaled silica particles have a filler effect by filling up the voids between the cement grains. With the right composition, the higher packing density results in a lower water demand of the mixture and it also contributes to strength enhancement due to the reduced capillary porosity. Beside this physical effect as obtained by addition, nanosilica has a pozzolanic reactivity which is much higher compared to silica fume. Thus, both the effects are very important in developing ultra-high performance concrete [6–8] (Fig. 1). There may be two possible reaction mechanisms during hydration of cement in presence of nanosilica. Hydration of cement can be accelerated by addition of nanosilica. When nanosilica is added to cement grains, H2SiO2 4 forms and reacts with the available Ca2+ which forms an additional calcium–silicate–hydrate (C–S–H) and these C–S–H particles are spread in the water between the cement particles and serve as seeds for the formation of more compact C– S–H phase. The formation of the C–S–H phase is no longer limited on the grain surface alone, as in the pure C3S, but also takes place in the pore space. The formation of large numbers of seeds thereby causes an acceleration of early cement hydration.

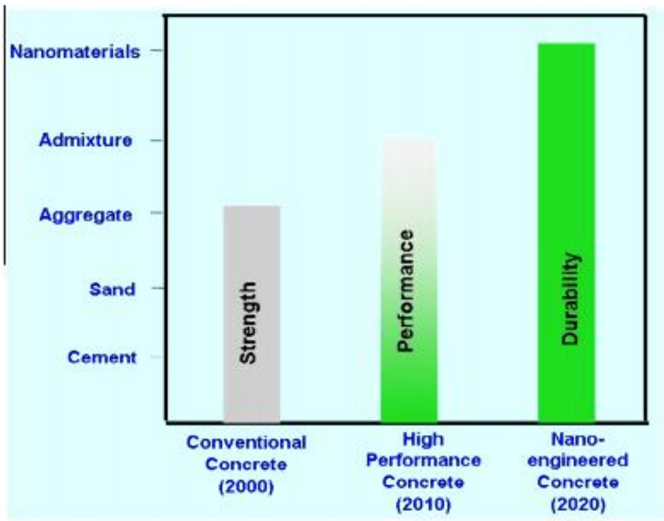


**Fig.No-1** Development of green concrete using nanotechnology

## 1.2 Research Objective

Because plain concrete is brittle by nature, the need to transform it into a ductile material is critical. The use of fibers as a randomly dispersed reinforcement is an alternative solution; the presence of fiber improves tensile, flexural, and ductility, as well as being much more effective at regulating cracking at the aggregate–matrix interface, but it reduces workability. The addition of a super plasticizer will improve the workability of the material.

## 2. LITERATURE REVIEW

- **J.Bernal, E Rayes, J.Massana, N leon, E sanchez (2018).** “Fresh and Mechanical Behaviour of a self compacting concrete with additions of nano silica, silica fume and ternary mixtures”. This paper examines the behaviour of 10 mixtures of SSC prepared with binary and ternary dosages through use of Portland cement, mSi and nSi. A self compacting concrete was designed which used no mineral admixtures, with the rest of the dosages using different percentages.
- **Mojtaba Fathi, Abed Yousefipour, Ehsan Hematpoury Fakheri (2017).** “Mechanical and physical properties of expanded polystyrene structural concretes containing Micro silica and Nano-Silica” In the specimens without EPS beads, replacement of Micro Silica and Nano Silica upto 15 and 3 wt % of cement respectively led to compressive strength increase and water absorption decrease and after that these trends were carried vice versa.
- **Ehasan Ghafari et.al (2014)** “Effect of nano-silica addition on flowability, strength and transport properties of ultra-high performance concrete” Ehasan Ghafari et.al studied the effect of nano-silica addition on flowability, strength and transport properties of ultra-high performance concrete. They concluded that compressive strength of ultra high performance concrete increases with the rise in nano-silica content. The ultra-high performance concrete containing nano-silica is significantly denser and more homogeneous.
- **Peng-ku Hou et.al (2012)** “Effect of colloidal nano-silica on rheological and mechanical properties of fly ash cement mortar” Peng-ku Hou et.al presented study on effect of colloidal nano-silica on rheological and mechanical properties of fly ash-cement mortar. They found that the addition of colloidal nano-silica enhances hardening process of fly ash cement paste. It also increases the viscosity of cement paste. The compressive strength of fly ash cement mortars can be greatly improved.
- **Anwar M. Mohamed et.al (2014)** “Influence of nano materials on flexural behaviour and compressive strength of concrete” Anwar M. Mohamed et.al presented study on Influence of nano materials o flexural behaviour and compressive strength of concrete. Nano-silica on wet condition and nano clay on dry condition have remarkable improvement on compressive strength of high performance concrete. There also appears improvement for flexural strength of concrete due to use of nano particles.
- **Min-Hong Zhang et.al (2011)** “Use of nano-silica to reduce setting time and increase early strength of concretes with high volume of fly as or slag”Min-Hong Zhang et.al presented study on Use of nano-silica to reduce setting time and increase early strength of concretes with high volume of fly as or slag. The results indicate that length of dormant period was shortened and rate of cement sand slag accelerated with 1 percent nano-silica. The nano-silica reduces the setting time and increases the early strength of high volume fly ash or slag.
- **Miguel Angel et.al (2015)** “Effect of silica fume fineness on the improvement of Portland cement strengthperformance” Miguel Angel et.al presented study on effect of silica fume fineness on the improvement of Portland cement strength performance. The partial replacement of Portland cement with 25 percent of silica fume produces high strength mortar and such fineness gives high strength and it can be used to produce high performance concrete.
- **S.T. Lee, Mr. H.Y. Moon and Mr. R.N. Swamys (2003)** “Sulphate attack and role of silica fume in resisting strength loss” This paper presented study on sulphate attack and role of silica fume in resisting strength loss. This study presents a detailed study on the process of deterioration and the formation of reactants by

chemical reaction of mortars and pastes without or with SF in sodium and magnesium sulphate solutions.

- **Vimal jyothi (2017) Volume 4** "An experimental Investigation on strength properties of concrete containing Micro silica and nano silica" This paper conducts the experiment by replacing the cement by mixture of nano silica and silica fume at different percentages. The compressive strength, flexural strength and tensile strength is increases when the percentage of nano silica at 1.5% and percentage of micro silica at 10%.
- **Sakshi Gupta,** concluded that Nanotechnology has the potential to be the key to a brand new world in the field of construction and building materials. The role and application of the nano and micro silica particles with cementitious materials have been reviewed and discussed in details. It is evident from the literatures reviewed that none of the researchers have carried out extensive or comprehensive study of the properties of paste and mortar, with nano silica, micro silica and their simultaneous use. There is a limited knowledge about the mechanisms by which nano silica & micro silica affects the flow properties of cementitious mixes. In India, the research work on use of nano silica is still in elementary stage. Thus, a need arises to study extensively the various properties of paste, mortar, and concrete containing various percentages of nano silica, micro silica alone as partial replacement of cement and then studying their combined percentage effects. As the properties of nanosilica and micro-silica reported in literatures relate with those manufactured or exported from abroad, there is urgent need to study the effect of these materials (manufactured in India) on various properties of cement paste, mortar and concrete. Major parties in the construction materials industry should divert more funds to research work on incorporating nanotechnology in construction materials. Thus, the main motive is to provide practical information, regarding the strength, sustainability & durability properties of nano silica, micro silica and their simultaneous use in paste, mortar and concrete. Also, the aim is to carry out the extensive studies to conceive the general purpose of testing new sustainable building processes and modern production systems, aimed at saving natural raw materials and reducing energy consumption. Taking advantage of nanostructure and microstructure characterization tools and materials, the simultaneous and also separate optimal use of microsilica and nano-silica will create a new concrete mixture that will result in long lasting concrete structures in the future. Thus, there is a gap or room available for further research towards the fruitful application of especially nano-silica for construction with different nano structure characterization tools, which will be enable to understand many mysteries of concrete.

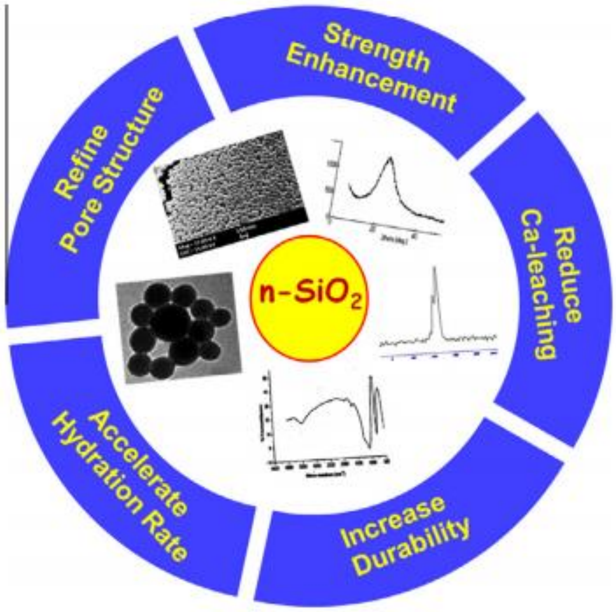


**Fig.No-2** Role of nanosilica in cementitious system

### 3. MATERIALS AND METHODS

The cement used in this research was Portland cement (53 grade), Coarse aggregate (CA) and fine aggregate (FA) were locally supplied from crushed stone and river sand, respectively. Super plasticizers were used to maintain the workability of concrete. Commercial NS having a relatively small surface area (51.40 m2 /g), named NS-50. The NS was in the colloidal suspension silica form.

The mixtures were prepared with various contents of NS including 1%, 1.25%, 1.5%, 2%, 3%.

Details of concrete mix proportions are given in Table. In order to achieve a comparative study, all procedures related to mixing and curing were kept the same for all mixes except replacing cement by the required quantity of NS. It is important to mention that the mixing water was adjusted based on the content of silica and the amount of water present in the solution for each NS type. Experimental testing was mainly focused on the influence of NS on compressive strength as a representative of the mechanical properties of concrete. The compressive strength of concrete was performed in accordance with IS Code on cubes (100*100*100 mm) after 7 and 28 days of curing.

**Concrete mix proportions**

| W/C Ratio | Mix proportions (Kg/m3) | | | | NS% | SP% |
|---|---|---|---|---|---|---|
| | C | W | FA | CA | | |
| 0.4 | 450 | 180 | 664 | 1180 | 0%,1%, 1.25%, 1.5%, 2% & | 0,0.5, 0.75, 1,1.25 , 1.5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | 3%. | |
| **0.5** | **400** | **200** | **615** | **1205** | **0%,1%, 1.25%, 1.5%, 2% & 3%.** | **0,0.5, 0.75, 1,1.25 , 1.5** |

**Table-1** Concrete mix proportions

## 4. RESULTS AND DISCUSSIONS

All the tests have been performed in standard procedures and the results and load values obtained were tabulated and calculated in following sections.

### 4.1 Compressive Strength

Compressive strength tests were conducted on cured cube specimen at 7 days and 28 days age using a compression testing machine of 200 kN capacity. The cubes were fitted at center in compression testing machine and fixed to keep the cube in position. The load was then slowly applied to the tested cube until failure.

| Sl.no | Mix (days) | NS% | Cube Compressive strength (N/mm$^2$) |
|---|---|---|---|
| 1 | 7 | 0% | 24 |
| | | 1% | 27.12 |
| | | 1.25% | 26.16 |
| | | 1.5% | 27.54 |
| | | 2% | 28.26 |
| | | 3% | 28.92 |
| 2 | 28 | 0% | 40 |
| | | 1% | 45.2 |
| | | 1.25% | 43.6 |
| | | 1.5% | 45.9 |
| | | 2% | 47.1 |
| | | 3% | 48.2 |

**Table -2** Compressive strength of concrete containing NS for w/c = 0.4 at curing time: 7 days & 28 days

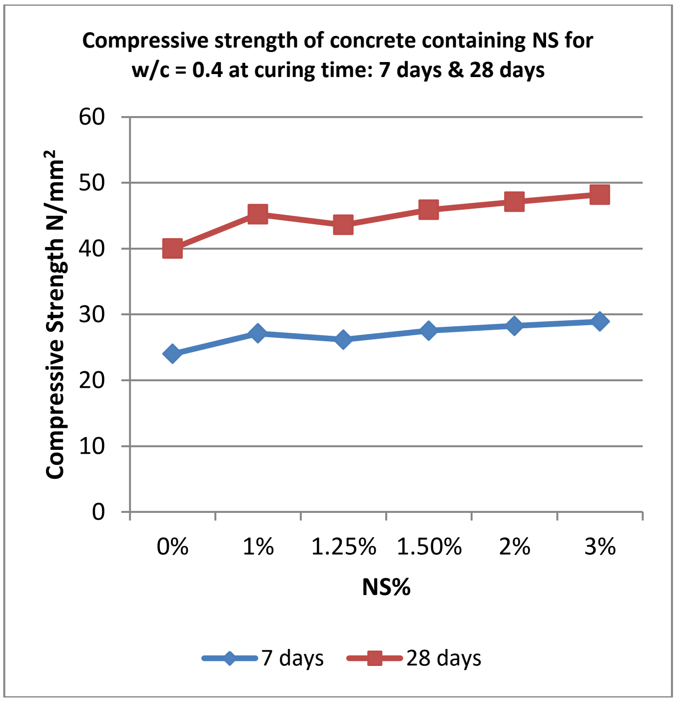


**Fig.No-3**: Compressive strength of concrete containing NS for w/c = 0.4 at curing time: 7 days & 28 days

| Sl.no | Mix (days) | NS% | Cube Compressive strength (N/mm$^2$) |
|---|---|---|---|
| 1 | 7 | 0% | 19.37 |
| | | 1% | 20.93 |
| | | 1.25% | 19.565 |
| | | 1.5% | 22.49 |
| | | 2% | 23.465 |
| | | 3% | 24.245 |
| 2 | 28 | 0% | 29.8 |
| | | 1% | 32.2 |
| | | 1.25% | 30.1 |
| | | 1.5% | 34.6 |
| | | 2% | 36.1 |
| | | 3% | 37.3 |

**Table -3** Compressive strength of concrete containing NS for w/c = 0.5 at curing time: 7 days & 28 days

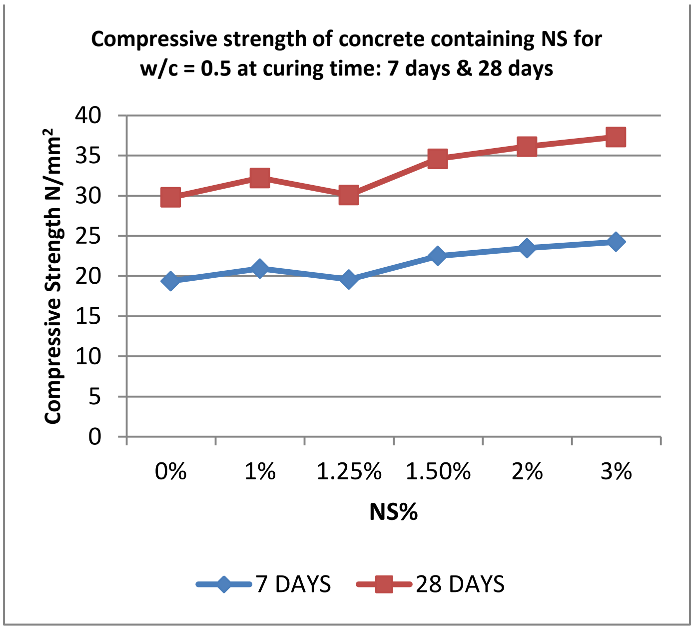


**Fig.No-4** Compressive strength of concrete containing NS for w/c = 0.5 at curing time: 7 days & 28 days

## 5. SUMMARY AND CONCLUSIONS

Compressive strength is considered as the most important property of concrete as it can be an indicator for other properties. The variation of compressive strength at 7 and 28 days with NS content are presented in Figs. for different w/c ratios. For w/b = 0.4, it can be observed that the compressive strengths of concrete containing NS at 7 and 28 days were higher than that of control concrete for all mixes as shown in Fig.

This can be supported by the fact that with smaller silica particles, the rate of cement hydration can also be enhanced due to the increase of the heat release by C3S-accelerated hydration rate. By adding NS over 1%, more improvements were observed at 7 days for NS-50 to reach the highest strength gain (18.3%) at 3%.

Beyond 3% the compressive strength reduces according to literature review data and this reduction in the performance may be due to the excess of NS particles, causing no further chemical reaction, and hence the particles only act as fillers without any more contribution to compressive strength.

It can be noted that all concrete containing NS enhanced compressive strength compared to the control mix.

Overall, NS-50 was more beneficial for the formation of C-S-H gel than ordinary cement by achieving the best strength throughout this investigation. However, the enhancement achieved for w/b = 0.5 was better than that for concrete having w/b = 0.4, agreeing with the results of, who reported that NS particles are more efficient in lower cement content.

## ACKNOWLEDGEMENT

We are thankful to **Dr. Mohammed Masood,** Principal, ISLEC, for his encouragement throughout the project. We would also like to express our heartfelt thanks to **Ms. K. Nanchari,** Head of Civil Engineering Department, ISLEC for her help and unending cooperation with us during completion of this work.

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**BIOGRAPHIES**

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