A SCHEMATIC ENHANCEMENT IN FINDING THE COMPRESSIVE STRENGTH OF CONCRETE DUE TO EFFECT OF NANO SILICA

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ABSTRACT:

Nano technology is an emerging field of interest for civil engineering application. Among the Nano materials presently used in concrete, nano-silica possess more Pozzolanic nature. It has the capability to react with the free lime during the cement hydration and forms additional C-S-H gel giving strength, impermeability and durability to concrete. Present paper investigates the effects of addition of nano silica in normal strength concrete. Three types of Nano-silica in the form of Nano suspension having different amount of silica content have been investigated. Mix design has been carried out by using particle packing methodThe application of nanotechnology in concrete has added a new dimension to the efforts to improve its properties. Nanomaterial, 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.

Keywords: *concrete, Nano silica, compressive strength, microstructure*

1.0 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 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.

Cement- Composition and Hydration:

Cement can be described as a crystalline compound of calcium silicates and other calcium compounds having hydraulic properties the four major compounds that constitute cement(Bogue's Compounds) are Tricalcium silicate, abbreviated as C3S, Dicalcium silicate (C2S), Tricalcium aluminate (C3A), Tetracalcium aluminoferrite (C4AF) where C stands for

Ca_O, S stands for SiO2, A stands for Al2O3 and F for Fe2O3. Tricalcium silicate and dicalcium silicate are the major contributers to the strength of cement, together constituting about 70 % of cement. Dry or anhydrous cement does not have adhesive property and hence cannot bind the raw materials together to form concrete. When mixed with water chemical reaction takes place and is referred to as 'hydration of cement'. The products of this exothermic reaction are C-S-H gel and $Ca(OH)_2$. Calcium hydroxide has lower surface area and hence does not contribute much to the strength of concrete. On hydration of cement aluminates a product is formed known as ettringite, which has needle like morphology and contributes to some early strength of concrete.

1.1.2 Nanomaterial's- use in concrete:

Nanomaterial is very small sized materials with particle size in nanometers. 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 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 Nanomaterial's 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.

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.

2.0 LITERATURE REVIEW:

H. Li et.al. (2006) studied the abrasion resistance of concrete blended with Nano particles of TiO2and SiO2 Nano particles along with polypropylene (PP) fibers. It was observed that abrasion resistance can be improved considerably by addition of Nano particles and PP fibers. Also the combined effect of PP fiber + Nano particles shows much higher abrasion resistance than with Nano particles only. It was found that abrasion resistance of Nano TiO2 particles is better than Nano SiO2 particles. Also relationship between abrasion resistance and compressive strength is found to be linear.

AlirzaNajiGivi et.al (2010) studied the size effect of Nano silica particles. They replaced cementwith Nano silica of size 15nm and 80nm with 0-5, 1, 1.5 & 2% b.w.c. An increase in the compressive strength was observed with 1.5% b.w.c showing maximum compressive strength. A comparison between particle size showed that for 80nm particles the maximum strength was more than for 15nm particles, also a considerable improvement in flexural and split tensile strength of Nano SiO2 blended concrete was observed.

Ali Nazari et.al. (2010) studied the combined effect of Nano SiO2 particles and GGBFS onproperties of concrete. They used Nano silica with 3% b.w.c. replacement and 45% b.w.c. GGBFS, which shows improved split tensile strength. An improvement in the pore structure of SCC with silica particles was observed. Apart from this hey have studied the effect of ZnO2 Nano particles on SCC concrete with constant w/c ratio of 0.4.The results showed that by increasing the content of super plasticizer flexural strength decreases. Up-to 4% b.w.c. of ZnO2 content an increase in the flexural strength of SCC was recorded. In another experiment the same author studied effect of Al2O3 Nano particles on the properties of concrete. The results showed that cement could be replaced up to 2% for improving mechanical properties of concrete, but Al2O3 Nano particles decreased percentage water absorption of concrete. XRD analysis of the sample showed that there is more rapid formation of hydrated product.

Surya Abdul Rashid et.al(2011) worked on the effect of Nano SiO2 particle on both mechanicalproperties (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.

3.0 METHODOLOGY:

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

Material properties:

The materials used to design the mix for M25 grade of concrete are cement, sand, coarse aggregate, water and Nano SiO_2. The properties of these materials are presented below 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

Table 3.1: Properties of Portland slag cement

Specific Gravity	Fineness by sieve analysis	Normal consistency
30.14	2.0 %	33%

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.

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 Shows the Nano silica used in the experiment

Fig. Image of the Nano SiO_2used

Table 3.3: Properties of Nano SiO_2

TEST ITEM	STANDARD REQUIREMENTS	TEST RESULTS
SPECIFIC SURFACE AREA (m^2/g)	200 $\pm$ 20	202
PH VALUE	3.7 – 4.5	4. 12
LOSS ON DRYING @ 105 DEG.C (5)	$\leq$ 1. 5	0. 47
LOSS ON IGNITION @ 1000 DEG.C (%)	$\leq$ 2.0	0.66
SIEVE RESIDUE (5)	$\leq$ 0. 04	0. 02
TAMPED DENSITY (g/L)	40 – 60	44
SiO2 CONTENT (%)	$\geq$ 99. 8	99. 88
CARBON CONTENT (%)	$\leq$ 0. 15	0. 06
CHLORIDE CONTENT (%)	$\leq$ 0. 0202	0. 009
Al2O3	$\leq$ 0. 03	0. 005
TiO2	$\leq$ 0. 02	0. 004
Fe2O3	$\leq$ 0. 003	0. 001

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: $f_{target} = f_{ck} + 1.65sd$ =31.6 MPa

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

Selection of water content: Maximum water content per cubic meter of concrete (refer Table 2 of IS: 10262-1982):

W_{max} = 186L (for 50 mm slump).

Since, the slump was less than 50 mm, no adjustment was required.

Calculation of cement content:

Mass of water selected per cubic meter of concrete = 186 kg.

Mass of cement per cubic meter of concrete = 186/0.43 = 433 kg.

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

Maximum cement content = 450 kg/m^3 the selected cement content is alright.

Proportion of volume of coarse aggregate and fine aggregate content:

Volume of coarse aggregate per unit volume of total aggregate = 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

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

Mix calculations:

Volume of concrete = 1 m^3

Volume of cement = 433/(3.01×1000)
= 0.144 m^3

Volume of water = 186/1000 = 0.186 m^3

Volume of all aggregates = 1-0.144-0.186
= 0.67 m^3

Mass of coarse aggregate
= 0.654×0.67×2.72×1000 = 1192 kg

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

= $(0.15)^3 \times 6 \times 1.2$ = 0.024 m^3 (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

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

Fig: UPV Test apparatus

Experimental evidence and microstructure analysis:

This chapter is concerned with the presentation of results of the experiments carried out towards the objective of the project. It includes results from compressive strength test, UPV Test and FESEM. The results are supplemented with graphs in order to have a better analysis of the results.

Table: UPV Test for control specimen for 7 days

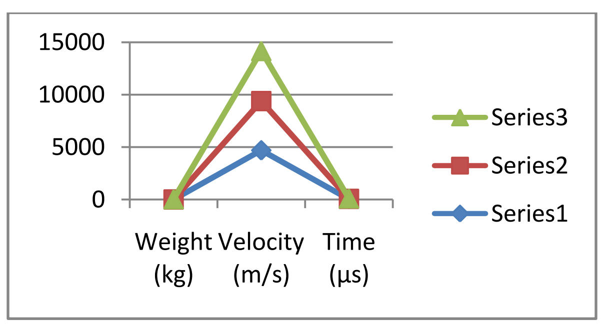
Weight (kg)	Velocity (m/s)	Time (µs)
8.10	**4678**	32.2
8.34	**4702**	31.9
8.36	**4777**	31.4

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

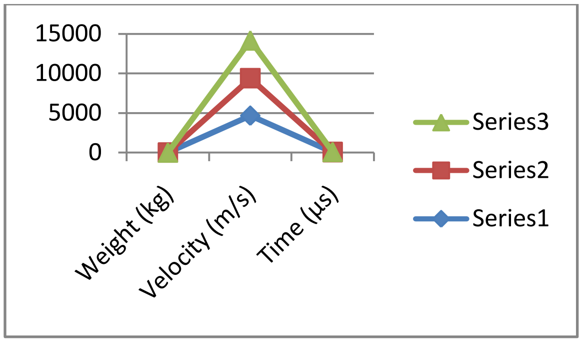
Weight (kg)	Velocity (m/s)	Time (µs)
8.18	**4678**	33.4
8.22	**4702**	33.4
8.24	**4777**	34.2

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

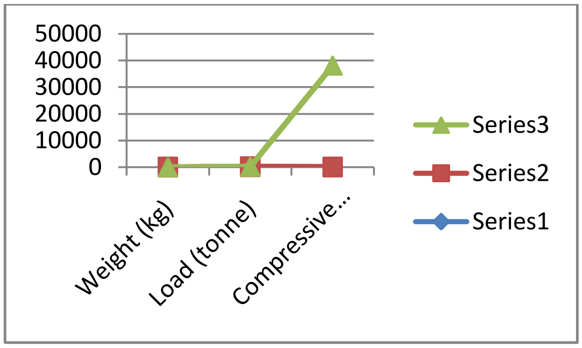
Weight (kg)	Load (tonne)	Compressive Strength (MPa)
8.18	**83**	36.19
8.24	**80**	34.88
8.22	**88**	38037



UPV Test for control specimen for 7 day



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



Graph: Compressive Strength of specimen with Nano-silica 0.6% b.w.c for 28 day

The quality of concrete is very good. The 28-day quality is better than the 7-day quality. The control specimen is found to have better quality compared to the blended concrete specimen. A high concentration silicon and low concentration of calcium and oxygen shows that silica has got into the structure but hasn't reacted with the Ca(OH)2 to produce C-S-H gel of which calcium occupies a good portion. These silica particles occupy the pores in the gel and make the microstructure uniform. Composition of concrete specimen with NS 0.6% b.w.c This figure looks contradicting due to high percentage of silica and low percentage of calcium. A good percentage of oxides can be due to the reaction of silica with Ca(OH)2 which produces C-S-H gel.Another explanation to the increase in strength can be due to the availability of sufficient silica to make the microstructure denser and uniform. Nano SiO2 sets quicker compared to normal concrete. Since, the mix design is carried out without the aid of supper-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 SiO2 the compaction gets tougher.

4.0 CONCLUSIONS:

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.

5.0 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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