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A STUDY TO ANALYSE THE PERFORMANCE OF CONCRETE WITH AN ADDITION OF NANO-SILICA

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Abstract: The application of nanotechnology in concrete has added a new dimension to the efforts to improve its properties. Nano silica, 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 show 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.
Keywords: Modified Concrete, Nano silica, Ultrasonic Pulse Velocity Test, 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 materials 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 cementitious 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.

Nanomaterials are very small sized materials with particle size in nanometres. 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 (AlirezaNajiGivi, 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 nanomaterials improve the strength and permeability of concrete by filling up the minute voids and pores in the microstructure. The use of nanosilica 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.

II. LITERATURE REVIEW

The relevant literature on present study was thoroughly reviewed and presented here.

Surya Abdul Rashid et.al. (2011) worked on the effect of Nano SiO2 particle on both mechanical properties (compressive, split tensile and flexural strength) and physical properties (water permeability, workability and setting time) of concrete which shows that binary blended concrete with nano SiO2 particles up to 2% has significantly higher compressive, split tensile and flexural strength compared to normal concrete. Another inference drawn was that partial replacement of nano SiO2 particles decreases the workability and setting time of fresh concrete for samples cured in lime solution. Ali Nazari et.al. (2011) studied strength and percentage water absorption of SCC containing different amount of GGBFS and TiO2 nano particles. The findings of the experimentation are that replacement of Portland cement with up to 45% weight of GGBSF and up to 4% weight of TiO2 nano particles gives a considerable increase to the compressive, split tensile and flexural strength of the blended concrete. This increase is due to more the formation of hydrated products in presence of TiO2; also the water permeability resistance of hardened concrete was improved. The author also studied effect of CuOnano particles on SCC and observed that increased percentage of polycarboxylate admixture content results in decreased compression strength. The CuOnano particles of average particle size 15nm content with up to 4% weight increased the compressive strength of SCC. CuOnano particles up to 4% could accelerate the first peak in conduction calorimetric testing which is related to the acceleration of formation of hydrated cement products.

Sekari and Razzaghi (2011) studies the effect of constant content of Nano ZrO2, Fe2O3, TiO2, and Al2O3 on the properties of concrete. The reults showed that all the nano particles have noticeable influence on improvement on durability properties of concrete but the contribution of nano Al2O3 on improvement of mechanical properties of HPC is more than the other nano particles.

A.M. Said et.al. (2012) studied the effect of colloidal Nano silica on concrete by blending it with class F fly ash and observed that performance of concrete with or without fly ash was significantly improved with addition of variable amounts of nano silica. The mixture containing 30% FA and 6% CNS provides considerable increase in strength. Porosity and threshold pore diameter was significantly lower for mixture containing Nano silica. The RCPT test shows that passing charges and physical penetration depth significantly improved.

AlirezaNajiGivi et.al. (2012) studied the effect of Nano SiO2 particles on water absorption of RHA blended concrete. It is concluded that cement could be replaced up to 20% by RHA in presence of Nano SiO2 particle up to 2% which improves physical and mechanical properties of concrete.

Heidari and Tavakoli (2012) investigated the combined effect of replacement of cement by ground ceramic powder from 10% to 40% b.w.c. and nano SiO2 from 0.5 to 1%. A substantial decrease in water absorption capacity and increase in compressive strength was observed when 20% replacement is done with ground ceramic powder with 0.5 to 1% as the optimum dose of Nano SiO2 particles.

J.Comiletti et.al. (2012) investigated the effect of micro and nano CaCO3 on the early age properties of ultra-high performance concrete (UHPC) cured in cold and normal field conditions. The micro CaCO3 was added from 0 to 15% b.w.c. and nano CaCO3 was added at the rate of 0, 2.5 and 5% b.w.c. Results show that by incorporating nano and micro CaCO3 the flow ability of UHPC is higher than the control mix which increases the cement replacement level. The mixture containing 5% nano CaCO3 and 15% micro CaCO3 gives shortest setting time at 10 °C and at 20°C the highest 24 hrs compressive strength is achieved by replacing cement with 2.5% nano and 5% micro CaCO3 and highest compressive strength at 26 days was achieved at 0% nano and 2.5% micro CaCO3.

Min. Hong Zhang et.al. (2012) studied the effect of NS & high volume slag mortar on setting time and early strength and observed that rate of hydration increases with addition of NS, compressive strength of slag mortar increases with increase in NS dosages from 0.5 to 2% by weight of cement. 2% NS reduces initial and final setting time and compressive strength increases by 22% and 18% at 3 days and 7 days with addition of 50% slag. NS with particle size 7 & 12 nm are more effective in increasing cement hydration and reaction compared with silica fume.

G. Dhinakaranet. al. (2014) analysed the microstructure and strength properties of concrete with Nano SiO2. The silica was ground in the planetary ball mill till nano size reached and it was blended in concrete with 5%, 10% and 15% b.w.c.. The experimental results showed gain in compressive strength with maximum strength for 10% replacement.

Mukharjee and Barai (2014) the compressive strength and characteristics of Interfacial Transition Zone (ITZ) of concrete containing recycled aggregates and nano-silica. An improvement in the compressive strength and microstructure of concrete was observed with the incorporation of nano-silica.

III. OBJECTIVE OF 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.

IV. MATERIALS AND METHODS

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

Properties of Cement: Portland slag cement of 43 grades conforming to IS: 455-1989 is used for preparing concrete specimens. The properties of cement used are given in the Table 1.

Table 1. Properties of Cement

Specific Gravity	Fineness by sieve analysis	Normal consistency
3.014	2.01%	33%

Properties of fine and coarse aggregate:

Table 2: Properties of coarse aggregate and fine aggregate

Property	Coarse Aggregate	Fine Aggregate
Specific Gravity	2.72	2.65
Bulk Density (kg/L)	1.408	-
Loose Bulk Density (kg/L)	1.25	-
Water Absorption (%)	4.469	0.0651
Impact Value	26.910	-
Crushing Value	26.514	-
Fineness Modulus	3.38	2.84

Properties of Water: Tap water was used in this experiment. The properties are assumed to be same as that of normal water. Specific gravity is taken as 1.00.

Properties of Nano SiO_2: 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. Fig. 3. Shows the nano silica used in the experiment.

Table 3: Properties of Nano SiO2

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 Deg.C (5)	< 1. 5	0. 47
Loss On Ignition @ 1000 Deg.C (%)	<2.0	0.66
Sieve Residue (5)	< 0.04	0. 02
Tamped Density (G/L)	40 – 60	44
Sio2 Content(%)	> 99. 8	99. 88
Carbon Content (%)	< 0. 15	0. 06
Chloride Content (%)	< 0. 0202	0. 009
Al2O3	< 0.03	0. 005
Tio2	< 0.02	0. 004
Fe2O3	< 0. 003	0. 001

Fig. 1: Image of the Nano SiO2 used

METHODS:

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

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).

Table 4: Mix Proportions

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

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.

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 5 shows the quality of concrete for different values of pulse velocity.

Table 5: 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

V. RESULTS AND DISCUSSIONS

UPV Test Results:

Table 5: UPV Test for control specimen for 7 day

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

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

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

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

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

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

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

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

Compressive Strength Test Results:

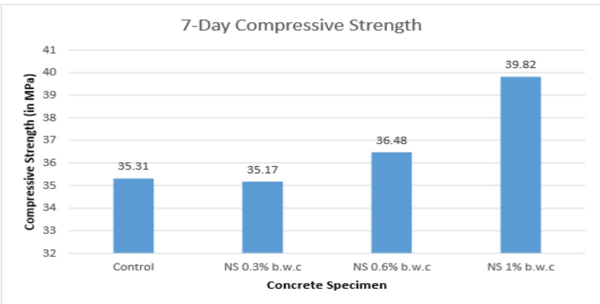

Fig. 2: 7-day compressive strength of four specimen

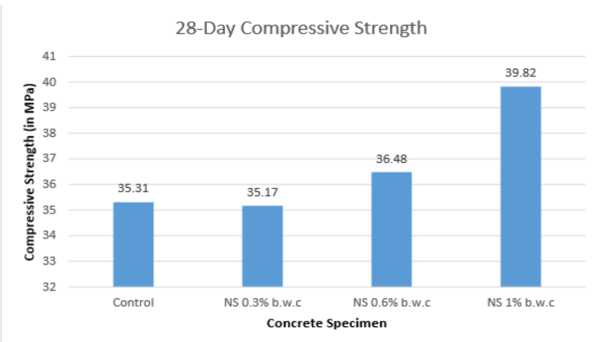

Fig. 3: 28-day compressive strength of four specimen

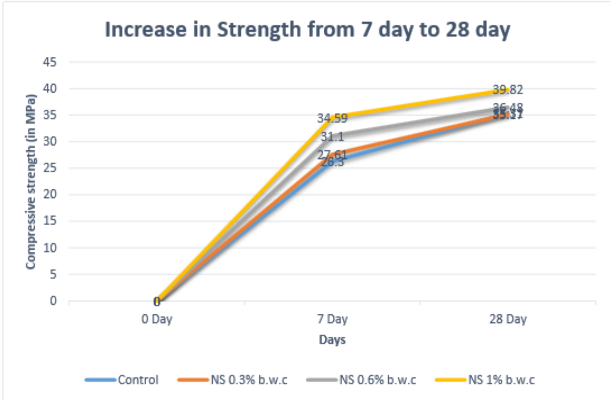

Fig. 4: Change in compressive strength of four specimen from 7 day to 28 days

VI. CONCLUSIONS

From the test results, the SEM micrographs and the relative chemical composition of the specimen a number of conclusions can be drawn.. 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 SiO2. 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 SiO2 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 SiO2 but the overall quality of concrete is preserved.

iv. The FESEM micrograph shows a uniform and compact microstructure on addition of Nano-SiO2.

v. The increase in compressive strength can be attributed to the filling of voids in the microstructure by the Nano SiO2 particles which prevents the growth of Ca(OH)2 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)2 content is the reason for increase in compressive strength of concrete.

vi. Ca(OH)2 crystals are present in the Interfacial Transition Zone (ITZ) which is between the aggregates and the hardened cement paste. Nano SiO2 reacts with these crystals and decreases their concentration, hence, strengthen the ITZ. Due to lesser concentration Nano SiO2 are consumed in the reaction and hence the increase in strength is inhibited with time.

vii. A study of relevant papers show that concrete blended with Nano SiO2 sets quicker compared to normal concrete. Since, the mix design is carried out without the aid of superplasticizers, 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 SiO2 the compaction gets tougher. This is the reason for degradation in its quality. It is advisable to use superplasticizers with nano silica.

viii. The Nano SiO2 added to the mix filled up the pores in between the C-S-H gel, hence, making the microstructure more compact and uniform.

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REFERENCES

[1] IS:2386-1963 (Part-III). Methods of Test for aggregates for concrete Part III specific gravity, density, voids, absorption and bulking. Bureau of Indian Standards.
[2] IS:383-1970. Specification for coarse aggregate and fine aggregate from natural sources for concrete. Burea of Indian Standards.
[3] IS:455-1989. Portland Slag Cement- Specification. Burea of Indian Standards.
[4] IS:456-2000. Plain and Reinforced concrete- code of practice (Fourth Revision). Bureau of Indian Standards.
[5] Hui Li, Hui-gang Xiao, Jie Yuan and Jinping Ou. (2004). Microstructure of cement mortar with nanoparticles. Composites: Part B 35, 185-189.
[6] Ji, Tao. (2005). Preliminary study on the water permeability and microstructure of concrete incorporating nano-SiO2. Cement and Concrete Research 35, 1943-1947.
[7] Byung-Wan Jo, Chang-Hyun Kim, Ghi-ho Tae and Jang-Bin Park. (2007). Characteristics of cement mortar with nano-SiO2 particles. Construction and Building Materials 21, 1351-1355.
[8] Ali Nazari, ShadiRiahi, Shirin Riahi, SaydehFatemehShamekhi and A. Khademno. (2010). Mechanical properties of cement mortar with Al2O3 nanoparticles. Journal of American Science 6(4), 94-97.
[9] AlirezaNajiGivi, Suraya Abdul Rashid, Farah Nora A. Aziz and Mohamad AmraMohdSalleh (2010). Experimental investigation of the size effects of SiO2 nano particles on the mechanical properties of binary blended concrete. Composites: Part B 41, 673-677.

