

AN ENHANCEMENT IN FINDING THE STRENGTHENING PROPERTIES OF NANOSILICA ADDED CONCRETE

C.H. SWAMYDAS

M.Tech Structural Engineering
Indira Institute of Technology and
Sciences, Markapur

D.THRIMURTHI NAIK

M.Tech (Asst. Professor)
Indira Institute of Technology and
Sciences, Markapur

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 article presents a critical review of the literature on the influence of nano silica in concrete and its application for the development of sustainable materials in the construction industry and to study the pore filling effect and its pozzolanic activity with cement towards improvement of mechanical properties and durability aspects. It has been observed that the addition of nano-silica in normal strength concrete increased the compressive strength and decreased the split tensile strength and flexural strength. Also, Rapid chloride permeability test (RCPT) has been conducted to know the chloride permeability of control concrete, nano modified concrete, and nano coated concrete. In this experimental approach the cement is partly replaced via 20% and 30% of Fly Ash and Nano-Silica through 1.5%, 3.0% and 4.5% by using weight. The nature of mixed Fly Ash and Nano-Silica on compressive strength, Split tensile power, flexural energy of M30 grade of concrete is investigated. The variation of various test results of concrete organized with different proportions of Fly Ash and Nano-Silica shows the equal trend. It may be that concrete organized with 20% Fly Ash and 3.0% Nano-Silica addition possesses enhanced characteristics compared to the control concrete.

Keywords: concrete, nano silica, compressive strength, microstructure

1.0 INTRODUCTION

In recent years, modification of cement composites by nanoparticles has attracted intense attention among researchers. Concrete, as the most popular cement

composite in practical applications, was also subjected to modification by replacing a portion of binder with various nanoparticles such as TiO_2 , Fe_2O_3 , Al_2O_3 , and SiO_2 . Among those, nanosilica (NS) incorporation into concrete was of interest for many researchers not only because of the similarity of its chemical composition to constituents of C-S-H, but also because of the capability of NS to potentially improve cement composites properties through different mechanisms. NS, as well as silica fume, is a highly reactive pozzolan and could consume calcium hydroxide (CH) to form secondary C-S-H. However, some researchers believe that the addition of NS mostly affects initial silicate polymerization rather than ultimate amount of C-S-H formed. Another mechanism, by which NS can influence cement composite properties, is seeding effect. NS could provide extra sites for the precipitation of hydration products, leading to the acceleration of early stage hydration. Nano silica is the most abundant material that makes the earth. It has the chemical composition of SiO_2 which is similar to a diamond structure. It is a white and crystal-formed material. Nano silica is one of the most applied nanoparticles in concrete. It is a new pozzolanic material which is in water in a solid or liquid form. In the concrete industry, nano silica is one of the most

famous materials that determine viscosity and filling state of the concrete. According to figure 1, nano silica is made up of bullet-formed particles with diameter less than 100 nanometer, or dry-powder particles, or particles which could be dispersed in the liquid. The researchers pay attention to nano silica as one of the products of nanotechnology that plays an important role as a very active pozzolan in the concrete. Adding nanoparticles of concrete could maintain its strength during physical and chemical reactions and also compress the particles.

OBJECTIVE OF THE STUDY

The objectives of the prevailing research work are to examine the impact of Fly ash content material on compressive strength, split tensile strength and flexural strength of concrete, combined effect of application of Nano-Silica and Fly ash on compressive strength, split tensile energy and flexural strength and assessment of the consequences of traditional Concrete, with the influence of Fly ash and Nano-Silica as substitute of Cement.

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-day and the FESEM analysis has been done for 28-day only. The size of the nano-silica was identified using Particle Size Analyser.

2.0 LITERATURE REVIEW:

G. Dhinakaran et. al. (2014) analysed the microstructure and strength properties of concrete with Nano SiO₂. The silica was

ground in the planetary ball mill till nano size reached and it was blended in concrete with 5%, 10% and 15% b.w.c.. The experimental results showed gain in compressive strength with maximum strength for 10% replacement.

Alireza Naji Givi et.al. (2012) studied the effect of Nano SiO₂ particles on water absorption of RHA blended concrete. It is concluded that cement could be replaced up to 20% by RHA in presence of Nano SiO₂ particle up to 2% which improves physical and mechanical properties of concrete.

Sekari and Razzaghi (2011) studies the effect of constant content of Nano ZrO₂, Fe₂O₃, TiO₂, and Al₂O₃ on the properties of concrete. The results showed that all the nano particles have noticeable influence on improvement on durability properties of concrete but the contribution of nano Al₂O₃ on improvement of mechanical properties of HPC is more than the other nano particles.

Rao et al. (2001) reported no change in carbonation resistance of mortar containing NS, while Lim and Mondal found that 5% NS addition to cement paste led to reduction in the degree of carbonation. Although there are some works considering carbonation resistance of cementitious materials, detailed quantitative data on NS impact on the advancement of carbonation in time, especially in concrete, are lacking in the literature.

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.

3.0 MATERIALS AND METHODS

Taking advantage of nanostructure characterization tools and materials, the optimal use of nano silica will create a new concrete mixture that will result in long lasting concrete structures in the future. Generally, concrete is two phase system with cement paste and aggregate, but the aggregates are inert in nature. The hydrated cement paste is composed of capillary pores and the hydration product - 'gel' pores, C-S-H, CH, Aft [Ettringite], AFm [Monosulfates] etc and one third of the pore space is comprised of gel pores and the rest are capillary pores. There are various indications that confirm the layered nature of C-S-H. Study conducted by Feldman and Sereda indicated that the cement paste inflow increases as water is removed until a point, at which the flow decreases. This point is the indication of a possible collapse in the nano-structure of hydration products and the C-S-H that is produced during the hydration of Portland cement has the microstructure as shown in figure.

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.

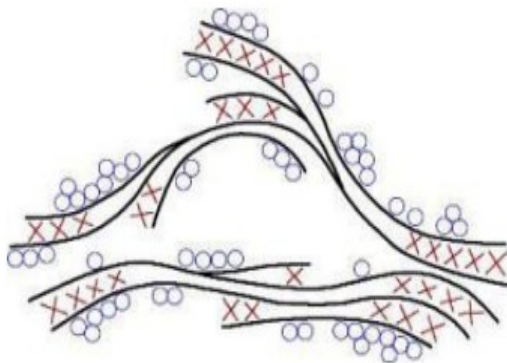


Fig 3.1 Model for the microstructure of C-S-H Black lines: C-S-H sheet, Circles: Adsorbed water, Crosses: Interlayer water



Fig. 3.2: Image of the Nano SiO₂ used

Table 3.1: Properties of Nano SiO₂

TEST ITEM	STANDARD REQUIREMENTS	TEST RESULTS
SPECIFIC SURFACE AREA (m ² /g)	200 ± 20	202
PH VALUE	3.7 – 4.5	4. 12
LOSS ON DRYING @ 105 DEG.C (5)	≤ 1. 5	0. 47
LOSS ON IGNITION @ 1000 DEG.C (%)	≤ 2.0	0.66
SIEVE RESIDUE (5)	≤ 0. 04	0. 02
TAMPED DENSITY (g/L)	40 – 60	44
SiO ₂ CONTENT (%)	≥ 99. 8	99. 88
CARBON CONTENT (%)	≤ 0. 15	0. 06
CHLORIDE CONTENT (%)	≤ 0. 0202	0. 009
Al ₂ O ₃	≤ 0. 03	0. 005
TiO ₂	≤ 0. 02	0. 004
Fe ₂ O ₃	≤ 0. 003	0. 001

Concrete was cast with CEM I 42.5R; crushed limestone aggregates, divided in five different classes (sand and calc1–calc4), with maximum size of 12.5 mm were used; the combination was chosen in order to fit Fuller's grading curve (Figure). Saturated surface dried (SSD) density, absorption (%) and fraction combination of five classes of aggregates are summarized in Table. Commercial NS suspension with the concentration of 10% by weight of water with nominal mean particle size of 20 nm was used. SEM image of dried NS (Figure) shows particle size lower than 100 nm, which could be the agglomeration of 3-4 nanoparticles and it probably was caused by drying process for SEM observation. Particles size distribution and cumulative distribution,

conducted by measurement technique of dynamic light scattering (DLS), showed that 51% of the volume of suspension had particle size finer than 21 nm and the most probable particle size belongs to 18 nm, that is, 25% of the suspension volume (Figure). Furthermore, only 5% volume fraction of the tested suspension had the size higher than 100 nm. Thus, NS suspension was well dispersed in water with little degree of agglomeration; however, this did not guarantee uniform dispersion of NS after mixing with solids inside concrete.

METHODS:

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: $f_{ck} = 25 \text{ MPa}$

Assumed standard deviation (Table 1 of IS 10262:1982): $sd = 4 \text{ MPa}$

Target average compressive strength at 28 days: $f_{target} = f_{ck} + 1.65sd = 31.6 \text{ MPa}$

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.

4.0 EXPERIMENTAL RESULTS:

UPV Test Results:

Table 4.1: UPV Test for control specimen for 7 day

7-DAY TEST RESULT			
Sample No.	Weight (kg)	Velocity (m/s)	Time (μs)
1	8.1	4678	32.2
2	8.34	4702	31.9
3	8.36	4777	31.4

Table 4.2: UPV Test for specimen with nano-silica 1% b.w.c for 7 day

7-DAY TEST RESULT			
Sample No.	Weight (kg)	Velocity (m/s)	Time (μs)
1	8.24	4491	33.4
2	8.14	4360	34.4
3	8.30	4559	32.9

Table 4.3: UPV Test for specimen with nano-silica 0.3% b.w.c for 28 day.

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Velocity (m/s)	Time (μs)
1	8.06	4673	32.1
2	8.32	4732	31.7
3	8.22	4854	30.9

COMPARISON OF RESULTS

Comparison of Compressive Strength Results

The change in compressive strength for the blended sample (in %) for 7 and 28 day is shown in Table 4.17 and Table 4.18 respectively. A graphical representation of this result is shown in Fig. 4.1 and Fig. 4.2. The change in compressive strength from 7 day to 28 day is shown in Fig 4.3.

Table 4.4: Comparison of compressive strength for 7 day

7-DAY RESULTS	STRENGTH (MPa)	INCREASE IN STRENGTH (%)
CONTROL	26.3	-
NS 0.3% b.w.c	27.61	4.98
NS 0.6% b.w.c	31.1	18.25
NS 1% b.w.c	34.59	31.52

NS= Nano SiO₂

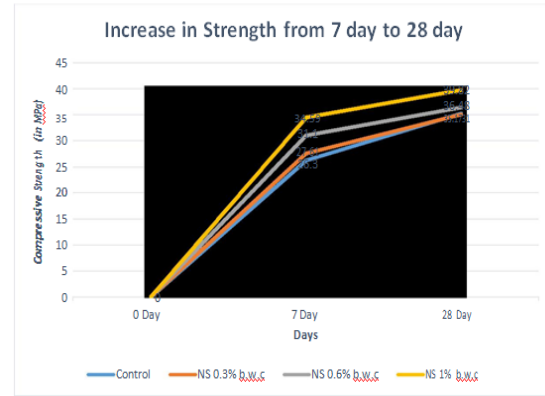


Fig. 4.3: Change in compressive strength of four specimen from 7 day to 28 day

The tables and graphs show that there is an improvement in the early strength of concrete blended with nano silica but later the increase in strength is subdued.

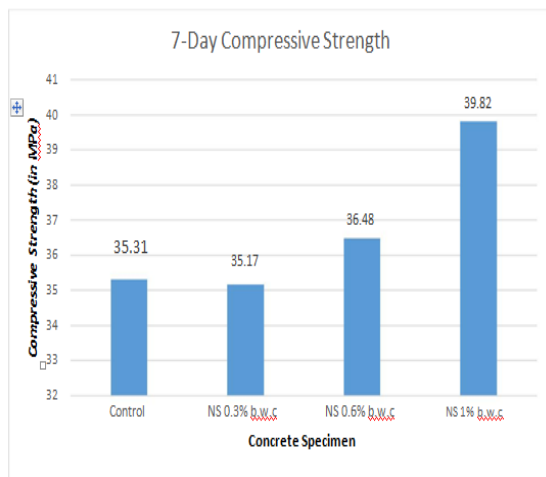


Fig. 4.1: 7-day compressive strength of four specimen

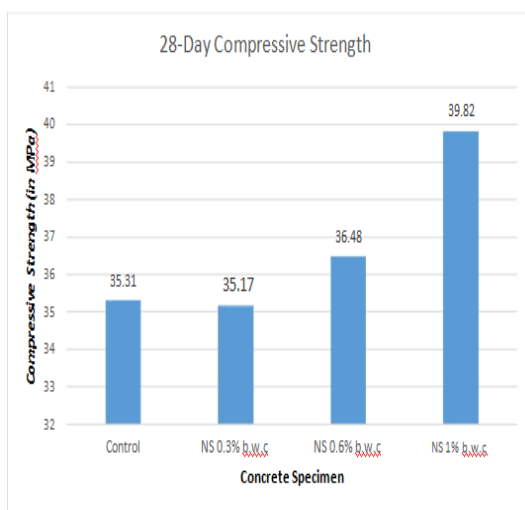


Fig. 4.2: 28-day compressive strength of four specimen

5.0 CONCLUSION

From the test results, the SEM micrographs and the relative chemical composition of the specimen a number of conclusions can be drawn. These conclusions are justified in the next section. The conclusions drawn are:

The above discussions described that the influence of NS along with cement, cement mortars, concretes, supplementary cementitious materials and other cementitious materials. Considerable improvement in the properties of permeability, pore filling effects, reduction of CH leaching, rheological behaviour of cement pastes, heat of hydration, micro structure analysis, the pozzolanic activity or reactions and workability, strength and durability were reported. As a whole, the entire review showed the ultimatum in using the nano technology in general and nano silica in particular. All the properties studied by various researchers have not directly dealt with remediation of concrete cracking whereas the entire attempts were

made indirectly towards that. However, there is a gap or room available for further research towards the fruitful application of nano silica for construction with different nano structure characterization tools, which will be enable to understand many mysteries of concrete.

6.0 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.

7.0 REFERENCES:

1. T.H. Wee, A.K. Suryavanshi, S.S. Tin, *Influence of Aggregate Fraction in the Mix on the Reliability of the Rapid Chloride Permeability Test*, *Cement & Concrete Composites*, **21**, 1, 59-72, 1999.
2. J.Y. Shih, T.P. Chang, T.C. Hsiao, *Effect of nanosilica on characterization of Portland cement composite*, *Cement Concrete Research*, **36**, 697-706, 2006.
3. B.W. Jo, C.H. Kim, G. Tae, J.B. Park, *Characteristics of cement mortar with Nano-SiO₂ particles*, *Construction and Building Materials*, **21**, 6, 1351-1355, 2007.
4. K.L. Lin, W.C. Chang, D.F. Lin, H.L. Luo, M.C. Tsai, *Effects of Nano-SiO₂ and different ash particle sizes on sludge ash-cement mortar*, *Journal of Environmental Management*, **88**, 4, 708-714, 2008.
5. A. Sadrmohtazi, Fasihi, F. Balalaei, A.K. Haghi, *Investigation of mechanical and physical properties of mortars containing silica fume and Nano-SiO₂*, *The third International Conference on Concrete & Development*, 1153-1161, 2009.

6. L. Senff, J.A. Labrincha, V.M. Ferreira, D. Hotza, W.L. Repette, *Effect of nano-silica on rheology and fresh properties of cement pastes and mortars*, *Construction and Building Materials*, **23**, 7, 2487-2491, 2009.
7. A.N. Givi, S.A. Rashid, F.N.A. Aziz, M.A.M. Salleh, *Experimental investigation of the size effects of SiO₂ nano-particles on the mechanical properties of binary blended, concrete Composites Part B: Engineering*, **41**, 8, 673-677, 2010.
8. A. Wang, C. Zhang, N. Zhang, *Study of the influence of the particle size distribution on the properties of cement*, *Cement and Concrete Research*, **29**, 11, 685-695, 1997.
9. P. Domone, C.H. Wen, *Testing of binders for high performance concrete*, *Cement and Concrete Research*, **27**, 8, 1141-1147, 1997.
10. Sanchez F. and Sobolev K., *Nano Technology in concrete - a review*, *Constr. Build Mater.*, **24**, 2060-71 (2010)
11. Bjornstrom J., Martinelli A., Matic A., Borjesson L. and I. Panas, *Accelerating effects of colloidal nano-silica for beneficial calcium-silicate-hydrate formation in cement*, *Chemical Physics Letters*, **392**, 242-248 (2004)
12. Ji T., *Preliminary study on the water permeability and microstructure of concrete incorporating nano-SiO₂*, *Cem. and Con. Res.*, **35**, 1943-1947 (2005)
13. Ye Qing, Zenan Z., Deyu K. and Ch. Rongshen, *Influence of nano-SiO₂ addition on properties of hardened cement paste as compared with silica fume*, *Constr. Build Mater.*, **21**, 539-545 (2007)
14. Jo Byung-Wan, Kim Chang-Hyun, Lim Jae-Hoon, *Characteristics of cement mortar with nano-SiO₂ particles*, *ACI Mat. Jl.*, **104**(4), 404-407 (2007)
15. Gaitero J.J., Campillo I. and Guerrero A., *Reduction of the calcium leaching rate of cement paste by addition of silica nano particles*, *Cem. and Con. Res.*, **38**, 1112-1118 (2008)
16. Senff L., Labrincha J.A., Ferreira V.M., Hotza D. and Repette W.L., *Effect of nanosilica on rheology and fresh properties of cement pastes and mortars*, *Constr. Build Mater.*, **23**, 2487-2491 (2009)

**ANVESHANA'S INTERNATIONAL JOURNAL OF RESEARCH IN ENGINEERING AND APPLIED SCIENCES**

17. Jo Byung-Wan, Kim Chang-Hyun, and Lim Jae-Hoon, *Characteristics of cement mortar with nano-SiO₂ particles*, *ACI Mat. J.*, 104(4), 404-407 (2007)

18. Berra M., Carassiti F., Mangialardi T., Paolini A.E., Sebastini M., *Effect of nanosilica addition on workability and compressive strength of Portland cement pastes*, *Constr. Build Mater.*, 35, 666-675 (2012)