Effects of Nanosilica Additions on Mechanical Performance of Concrete

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Abstract— The application of nanotechnology in building materials are gaining wide spread attention in construction field. One of the most referred and used nano materials is nano-silica with particle size in nano range. In this work, the mechanical properties such as Compressive, Flexural, and split tensile strengths together with Young's modulus of different proportions of nano-silica added concrete were experimentally studied. The workability resulted to be significantly lower than expected due to the interaction between nano-silica and liquid phase of the cement paste. The resulting reduction of workability was avoided by suitable addition of super plasticizer. The strength of the specimens has increased by adding SiO_2 nano particles in the mix. SiO_2 nano particles can accelerate C-S-H gel formation due to the increased $Ca(OH)_2$ at the early age of hydration and increase the strength of the specimens. Additionally, SiO_2 nano particles can able to act as a nano-filler by decreasing the harmful pores. The obtained results showed that an efficient use of nano-silica in concrete can improve its mechanical properties and also an activator to promote pozzolanic reaction.

Index Terms— Compressive Strength, Filler effect, Nano Silica, Permeability, Pozzolanic effect, Super plasticizer, Workability.

1 INTRODUCTION

Nanotechnology is being used or considered for use in many applications and it has received increasing attention in building materials. One of the most referred to and used new cementitious nano-materials is nano silica with a particle size in the nano-range. It has been reported that nano-silica addition increases the compressive strength and reduces the overall permeability of hardened concrete due to the pozzolanic properties, which are resulting in finer hydrated phases (C-S-H gel) and densified microstructure. This improves specific density, specific surface area, pore structure, and reactivity. The aim of the paper is to study the application of ultra-fine additives like nanosilica in cementitious systems to improve the characteristics of the hardened material. Nano-scaled silica particles have a filler effect by filling up the voids between the cement grains and it also contributes to strength enhancement due to the reduced capillary porosity. Beside this physical effect as obtained by addition, nanosilica has a pozzolanic reactivity. Thus, both the effects are very important in developing strengthened concrete. Cement paste workability resulted to be significantly lower than expected, due to the interactions between nanosilica and the liquid phase of cement pastes.The resulting reduction of the mix workability was avoided by suitable addition of superplasticizers.Thus the addition of nanosilica greatly increases the water demand of cementitious mixes, as compared to control ones. With regard to the influence of nanosilica on the mechanical strength development of cementitious materials, the addition of nanosilica to Ordinary Portland Cement (OPC) paste was found to increase the compressive strength to an extent that was dependent on the nanosilica content, water-to-binder weight ratio (w/b), and curing time.In this work, the mechanical properties such as Compressive and split tensile strengths together with Young's modulus of different proportions of nano-silica added concrete were experimentally studied. The obtained results showed that an efficient use of nano-silica in concrete can improve its mechanical properties and also an activator to promote pozzolanic reactions.

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2.0 MATERIALS

2.1 Aggregate

River sand confirming to zone II as per IS: 383-1970 was used as fine aggregate (F.A). Specific gravity of fine aggregate was 2.6. Broken stones from the local quarry at Reddiarchattiram, near dindigul confirming to IS 383-1970 was used as coarse aggregate (C.A). Specific gravity of coarse aggregate was 2.76. The maximum size of aggregates was 4.75 mm for fine aggregates and 20 mm for coarse aggregates.

2.2 Cement

Cement used was Ordinary Portland Cement (OPC) Specific gravity of cement was 3.25. Analysis of the cement is given in the Table 1.

Table 1
CHEMICAL ANALYSIS OF CEMENT

Chemical Analyis of Cement	%
Silicon di oxide SiO2	21.56
Aluminium oxide Al2O3	5.39
Ferric oxide Fe2 O3	3.39
Magnisium oxide Mgo	1.19
Calcium oxide CaO	65.5
Sulphur tri oxide SO3	2.76

Loss of Ignition

2.3 Water
Ordinary portable water is used in the concrete.

2.4 Nano Silica
Nano Silica is a new pozzolanic material whose particle size in a nano range. The Nano-particle sizes ranges from 1 to 100 nanometers. So it is clear that it can go inside very minute pores of concrete. So this will give good packing capacity. Its pozzolonic and pore filling activity make the concrete denser. Analysis of the nano silica is given in the Table 2.

Table 2
CHEMICAL ANALYSIS OF NANO SILICA

Chemical Analysis of Nano Silica	%
Specific Surface Area (M2/G)	201
pH value	4.37
SiO_2 Content	99.88
Carbon Content	0.03
Chloride Content	0.011
Al_2O_3	0.007
TiO_2	0.006
Fe_2O_3	0.001

2.5 Concrete Mixtures
The content of nano-particles in each of the specimens added in the range of 0.5% to 2% of the weight of cementitious materials.The superplasticizer (SP) used was Sikament NN and its chemical base is Modified Melamine Formaldehyde.

2.6 Concrete Mix proportion
Five different mix proportions were used for this study. Plane concrete with water cement ratio of 0.5 was used as control mix. In addition to that, 0.5%, 1%, 1.5% and 2% proportions of nano silica added to the mix by the weight of the cement. The mix proportions are given in Table 3.

Table 3
MIX PROPORTION FOR CONCRETE IN %

Concrete	Silica	Cement	F.A	C.A	SP
Ordinary	0	1	1.6	3.03	0
0.5% NS	0.5	1	1.6	3.03	0.45
1% NS	1	1	1.6	3.03	0.5
1.5% NS	1.5	1	1.6	3.03	0.6
2% NS	2	1	1.6	3.03	0.75

3. Results and Discussions

3.1 Cosistency Test
The fig. 1 shows the Consistency values of the concrete cubes by the addition of the different proportions of nano silica in to the cement paste. It is clear in the figure that 2% NS addition showing more water requirement compare to other. With increasing the NS content, fresh pastes grew thicker gradually and their penetration depths (consistencyvalue) decreased gently as compared with that of control sample.Due to the high surface area of nano silica, water demand will be more and thus nano silica makes cement paste thicker and accelerates the cement hydration process [10].

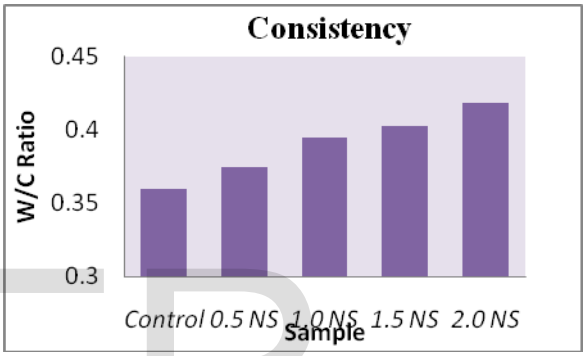

Fig 1 Cosistency Values of examined specimens

3.2 Fresh Concrete Test
There is an increase in the water demand when nano siilca is added to the concrete mix. This is mainly due to the increase in the surface area of the nano particles. Thus the Cement paste workability resulted to be significantly lower than expected, due to the interactions between nanosilica and the liquid phase of cement pastes. The resulting reduction of the mix workability was avoided by suitable addition of superplasticizer.

Super Plasticizer requirement are shown in Fig. 2. It is clear in the figure that 2% NS added concrete showing more plasticizer requirement compare to **other**.

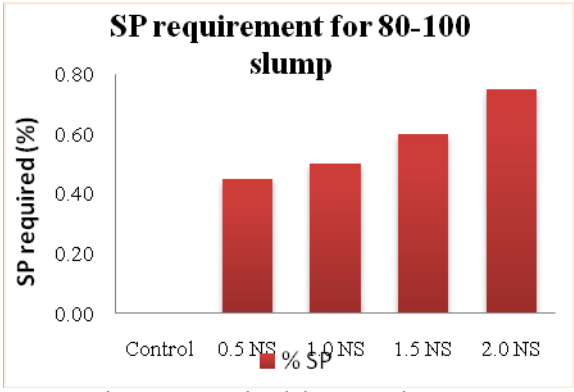

Fig 2 Super Plasticizer requirement

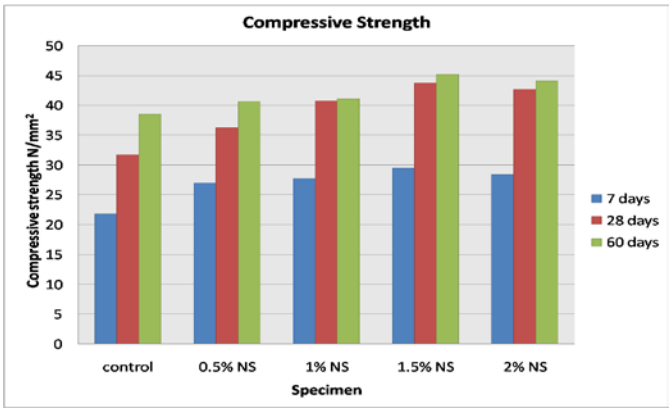

Fig 3 Compressive strength of Specimens

3.3 Hardened concrete: mechanical properties

To test the properties of hardened concrete, 9 cubes (150 mm) were casted for each mix, stripped from the mould after 24 hours and cured subsequently in water until their test age was reached. The compressive strength was determined after 7, 28 and 60 days on 3 cubes for each proportions of nano silica added concrete. Thus the compressive strength test was performed. In addition, Young's modulus and the split tensile strength was determined after 28 days on 3 cylinders (300 X 150mm) for each propotions of nano silica added concrete.

3.4 Compressive Strength of concrete

Cubic samples were used for measuring the compressive strength. The figure 3 shows the compressive strength of the concrete cubes by the addition of the different proportions of nano silica in to the concrete at 7, 28 and 60th day. It can be clearly seen that 1.5% NS addition gives more strength than other. More over, there is a reduction in strength at 2% NS addition.The higher strength gain is due to the pozzolanic activity and filler effect of nano silica, thus giving rise to a denser concrete. The reduced compressive strength by adding 2% SiO2 nanoparticles may be due to the fact that the quantity of SiO2 nanoparticles present in the mix is higher than the amount required to combine with the liberated lime during the process of hydration thus leading to excess silica leaching out and causing a deficiency in strength. Also, it may be due to the defects generated in dispersion of nanoparticles that causes weak zones. However, large quantities of nano silica produces agglomerate effect and thus results in the reduction of compressive strength [1].

3.5 Split Tensile Strength

The fig. 4 shows the compressive strength of the concrete cubes by the addition of the different proportions of nano silica in to the concrete at 28th day. It can be clearly seen that 1.5% NS addition gives more strength than other. More over, there is a reduction in strength at 2% NS addition.

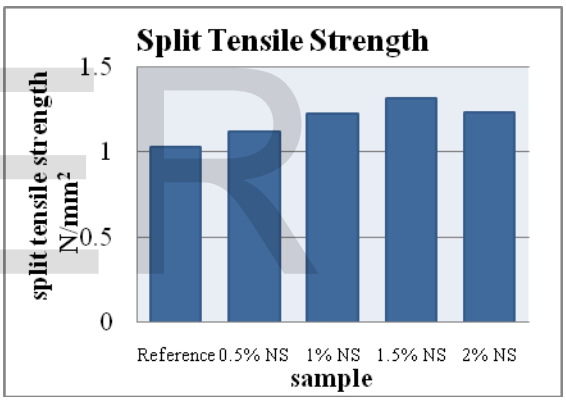

Fig 4 Split Tensile Strength of Specimens

3.6 Young's Modulus

The Fig. 5 shows the Young's modulus of the concrete cylinders by the addition of the different proportions of nano silica in to the concrete on 28th day.

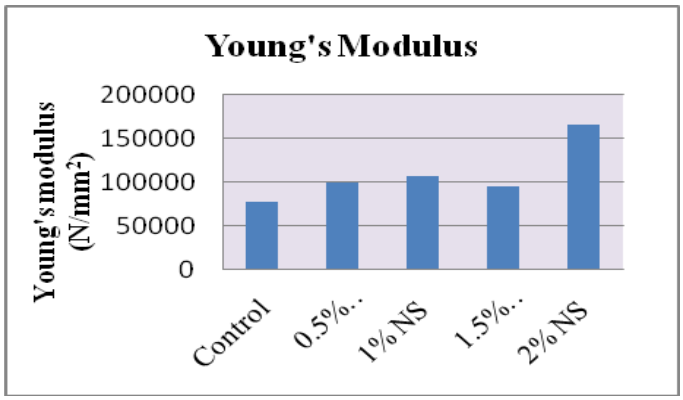

Fig 5 Young's Modulus of Specimens

4. CONCLUSIONS

Based on the experimental investigations, the following conclusions can be drawn:

1. The overall performance of concrete was significantly improved with the addition of variable dosages of nano-silica.
2. From the above results , it is clear that 1.5% NS addition is the best proportion
3. Resulting reduction of workability can be avoided by suitable addition of super plasticizer.
4. There was a good improvement in split tensile strength.
5. Nano silica can be very effective in improving the mechanical properties and also as an activator to promote the pozzolonic reactions

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