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Experimental Evaluation of the Influence of Nanosilica On The Properties Of Concrete

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Abstract

Nanosilica is a nano product by its addition in concrete leads to the improvement of performance of concrete. One of the major inherent factors that cause deterioration of structural component is the corrosion of the steel reinforcement accelerated by the formation of micro cracks. By the introduction of nanosilica into the concrete matrix this problem can be resolved to a certain extent. This study investigated the effect of colloidal nanosilica on concrete incorporating single (ordinary cement) and binary (ordinary cement and Class F fly ash) binders. In addition to the mechanical properties, the experimental program included tests for durability properties and flexural properties on reinforced concrete beams. The nanosilica having size only 17nm is used for experimental studies. The properties of nanosilica concrete were studied and compared with control mix. Based on the preliminary investigation, total 7 different mixes are prepared. Three mixes are prepared by replacing cement by 25% of fly ash (kept constant) and varying the percentage of NS in 0.5%,1.5% and 3% of the total weight of cementitious materials . The other three mixes are prepared by replacing cement by NS in 0.5%,1.5% and 3% of the total weight of cementitious materials. Standard specimens were tested to study the properties of hardened concrete viz, compressive strength, flexural strength, split tensile strength, modulus of elasticity, and impact strength. The durability study includes sulphuric acid test, sulphate attack test and bulk diffusion test. The parameters considered for flexural study were deflection, crack pattern, crack width, first cracking load and ultimate load carrying capacity. Significant improvement was observed in mixtures incorporating nanosilica in terms of workability, mechanical and durability properties. The higher strengths are attributed to accelerated cement hydration, pozzolanic reaction, reduced pores and improved interface bonding between hardened cement paste and aggregate and also due to the filler effect of nanosilica.

I INTRODUCTION

Building materials are the backbone of civil engineering construction. Of all the modern building materials, concrete is one of the oldest, but most versatile materials, with an annual worldwide production of over 4.5 billion metric tonnes. The cement industry is considered to be one of the most energy consuming industries, with a high rate of carbon dioxide (CO_2) emissions. Every year, it is responsible for approximately 5% of the global manmade CO_2 emissions 50% of these emissions are caused by chemical manufacturing processes and 40% are due to burning fuel. Extensive research works have been directed to reduce the effect of the cement industry on greenhouse gases either by improving the qualityof the cement manufacturing process or by using supplementary cementitious materials (SCM), which partially replace ordinary cement. Various SCM have been investigated, including flyash ground granulated blast furnace slag, natural pozzolans , and silica fume. Recent studies have indicated that the use of new technologies may cause industrial breakthroughs for the manufacture of SCM. It is believed that nanotechnology is one of the most promising research fields that may significantly improve the mix design, as well as the performance and production of cement-based materials. In recent years, there has been a growing interest in the use of nanosilica in concrete. It is believed that nanosilica has as much finer particle sizes and higher pozzolanic reactivity than silicafume, thus can act as fillers, pozzolanas and seeds more effectively.

II Nano Silica In Concrete

Nanosilica is a nano product by its addition in concrete leads to the improvement of performance of concrete. The nano particles in powder are often in an aggregated (firmly-held clusters) or agglomerated (loosely held clusters) form with final grain size from submicron to as high as 100nm due to their very high specific surface area and energy. Even in the well-dispersed colloidal dispersion, the nano-particles still exist as aggregates with grain size in submicron. By using colloidal silica sol, it is often assumed that the mono-dispersed nano-particles can act as fillers and seeds much more effectively than those agglomerates in powder or dispersion. Neverthless, the investigations revealed that the silica sol will gel or coagulate immediately when the cement is mixed in to the water containing sol due to rapid increase of ionic strength in paste. As a result, no matter what source of nanosilica is used, it is the behaviour of final agglomerates, rather than that of individual nano-particles, which controls the filling, pozzolanic and seeding effects on cement hydration and microstructure improvement. At first, it was believed that the better improvement in concrete performance due to the addition of nanosilica particle is characterised to its filler effect and its pozzolanic reaction. But recently, however, it has been reported that the very small size of nanosilica particle provides a larger surface area, which speeds up the rate of cement hydration and pozzolanic reactions.

III Material Properties

A Cement- Ordinary Portland cement (OPC) conforming to IS 12269 (53 Grade) was selected and used for this evaluation of work. Laboratory tests were conducted on cement to determine specific gravity, standard consistency ,fineness, compressive strength, initial setting time and final setting time .

B Nanosilica- Nanosilica was supplied by Visa chemical Industries Chemical Analysis of nanosilica was done by the manufacturer itself. The mean particle diameter (particle size) was only 17.00 nm.

C Flyash- The fly ash, also known as pulverised fuel ash, is produced from burning powdered coal in electric power generating plants. It is generally finer than Portland cement. Diameter of fly ash particles ranges from less than 1–150 µm. Fly ash colour depends upon its chemical and mineral constituents. It can be tan to dark gray.

D Fine aggregate - Locally available good quality river sand was used. Laboratory tests were conducted on fine aggregates to determine the different physical properties as per IS 383 (Part III)-1970. River sand having fineness modulus 2.87 and specific gravity 2.63 was used as fine aggregate.

E Coarse aggregate- The size of aggregate between 20mm and 4.75mm is considered as coarse aggregate. Laboratory tests were conducted on coarse aggregates to determine the different physical properties as per IS 383 (Part III)-1970.This test was conducted for 20mm size aggregate.

F Superplasticizer-The superplasticizer used was SikaViscocrete 20 HE is a high performance new generation superplasticizer cum retarding admixture which lowers the surface tension of water and makes cement particles hydrophilic, resulting in excellent dispersion as well as controls the setting of concrete, depending on dosage.

G Water-Potable water is generally considered as being acceptable. Hence clean drinking water available in the college water supply system was used for casting as well as curing of the test specimens.

H Reinforcement- HYSD bars of diameter 10mm and 8mm were used as main reinforcement and stirrup holders respectively. Two legged 8mmΦ stirrups at 125mm c/c spacing were used as shear reinforcement.

IV Mix Designation

The study is limited to the preparation of 7 different types of mixes. One control mix and other three concrete mixes by replacing cement by NS in 0.5%,1.5% and 3% of the total weight of cementitious materials. The remaining three mixes are prepared by replacing cement by 25% of fly ash (kept constant) and varying the percentage of NS in 0.5%,1.5% and 3% of the total weight of cementitious materials.. The various mix designation are shown in table 1

TABLE 1 **Mix Designation**

Mix Designation	*Cement (%)*	*Fly ash (%)*	*Nano Silica (%)*
R1	*100*	*0*	*0*
R2	*74.5*	*25*	*0.5*
R3	*73.5*	*25*	*1.5*
R4	*72.0*	*25*	*3.0*
R5	*99.5*	*0*	*0.5*
R6	*98.5*	*0*	*1.5*
R7	*97*	*0*	*3.0*

V Mechanical Properties of Hardened Concrete

A Compressive strength- Testing of hardened concrete is important for controlling the quality of concrete. The main purpose of testing hardened concrete is to conform that the concrete has developed required strength. The compressive strength is one of the most important properties of hardened concrete and in general it is the characteristic value for classification of concrete in various codes. The compression test was carried out on cubical specimen of size 150mm × 150mm × 150mm in a compression testing machine of capacity 2000 kN, at a loading rate of $14 N/mm^2$per minute as per IS 516:1959 specification.To find cylinder compressive strength, the cylinder of size 150mm dia and 300mm height is kept on the bottom plate of the machine and the position of the cylinder is carefully checked to be in the centre of the plate. The cylinder is loaded at the rate of 14 N/mm^2/min up to failure.

B Split tensile strength- The split tensile strength test is a well known indirect test used for determining the tensile strength of concrete. Test was carried out on concrete cylinder of size 150mm × 300mm as per IS 5816:1999 specification.

C Modulus of elasticity-The modulus of elasticity was determined by subjecting cylinder specimen having 150 mm diameter and 300 mm height to uniaxial compression as per IS 516:1959 specification. The corresponding deformation by means of compressometer has been taken at each increment of loads. The gauge length of the compressometer is 20 cm.

D Flexural strength - Beam tests are found to be dependable to measure flexural strength property of concrete.Three beam specimens of size 100mm×100mm×500mm were tested for determining the flexural strength as per IS 516:1959 specification. Two-point loading was applied and breaking load was noted.

VI Workability Test Results

At present standard methods are available to measure the workability of NS concrete. The slump test, compacting factor test, flow test , vibe test are the standard test available to measure the workability of NS concrete. The workability of various mixes was assessed as per the IS 1199:1959 specification.

Table 2 **Workability results of various mixes**

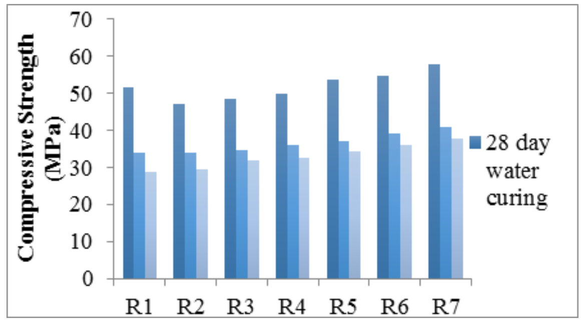
Type of Mix	***Workability***			
	Compacting Factor	***Slump(mm)***	***Flow Test (%)***	***Veebee (sec)***
R1	0.926	42	50.66	6.8
R2	0.946	47	56	6.3
R3	0.953	50	59.87	6.1
R4	0.962	52	61.3	5.9
R5	0.935	45	53.2	6.5
R6	0.942	46	54.7	6.4
R7	0.951	49	57.33	6.3

VII Results Of Mechanical Properties

A Compressive strength - For each NS mix, three cube specimens of size 150mm × 150mm × 150mm and cylinder specimens of 150mm dia and 300mm height were tested for compressive strength. Cubes were tested after 3, 7, 28, 56 and 90 days of water curing and cylinders after 28 day and 56 day of water curing.

Table 3 **Average cube compressive strength for various mixes**

Mix	***Cube Compressive strength for various mixes (N/mm^2)***				
	3 day	***7 day***	***28 day***	***56 day***	***90 day***
R1	29.48	39.36	51.56	56	60.14
R2	25.19	32.74	47.26	51.26	54.81
R3	25.63	33.04	48.29	52.59	55.70
R4	26.22	34.22	49.78	53.78	56.14
R5	30.81	41.92	53.62	58.81	63.70
R6	31.85	42.81	54.81	59.90	64.88
R7	33.11	45.03	57.92	61.77	66.22



B Split tensile strength- For each NS mix, cylinder specimens of size 150mm dia and 300mm height were tested for determining the split tensile strength. Table 4 shows the details of test results for split tensile strength.

Table 4 **Split tensile strength for various mixes**

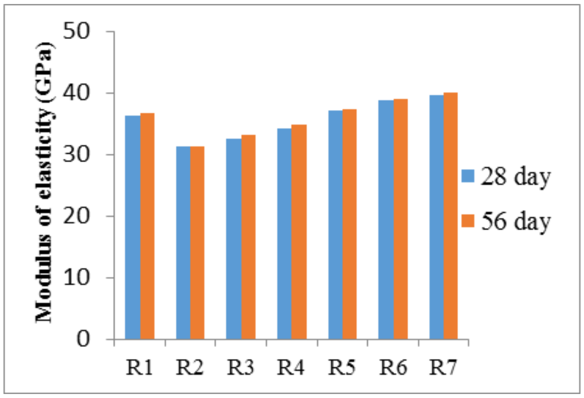
Mix	***Split Tensile strength (N/mm^2)***	
	28 day	***56 day***
R1	4.24	4.46
R2	4.67	3.75
R3	3.81	3.89
R4	4.03	4.04
R5	4.52	4.67
R6	4.74	4.81
R7	4.88	5.02

C Modulus of elasticity - The Young's modulus values are obtained from stress-strain diagram obtained by carrying out the test on 150mm dia and 300mm height cylinders.

Table 5 **Modulus of elasticity for various mixes**

Mix	***Modulus of Elasticity (N/mm^2)***	
	28 day	***56 day***

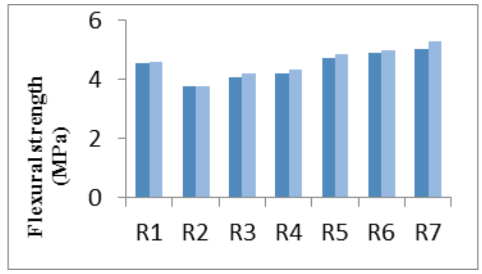
R1	36.2	36.8
R2	31.23	31.29
R3	32.63	33.1
R4	34.24	34.89
R5	37.1	37.3
R6	38.9	39.1
R7	39.59	39.97



D Flexural strength - Beam specimens of size 100mm×100mm×500mm were tested for determining the flexural strength of various NS mixes.

Table 6 **Flexural strength for various mixes**

Mix	***Flexural strength for (N/mm²)***	
	28 day	***56 day***
R1	4.46	4.59
R2	3.78	3.79
R3	4.05	4.19
R4	4.19	4.32
R5	4.72	4.86
R6	4.88	4.99
R7	5.04	5.27



VIII Durability Test Results

A Sulphate attack test- The concrete cubes were found visually intact after immersion of cubes in (52gm $MgSO_47H_2O$ in one liter solution) sulphate solution for 56 and 90 days after 7 days of water curing. After exposure to sulphate solution, white patches were found on the surface of concrete specimens. This white precipitation layer was significant in control specimens

B Sulphuric acid attack test - 7 day water cured cube specimens of size 100mm×100mm×100mm, after being exposed to sulphuric acid solution for 56 and 90 day were tested, and the result is compared with 28 day water cured specimens of the same mix.

The strength loss of cubes in 3% sulphuric acid solution was determined by the cube compressive strength.

C Bulk diffusion test - The test was carried out to determine the depth of penetration of chloride ions by spraying 0.1M $AgNO_3$ solution to the split face of the cylinder exposed to 1.8 M Nail solution, a white precipitation will form up to the penetrated depth of chloride ion. After 7 days of water curing the concrete specimens were exposed to NaCl solution for 56 days and 90 days. The depth of penetration of chloride ions is measured in millimetre. Load-Deflection Characteristics

Table 7 **Deflection of R_1 Beam Specimen**

Load (kN)	***Deflection (mm)***		
	Load point 1	***Mid span***	***Load point 2***
0	0	0	0
2.234	0.14	0.14	0.15
4.469	0.26	0.27	0.28
6.703	0.38	0.4	0.39
8.938	0.52	0.54	0.5
11.172	0.64	0.67	0.64
13.406	0.81	0.82	0.8

15.641	0.98	1.02	0.98
17.875	1.2	1.27	1.21
20.11	1.43	1.55	1.45
22.344	1.93	2.02	1.95
24.578	2.46	2.51	2.48
26.813	2.66	2.74	2.66
29.791	2.86	3.19	2.89
33.514	3.29	3.57	3.31
37.237	4.12	4.38	4.12
40.957	4.50	4.62	4.55
44.677	4.85	5.03	4.82
52.117	5.14	5.45	5.17
Ultimate Load = 54.36 kN			

IX CONCLUSION

The main objective of the present investigation was to study the effect of nanosilica on the mechanical and durability and flexural properties of concrete. From the present investigation the performance of nanosilica concrete with and without flyash was studied and they were compared to the performance of control mix. Fresh properties of the concrete was determined by carrying out the workability test, compacting factor, veebee, and flow test. The mechanical properties are determined by compressive strength, split tensile strength, modulus of elasticity, flexural strength and impact resistance. The durability properties are determined by acid attack test, sulphate attack test, bulk diffusion test. The behavior of nanosilica beam under flexure was also studied by two point loading flexure test.

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