wjert, 2018, Vol. 4, Issue 1, 230-245. *Review Article* ISSN 2454-695X

World Journal of Engineering Research and Technology

WJERT

www.wjert.org

SJIF Impact Factor: 4.326

STUDY OF HIGH PERFORMANCE CONCRETE USING NANOSILICA AS AN ADMIXTURE-A REVIEW

Ashwini K.*[1] and Dr. Srinivasa Rao P.[2]

[1]Research Scholar, Civil Engineering Department, JNTUH College of Engineering, Kukatpally, Hyderabad, A.P, India.

[2]Professor of Civil Engineering, JNTUH College of Engineering, Kukatpally, Hyderabad, A.P, India.

Article Received on 25/10/2017 Article Revised on 15/11/2017 Article Accepted on 06/12/2017

***Corresponding Author**
Research Scholar, Civil Engineering Department, JNTUH College of Engineering, Kukatpally, Hyderabad, A.P, India.

ABSTRACT

High performance concrete(HPC) use in present days is increasing as conventional concrete does not meets the requirement. Hence it is necessary to develop HPC. For the production of HPC, the pozzolanic materials (silica fume, ground granulated blast furnace slag, fly ash) are widely utilized. Nevertheless, the new developments of nanotechnology guarantee that various forms of nano sized silica can be produced, which have higher purity and specific surface areas which could more effectively promote the strength development of concrete, compared to the other pozzolanic materials. In recognition of its importance, many researchers have attempted to investigate the effect of nanosilica on the mechanical properties of HPC. These researchers during their investigation used nanosilica of different sizes and combination of materials like silica fume, ground granulated blast furnace slag, fly ash, metakaoline etc. to prepare concrete of different grade and tested for workability, compression strength, split tensile strength and flexural strength. The other tests that were conducted was durability properties like; acid resistance, %weight loss, durability factors, rapid chloride permeability test, abrasion resistance, water permeability etc. the analysis of these investigations and their results are reviewed and presented in this paper.

KEYWORDS: Nanosilica, High performance concrete, Durability, Workability, Mechanical properties.

INTRODUCTION

Concrete is a durable and versatile construction material. It is not only Strong, economical and takes the shape of the form in which it is placed, but it is also aesthetically satisfying. 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. However experience has shown that concrete is vulnerable to deterioration, unless precautionary measures are taken during the design and production. For this we need to understand the influence of components on the behavior of concrete and to produce a concrete mix within closely controlled tolerances. 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 High performance 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 high performance 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.

Therefore present review presents information of such investigations that provide insight in to the effect of nano silica on mechanical properties of high performance concrete.

The effect of Ground Granulated Blast Furnace Slag (GGBS) and Nano-Silica (nS) as mineral admixtures in concrete was studied (V. Nagendra. et al 2016)[1] by conducting the experiment in two stages. In the first stage the effect of GGBS was studied along with the specific particle sizes passing through sieves of 250µm, 125µm, 90µm, 45µm and 20µm. The percentage replacement of cement with GGBS was varied from 10% to 40% with an increment of 10%. From this effective replacement dosage of GGBS is identified. In the second stage the nS in the ratio of 2, 4 and 6% was mixed with the effective dosage of GGBS. A total of 420 standard cubes of M20 grade concrete and w/c ratio of 0.5 were cast and tested for compressive strength at 7, 14, 21 and 28 days.

It was reported that for 20µm particle size, the 28 day compressive strength is optimum, the percentage increase when compared with control mix for 20µm particle size is equal to 12% and that for 250µm particle size, it is slightly lower than the control mix. The replacement of nanosilica with GGBS for compressive strength has yielded an optimum strength at 20%GGBS and 4% NS replacement level. The percentage increase in strength when compared with control mix is 37%, whereas for 250 micrometer particles, the strength is nearly equal to the control mix.

Behaviour of GGBS and nano-silica on strength properties of concrete experimental investigated (Ramesh. N. et al 2016)[2] by partially replacing cement with 10%, 20% and 30% of GGBS and Nano-Silica 1%, 2% and 3% by weight. The influence of combined application of GGBS and Nano-Silica on compressive strength, split tensile strength, flexural strength of M30 grade of concrete is studied.

The above investigation reported that Cement replacement upto 30%with GGBS and upto 2% NS leads to increasing compressive strength and split tensile strength. Beyond that there is decreasing in compressive strength and split tensile strength. Nano silica addition decreases the initial and final setting time of mix when added 2% by weight of cement as it contributes to increased CH production of early age.

Experimental investigation on behaviour of nano concrete is done(R. Sakthivel. et al 2016)[3] by replacing the cement with 2.5%, 3%, and 3.5% of Nano-Silica for M25 mix. Laboratory tests were conducted to determine the compressive strength, split tensile and flexural strength of Nano-Silica concrete at the age of 7 and 28 days.

Results indicated that the concrete, by using Nano-Silica powder, was able to increase its compressive strength. However, the density is reduced compared to standard mix of concrete. The replacement of cement with 3% Nano-Silica results in higher strength and reduction in the permeability than the controlled concrete. The replacement of cement with Nano-Silica more than 3% results in the reduction of various properties of Nano-Silica concrete.

Effect of nano-silica additions on mechanical and microstructure analysis of high performance concrete is studied (P. Jaishankar. et al 2016)[4] partially replacing cement with 1%, 2%, 3% and 4% nano-silica as admixture for M60 concrete mix. Compressive test, Split tensile test, Flexural test and test for Modulus of elasticity are carried out to study the mechanical properties. TEM, EDS and SEM techniques are used to study the microstructure of the concrete.

The above investigation reported that 3% of nano silica increases the compressive strength and split tensile strength of concrete 14% more compared to control concrete but increase in flexural strength is only 2% at 3% Nano-silica partially replacing concrete compared to control concrete. It has also been observed that for combination of 4% Nano-silica the strength is decreased as the dosage might have been crossed the optimum level. Therefore the optimum amount of Nano-Silica partially replacing cement is 3%. Nano-silica in high performance concrete cause to reduce in pores size and the concrete structures will be more dense and durable.

Ternary effects on cement blends of concrete containing nano silica, metakaolin and zeolite with fibers was investigated (P Jayapradha. et al 2015)[5] to evaluate the mechanical properties of concrete using water to binder ratio of 0.42 wt% and at various replacements ratio of metakaolin (5%, 10%, 15%) nano silica (2.5%) and zeolite (5%, 10%, 12.5%) by weight of cement. After 28 days of curing the specimen was tested for compressive strength. From the above mix the one which gives the higher strength was taken and the natural fibre such as sisal fibre and coir fibre up to 1.25% is added to determine the compressive strength, split tensile strength and flexural strength of the concrete.

It was concluded that replacement of cement 17.5% by the pozzolanic materials such as metakaolin (5%), zeolite (5%) and nano silica (2.5%) gave 52% higher compressive strength than the plain concrete but with the addition of zeolite (10%), metakaolin(15%) and nano silica (2.5%) that the compressive strength is decreased about 15% lower than the reference mix. This mix was taken for further investigation, and the natural fibres (coir and sisal) are added up to 1.25%. At lower content of fibre (coir fibre and sisal fibre), up to 1%, the relative increase in strength is observed about 20 to 50% higher than the plain concrete.

The Effect of nanosilica in compensating the strength loss caused by using high volume fly ash in high strength mortars was studied (Dr. Rahel Kh. Ibrahim. et al 2015)[6] by using colloidal nanosilica that contains 50% amorphous nanosilica having average particle size of 50nm. Mixtures with three different fly ash levels 25%, 35% and 45% and three different (nanosilica + fly ash) levels of 2.5%+25%, 5%+35%, and 7.5%+37.5% of cement were casted next to the Portland cement mix. The specimens were tested for compression strength and flexural test. The X- ray diffraction (XRD) test was performed using control paste specimen and cement paste specimens containing 45% fly ash and 45% (fly ash + nano silica).

It was concluded that high strength mortars with compressive strength can be produced by adding nano silica to high volume fly ash mortars, containing 45% less cement. SEM images and XRD test showed that nanosilica enhances the microstructures of mortars and concrete by acting as nucleus in producing more compacted structure of C-S-H and have a high pozzolanic activity in converting calcium hydroxide to calcium silicate hydrate which contribute to strength of concrete.

Durability properties of high volume fly ash concrete containing nano-silica are studied (Steve Wilben Macquarie Supit. et al 2014)[7] concretes containing 2 and 4 %of nS prepared at a constant water/binder ratio of 0.4 for testing ages of 3, 7, 28, 56 and 90 days. The compressive strength and durability tests including water sorptivity, volume of permeable voids (VPV), chloride permeability and porosity are investigated experimentally.

It was concluded that incorporating 2 % nS in HVFA concretes significantly improved the compressive strength at early days. XRD analysis showed that the reactivity of nS is higher in HVFA system containing 38 % fly ash than that containing 58 % fly ash. The addition of 2 % nS reduced the sorptivity of ordinary concrete by about 20–40 %. In HVFA concretes containing 40 % and 60 % fly ash this reduction is also significant between 27 and 50 % and between 7 and 22 %, respectively. Reduction in VPV in HVFA concretes is also noticed due to addition of 2 % nS, however, that is in lesser extent. The addition of 2 % nS also showed significant reduction in chloride ion penetration in HVFA concretes by about 28–38 % in concrete containing 40 % fly ash and to a lesser extent of 8–20 % in concrete containing 60 % fly ash. The use of nS leads to a more compact paste with a significant reduction of the pores between 0.1 and 10 micro meters.

Effect of nano-SiO2 particles on fracture properties of concrete composite containing fly ash studied(Peng Zhang. et al 2015)[8] experimentally using five different nano-SiO2 contents (1, 3, 5, 7 and 9). By means of three-point bending method, the fracture parameters of the effective crack length, initial fracture toughness, unstable fracture toughness, fracture energy, critical crack opening displacement, maximum crack opening displacement and maximum mid-span deflection of the beam specimen were measured.

It was concluded that when the nano-SiO2 content increased from 0% to 5%, the fracture parameters increased gradually and the fracture relational curves became thicker with the increase in nano-SiO2 content. However the fracture parameters began to decrease and the curves became thinner when nano-SiO2 content exceeded 5%. The variation rules of fracture parameters and fracture relational curves indicate that the contribution of nano-SiO2 to the improvement of fracture properties of concrete composite containing fly ash is significant only when the nano- SiO2 content does not exceed 5%.

The effects of nano-silica incorporation on an eco-friendly alkali activated slag–fly ash blends is investigated (X. Gao, Q.L. Yu. et al 2015).[9] The effects of nano-silica addition on slump flow, setting times, reaction kinetics, gel characteristics, porosity and compressive strength of alkali activated slag–fly ash blends designed with two slag/fly ash ratios; and the role of nano-silica in alkali activated system is studied.

It was reported that incorporation of nano-silica significantly decreases the slump flow of paste samples due to its high surface area, also mixes with a lower slag/fly ash ratio contribute to a better flowability. Both initial and final setting times are slightly increased with the increase of nano-silica content, but slag/fly ash ratio shows a more considerable effect on setting. The nano-silica replacement slightly retards the reaction process at early ages and also leads to a slight reduction of the peak intensity in the main reaction stage. Gel character analyses conducted by FTIR and TG/DSC show that the addition of nano-silica slightly increases the chemically bound water content. A nanosilica addition up to around 2% benefits the compressive strength at typical curing ages of 3, 7 and 28 days, while a further higher nano-silica content shows negative effects. All mixes show an optimum nano-silica content of around 2% in terms of porosity reduction.

Performance of nano-Silica modified high strength concrete at elevated temperatures is studied (Morteza Bastami. et al 2014)[10] using six sample mixtures contained varying amounts of nS and two samples without nS. The mixtures used nS, 0, 1.5%, 3% and 4.5% cement, and 0%, 33.3%, 100% and 300% SF. The total mass for nS and SF was held constant in M1–M4 at 30 kg/m3 and in M5–M8 at 60 kg/m3. The ratio of water to binder, coarse aggregate, and fine aggregate were held constant to maximize the effect of nS. The mechanical properties of the modified HSC were measured by heating 150 x 300 mm sample cylinders of concrete to 400, 600 and 800 ^{o}C at a rate of 20 ^{o}C/min.

In the above investigations it was observed that mixtures containing nS had higher normal compressive strength (87.43 MPa) than those without nS (84.92 MPa). The addition of nS was more effective than SF for increasing residual compressive strength of heated specimens. There was no visible effect on the surface of heated specimens up to 400 ^{o} C. Large cracks and partial spalling were observed at 600 ^{o} C and aggregates decomposed and lost their integrity as the temperature reached 800 ^{o} C. At 400 ^{o} C, all mixtures containing nS showed decreased mass loss as the ratio of nS increased. nS is more efficient than SF in increasing the residual tensile strength of specimens heated to higher temperatures.

Experimental investigation on the effect of multiwalled carbon nanotubes (MWCNTs) and nano-SiO2 (nS) addition on mechanical properties of hardened cement paste (Anand Hunashyal. et al 2014)[11] is done using MWCNTs and nS of 0.75 and 0.5% by weight of cement. Dispersion of both MWCNTs and nS was carried out using ultrasonic energy method and mechanical properties such as compressive strength, flexural strength, toughness and ductility are evaluated.

Results of tests on the composite specimens have showed that addition of MWCNTs and nS almost doubled the flexural strength to in comparison with Plain cement. The SEM data showed non uniform dispersion of CNTs in the cement matrix because CNTs were sonicated was not good enough to disperse them in an effective manner.

Mechanical properties of fly ash concrete composite reinforced with nano-SiO2 and steel fibre (Peng Zhang. et al 2014)[12] is studied using Five different nano-SiO2 contents (1%, 3%, 5%, 7% and 9%) and five different steel fibre contents (0.5%, 1%, 1.5%, 2% and 2.5%).

It was concluded that both the slump and slump flow of fresh concrete composite containing fly ash decrease with the addition of nano-SiO2 and steel fibres but the workability of the fresh concrete composite declines gradually. The compressive strength and compressive modulus of elasticity increases with increase in nano-SiO2 content up to 5%. The compressive strength and compressive modulus of elasticity of concrete composite containing fly ash and nano-SiO2 are more than that of the concrete composite without steel fibre.

An Experimental investigation on strength properties of concrete containing micro-silica and nanosilica (Dr. D. V. Prasada Rao. et al 2014)[13] on various strength properties of M40 and M50 grades of concrete is done by partially replacing cement by 5% and 10% of Micro-Silica and 1.5% and 3% of Nano-Silica by weight. Compressive strength, split tensile strength and flexural strength of the two grades of concrete prepared using different proportions nano-silica and micro-silica are obtained and the results are compared with that of controlled concrete.

It was concluded that with the increase in the percentage of nano-silica the various strength characteristics of concrete are increased up to 1.5% with further increase in the nanosilica the strength of concrete is decreased for various percentages of micro-silica. The split tensile strength and flexural strength of M40 and M50 grades of concrete also indicated the similar trend. Therefore the strength properties of concrete can be improved by the addition of 1.5% of nano-silica and 10% of micro-silica by weight of cement.

Comparative study of the characteristics of nanosilica, silica fume and fly ash incorporated cement mortars is done (Hasan Biricik. et al 2014)[14] to study influence of the high dosages of nS on the compressive and flexural strengths and structural properties of cement mortars at early (7th day) and standard (28th day) curing ages were compared with the effect of equal amounts of SF and FA. The structural changes of mortar specimens were characterized by Fourier transform infrared spectrometer (FTIR), thermo gravimeter differential thermo gravimeter (TG-DTG) and scanning electron microscope (SEM).

It was reported that the compressive strengths and flexural strengths developed in the mortar specimens containing nS particles were found considerably higher than those of the corresponding specimens of SF and FA over and above the control at both ages. FTIR, TG-DTG and SEM analyses results were consistent with the remarkable increase in the mechanical strength of the mortars with nS.

Durability performances of concrete with nanosilica is investigated (Hongjian Du. et al 2014)[15] to examine the transport properties related to durability performance of ordinary concrete containing nanosilica. In addition to strength, water permeability and sorptivity, chloride migration and diffusivity were determined for concrete at nanosilica dosages of 0%, 0. 3% and 0.9%.

In above investigations SEM observations found the paste morphology at ITZ was more homogeneous for concrete containing nanosilica MIP results showed that the pore size distribution became refined which reduced the ingress rate of water and chloride ions. The compressive strength and resistance against water and chloride ions for concrete increased with nanosilica even at small amount of 0.3% and reduction of 45%, 28.7% and 31% was observed for water penetration depth, chloride migration coefficient and diffusion coefficient into concrete.

The effect of nanosilica addition on flowability, strength and transport properties of ultra high performance concrete was investigated(Ehsan Ghafari. et al 2014)[16] to study the pozzolanic activity of nS in UHPC mixture with very low water/cement ratio. Pozzolanic activity of nS in cement pastes was studied as compared with silica fume using conductivity analysis, x-ray diffraction (XRD) and thermo gravimetric analysis (TGA).

It was concluded that nS with higher specific surface areas have higher rate of pozzolanic reactivity than SF, at early ages and The highest amount of nS that can be incorporated keeping an acceptable range of slump flow is 3 wt.%. TGA results revealed that nS consume much more Ca(OH)2 as compared to SF. The optimum amount of cement replacement by nS in cement paste to achieve the highest compressive strength was 3 wt.%. MIP measurements revealed that the pore structure of UHPC can be effectively refined by adding nS. The SEM observation on the cement paste matrix, containing nS, revealed that the extreme fine particles of nS act not only as a filler, but also as an effective pozzolanic material, since these react with Ca(OH)2 crystals, leading to an improvement in the pore structure.

Comparative Study on M-Sand Concrete and (Nano-Silica with M-Sand Concrete) (A. Jayaraman. et al 2014)[17] is done by optimizing fully replacement of manufactured sand by natural sand with 0.5% nano silica in high performance concrete for M30 grade concrete.

It was concluded that replacement of cement with 0.5% of nano-silica gives more strength than the M-sand mix and also the durability has been increased compared to the M-Sand Mix. The self weight of the nano mix is lighter than the M-sand and the conventional mix. The workability decreases with the addition of nano-silica compared to the conventional mix. The penetration level of chlorides and acids are less in nano concrete compared to that of conventional and M-Sand mix.

Effect of nano-silica on the hydration and microstructure development of Ultra-High Performance Concrete (UHPC) with a low binder amount was investigated(R. Yu. et al

2014).[18] The design of UHPC is based on the modified Andreasen and Andersen particle packing model.

It was reported that a dense and homogeneous skeleton of UHPC can be obtained with a relatively low binder amount utilizing this packing model. Moreover, due to the high amount of superplasticizer utilized to produce UHPC in this study, the dormant period of the cement hydration is extended. However, due to the nucleation effect of nano-silica, the retardation effect from superplasticizer can be significantly compensated. Additionally, with the addition of nano-silica, the viscosity and porosity of UHPC significantly increases.

Comparative studies on high strength concrete mixes using micro silica and nanosilica (A. Siva Sai. et al 2013)[19] to study the mechanical properties of M60 and M70 concretes with the use of micro silica and in combination with colloidal nano-silica.

It was reported that the compressive strength of concrete increased with the increase in the quantity of CSF but the increment was stopped when the nS was beyond 2% and CSF was beyond 10%. The percentage increase in compressive strength and split tensile strength of concrete with the combination of CSF at 10% and nS at 2% was 14% more compared to control concrete. The increase in flexural strength was only 2% compared to control concrete. Concrete Composites With Nano Silica, Condensed Silica Fume And Fly Ash – Study of Strength is done (Abdul Wahab. et al 2013)[20] to find the influence of nano silica on concrete composites consisting of other mineral admixtures like silica fume and fly ash with two triple blended combinations namely (OPC+CSF+nS) and (OPC+Fly Ash+nS).

It was reported that 2% nano silica gives the highest value of compressive strength, split tensile strength and flexural strength without any admixture. In case of triple blended concrete mixes 2% nano silica and 10% CSF gives highest compressive strength and split tensile strength as compared to fly ash and nano silica mix.

The use of nanosilica for improving of concrete compressive strength and durability is investigated(Jonbi. et al 2012)[21] using nano silica of particle size 40-80nm.

It was concluded that the combined use of nanosilica with silica fume can effectively increase the compressive strength and durability of concrete. To avoid the agglomeration effect, this study suggests the percentage of nanosilica in the concrete to be not more than 10%. SEM images gives helpful information and insight to appearances C-H and C-S-H morphologies.

Experimental investigation of the size effects of SiO2 nano-particles on the mechanical properties of binary blended concrete(Alireza Naji Givi. et al 2010)[22] using SiO2 nano-particles with two different sizes of 15 and 80 nm as a partial cement replacement by 0.5, 1.0, 1.5 and 2.0 wt.% is done.

It was reported that the cement could be advantageously replaced by SiO2 nano-particle up to maximum limit of 2.0% with average particle sizes of 15 and 80 nm to get higher compressive, flexural and tensile strength. Although the optimal replacement level of nano-SiO2 particles for 15 and 80 nm size were gained at 1.0% and 1.5%, respectively. From the view point of free energy, it can be concluded that the SiO2 particles with average diameter of 15 nm can improve the early age strength of the concrete more than particles with 80 nm, however, the final strength of specimens made with 80 nm of SiO2 particles at 90 days of moist curing was relatively enhanced.

Experimental study is designed to examine the chloride permeability and microstructure of portland cement mortar with nanomaterials admixed at 1% by weight of cement (Xiaodong He. et al 2008)[23] by performing electromigration test, Electrochemical Impedance Spectroscopy EIS test and Field Emission Scanning Emission Scanning Electron Microscopy (FESEM) test

The electromigration test results revealed that the small amount of nano-SiO2 and nanoclays markedly improved the chloride penetration resistance of the cement mortars. The EIS test indicated that the incorporation of nanomaterials in cement mortar significantly increased its ionic transport resistance and decreased its electric capacitance, and again such effects were especially significant when using nano-SiO2 and nanoclays. The FESEM test revealed that the admixing of nanomaterials not only led to denser cement mortar but also changed the morphology of cement hydration products.

CONCLUSION

The review provides the following conclusions based on the experimental investigations of various researchers.

- It was noticed GGBS addition with nanosilica for concrete has yielded the maximum compressive strength at 4%NS and 20% GGBS replacement for 20µm particle size for M20 concrete.

- Compressive strength and Tensile strength of concrete was found greater with 2% nano silica and 30% GGBS for M30 concrete.
- The compressive strength of concrete increased only up to 3% of Nano-Silica and also the permeability of concrete decreased with the increase in the percentage of Nano-Silica up to 3% due to the effect of Nano-Silica filling the voids in concrete.
- It was found that the Nano-silica addition reduces the pore amount and makes the concrete denser for optimum amount of Nano-Silica partially replaced by 3% of cement for M60 concrete mix.
- Mechanical properties of concrete improves by replacing cement with nano silica.
- The replacement of cement 17.5% by the pozzolanic materials such as metakaolin (5%), zeolite (5%) and nano silica (2.5%) gives 52% higher compressive strength than the plain concrete.
- The addition of fibres (sisal fibre and coir fibre) up to 1% with zeolite (10%), metakaolin(15%) and nano silica (2.5%) improves the strength properties of concrete.
- It is concluded that NS has a significant influence in decreasing the total capillary pores and pores diameter of HVFA pastes.
- High strength mortars with compressive strength can be produced by adding nano silica to high volume fly ash mortars, containing 45% less cement.
- Nanosilica enhances the microstructures of mortars and concrete by acting as nucleus in producing more compacted structure of C-S-H.
- The addition of 2 % NS reduced the sorptivity of ordinary concrete by about 20–40 %.
- The addition of 2 % NS also showed significant reduction in chloride ion penetration and VPV.
- Due to extremely large surface area and small particle size, the NS reacts more quickly with CH in the hydration reaction than fly ash and produced secondary C–S–H gel and reduced the capillary pores in the matrix.
- Fracture properties of concrete composite containing fly ash is significantly improve only when the nano-SiO_2 content does not exceed 5%.
- Nano-silica significantly decreases the slump flow of paste samples due to its high surface area, also mixes with a lower slag/fly ash ratio contribute to a better flowability.
- Both initial and final setting times slightly increases with the increase of nano-silica content and the addition of nano-silica also slightly increases the chemically bound water content.

- A nanosilica addition up to around 2% benefits the compressive strength at typical curing ages of 3, 7 and 28 days and also reduces porosity.
- The addition of nS was more effective than SF for increasing residual compressive strength of heated specimens.
- At 400 ^{o} C, all mixtures containing nS showed decreased mass loss as the ratio of nS increased.
- Nanosilica is more efficient than Silicafume in increasing the residual tensile strength of specimens heated to higher temperatures.
- All specimens heated to greater than 400 ^{o} C experienced spalling.
- Addition of MWCNTs and NS almost doubled the flexural strength to in comparison with Plain cement.
- The compressive strength and compressive modulus of elasticity of concrete composite containing fly ash and nano-SiO2 are more than that of the concrete composite without steel fibre.
- The slump and slump flow of fresh concrete composite containing fly ash decrease with the addition of nano-SiO2 and steel fibres but the workability of the fresh concrete composite declines gradually.
- Strength properties of concrete can be improved by the addition of 1.5% of nano-silica and 10% of micro-silica by weight of cement.
- The compressive strengths and flexural strengths developed in the mortar specimens containing NS particles were found considerably higher than those of the corresponding specimens of SF and FA over and above the control at both ages.
- FTIR, TG-DTG and SEM analyses results were consistent with the remarkable increase in the mechanical strength of the mortars with NS.
- The pore size distribution was refined due to which ingress rate of water and chloride ions reduced with the addition of nanosilica.
- The compressive strength and resistance against water and chloride ions for concrete increased with nanosilica even at small amount of 0.3% and reduction of 45%, 28.7% and 31% was observed for water penetration depth, chloride migration coefficient and diffusion coefficient into concrete.
- Mercury intrusion porosimetry measurements proved that the addition of nS particles leads to reduction of capillary pores. Scanning electron microscope observation revealed

that the inclusion of nS can also efficiently improve the interfacial transition zone between the aggregates and the binding paste.

- The addition of nS also resulted in an enhancement in compressive strength as well as in transport properties of UHPC. The optimum amount of cement replacement by nS in cement paste to achieve the best performance was 3 wt.%.
- Addition of 0.5 % nano-silica leads to a significance increase in the characteristic strength and durability of concrete compared to the conventional mix and the M-Sand mix.
- With the addition of nano-silica, the viscosity and porosity of UHPC significantly increases.
- A dense and homogeneous skeleton of UHPC can be obtained with a relatively low binder amount utilizing modified Andreasen and Andersen particle packing model.
- The percentage increase in compressive strength and split tensile strength of concrete with the combination of CSF at 10% and nS at 2% was 14% more compared to control concrete but increase in flexural strength was only 2% compared to control concrete.
- 2% nano silica gives the highest value of compressive strength, split tensile strength and flexural strength without any admixture. In case of triple blended concrete mixes 2% nano silica and 10% CSF gives highest compressive strength and split tensile strength as compared to fly ash and nano silica mix.
- The combined use of nanosilica with silica fume can effectively increase the compressive strength and durability of concrete.
- To avoid the agglomeration effect, this study suggests the percentage of nanosilica in the concrete to be not more than 10%.
- SEM images gives helpful information and insight to appearances C-H and C-S-H morphologies.
- Concrete specimens containing SiO2 particles with average diameter of 15 nm were harder than those containing 80 nm of SiO2 particles at the initial days of curing. But this condition was altered at 90 days of curing.
- The incorporation of nanoparticles (Fe2 O3, Al2O3, TiO2, and SiO2) and nanoclays (montmorillonite) improved the chloride penetration resistance of the mortar, as indicated by the reduced apparent diffusion coefficients of chloride anion.
- The nanomaterials also reduced the general ionic permeability of the mortar, as indicated by the reduced electric charge passing through.

REFERENCES

1. V. Nagendra, C. Sashidhar, S.M.P. Kumar and N.V. Ramana, GGBS and Nano Silica (NS) effect on concrete, IJCIET, September-October 2016; 7(5): 477–484.
2. Ramesh.N, Eramma.H, Behaviour of ggbs and nano-silica on strength properties of concrete, IJRET, eISSN: 2319-1163, Jun-2016; 5(6): 142-148.
3. R. Sakthivel and Dr. N. Balasundaram, Experimental investigation on behaviour of nano concrete, IJCIET, March-April 2016; 7(2): 315–320.
4. P. Jaishankar, B. Muthu siva chandru, P. Verparasan and A. Vigneshwaran, Effect of nano-silica additions on mechanical and microstructure analysis of high performance concrete, IJCRGG, ISSN: 0974-4290, 2016; 9(05): 453-461.
5. P. Jayapradha and Dr. N. Sakthieswaran, Ternary effects on cement blends of concrete containing nano silica, metakaolin and zeolite with fibers, IJOER, ISSN: 2321-7758, 14th June 2015; 3(3): 632-642.
6. Dr. Rahel Kh. Ibrahim and Dr. Faris Rashied Ahmed, The Effect of nanosilica in compensating the strength loss caused by using high volume fly ash in high strength mortars, IJESIT, March 2015; 4(2): 232-241.
7. Steve W.M. Supit and Faiz Uddin Ahmed Shaikh, Durability properties of high volume fly ash concrete containing nano-silica, Materials and structures, 2015; 2431-2445.
8. Peng Zhang, Xiao-Bing Dai, Ji-Xiang Gao and Peng Wang, Effect of nano-SiO2 particles on fracture properties of concrete composite containing fly ash, CURRENT SCIENCE, 10 June 2015; 108(11): 2035-2043.
9. X. Gao, Q.L Yu and H.J.H Brouwers, Characterization of alkali activated slag-fly ash blends containing nanosilica, Construction and Building Materials, 9 August 2015; 98: 397-406.
10. Morteza Bastami, Mazyar Baghbadrani, and Farhad Aslani, Perofrmance of nanosilica modified high strength concrete at elevated temperatures, Construction and Building Materials, 17 June 2014; 68: 402-408.
11. Anand Hunashyal, Nagaraj Banapurmath, Akshay Jain, Syed Quadric and Ashok Shettar, Experimental investigation on the Effect of multiwalled carbon nanotubes and nano-SiO2 addition on mechanical properties of hardened cement paste, Advances in materials, 30 October 2014; 3: 45-51.
12. Peng Zhang, Ya-Nan Zhan, Qing-Fu Li, Tian-Hang Zhang and Peng Wang, Mechanical properties of fly ash concrete composite reinforced with nano-SiO2 and steel fibre, Current Science, 10 June 2014; 106(11): 1529-1537.

13. Dr. D. V. Prasada Rao, U. Anil Kumar, An Experimental investigation on strength properties of concrete containing micro-silica and nanosilica, IJCIET, August 2014; 5(8): 89-97.
14. Hasan Biricik and Nihal Sarier, Comparative study of the characteristics of nanosilica, silica fume and fly ash incorporated cement mortars, Material Research, 2014; 17(3): 570-582.
15. Hongjian Du, Suhuan Du and Xuemei Liu, Durability performances of concrete with nanosilica, Construction and building materials, 9 October 2014; 73: 705-712.
16. Ehsan Ghafari, Hugo Costa, Eduardo Julio, Antonio Portugal and Luisa Duraes, The effect of nanosilica addition on flowability, strength and transport properties of ultra high performance concrete, Materials and Design, 1 March 2014; 59: 1-9.
17. A. Jayaraman, M. Saravanan, Dr. G. Anusha, Comparative study on M-Sand Concrete and (Nano-Silica with M-Sand Concrete), IJSETR, ISSN 2319-8885, March-2014; 03(03): 0444-0448.
18. R. Yu, P. Spiesz and H.J.H Brouwers, Effect of nanosilica on the hydration and microstructure development of ultra high performance concrete with a low binder amount, Construction and Building Materials, 4 April 2014; 65: 140-150.
19. A. Siva Sai, B.L.P Swami, B. Saikiran and M. V. S. S. Sastri, Comparative studies on high strength concrete mixes using micro silica and nanosilica, IJETR, ISSN:2321-0869, September 2013; 1(7): 29-34.
20. Abdul Wahab, B. Dean Kumar, M. Bhaskar, S. Vijaya Kumar and B.L.P. Swami, Concrete Composites With Nano Silica, Condensed Silica Fume And Fly Ash – Study of Strength Properties, IJSER, ISSN 2229-5518, May 2013; 4(5).
21. Jonbi, Ivindra Pane, Binsar Hariandja and Iswandi Imran, The use of nanosilica for improving of concrete compressive strength and durability, Applied Mechanics and Materials, 2012; 204-208: 4059-4062.
22. Alireza Naji Givi, Suraya Abdul Rashid, Farah Nora A. Aziz and Mohamad Amran Mohd Salleh, Experimental investigation of the size effects of SiO2 nanoparticles on the mechanical properties of binary blended concrete, Composites: Part B 41, 12 August 2010; 673-677.
23. Xiaodong He and Xianming Shi, Chloride permeability and micro structure of Portland cement mortars incorporating nonmaterial's, Journal of the Transportation Research Board, No. 2070, Transportation Research Board of the National Academics, Washington, D.C., 2008; 13-21.