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Effect of Incorporation of Nano-SiO₂ in Mortar and Its Durability Studies

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ABSTRACT: Nano science and technology is a new field of emergence in materials science and engineering, which forms the basis for evolution of novel technological materials. Nano technology finds application in various fields of science and technology. This report presents the influence of nano silica in mortar with the average diameter of 40 nm and to study the pore filling effect and its pozzolanic activity with cement towards improvement of mechanical properties and durability aspects. The strength, durability, microstructure and acoustical study of cement mortar incorporating nano-silica (NS) in various percentages such as 1%, 2%, 3%, 4% and 5% as a partial replacement of cement is compared with conventional mortar. The hardened properties of the mortar determined using compressive strength of all the specimens at the age of 7, 14 and 28 days. Durability properties have been carried out to determine the steel corrosion. The microstructure of the specimens has been determined by XRD and SEM studies. The results reveal that replacing nano silica upto 2% shows enhanced strength, durability and improved microstructure of mortar specimens resulting in better performance as compared to conventional specimens. Thus, there is a scope for development of crack free concrete towards sustainable construction.

KEYWORDS: Nano Silica, SEM, Compressive strength of Cement Mortar.

I. INTRODUCTION

Nanotechnology is one of the most active research areas that encompass a number of disciplines, including civil engineering and construction materials. It seems to hold the key that allows construction and building materials to replicate the features of natural systems improved until perfection for millions of years. Traditionally, nanotechnology has been concerned with developments in most of the fields like microbiology, medicine, electronic, chemical, and materials sciences. However, the potential for application of many of the developments in the nanotechnology field in the area of construction engineering has been growing. Nanotechnology is the use of very small particles of materials either by themselves or by its manipulation to create new large scale materials.

Nano, which comes from the Greek word for dwarf, indicates a billionth. One nano metre is a billionth of a metre. Definitions of 'nanotechnology' vary, but it generally refers to understanding and manipulation of matter on the Nano scale, say, from 0.1 nm to 100 nm. The significance and importance of controlling matter at the nanoscale is that at this scale different laws of physics come into play like quantum physics. There are two ways to approach the nanoscale: shrinking from the top down, or growing from the bottom up. The 'top down' approach entails reducing the size of the smallest structures towards the nanoscale by machining and etching techniques, whereas the 'bottom up' approach, often referred to as molecular nanotechnology, implies controlled or directed self-assembly of atoms and molecules to create structures. Addition of nanoscale materials into cement could improve its performance. Use of nano-SiO₂ could significantly increase the compressive for concrete, containing large volume fly ash, at early age and improve pore size distribution by filling the pores between large fly ash and cement particles at nanoscale. The dispersion/slurry of amorphous nano silica is used to improve segregation resistance for self-compacting concrete. It has also been reported that adding small amount of carbon nanotube (1%) by weight could increase both compressive and flexural strength. Many disciplines of civil engineering, including design and construction processes, can be benefited from nanotechnology. These include products that are for: Lighter structure, Stronger structural composites, e.g. for bridges

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and others. Low maintenance coating, Improved pipe joining materials and techniques, Better properties of cementitious materials, Reduced thermal transfer rate of fire retardant and insulation, Increased sound absorption of acoustic absorber, Increased reflectivity of glass, water repellents, nano-clay filled polymers, self-disinfecting surfaces, UV light protector, air cleaners, nano-sized sensors, and solar cells.

II. MATERIAL USED

CEMENT The Ordinary Portland Cement (OPC) is generally used for major construction practices conforming to IS 269-2013 (33 grade), IS 8112-2013 (43 grade) and IS 12269-2013 (53grade). It is the prime constituent of cement mortar and acts as a binder due to its high pozzolanic behavior. The most commonly available Ordinary Portland cement of 43 Grade was used for the investigation.

FINE AGGREGATE Aggregate of size less than 4.75 mm are usually called as fine aggregate. Sand is used as fine aggregate in mortar.

NANO SILICA Nano silica is available from natural resources in the form of crystalline mineral silica such as quartz, tridymite, cristobalite as well as synthesized in the labs. However, the nano silica extracted from natural resources generally contains metal impurities and is not advisable for advanced scientific and industrial applications. The synthetic nano silica is pure and produced mostly in amorphous powder forms such as silica gels, pyrogenic silica, and precipitated silica. Nano silica can be synthesized by using either of the two main approaches: top-down and bottom-up. In top-down technique, the dimension of the original size is reduced by utilizing special size reduction techniques. Bottom-up technique produces nano silica particles from atomic or molecular scale.

S.NO	Property	Results
1	Diameter(nm)	40
2	Surface volume ratio (m ² /g)	160
3	Density (g/cm ³)	1.14
4	Purity (%)	>99.9

Table 2.1 Property of Nano silica

III. EXPERIMENTAL INVESTIGATION AND RESULTS ANALYSIS

Compressive strength test Compressive strength of cement mortar is the most significant property in terms of structural use and is most convenient to determine through tests of standard specimen cubes. Hence compressive strength tests were performed for cement mortar specimens at desired curing ages. The testing was done as per IS: 516-1959 using compression testing machine (Figure 4.6). For compressive strength studies, thirty six cubes of 7.06 cm (IS: 10080 - 1982) were cast for total mix proportions. Compressive strength of NS0 were examined and then compared with that of the cement mortar of all the mixes with partial substitution of cement by nano silica (NS) at 7, 14 and 28 days.

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Fig 3.1 Compressive strength test for cement mortar cubes

specimen	% Replacement of nano silica	Average compressive strength (N/mm ²)		
		7 days	14 days	28 days
NS0	0	18.05	22.17	28.08
NS1	1	19.06	23.61	29.10
NS2	2	20.06	24.53	30.09
NS3	3	21.27	25.95	31.29
NS4	4	25.27	27.44	33.01
NS5	5	21.87	25.05	31.09

Table 3.1 Compressive strength of Mortar specimen

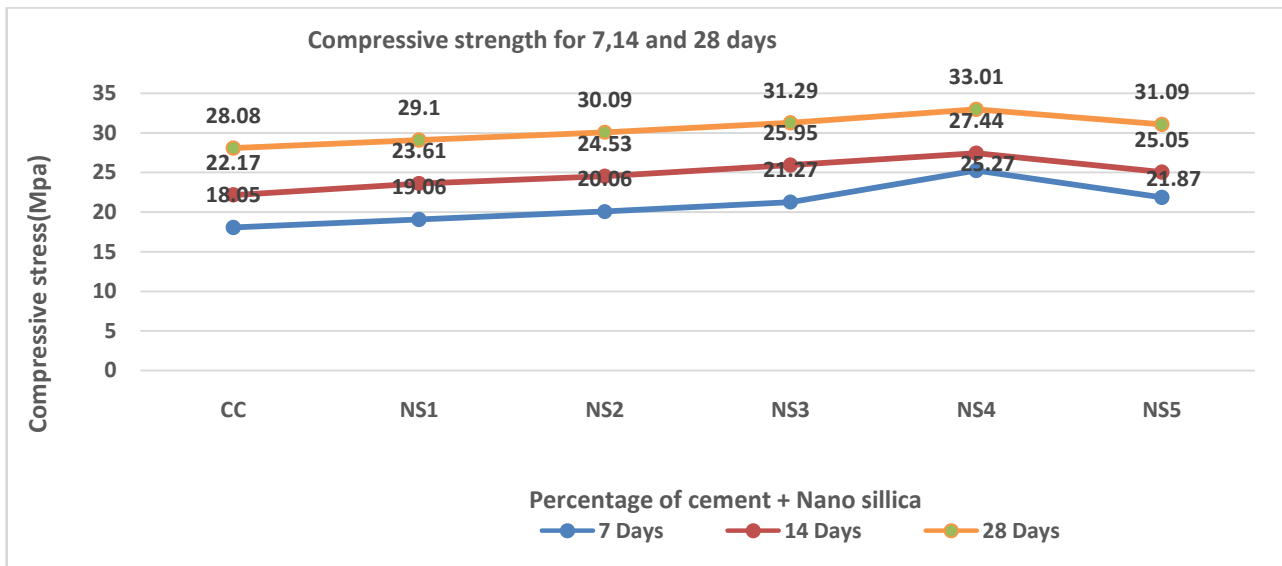


Fig 3.2 Graph for compressive strength of mortar specimen

Scanning Electron Microscopy(SEM): SEM image of nominal mortar shown in Fig.5.6 reveals the fine rods with almost uniform dimensions. The image does not show any other incorporation and it clearly explains the homogeneity of the mortar. Fig.5.7 shows the white agglomerates in between the rods. These white agglomerates are silica nanoparticles. From the image it is clear that silica nanoparticles is clearly incorporated into the mortar and it's uniformly distributed. The incorporated silica nanoparticle does not disturb the dimensions of the mortar where as it fills the pores between the rod forms and it also helps to fill the cracks. Thus it is evident that silica nanoparticles enhance the strength and it reduces the porosity of themortar.

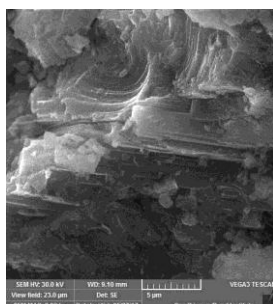


Fig 3.3 Mortar without Nanoparticles

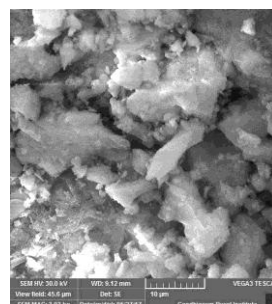


Fig 3.4Mortar with Nanoparticles

Durability test: Durability of a cementitious structure is the ability to resist against various deterioration processes viz. chemical, weathering, abrasion etc. in aggressive environmental conditions without any adverse affect on the identity, quality & performance of the cementitious structure during its service life. Many physical, chemical & electrochemical processes affect the durability of the cement mortar leading to cracking. It is difficult to classify the exact cause of deterioration of cement mortar because of interacting and reinforcing nature of various chemical & electrochemical factors. The durability studies of the specimens have been analyzed in terms of Steel Corrosion Test.

Water absorption:For water absorption test the cylinder size of 100mm dia and 50mm height was used. After De moulding the cubes are immersed in a water for 28 days. After 28 days of curing the cubes were taken out to measure

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saturated weight (w_2). Thus the specimen were dried in oven at a temperature of 105°C for 72 hours and taken it as an oven dried weight (w_1).

The water absorption was calculated as: $(w_2 - w_1) / w_1 \times 100$

Mix	Saturated weight (g)	Oven dried weight (g)	% of water absorption
Cc	854	818	4.40
1	863	820	5.52
2	866	825	4.96
3	871	828	5.19
4	879	831	5.77
5	887	837	5.97

Table 3.2 Water absorption results

Steel corrosion test: For the durability test, Steel Corrosion test, is carried out in which the % of losses in steel is calculated. With the increases in nano silica % loss in steel is decreases because due to voids the bar gets corroded fastly, by using nano silica the voids is filled, so it takes time for corrosion.

Sl. No	% of Nano Silica (SiO ₂)	% of loss in steel
1	0	8.33
2	0.5	6.66
3	1.0	5.00
4	1.5	3.33
5	2.0	2.42
6	2.5	1.98

Table 3.3 Steel corrosion test results

IV. CONCLUSION

This chapter deals with the conclusions drawn on the basis of results obtained by the study of effect of partial substitution of cement with NS on fresh, hardened and durability properties, microstructures of cement mortars in comparison to control mix (NS₀). Increase in content of Nano Silica from 1% to 5% resulted in a decrease in setting time of NS1, NS2, NS3, NS4 and NS5 cement pastes due to increase in thickening effect of ultra fine nano silicaparticles. Increase in content of Nano Silica with filler effect from 1% to 5% resulted in a decrease in flow of NS1, NS2, NS3, NS4 and NS5 mortar specimens due to increase in the homogeneity and stiffness of matrix. The compressive strength of NS0 was found to be lesser as compared to NS1, NS2, NS3, NS4 and NS5. An increase in compressive strength of NS1, NS2, NS3, NS4 and NS5 mortars was obtained with an increase in content of NS from 1% to 4% along with a slight reduction in strength of NS5 (5% NS) mortar as compared to NS4 (4% NS) mortar. Thus, 4 % content of NS was designated as the optimum percentage. With the increases in nano silica % loss in steel is decreases because due to voids the bar gets corroded fastly, by using nano silica the voids is filled, so it takes time for corrosion.

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