EXPERIMENTAL EVALUATION OF NANO COMPOSITE CONCRETE

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Abstract-The application of nanotechnology in concrete has added a new dimension to the efforts to improve its properties. Nano materials, by virtue of their very small particle size can affect the concrete properties by altering the microstructure. This study concerns with the use of nano silica of size 236 nm to improve the compressive strength of concrete. An experimental investigation has been carried out by replacing the cement with nano silica of 0.3%, 0.6% and 1% b.w.c. The tests conducted on it shows a considerable increase in early-age compressive strength and a small increase in the overall compressive strength of concrete. The strength increase was observed with the increase in the percentage of nano silica. The FESEM micrographs support the results and show that the microstructure of the hardened concrete is improved on addition of nano silica.

Index Terms— concrete, nano silica, compressive strength, microstructure

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. Nano materials are very small sized materials with particle size in nano meters. These materials are very effective in changing the properties of concrete at the ultrafine level by the virtue of their very small size. The small size of the particles also means a greater surface area (Alireza Naji Givi, 2010). Since the rate of a Pozzolanic reaction is proportional to the surface area available, a faster reaction can be achieved . Only a small percentage of cement can be replaced to achieve the desired results. These nano materials improve the strength and permeability of concrete by filling up the minute voids and pores in the microstructure.

The use of nano silica in concrete mix has shown results of increase in the compressive, tensile and flexural strength of concrete. It sets early and hence generally requires admixtures during mix design. Nano-silica mixed cement can generate nano-crystals of C-S-H gel after hydration. These nano-crystals accommodate in the micro pores of the cement concrete, hence improving the permeability and strength of concrete.

1.2 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 nano materials 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_2 can affect the properties of concrete largely, a proper study of its microstructure is essential in understanding the reactions and the effect of the nano particles. 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.

1.3 OBJECTIVE OF THE STUDY

The main objectives of the present study are as mentioned below:

- To study the effect of nano-silica on the compressive strength of concrete.
- To study the microstructure of the hardened cement concrete.
- To explain the change in properties of concrete, if any, by explaining the microstructure.

1.4 MATERIALSANDMETHODS

This chapter is concerned with the details of the properties of the materials used, the method followed to design the experiment and the test procedures followed. The theory is supplemented with a number of pictures to have a clear idea on the methods.

3.2 MATERIAL PROPERTIES

Specific Gravity	Fineness by sieve analysis	Normal consistency
3. 4 %	2.01 %	33 %

The materials used to design the mix for M25 grade of concrete are cement, sand, coarse aggregate, water and Nano SiO2. The properties of these materials are presented below.

3.2.1 Properties of Cement
Portland slag cement of 43 grade conforming to IS: 455-1989 is used for preparing concrete specimens. The properties of cement used are given in the Table 2.

Table 3.1: Properties of Portland slag cement

3.2.2 Properties of fine and coarse aggregate
Sand as fine aggregates are collected from locally available river and the sieve analysis of the samples are done. It is found that the sand collected is conforming to IS: 383-1970. For coarse aggregate, the parent concrete is crushed through mini jaw crusher. During crushing it is tried to maintain to produce the maximum size of aggregate in between 20mm to 4.75mm. The coarse aggregate particle size distribution curve is presented in Fig. 3.1. The physical properties of both fine aggregate and recycled coarse aggregate are evaluated as per IS: 2386 (Part III)-1963

3.2.4 Properties of Nano SiO2
The average size of nano silica was found to be 236 nm from Particle Size Analyzer, the report of which has been presented in the Appendix. The properties of the material are shown in Table 3.3. Fig. 3. Shows the nano silica used in the experiment.

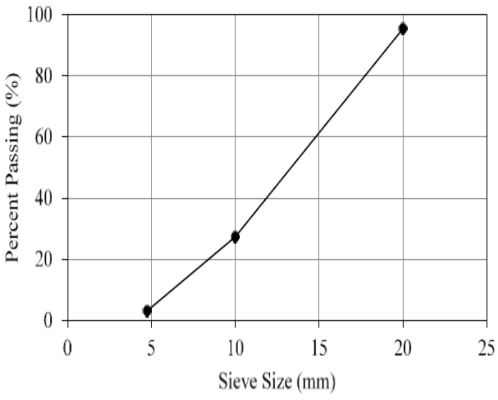

Fig. 3.1: Size distribution curve for coarse aggregate

Fig. 3.2: Image of the Nano SiO_2 used

3.3.1 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: fck = 25 MPa
Assumed standard deviation (Table 1 of IS 10262:1982): sd = 4 MPa
Target average compressive strength at 28 days: F target = fck + 1.65sd =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 meter of concrete (refer Table 2 of IS: 10262-1982): Wmax = 186L (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 meter of concrete = 186 kg. Mass of cement per cubic metre of concrete = 186/0.43 = 433 kg.
Minimum cement content = 300 kg/m3 (for moderate exposure condition, Table 5 of IS 456:2000)
Maximum cement content = 450 kg/m3 (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

V. MIX CALCULATIONS

i. Volume of concrete = 1 m3
ii. Volume of cement = 433/(3.01×1000) = 0.144 m3
iii. Volume of water = 186/1000 = 0.186 m3
iv. Volume of all aggregates = 1-0.144-0.186 = 0.67 m3
v. Mass of coarse aggregate = 0.654×0.67×2.72×1000 = 1192 kg
vi. Mass of fine aggregate = 0.346×0.67×2.65×1000 = 614 kg

MIX PROPORTION:
For a batch of 6 cubes of 150mm side, the volume of concrete required
= (0.15)3×6×1.2 = 0.024 m3 (taking into account 20 % extra for losses)
Cement required = 0.024x433 = 10.4 kg
Fine aggregate required = 0.024x614 = 14.7 kg
Coarse aggregate required = 0.024x1192 = 28.6 kg
Water required = 0.024x186 = 4.5 kg

3.3.2 PREPARATION OF TEST SPECIMEN
For conducting compressive strength test on concrete cubes of size 150 X150X 150 mm A rotary mixture is used for thorough mixing and a vibrator is used for mm are casted. compaction. After successful casting, the concrete specimens are de-moulded after 24 hours and immersed in water for 28 days maintaining 27+ C. Fig.

3.3 shows some concrete specimen casted in laboratory.

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

Fig. 3.3 (b): concrete cubes after de-moulding.

Fig. 3.3: (a) and (b) shows some concrete specimen cast in laboratory

3.3.3 Compressive Strength Test

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

Table 3.4: Criteria for quality of concrete

3.3.5 Other Tests
Some other tests performed were using Field Emission Scanning Electron Microscope (FESEM) and using Particle Size Analyser (PSA). Since these tests were performed by technical experts, these are not explained here and only the results are presented in the next chapter

Fig 3.4 (a): UPV Test apparatus

Fig. 3.4 (b): UPV Test of concrete specimen

Fig. 3.4: (a) and (b) shows UPV Test performed in laboratory

4.2 EXPERIMENTAL RESULTS

4.2.1 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 (µs)
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 (µs)
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 (µs)
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 (µs)
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 (µs)
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 (µs)
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 (µs)
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

4.2.2 Compressive Strength Test Results

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

Table 4.9: Compressive Strength of control specimen for 7 day

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

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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

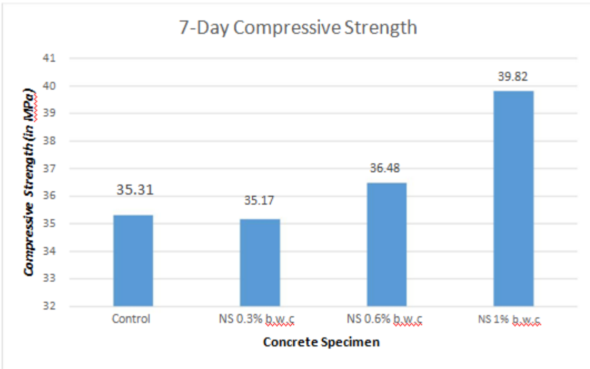
28-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.18	83	36.19
2	8.24	80	34.88
3	8.22	88	38.37
Mean			36.48

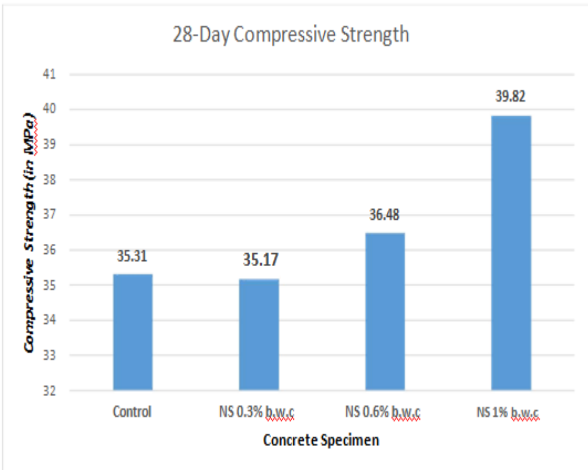
Table 4.16: Compressive Strength of specimen with nano-silica 1% b.w.c for 28 day

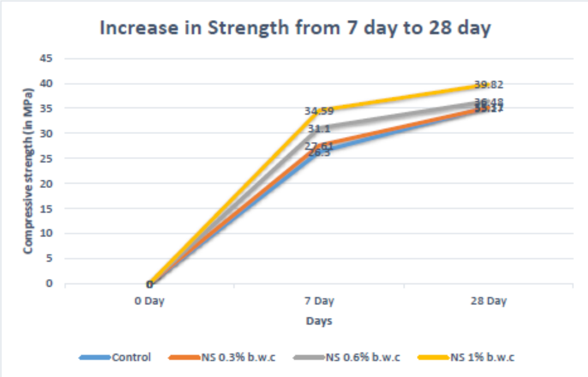
28-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.30	88	38.37
2	8.30	93	40.55
3	8.28	93	40.55
Mean			39.82

4.3 COMPARISON OF RESULTS

The change in compressive strength for the blended sample (in %) for 7 and 28 day is shown in Table 4.17 and Table 4.18 respectively. A graphical representation of this result is shown in Fig. 4.1 and Fig. 4.2. The change in compressive strength from 7 day to 28 day is shown in Fig 4.3







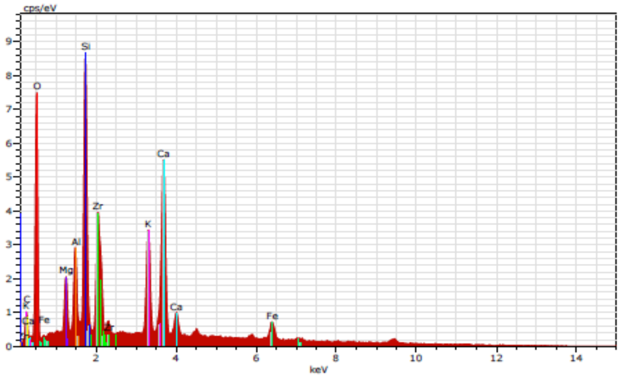


Fig. 4.8: Relative chemical composition for the control specimen

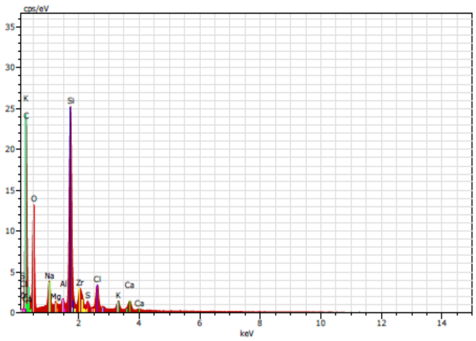


Fig. 4.9: Relative chemical composition for specimen with NS 0.3% b.w.c

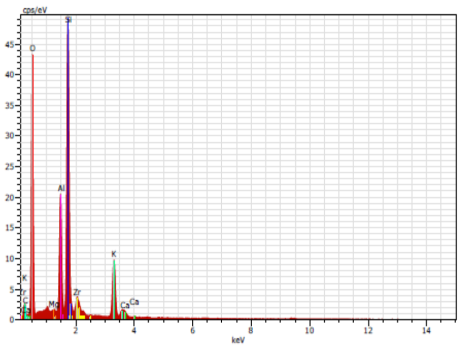


Fig. 4.10: Relative chemical composition for specimen with NS 0.6% b.w.c

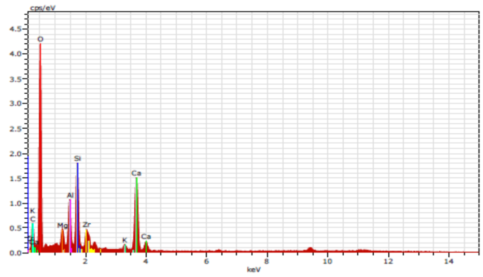


Fig. 4.11: Relative chemical composition for specimen with NS 1% b.w.c

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: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 SiO2. The increase in strength is maximum for NS 1% b.w.c and least for NS 0.3% b.w.c. On addition of Nano SiO2 there is a substantial increase in the early-age strength of concrete compared to the 28 day increase in strength.The UPV test results show that the quality of concrete gets slightly affected on addition of Nano SiO2 but the overall quality of concrete is preserved.The FESEM micrograph shows a uniform and compact microstructure on addition of Nano-SiO2.

5.4 SCOPE FOR FUTURE RESEARCH

Although a lot of work has been carried out involving the use of nano silica in concrete, a proper understanding has not been developed. In future, the size effects of nano silica can be studied in detail. A detailed study of the microstructure at specific intervals throughout a year can give a very good idea about the reactions taking place in the concrete. Looking at the price of the nano silica new methods can be designed for its production at a low cost.

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