



# EFFECT OF NANO SILICA ON THE COMPRESSIVE STRENGTH OF CONCRETE

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**Abstract:** The present study incorporates mix design based on the guidelines as per Indian Standard code IS 10262-2009. The Nano-silica used is imported from a supplier. The use of any kind of admixture is strictly prohibited in the mix design. The water content has been kept constant to facilitate a better comparison for different samples. The compressive strength measurements are carried out for 7-day and 28-day and the FESEM analysis has been done for 28-day only. The size of the nano-silica was identified using Particle Size Analyzer.

**Index Terms -** Nano-silica, mix design, FESEM, Analyzer.

## I. INTRODUCTION

Concrete is the material of present as well as future. The wide use of it in structures, from buildings to factories, from bridges to airports, makes it one of the most investigated material of the 21st century. Due to the rapid population explosion and the technology boom to cater to these needs, there is an urgent need to improve the strength and durability of concrete. Out of the various materials used in the production of concrete, cement plays a major role due its size and adhesive property. So, to produce concrete with improved properties, the mechanism of cement hydration has to be studied properly and better substitutes to it have to be suggested. Different materials known as supplementary cementations materials or SCMs are added to concrete improve its properties. Some of these are fly ash, blast furnace slag, rice husk, silica fumes and even bacteria. Of the various technologies in use, Nano-technology looks to be a promising approach in improving the properties of concrete.

## II. MOTIVATION OF THE STUDY

The increased use of cement is essential in attaining a higher compressive strength. But, cement is a major source of pollution. The use of nanomaterials by replacement of a proportion of cement can lead to a rise in the compressive strength of the concrete as well as a check to pollution. Since the use of a very small proportion of Nano SiO<sub>2</sub> can affect the properties of concrete largely, a proper study of its microstructure is essential in understanding the reactions and the effect of the nanoparticles. The existing papers show the use of admixtures in concrete mix. In the present study, no admixture has been used in order to prevent the effect of any foreign material on the strength of the concrete. This study is an attempt to explain the impact of a Nano-silica on the compressive strength of concrete by explaining its microstructure

## III. METHODOLOGY

### 3.1.1 Mix Design

The mix design for M25 grade of concrete is described below in accordance with Indian Standard Code IS: 10262-1982.

TARGET STRENGTH FOR MIX PROPORTIONING:

Characteristic compressive strength at 28 days:  $f_{ck} = 25$  MPa

Assumed standard deviation (Table 1 of IS 10262:1982):  $sd = 4$  MPa

Target average compressive strength at 28 days:  $f_{target} = f_{ck} + 1.65s_d = 31.6$  MPa

## I. SELECTION OF WATER-CEMENT RATIO:

From Table 5 of IS: 456-2000, maximum water-cement ratio = 0.50 To start with let us assume a water-cement ratio of 0.43

## II. SELECTION OF WATER CONTENT:

Maximum water content per cubic metre of concrete (refer Table 2 of IS: 10262- 1982):  $W_{max} = 186$ L (for 50 mm slump). Since, the slump was less than 50 mm, no adjustment was required.

## III. CALCULATION OF CEMENT CONTENT:

Mass of water selected per cubic metre of concrete = 186 kg. Mass of cement per cubic metre of concrete =  $186/0.43 = 433$  kg.

Minimum cement content =  $300 \text{ kg/m}^3$  (for moderate exposure condition, Table 5 of IS 456:2000)

Maximum cement content =  $450 \text{ kg/m}^3$  (Cl. 8.2.4.2 of IS 456:2000) So, the selected cement content is alright.

## IV. PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT:

Volume of coarse aggregate per unit volume of total aggregate (Table 3 of IS: 10262-1982) = 0.64

(This is corresponding to 20 mm size aggregate and Zone III fine aggregate for water-cement ratio of 0.50)

As the water-cement ratio is lowered by 0.05, the proportion of volume of coarse aggregate is increased by 0.01 (ref. Table 6 of IS: 10262-1982)

Corrected volume of coarse aggregate per unit volume of total aggregate =  $(0.64+0.014) = 0.654$

Volume of fine aggregate per unit volume of total aggregate =  $1-0.654 = 0.346$

## II. MIX CALCULATIONS

i. Volume of concrete =  $1 \text{ m}^3$

ii. Volume of cement =  $433/(3.01 \times 1000) = 0.144 \text{ m}^3$

iii. Volume of water =  $186/1000 = 0.186 \text{ m}^3$

iv. Volume of all aggregates =  $1-0.144-0.186 = 0.67 \text{ m}^3$

v. Mass of coarse aggregate =  $0.654 \times 0.67 \times 2.72 \times 1000 = 1192 \text{ kg}$

vi. Mass of fine aggregate =  $0.346 \times 0.67 \times 2.65 \times 1000 = 614 \text{ kg}$

## vii. MIX PROPORTION:

For a batch of 6 cubes of 150mm side, the volume of concrete required

=  $(0.15)^3 \times 6 \times 1.2 = 0.024 \text{ m}^3$  (taking into account 20 % extra for losses)

Cement required =  $0.024 \times 433 = 10.4 \text{ kg}$

Fine aggregate required =  $0.024 \times 614 = 14.7 \text{ kg}$

Coarse aggregate required =  $0.024 \times 1192 = 28.6 \text{ kg}$

Water required =  $0.024 \times 186 = 4.5 \text{ kg}$

## Preparation of Test Specimen

For conducting compressive strength test on concrete cubes of size 150×150×150mm are casted. A rotary mixture is used for thorough mixing and a vibrator is used for good compaction. After successful casting, the concrete specimens are de-moulded after 24 hours and immersed in water for 28 days maintaining 27 ± 1°C



Fig. 3.3 shows some concrete specimen casted in laboratory



Fig. 3.3 (a): concrete cubes casted in the mould

### 3.1.1 Compressive Strength Test

The compressive strength of specimens is determined after 7 and 28 days of curing with surface dried condition as per Indian Standard IS: 516-1959. Three specimens are tested for typical category and the mean compressive strength of three specimens is considered as the compressive strength of the specified category.

### 3.1.2 Ultrasonic Pulse Velocity (UPV) Test

It is a non-destructive testing technique (NDT). The method consists of measuring the ultrasonic pulse velocity through the concrete with a generator and a receiver. This test can be performed on samples in the laboratory or on-site. The results are affected by a number of factors such as the surface and the maturity of concrete, the travel distance of the wave, the presence of reinforcement, mixture proportion, aggregate type and size, age of concrete, moisture content, etc., furthermore some factors significantly affecting UPV might have little influence on concrete strength. Table

3.2 shows the quality of concrete for different values of pulse velocity. The images of the UPV Testing Machine used in the laboratory is shown in Fig. 3.4.

Table 3.4: Criteria for quality of concrete

PULSE VELOCITY	CONCRETE QUALITY
>4000 m/s	Excellent
3500-4000 m/s	Very Good
3000-3500 m/s	Satisfactory
<3000 m/s	Poor

#### IV RESULT AND DISCUSSION

##### UPV Test Results:

Fig 4.1-4.8 show UPV test results for specimen for 7 day and Fig 4.5-4.8 show UPV test results for specimen for 28 day.

Table 4.1: UPV Test for control specimen for 7 day

7-DAY TEST RESULT			
Sample No.	Weight (kg)	Velocity (m/s)	Time ( $\mu$ s)
1	8.10	4678	32.2
2	8.34	4702	31.9
3	8.36	4777	31.4

Table 4.2: UPV Test for specimen with nano-silica 0.3% b.w.c for 7 day

7-DAY TEST RESULT			
Sample No.	Weight (kg)	Velocity (m/s)	Time ( $\mu$ s)
1	8.18	4491	33.4
2	8.22	4491	33.4
3	8.24	4386	34.2

Table 4.3: UPV Test for specimen with nano-silica 0.6% b.w.c for 7 day

7-DAY TEST RESULT			
Sample No.	Weight (kg)	Velocity (m/s)	Time ( $\mu$ s)
1	8.26	4630	32.4
2	8.08	4630	32.4
3	7.98	4702	31.9

Table 4.4: UPV Test for specimen with nano-silica 1% b.w.c for 7 day

7-DAY TEST RESULT			
Sample No.	Weight (kg)	Velocity (m/s)	Time ( $\mu$ s)
1	8.24	4491	33.4
2	8.14	4360	34.4
3	8.30	4559	32.9

Table 4.5: UPV Test for control specimen for 28 day

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Velocity (m/s)	Time ( $\mu$ s)
1	8.42	4808	31.2
2	8.36	4854	30.9
3	8.14	4777	31.4

Table 4.6: UPV Test for specimen with nano-silica 0.3% b.w.c for 28 day

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Velocity (m/s)	Time ( $\mu$ s)
1	8.06	4673	32.1
2	8.32	4732	31.7
3	8.22	4854	30.9

Table 4.7: UPV Test for specimen with nano-silica 0.6% b.w.c for 28 day

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Velocity (m/s)	Time ( $\mu$ s)
1	8.18	4702	31.9
2	8.24	4777	31.4
3	8.22	4777	31.4

Table 4.8: UPV Test for specimen with nano-silica 1% b.w.c for 28 day

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Velocity (m/s)	Time (µs)
1	8.30	4658	32.2
2	8.30	4702	31.9
3	8.28	4808	31.2

#### 4.1.1 Compressive Strength Test Results

\*Compressive Strength =  $(52 \times 9.81 \times 1000) \div (150 \times 150) = 22.67 \text{ MPa}$

Table 4.9: Compressive Strength of control specimen for 7 day

7-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.10	52	22.67 *
2	8.34	68	29.65
3	8.36	61	26.59
Mean			26.30

Table 4.10: Compressive Strength of specimen with nano-silica 0.3% b.w.c for 7 day

7-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.18	67	29.21
2	8.22	71	30.95
3	8.24	52	22.67
Mean			27.61

Table 4.11: Compressive Strength of specimen with nano-silica 0.6% b.w.c for 7 day

7-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.26	66	28.77
2	8.08	72	31.39
3	7.98	76	33.14
Mean			31.1

Table 4.12: Compressive Strength of specimen with nano-silica 1% b.w.c for 7 day

7-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.24	77	33.57
2	8.14	79	34.44
3	8.30	82	35.75
Mean			34.59

Table 4.13: Compressive Strength of control specimen for 28 day

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.42	84	36.62
2	8.36	84	36.62
3	8.14	75	32.70
Mean			35.31

Table 4.14: Compressive Strength of specimen with nano-silica 0.3% b.w.c for 28 day

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.06	66	28.78
2	8.32	88	38.37
3	8.22	88	38.37
Mean			35.17

Table 4.15: Compressive Strength of specimen with nano-silica 0.6% b.w.c for 28 day

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.18	83	36.19
2	8.24	80	34.88
3	8.22	88	38.37
Mean			36.48

Table 4.16: Compressive Strength of specimen with nano-silica 1% b.w.c for 28 day

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.30	88	38.37
2	8.30	93	40.55
3	8.28	93	40.55
Mean			39.82

## Discussion

i. The increase in compressive strength can be attributed to the filling of voids in the microstructure by the Nano SiO<sub>2</sub> particles which prevents the growth of Ca(OH)<sub>2</sub> crystals. In addition to it the nano silica reacts with calcium hydroxide crystals converting them into C-S-H gel. The reduction in the Ca(OH)<sub>2</sub> content is the reason for increase in compressive strength of concrete.

ii. Ca(OH)<sub>2</sub> crystals are present in the Interfacial Transition Zone (ITZ) which is between the aggregates and the hardened cement paste. Nano SiO<sub>2</sub> reacts with these crystals and decreases their concentration, hence, strengthen the ITZ. Due to lesser concentration Nano SiO<sub>2</sub> are consumed in the reaction and hence the increase in strength is inhibited with time.

iii. A study of relevant papers show that concrete blended with Nano SiO<sub>2</sub> sets quicker compared to normal concrete. Since, the mix design is carried out without the aid of super- plasticizers, the mix dried up fast which affected the compaction of the mix using mechanical vibration. Lumps of the mix could be seen during the mixing of concrete. With increase in percentage of Nano SiO<sub>2</sub> the compaction gets tougher. This is the reason for degradation in its quality. It is advisable to use superplasticizers with nano silica.

iv. The Nano SiO<sub>2</sub> added to the mix filled up the pores in between the C-S-H gel, hence, making the microstructure more compact and uniform.

## V CONCLUSION

From the test results, the SEM micrographs and the relative chemical composition of the specimen a number of conclusions can be drawn. These conclusions are justified in the next section. The conclusions drawn are:

i. From the compressive strength results, it can be observed that increase in compressive strength of concrete is observed on addition of a certain minimum quantity of Nano SiO<sub>2</sub>. The increase in strength is maximum for NS 1% b.w.c and least for NS 0.3% b.w.c.

ii. On addition of Nano SiO<sub>2</sub> there is a substantial increase in the early-age strength of concrete compared to the 28 day increase in strength.

iii. The UPV test results show that the quality of concrete gets slightly affected on addition of Nano SiO<sub>2</sub> but the overall quality of concrete is preserved.

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