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EXPERIMENTAL ANALYSIS ON EFFECT OF NANO SILICA ON THE COMPRESSIVE STRENGTH OF CONCRETE

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Abstract – The *application of nanotechnology in concrete has added a new aspect to the efforts to improve its properties. Concrete is a mixture of cement, sand, aggregate and water. Concrete is one of the largest used materials in the world. Nanomaterial's, by virtue of their very small element size can affect the concrete assets by changing the microstructure. This study concerns with the use of nano silica of size 230 nm to improve the compressive strength of concrete. An experimental investigation has been carried out by replacing the cement with nano silica of 0.25%, 0.5%, 0.75% and 1%. The tests accompanied on it shows a significant increase in early-age compressive strength and also a small increase in the overall compressive strength of concrete. The strength increase was observed with the increase in the percentage of nano silica.*

Key Words: *concrete, nano silica, compressive strength, nano technology.*

1. 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 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. 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.

1.1 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 check the percentage use of nano silica in concrete.
- To reduce the use of cement in concrete so that pollution can be decreased.

1.2 SCOPE OF WORK

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-days. The size of the nanosilica was identified using Particle Size Analyser.

1.3 ORGANIZATION OF THE THESIS

This thesis has been organised into five chapters as shown below:

i. The first chapter is the 'Introduction' which gives an idea of the theory involved and the importance of the present work. This is the ongoing chapter.

ii. A 'Review of Literature' follows this chapter which gives an understanding of the various work carried on this field by different authors.

iii. The third chapter, 'Materials and Methods' explains all the material properties and methods used in the experiment.

iv. The fourth chapter, 'Experimental Evidence and Microstructure Analysis' deals with the experimental results of various tests carried on concrete and a comparative analysis of the results with the help of tables and graphs.
v. The last chapter, 'Conclusion and Discussion' summarizes the results and interpretations of the study.

2. LITERATURE REVIEW:

H. Li et. al. (2004) experimentally investigated the mechanical properties of nano-Fe2O3 and nanoSiO2 cement mortars and found that the 7 and 28 day strength was much higher than for plain concrete. The microstructure analysis shows that the nanoparticles filled up the pores and the reduced amount of Ca(OH)2 due to the pozzolanic reaction. Tao Ji (2005) experimentally studied the effect of Nano SiO2 on the water permeability and microstructure of concrete. The findings show that incorporation of Nano SiO2 can improve the resistance to water of concrete and the microstructure becomes more uniform and compact compared to normal concrete.

H. Li et.al. (2006) studied the abrasion resistance of concrete blended with nano particles of TiO2 and 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.

B.-W Jo et. al. (2007) studied the characteristics of cement mortar with Nano SiO2 particles experimentally and observed higher strength of these blended mortars for 7 and 28 days. The microstructure analysis showed that SiO2 not only behaves as a filler to improve microstructure, but also as an activator to the pozzolanic reaction.

M.Nill et.al. (2009) studied the combined effect of micro silica and colloidal nano silica on properties of concrete and found that concrete will attain maximum compressive strength when it contains 6% micro silica and 1.5% nano silica. The highest electrical resistivity of concrete was observed at 7.5% micro and nano silica. The capillary absorption rate is lowest for the combination of 3% micro silica and 1.5% nano silica.

Alirza Naji Givi et.al. (2010) studied the size effect of nanosilica particles. They replaced cement with nanosilica 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.

3. 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 grade conforming to IS: 455-1989 is used for preparing concrete specimens. The properties of cement used are given in the Table

Specific Gravity	Fineness by sieve analysis	Normal consistency
3.014	2.01%	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. The physical properties of both fine aggregate and recycled coarse aggregate are evaluated as per IS: 2386 (Part III)-1963 and given in Table below:-

Property	Coarse Aggregate	Fine Aggregate
Specific Gravity	2.72	2.65
Bulk Density (kg/L)	1.408	-
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 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 and Fig. 1. Shows the nano silica used in the experiment

Fig 1:- Image of the Nano SiO2 used

TEST ITEM	STANDARD REQUIREMENTS	TEST RESULTS
SPECIFIC SURFACE AREA (m2 /g)	200 + 20	202
PH VALUE	3.7 – 4.5	4.15
LOSS ON DRYING @ 105 DEG.C (5)	< 1. 5	.48
LOSS ON IGNITION @ 1000 DEG.C (%)	< 2.0	.68
SIEVE RESIDUE (5)	< 0. 04	.02
TAMPED DENSITY (g/L)	40 – 60	46
CARBON CONTENT (%)	< 0. 15	.06
CHLORIDE CONTENT (%)	< 0. 0202	.009

4. Preparation of Test Specimen: -

For conducting compressive strength test on concrete cubes of size 150×150×150 mm are casted. A rotary mixture is used for thorough mixing and a vibrator is used for good compaction. After 18 successful casting, the concrete specimens are de-moulded after 24 hours and immersed in water for 28 days maintaining 27 0 ±1 C.

Fig. 2 shows some concrete specimen casted in laboratory.

Fig 2 concrete cubes after de-moulding

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.

5. RESULTS

Compressive Strength of specimen with nano-silica 0.25%

7-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.22	67	29.21
2	8.18	71	30.95
3	8.20	52	22.67
		MEAN	27.61

Compressive Strength of specimen with nano-silica 0.5%

7-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.26	66	29.21
2	8.08	72	30.95
3	8.09	76	22.67
		MEAN	27.61

Compressive Strength of specimen with nano-silica 1%

7-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.24	77	33.57
2	8.12	79	34.44
3	8.30	82	35.75
		MEAN	34.59

Compressive Strength of specimen with nano-silica 0.5%

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

Compressive Strength of specimen with nano-silica 0.5%

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.18	83	26.19
2	8.22	80	34.88
3	8.24	88	38.37
		MEAN	36.48

Compressive Strength of specimen with nano-silica 1%

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
1	8.18	83	26.19
2	8.22	80	34.88
3	8.24	88	38.37
		MEAN	36.48

6. CONCLUSIONS

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.
ii. The increase in strength is maximum for NS 1% b.w.c and least for NS 0.5% b.w.c.
iii. 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.
iv. 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

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