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# An Experimental Study on Effect of Nano Silica and the Behaviour of OPC and Blended Cements

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**Abstract:**
Concrete is the most common material for construction. The total production depends upon the cement content only. Due to the usage large amount of cement produces increasing the $CO_2$ emissions, to reduce the cement percentage in concrete mixes the nano silica ($nSiO_2$) is used as the replacement of the cement. This project obtained the experimental study of the effect of nano silica on the behaviour of mortar and concrete by using OPC and Blended cement. The nano silica is available in 10-50 nm as particle size. The 17 nm particle size is used for the whole project. This paper aim is to study the mechanical properties of the specimen using the nano silica by replacement of the cement. The ratio in weight of the nano cement with respect to normal cement. The mortar specimen size is 70.6 x 70.6 x 70.6 mm. The concrete cube size is 150 x 150 x 150 mm was maintained and water cement ratio 0.40 was maintained throughout the project. The 0 %, 1.5%, 3.5%, 5.5% and 7.5 % of nano silica should be replaced with weight of the cement.

**Key words:**
Nano silica, Compressive strength, Split tensile strength, SEM analysis, Cement type: OPC and Blended Cement.

## 1. Introduction:

Concrete's versatility durability and economy have made it the world's most used construction material. The India utilizes about 7.3 million cubic meter of concrete each year. Due to this the cost of construction increases and causes environment pollution. As the demand for concrete as a construction material increase, so also the demand for fine aggregate increases. In recent years, Global warming and environmental destruction have become major problems. Heightening concern about worldwide ecological issues, changeover the large scale manufacturing, mass-utilization, mass-waste, society of the past to a zero-emission society is presently seen as essential. For reducing the pollution we used the nano silica as the percentage replacement of the cement. One of the most used nanosized material is nano silica. Nano silica addition increases the compressive strength and it reduces the permeability of hardened concrete. The interesting properties of and the incorporation of nano –silica deteriorate consistency of cementations composites. The presence of nano silica contributed to the improvement of the compressive strength and split tensile strength. The performance of cementations based material is strongly dependent on nano sized particles. The particles of calcium-silicate-hydrates (C-S-H) at the interfacial transition zone between the cement and aggregate. The nano silica decreases the setting time when comparing with the silica fume. In view of this advance the main aim of this experiment is to study the mechanical properties of the structure. In this study the influence of size 17 nm and quantity 0, 1.5, 3.5, 5.5

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and 7.5% by weight of cement of nSiO2 on the mechanical properties have been examined.

## Production Method of Nano Silica:

Now days, there are different methods to produce $nSiO_2$ products. One method is based on a sol-gel process at a room temperature. The starting materials are added in a solvent, and then the PH of the solution is changed to silica gel. The produced gel is aged to become a xerogel. The xerogel is dispersed again with stabilized agent Na, K, $NH_3$ to produce a concentrated dispersion, and it is suitable for use in concrete industry. An alternative production method is Vaporization of silica by reducing quartz at 1500 to 2000$^oC$. Further, $nSiO_2$ is produced as a byproduct of the manufacture of silicon metals and ferro-silicon. Nano-silica produced by this method is very fine powder consisting of spherical particles. Finally $nSiO_2$ can produce by precipitation method. In this method, nSiO2 is precipitated from a solution at temperature is 50 to 1000C. It was developed by Iller in 1954, and this method they used the different precursors .Such as sodium silicate (Na2SiO3), burned rice husk ash (RHA),magnesium silicate.

## Effects of Nano Silica in Mortars and Concrete:

In concrete, the micro-silica works on two levels. The first one is chemical effect and the second one is physical effects. At the chemical effect: the pozzollanic reaction of silica with calcium hydroxide, and it is forms CSH-gel at final stage. At the physical effect: micro silica is about 100 times smaller than the cement. Some researches found that the 1 kg of silica permits to reduction of about 4 kgs of cement, and this can be higher if nano silica is used. Micro silica can fill the voids in the hydrated cement paste. Nano silica addition in mortar and concrete can result in different effect. The main mechanism is related to high surface are of nano silica, because it works as nucleation for the precipitation of CSH- gel. It has not determined whether the more rapid hydration of cement in the presence of nano silica is due to chemical reaction.

The effect of nano silica addition on concrete water permeability and microstructure. Different concrete mixes were evaluated incorporating nano silica particles of 10 nm to 20 nm. Fly ash and gravel to obtain the same slump time for nano silica concrete and plain concrete. The results can show that nano silica can improve the micro structure and it reduces the water permeability for hardened concrete. Decreasing the permeability in concrete with nano silica concentration and fly ash content. Nano silica concrete is more uniform and compact than for normal concrete. The most effect of nano silica is the impact on the mechanical properties of mortar and concrete, and the nano silica content increases the density and reduces the porosity and improve the bond between the aggregates and cement matrix. The addition nano silica concrete shows higher compressive and higher split tensile strength when comparing to the plain concrete.

## Literature Review:

Alireza Naji Givi (2010) et al explained the effects of $SiO_2$ nano particles on both physical properties(water permeability, workability and setting time) and mechanical properties (compressive, split tensile and flexural strength) of binary blended concrete have been investigated. It was concluded that the $SiO_2$ nano particles can improve the filler effect and its ultra high pozzolanic activity causes more C–S–H gel formation when cured in lime solution, and the lime solution can reduce the strength of control concrete. Majid Monshizadeh, Masoud Rajabi (2013) - This project deals with the Synthesis and characterization of nano-silica from rice husk ash by Precipitation method. The size of the particle is determined from the number averaged particle radius by LPS that show nano-silica particles which obtained from the rice husk ash. Denni Asra Awizar (2013) et al the project was found that the nano silicate act excellently as corrosion inhibitor for carbon steel in distilled water medium. The surface morphology of carbon steel with and without inhibitor was investigated by SEM-EDX. M.J. Pellegrini (2013)-Cervantes the main purpose is to determining the performance of the OPC replacements on the

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properties of the mortar, resulting in the most effective use with simultaneous decrease in porosity and increased compressive strength and corrosion respectively. The use of ashes to improve the properties of mortar has also been studied, and the study of synergy in the simultaneous use of NP and ashes is scarce, research has focused on improving the mechanic properties and chemical properties of mortar. S. Maheswaran (2013) et al main aim of this paper is an overview of the influence of nano silica in concrete. Nano technology finds application in various fields of science and technology and this article presents a critical review of the literature on the influence of nano silica in concrete and its application for the pore filling effect and its pozzolanic activity with cement towards improvement of mechanical properties and durability aspects.

## Materials and Methods:

The cement used in this study is Ordinary Portland Cement and Blended Cement is used for the cement mortar cubes. And for the concrete cubes and cylinders used the OPC cement only. The two types of fine aggregate should used for this study. For the concrete specimen used the local available fine aggregate and for the cement mortar Ennore sand should be used. The nano silica is used as the pozzolanic material in this study to improve the mechanical properties of the material. The properties of nano silica are described in Table-1.

**Table-1 Properties of Nano Silica**

| Test item | Standard requirements | Test results |
|---|---|---|
| Specific surface area ($M^2/G$) | 200±20 | 202 |
| pH value | 3.7-4.5 | 4.12 |
| Loss on drying @$105^0$ C | ≤1.5 | 0.47 |
| Loss on ignition @$1000^0$ C (%) | ≤2.0 | 0.66 |
| Sieve residue | ≤0.04 | 0.02 |
| Tampered density g/L | 40-60 | 44 |
| $SiO^2$ content (%) | ≥99.8 | 99.88 |
| Carbon content (%) | ≤0.15 | 0.66 |
| Chloride content (%) | ≤0.0202 | 0.009 |
| $Al_2O_3$ | ≤0.03 | 0.005 |
| $TiO_2$ | ≤0.02 | 0.004 |
| $Fe_2O_3$ | ≤0.003 | 0.001 |
| Specific gravity | 2.2-2.4 | |
| Particle size | 17 nm | |

## Mix Proportioning and Curing:

The five different percentage of silica used by weight of the cement. The percentages is 0%, 1.5 %, 3.5 %, 5.5 %and 7.5 % of nano silica is replaced by weight of the cement. The water cement ratio is 0.40 should be taken. The $M_{25}$ grade was used.

## Sample Preparation and Testing:

The mortar cube of specimen size is 70.6 x 70.6 x 70.6 mm were casted for determining the compressive strength for OPC and Blended cement. The casted specimen should be tested at 3days, 7days, 14days and 28days strength. The concrete cube of specimen size is 150 x 150 x 150 mm were casted for determining the compressive strength and the cylinders were casted for determining the split tensile test for OPC cement. The casted specimen should be tested at 3days, 7days, 14days and 28days strength.

## Results and Discussion:

**Table 2-Mortar Results for OPC:**

| Sl.No | % replacement of nano silica | Description | 3 days | 7 days | 14 days | 28 days |
|---|---|---|---|---|---|---|
| 1 | 0 | P.C | 11.9 | 16.5 | 23.5 | 29.4 |
| 2 | 1.5 | $nSiO_2$ | 12.1 | 16.8 | 24.6 | 30.7 |
| 3 | 3.5 | $nSiO_2$ | 12.9 | 17.3 | 26.9 | 31.6 |
| 4 | 5.5 | $nSiO_2$ | 12.7 | 15.9 | 24.9 | 28.6 |
| 5 | 7.5 | $nSiO_2$ | 10.6 | 15.6 | 22.8 | 28.7 |

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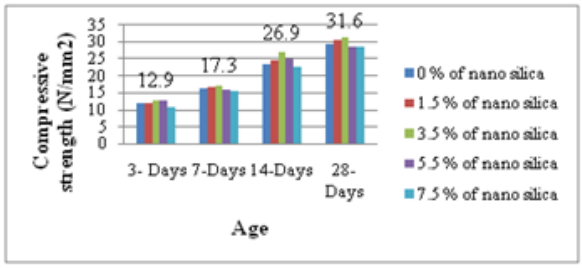
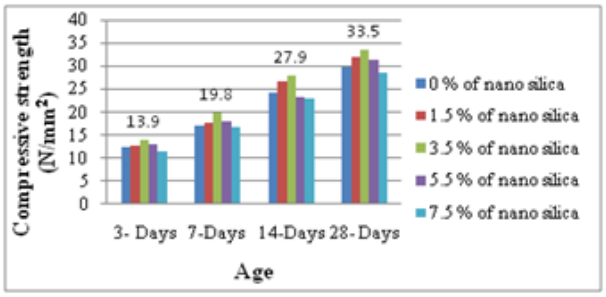



**Graph -1: Mortar using OPC**

It shows that the addition of 3.5 % of nano silica gives the high strength at 3days, 7days, 14days and 28 days strength when comparing to the conventional mortar cubes.

**Table -3 Mortar Results for Blended Cement**

| Sl.No | % replacement of nano silica | Description | 3 days | 7 days | 14 days | 28 days |
|---|---|---|---|---|---|---|
| 1 | 0 | P.C | 12.5 | 16.9 | 24.1 | 29.9 |
| 2 | 1.5 | $nSiO_2$ | 12.7 | 18.6 | 26.8 | 32 |
| 3 | 3.5 | $nSiO_2$ | 13.9 | 19.8 | 27.9 | 33.5 |
| 4 | 5.5 | $nSiO_2$ | 13.1 | 17.9 | 23.4 | 31.2 |
| 5 | 7.5 | $nSiO_2$ | 11.5 | 16.8 | 22.8 | 28.6 |

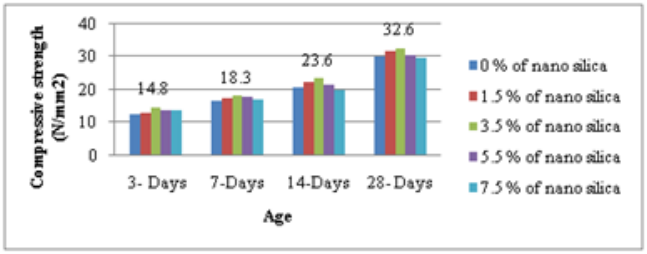



**Graph - 2: Mortar using Blended Cement**

It shows that the addition of 3.5 % of nano silica gives the high strength at 3days, 7days, 14days and 28 days strength when comparing to the conventional mortar cubes and comparing to the OPC mortar cubes and Blended cement mortar cubes the blended cement mortar cubes gives the higher strength.

**Table 4-Compressive strength for concrete by using OPC**

| Sl.No | % replacement of nano silica | Description | 3 days | 7 days | 14 days | 28 days |
|---|---|---|---|---|---|---|
| 1 | 0 | P.C | 12.5 | 16.8 | 21 | 30.4 |
| 2 | 1.5 | $nSiO_2$ | 13 | 17.6 | 22.5 | 31.9 |
| 3 | 3.5 | $nSiO_2$ | 14.8 | 18.3 | 23.6 | 32.6 |
| 4 | 5.5 | $nSiO_2$ | 13.9 | 17.9 | 21.6 | 30.6 |
| 5 | 7.5 | $nSiO_2$ | 13.8 | 17 | 20 | 29.8 |

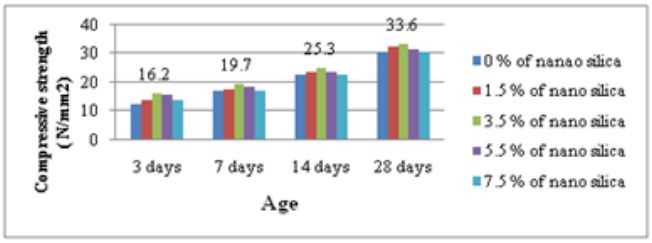



**Graph – 3: Compressive strength for concrete using OPC**

It shows that the addition of 3.5 % nano silica gives the high strength at 3days, 7days, 14days and 28days when comparing to the increases of addition of nano silica and conventional concrete.

**Table 5-Compressive strength for concrete by using Blended Cement**

| Sl.No | % replacement of nano silica | Description | 3 days | 7 days | 14 days | 28 days |
|---|---|---|---|---|---|---|
| 1 | 0 | P.C | 12.7 | 17.4 | 22.8 | 30.6 |
| 2 | 1.5 | $nSiO_2$ | 14.1 | 17.8 | 23.6 | 32.4 |
| 3 | 3.5 | $nSiO_2$ | 16.2 | 19.7 | 25.3 | 33.6 |
| 4 | 5.5 | $nSiO_2$ | 15.8 | 18.6 | 23.7 | 31.7 |
| 5 | 7.5 | $nSiO_2$ | 14 | 17.4 | 22.6 | 30.9 |




**Graph - 4: Compressive strength for concrete using Blended Cement**

It shows that the addition of 3.5 % of nano silica gives the high strength at 3days, 7days, 14 days and 28 days strength when comparing to the conventional mortar cubes and comparing to the OPC mortar cubes and

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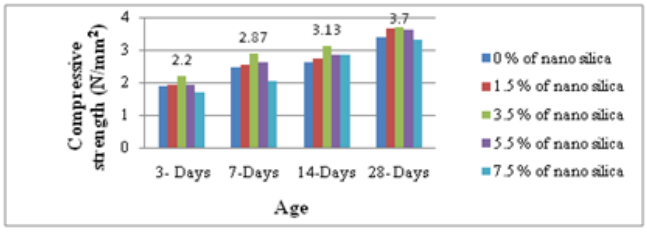
Blended cement mortar cubes the blended cement mortar cubes gives the higher strength.

### Table6- Split Tensile Test Results:

| SI. No | % replacement of nano silica | Description | 3 days | 7 days | 14 days | 28 days |
|---|---|---|---|---|---|---|
| 1 | 0 | P.C | 1.87 | 2.47 | 2.63 | 3.4 |
| 2 | 1.5 | $nSiO_2$ | 1.93 | 2.53 | 2.73 | 3.67 |
| 3 | 3.5 | $nSiO_2$ | 2.2 | 2.87 | 3.13 | 3.7 |
| 4 | 5.5 | $nSiO_2$ | 1.93 | 2.63 | 2.83 | 3.63 |
| 5 | 7.5 | $nSiO_2$ | 1.7 | 2.03 | 2.83 | 3.16 |

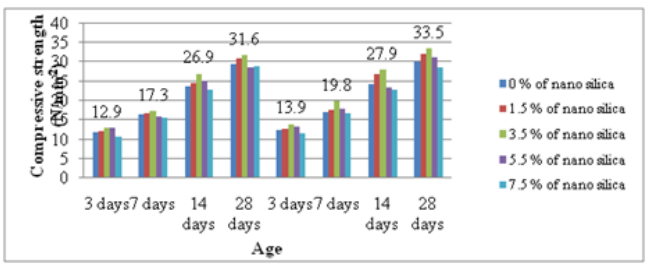



**Graph - 5: Split Tensile Test for OPC**

It shows that the addition of 3.5 % nano silica gives the high strength at 3days, 7days, 14days and 28days when comparing to the increases of addition of nano silica and conventional concrete.

### Table 7- Comparison of cement mortar for OPC and Blended cement

| % Replacement of nano silica | OPC | | | | Blended Cement | | | |
|---|---|---|---|---|---|---|---|---|
| | 3 days | 7 days | 14 days | 28 days | 3 days | 7 days | 14 days | 28 days |
| 0 | 11.9 | 16.5 | 23.5 | 29.4 | 12.5 | 16.9 | 24.1 | 29.9 |
| 1.5 | 12.1 | 16.8 | 24.6 | 30.7 | 12.7 | 18.6 | 26.8 | 32 |
| 3.5 | 12.9 | 17.3 | 26.9 | 31.6 | 13.9 | 19.8 | 27.9 | 33.5 |
| 5.5 | 12.7 | 15.9 | 24.9 | 28.6 | 13.1 | 17.9 | 23.4 | 31.2 |
| 7.5 | 10.6 | 15.6 | 22.8 | 28.7 | 11.5 | 16.8 | 22.8 | 28.6 |

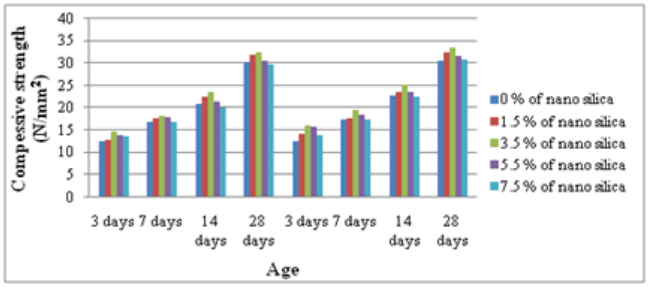



**Graph-6: Comparison of Mortar Cubes for OPC and Blended Cement**

It shows that the addition of 3.5 % nano silica gives the high strength at 3days, 7days, 14days and 28days when comparing to the increases of addition of nano silica and conventional concrete. When Comparing with OPC and blended cement addition the Blended cement addition gives the high strength.

### Table 8: Comparison of concrete by using OPC and Blended cement

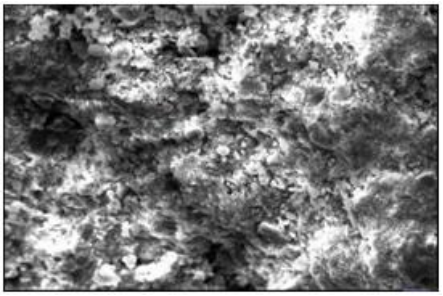
| % Replacement of nano silica | OPC | | | | Blended cement | | | |
|---|---|---|---|---|---|---|---|---|
| | 3 days | 7 days | 14 days | 28 days | 3 days | 7 days | 14 days | 28 days |
| 0 | 12.5 | 16.8 | 21 | 30.4 | 12.7 | 17.4 | 22.8 | 30.6 |
| 1.5 | 13 | 17.6 | 22.5 | 31.9 | 14.1 | 17.8 | 23.6 | 32.4 |
| 3.5 | 14.8 | 15.3 | 23.6 | 32.6 | 16.2 | 19.7 | 25.3 | 33.6 |
| 5.5 | 13.9 | 17.9 | 21.6 | 30.6 | 15.8 | 18.6 | 23.7 | 31.7 |
| 7.5 | 13.8 | 17 | 20 | 29.8 | 14 | 17.4 | 22.6 | 30.9 |




**Graph-7: Comparison of concrete cubes for OPC and Blended Cement**

It shows that the addition of 3.5 % nano silica gives the high strength at 3days, 7days, 14days and 28days when comparing to the increases of addition of nano silica and conventional concrete. When Comparing with OPC and blended cement addition the Blended cement addition gives the high strength.

### SEM analysis:



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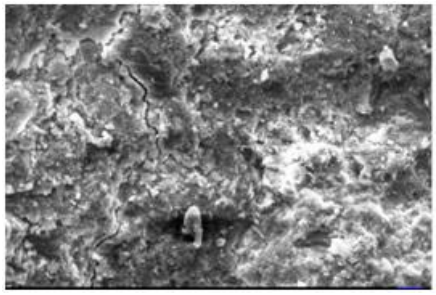

**Fig 1: SEM analysis for (a) 3.5% of nano silica (b) 5.5% of nano silica**

The morphology of the nano silica samples with (3.5% and 5.5%)nano silica addition is explained by using Scanning Electron Microscope and are shown in fig 1(a) and (b).

## CONCLUSION:

1. The compressive strength of the OPC cement is lower than the Blended cement.

2. The strength will increase by using the increase percentage of the nano silica.

3. Upto 3.5 % replacement of nano silica should increase the strength and at 5.5 % and 7.5% of silica replacement decreases the strength.

4. Compressive strength increases with increasing the nano silica content upto 3.5 % of replacement by weight of cement.

5. The consistency and setting time is different for the percentage increase of $nSiO_2$.

6. To optimize the performance of nano silica in OPC and Blended cement.

7. Based on the mechanical properties results it can conclude that nano silica can improve the mechanical properties strength.

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