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THE ROLE OF NANOSILICA IN ENHANCING THE PERFORMANCE OF CONCRETE – A REVIEW

Kakara S J Kumar[1], M V Seshagiri Rao[2], V Srinivasa Reddy[3], R Sai Srinivas[4], B Sai Priya[4]

[1]*Research Scholar of Civil Engineering, JNTUH CEH, Hyderabad,*
[2]*Retd. Professor of Civil Engineering, JNTUH CEH, Hyderabad,*
[3]*Professor of Civil Engineering, GRIET, Hyderabad,*
[4]*P.G. Students, Department of Civil Engineering (Structural Engg.), GRIET Hyderabad.*

Abstract- This review paper reports the up-to-date developments concerning use of nano-materials in construction industry. In this paper, exhaustive research work done on the application of nanosilica in the concrete is reported along with their research findings on the enhanced properties of concrete incorporated with nanosilica. It is reported that nanosilica based enhances the mechanical and durability properties significantly. Compressive strength at as early as 3 and 7 days is increased by nearly 25-30%, with overall strength improvement at 28 days is about 30-40%. Compressive strength at age after 90 days found to increase by nearly 15-20%. Setting times and workability are found to be reduced in nanosilica concrete due to its very fineness and high reactivity. The effect of nanosilica on the properties of standard to high strength grade concrete is found to be very high than ordinary grade concrete. Dense microstructure due to refined pore diameters by nanosilica particles proved to be excellent durable construction material.

Keywords: nanosilica, microsilica, compressive strength, durability, nanotechnology

I. INTRODUCTION

With advent of supplementary cementitious materials and other siliceous and aluminous materials, today's concrete technology has achieved enormous potential applications, by the way of reduction in cement consumption, enhanced properties and reduced carbon foot print. This study focusses on use of nano science to produce high performance concrete. Nano-science is a branch of science that deals with atoms and molecules and is very effective in creation of new concretes in the present century. When a material has at least one component smaller than 100 nm, it can be called a Nano-material. In other words, "a nanomaterial refers to a solid whose atomic arrangement, size of its crystals, and its chemical composition could be extended in a multi-nanometer scale" (Porro, A., 2005) [20]. Concrete is made up of granular materials of different sizes from 300 nm to 32 mm which governs the properties of the concrete (B. Wangjo, C. Kim and J. Li 2007) [1]. The properties such as flow properties and workability are governed by the particle size distribution, also the properties of the concrete such as strength and durability depends on the mix grading and subsequent particle packing. One way to improve the particle packing is to increase the particle size spectrum, e.g. by including particles with sizes below 300 nm. Currently available nano materials whose particles with sizes below 300 nm are grounded limestone and silica fines such as silica flour (Sf), microsilica (mS) and nanosilica (nS) (Bartos, P.J.M., 2008) [3]. Nano particle is defined as the one that has at least one of its dimensions in nanometers or 10^{-9} m. The properties of the particles have been observed to drastically change when they are milled to nano size. The cement particles varies in size from 1 to 100 micrometers. It is believed that finer particles (in nano scale) have larger surface area per unit volume so large surface area of binder increases the early and later strengths due to faster and more effective hydration reactions. Recently nano technology is being used or considered for use in many applications and it has received increasing attention in building materials, with potential advantages and drawbacks being underlined. At present, a significant amount of research is being done on the use of nS in cement based materials. However, there is a limited knowledge about the mechanism by which nS affects the flow properties, setting times, consistency, workability, rheology, micro structure, mechanical and durability properties of cementitious mixes. Nanosilica is available in powder and colloidal form. Due to the high specific surface area for colloidal nano silica (CNS) particles they contribute a highly reactive siliceous material. However, it has not been established whether the more rapid hydration of cement in the presence of nS is due to its chemical reactivity upon dissolution (Pozzolanic activity) or to a considerable surface activity.

Reusing by-products such as fly-ash, silica fume, and nanosilica is very much essential to achieve sustainability goals in civil engineering. Performance and efficiency of concrete heavily relies on nano size constituents such as calcium silicate hydrates (C-S-H) particles. These additives are believed to increase strength and durability of concrete because they comprise of fine particles and has large surface area, and reactive silica (Balaguru, P., and Chong, K., 2008) [2]. Nanosilica is preferred over other nanoparticles because it has a high capability of improving microstructure of cement-based products like concrete (Porro, A., 2005) [20]. Use of even small amount of nanosilica can improve performance of cement composites.

II. SUPPLEMENTARY CEMENTITIOUS MATERIALS

A. MICROSILICA (mS)

Silica is the common name for materials composed of silicon dioxide (SiO_2) and occurs in crystalline and amorphous forms. Silica fume or microsilica is a byproduct of the smelting process in the silicon and ferrosilicon industry. The American concrete institute defines silica fume as "very fine non-crystalline silica produced in electric arc furnaces as a by-product of production of elemental silicon or alloys containing silicon" (ACI Committee 226. 1987b). It is a grey colored powder, similar to Portland cement or fly ashes. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle size (diameter) of 150 nm. The main field of application is as pozzolanic material for high performance concrete (Campillo, I.; Dolado, J.S.; and Porro, A., 2003) [5]. Microsilica improve the properties of concrete by two mechanisms (1) it's very fine size (micro) plugs the voids between cement particles and the voids between cement particles and aggregates; and (2) it react pozzolanically with CH to produce CSH gel, increasing the binding quality and decreasing the capillary porosity of concrete. The CSH gel formed during hydration of cement is a strong bond and forms strong connection between the concrete particles. On the other hand, Portlandite (CH) is a soluble product and leaches out in water through weak link between the concrete particles. The addition of silica particles to the concrete mix converts the weak CH into stronger CSH. 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. Thus it is well established that microsilica increase the strength of the concrete and produce a denser and more homogeneous matrix. Microsilica has been recognized as a pozzolanic and cementitious admixture which is effective in enhancing the mechanical properties to a great extent. The pozzolanic reaction due to microsilica results in a reduction of the amount of calcium hydroxide in concrete and subsequently reduces porosity and improves durability. It accelerates the dissolution of C-S and formation of C-S-H with its activity being inversely proportional to the size, and also provides nucleation sites for C-S-H. It is responsible for an additional increase in strength and chemical resistance and decrease in water absorption (Collepardi, M.; Collepardi, S.; Skarp, U.; and Troli, R., 2004) [6].

B. NANOSILICA (nS)

There are two main ways for the production of nanosilica – (1) Silica by sol gel process: In this process silica monomers are allowed to condense to colloidal particles (Figure 1). These particles form aggregates, (2) Pyrogenic Silica: This is a highly dispersed silicas formed from the gas phase at high temperature. Apart from silica produced by these processes, we can consider nano scale sized silica fume which is a byproduct of the reduction of quartz for the production of silicon and ferrosilicon. Nanosilica is typically a highly effective pozzolanic material of very fine vitreous particles approximately 1000 times smaller than the average cement particles. It has proven to be an excellent admixture for cement to improve strength and durability (Garboczi, E.J., 2009) [8]. In concrete, for example, the microsilica on chemical reaction with calcium hydroxide [CH] produce more C-S-H gel at later stage filling up the voids and pores in the fresh and hardened cement paste thereby increasing the concrete's density. Some researchers found that the addition of 1 kg of microsilica permits a reduction of 4 kg of cement, and this can be more if nS is used.

Figure 1: Colloidal Nano Silica

III. EFFECT OF NANOSILICA ON MICROSTRUCTURAL PROPERTIES

Various literatures have been reviewed to understand the influence of micro and nanosilica on fresh, hardened and microstructural properties of paste, cement mortar and concrete. Taking advantage of nanostructure and microstructure characterization tools and materials, the simultaneous and also separate optimal use of micro-silica and nanosilica will create a new concrete mixture that will result in long lasting concrete structures in the future.

Givi A.N., Rashid S.A., Aziz F.N.A., Salleh M.A.M. (2010) [9] performed XRD studies which clearly shows the formation of an additional C_3S in the nano modified materials when compared to the control mix, that could led to the formation of C-S-H gel, which is a strength giving phase and betterment of packing in concrete. Moreover, it is also seen that the intensity reduction of $CaOH_2$ phases in the nano modified concrete compared to the controlled concrete gives the indication of early consumption of the calcium hydroxide for the formation of C-S-H in the presence of C_3S. For X-ray diffraction (XRD) studies , the samples are obtained from controlled and nano modified concrete cubes and were finely grounded using mortar and pestle and then sieved through 25 micron sieve. The XRD and Scanning Electron Microscope (SEM) studies revealed that the nano-particles were not only acting as filler but also as an activator to promote hydration and to improve the microstructure of the cement paste if the nano-particles were uniformly dispersed (Li et al., 2004) [7][16][17][18]. The results of the experimental analysis indicated that nano-scale SiO_2 behaves not only as a filler to improve microstructure, but also as an activator to promote pozzolanic reaction (Qing et al., 2007 [21]; Jo et al., 2007 [12][13]). The nS addition contributed to an increased production of CH at early age compared with samples without nanosilica (Senff et al., 2010) [22] [23]. Impressive changes were recorded in the structure of nano-modified samples as the calcium silicate crystal size was larger in samples with high nano-SiO_2 content (Stefanidou and Papayianni (2012) [27]. This was obvious in pastes with 5% nanoparticles where crystals were formed at 14 days, while at the same age, in pastes with 1% nano-SiO2 the average crystal size was 600 nm. Microstructure observation also recorded a denser structure in nano-modified samples. The results showed that nS can reduce the size of CH crystals at the interface more effectively than mS (Qing et al., 2007) [21]. In nS based concrete, it was showed that C–S–H gels from pozzolanic reaction of the agglomerates cannot function as binder. The nano-indentation test results revealed that the pozzolanic C–S–H gels from reacted agglomerates showed nearly the same properties as the C–S–H gels from cement hydration (Kong et al., 2012) [15]. The effect of nanosilica on concrete and significant improvement was observed pertaining to refinement of pore structure and densification of interfacial transition zone. Micro-structural and thermal analyses indicated that the contribution of pozzolanic and filler effects to the pore structure refinement depended on the dosage of nanosilica (Said et al., 2012). Kong D., Du X., Wei S., Zhang H., Yang Y., Shah S.P. (2012) [15] investigated the hydration process of tri-calcium silicate (C_3S) cement and established the accelerating effects of colloidal silica (CNS) and role of water during hydration. From their study, it was observed that CNS accelerate dissolution of C_3S phase, thereby renders the rapid formation of C-S-H phase. If the nano particles are integrated with cement based materials, the new materials might possess some outstanding durability properties. The pozzolanic activity of nS is more obvious than that of mS counterpart. The nS can react with CH crystals, which are arrayed in the interfacial transition zone (ITZ) between hardened cement paste and aggregates and produce C-S-H gel. Thus, the size and amount of CH crystals are significantly decreased and the early age strength of hardened cement paste in increased.

The important phenomena such as crystallite size, Full Width at Half Maximum [FWHM] and arrangement of atoms or molecules need to be studied for nano modified composites as well as for cement to understand the reactions and responses.

The microstructural analysis of the hardened SCC reveals that the additions of nanosilica particles produced a homogeneous microstructure, characterized by compact and small sized C-S-H gel. As a consequence, a denser ITZ was produced. The additions of nanosilica caused a refinement of the microstructures (less interconnected pore structure) and induced precipitation of small sizes C-S-H gel having high stiffness. The improvement of the microstructure was reflected by the mechanical properties due to the fact that the pozzolanic gel structure presents better mechanical properties than the C-S-H gel precipitated in standard OPC concrete.

IV. MIX DESIGN FOR NANO CONCRETE

Particle packing is one of the mix design methods, which leads to a better and cost effective concrete. The main principle behind this concept is the minimization of void content by optimized packing of concrete ingredients(S Gopinath et al.) [19]. This will lead to the lowest cement consumption, porosity, and shrinkage and thus the concrete with the highest performance can be achieved. This concept was used in mix design of high performance cementitious mixes. The particle size distribution (PSD) of the sand and gravel is determined by sieve analysis. It was observed that the effect of nano material in filling can’t be depicted correctly using the particle packing method. To know the optimum quantity of nano material, more trial experiments have to be carried out. Vempada et al. (2018) [14] derived mix proportions for self-compacting concrete after several trail mixes on the materials computed from Nan Su mix design method (H. Okamura 1997)[10] .

V. EFFECT OF NANOSILICA ON WORKABILITY AND MECHANICAL PROPERTIES

Nanosilica particles are more effective if used instead of microsilica. Various researchers added nanosilica particles in concrete and published their experimental data. Senffa L., Hotza D., Lucas S., Ferreira V.M., Labrincha J.A. (2012) [24]have reported up to 70% increase of concrete compressive strength by incorporating nanosilica particles in high grade concretes. Yang [23] mixed 0.75% nano silica particles by mass of cement and reported 7.5% increase in bending tensile strength of concrete. Sobolev, K.; Flores, I.; Hermosillo, R.; and Torres-Martínez, L.M., 2008 [25] added 3.8% nano silica particles by mass of cement and reported 21.5% increase in split tensile strength of concrete at 28 days and 13% increase in compressive strength at 91 days. One remarkable observation they reported was that while the reference concrete showed no improvement of compressive strength beyond 28 days, the nano silica concrete increased its strength by 15% from 28 to 91 days. Sobolev, K.; Flores, I.; Torres-Martínez, L.M.; Valdez, P.L.; Zarazua, E.; and Cuellar, E.L., 2009 [26] have reported significant improvement in concrete having nanosilica is due to strength development, refinement of pore structure and densification of interfacial transition zone. They attributed all this to the large surface area of nanosilica particles. Nanosilica concrete has higher initial compressive strength at 3, 7 days and greater compressive strengths at 56 or 90 days when compared with controlled concrete. Nanosilica incorporated concrete has higher workability, and lower permeability. Moreover, higher tensile strength and segregation resistance are also achieved. This new concrete is named as Ultra High Strength Concrete. It was established that the nano-particles enhances strength and durability properties of concrete than microsilica. Many conclusions were made regarding the effect of nanosilica that made cement paste thicker and accelerated the cement hydration process. Compressive strengths of hardened cement paste increased with increasing the nano-SiO_2 content, especially at early ages. The pozzolanic activity of nano-SiO_2 is much superior to that of microsilica (Qing et al., 2007) [21]. Researchers carried out an experimental investigation to study the effect of nanosilica on rheology and fresh properties of cement pastes and mortars. It was observed that nano-SiO_2 modified the characteristics of fresh mortars. The cement mortar made with nanosilica showed the decrease in consistency and initial and final setting times. The addition of nanosilica reduced the spread diameter on the flow table of mortars due to the gain in cohesiveness of the paste (Vempada et al., 2018) [14]. It was found that the cement could be advantageously replaced by nano-SiO_2 up to maximum limit of 2.0% with average particle sizes of 15 and 80 nm. Although the optimal replacement level of nanosilica particles for 15 and 80 nm size were gained at 1.0% and 1.5%, respectively (Givi et al., 2010) [9]. The addition of nanosilica to cementitious mixes produced a remarkable reduction of the mix workability (Berra et al., 2012) [4]. It was established that nano-SiO_2 appeared to affect the mechanical properties and the structure of high-strength cement pastes even in low concentration. Cement paste workability resulted to be significantly lower than expected for the adopted water/binder ratios, as a consequence of instantaneous interactions between nanosilica sol and the liquid phase of cement pastes, which evidenced the formation of gels characterized by significant water retention capacity. The resulting reduction of the mix workability was avoided by suitable addition procedures of super plasticizers. The incorporation of 2% nS by mass of cementitious materials reduced initial and final setting times by 90 and 100 min, and increased 3 and 7 day compressive strengths of high-volume fly ash concrete by 30% and 25%, respectively, in comparison to the reference concrete with 50% fly ash (Surenra P. Shah, et al. 2010) [28]. The effect of micro and nanosilica under various dosages of PCE based superplasticizer on the rheological properties of grouts in the fresh state was determined. Data mentioned that the maximum strength in nS-system was reached at 1.0 wt % by weight of powder, whereas in mS-systems, it was at a level of replacement in the order of 15 wt%. Thus, it was found that in most of the cases, addition of nanosilica and silica fume together enhanced the compressive strength with optimized percentages as shown in Table 1.

TABLE 1: COMPRESSIVE STRENGTHS OF M20 GRADE CONCRETE CONTAINING NANOSILICA AND MICRO-SILICA

(V Srinivasa Reddy, M V Seshagiri Rao and K J Kumar, 2018) [14]

Compressive Strength (MPa)			
Type of Concrete Specimen	**7 days**	**28 days**	**90 days**
M20	17.3	25.9	27.3
M20MS5	22.7	35.7	36.7
M20MS10	24.1	38.1	40.5
M20MS15	25.0	39.0	40.9
M20NS0.3	40.1	54.1	62.3
M20NS0.5	45.3	62.1	72.3
M20NS1.0	49.9	68.9	73.9
M20NS1.5	50.8	70.2	75.6

The SCC with colloidal nanosilica presented a denser paste matrix and a better aggregates ITZ than the SCC without nano-silica. In addition, a refined microstructure was obtained (no Ettringite needles were found or identified). These refined were translated in better mechanical and durability properties of the SCC tested (Vempada et al. 2018) [14]. Senffa L., Hotza D., Lucas S., Ferreira V.M., Labrincha J.A. (2012) [24] studied the size effect of nano SiO_2 particles of size 15nm and 80nm by replacement with 0.5, 1, 1.5 & 2% by weight of cement and results showed that at 1.5% gets maximum compressive strength and there after it decreases. Vempada et al. 2018 [14] studied the effect of Nano SiO_2 particles along with 3% replacement of nano particles and 45% replacement of cement by GGBFS shows improved split tensile strength. The pore structure of SCC containing SiO_2 particles is improved with reduced mega pores and macro pores. Thermo gravimetric analysis shows that SiO_2 nano particles could increase the weight loss of specimen when partially added to cement paste up to 3%. Similarly more rapid formation of hydrated products confirmed by XRD analysis. M. Collepardi et al. (2004) [6] studied the ternary combination of silica fume, fly ash and ultrafine amorphous colloidal silica (UFACS and concluded that steam cured concrete containing silica fume (SF) and fly ash (FA) alone are much stronger than normal concrete (NC) cured at room temperature at early age where as compressive strength at 28-90 days of steam cured concrete is less than NC cured at room temperature. So author advised to use SF, FA and UFACS for the manufacturing of precast unit. Vempada et al. 2018 [14] compared the effect of two types of nanosilica, i.e. powdered and colloidal on mechanical properties of concrete. They found that powdered nS is effective in order to improve the mechanical properties of cement mortar. They also mentioned that compressive strength and gel/space ratio of hardened mortar with powdered nanosilica were better compared to colloidal nanosilica. They further indicated that the powdered nS acted as a filler to develop cement microstructure, which results in a denser morphology.

Vempada et al. 2018 [14] examined the influence of adding two kinds of nanosilica, i.e. fumed powder silica and precipitated silica in colloidal suspension on mechanical properties and water permeability of concrete. They found that the compressive and split tensile strengths of the concretes increased by using the above mentioned types of nanosilica. They also reported that the maximum compressive strength was achieved by adding the colloidal nanosilica while the maximum split tensile strength was obtained by addition of powdered nanosilica.

The addition of micro and nano silica particles to cement paste could effectively reduce the degradation rate as well as its negative consequences. Even small additions (0.5 wt. % binder) of these particles are very efficient in terms of improvement in mechanical properties of cement based materials. This is especially pronounced at early ages and for concretes with regular strength grade. Therefore, application of mS and nS could be a successful method for improvement of low strengths of cement based materials. With the experimental analysis, it was proved that the compressive and flexural strengths of the cement mortars with nanosilica were both higher than that of the plain cement mortar with the same water to binder ratio (Li et al., 2004) [7][16][17][18]. When mortars with nS and mS are produced using low water content, the resulting material has inadequate workability for most applications. In this case, adding extra amount of water has to be done, but the benefits of mineral additions on the hardened state properties would be minimized. The use of plasticizers and super plasticizers (SP) is always desirable to improve the rheological properties without the need for addition of extra water (Qing et al., 2007) [21].

VI. EFFECT OF NANOSILICA ON DURABILITY PROPERTIES

The water absorption, capillary absorption and distribution of chloride ion tests indicated that the nanosilica concrete has better permeability resistance than the normal concretes. The test results indicated that the addition of nano-particles refines the pore structure of concrete and enhances the resistance to chloride penetration of concrete. The nS addition decreased the apparent density and increased the air content in the mortars. It was investigated that the addition of super plasticizers in 1% by weight of cement reduced the water demand and the strength increase varied from 30% to 35% (Stefanidou and Papayianni 2012) [27]. Ji (2005) [11] studied that the water permeability tests showed that nS-concrete has better water resistant permeability than control sample, and microstructure of the nS revealed that the uniform and more compaction of nS in concrete. Similar kind of study was carried out by Ye Qing et al. [21], but with comparison of mS and with influence of NS, they found that the setting times and consistency for mS and nS incorporated concrete were different. Nanosilica makes the cement paste thicker and accelerated cement hydration. Compare to mS concrete, nS showed improved compressive strength and bond strength too. Calorimetric investigations for the heat of hydration values depicted that the amount of CH formed by the addition of nS could increase the amount of heat evolved during setting and hardening of the cement. The reduced calcium leaching behaviour of cement paste by the addition of nS were reported by Qing Y., Zenan Z., Deyu K., Rongshen C. (2007) [21] and revealed that the calcium leaching was a degradation process that consisted in the progressive dissolution of the cement paste as a consequence of the migration of Ca^{2+} ions to the aggressive solution. Nanosilica particles modified the cement paste in three different ways viz. reduced porosity; transforming Portlandite (CH) into C-S-H gel by means of pozzolanic reaction; and modified the internal structure of the C-S-H gel increasing the average chain length of the silicate chains. According to Sololev et al.[25], the role of nano particles of silica act as fillers in the voids or empty spaces. The well dispersed nS act as a nucleation or crystallization centers of the hydrated products, thereby increasing the hydration rate, that is, nS assisted towards the formation of smaller size CH crystals and homogeneous clusters of C-S-H composition. Moreover, they found that nS improved the structure of the transition zone between aggregates and paste. The drawback in using nS in concrete is self - desiccation due to increased surface area and it will lead to autogenous shrinkage at high concentration and thereby produces cracks in concrete. However, it can be controlled by carefully adding super plasticizers and by appropriate curing methods. It was proved that cement paste and mortar with nS addition requires more water in order to keep the workability of mixtures constant, and it was concluded that nS shows stronger tendency for adsorption of ionic species in aqueous medium and the formation of agglomerates was also as expected. Moreover, it is important to note that it was necessary to use a dispersing additive or plasticizer to reduce the agglomeration effect. From the pore analysis study, it was reported that the relative permeability and pore sizes of concrete were decreased.

B. Wangjo, C. Kim and J. Lim [1] reported that the large capillary porosity decreased and medium porosity increased in the slag cement pastes at 28 days. However, the incorporation of 2% nS by mass of cementitious materials densify the pastes-aggregates interface compared with slag concrete without nS addition. Further reduction of size of nS appeared to be more effective in increasing the rate of cement hydration and reaction compared with mS. Similar action of chloride permeability of the NS with slag and fly ash concrete were reported compared with control concrete. Another interesting study was reported by Mastafa Jalal et al. about the mechanical, rheological, durability and micro structural properties of high performance self-compacting concrete [HPSCC] containing silica of micro and nano size (blended nS and mS). They described that the enhancement of strength was not only because of pore filling effect, but also by the accelerated cement hydration due to their higher reactivity of nS. According to SEM microstructure studies, more refined microstructure and smaller pores were achieved by the addition of nS and mS, which can led to enhancement of mechanical, durability and micro structural properties of HPSCC. The effect of colloidal nS [CNS] on the cement hydration process in comparison with mS, as well as its influence on the gel structure and nano scale mechanical properties of cement paste were studied by Hou et al. and showed that the pozzolanic activity of colloidal nS (instead of nS powder) was higher than that of mS and its hydration acceleration effect was also higher than mS in the early age, but this effect was comparable to that of mS in the later stage. Kontoleontos et al. studied the influence of CNS on ultrafine cement hydration in terms of physiochemical and micro-structural characterization. CNS behaved not only as a filler to improve cement micro-structure (decrement in porosity), but also a promoter of pozzolanic reaction by transforming CH in to C-S-H gel. At the same time, the setting time and workability decreased, because of rapid agglomeration of the slurry from the suspending state. Also nS improved the packing of particles, which contributes to the growth of paste viscosity and was proved as an agent that improved the micro-structure of the ultrafine cement pastes and showed the cement with NS presented a denser microstructure. The pore size refinement at later ages, as a result of pozzolanic reaction, also led to a significant enhancement of the durability properties.

Mercury Intrusion Porosimetry results proves that the porosity and threshold pore diameter was significantly reduced for mixture containing nanosilica. The Rapid chloride penetration test shows that passing charges and physical penetration depth significantly improved. Ji et al. [11] studied the effect of Nano-SiO_2 particle size on water absorption of rice husk ash blended concrete, it is concluded that cement could replace up to 20% by RHA in presence of Nano-SiO_2 particle up to 2% which improves physical and mechanical properties of concrete. Ali Ji et al. [11] studied the effect of replacement of cement by ground ceramic powder from 10 to 40% b.w.c. and nano-SiO_2 from 0.5 to 1% replacement result shows that there is dramatic decrease in water absorption capacity and increase in compressive strength when 20% replacement is done with ground ceramic powder with 0.5 to 1% as the optimum dose of Nano-SiO_2 particles. The highest electrical resistivity of concrete was observed at 7.5% micro silica and 1.5 % nano silica. The capillary absorption rate is lowest at 3% micro silica and 1.5% nano silica.

VII. LIMITATIONS ON THE USE OF NANOSILICA

Apart from benefits, there are certain serious risks associated with the exposure to nano particles. Nano particles are very fine in size; hence they are highly airborne and waterborne. The drawback in using nS in concrete is self - desiccation due to increased surface area and it will lead to autogenous shrinkage at high concentration and thereby produces cracks in concrete. However, it can be controlled by carefully adding super plasticizers and by appropriate curing methods. Nanosilica is expensive and costs about 100 rupees per kg. If nanosilica is used in colloidal form (suspension form), suitable water corrections are to be made in the mix proportions.

VIII. CONCLUSIONS

The role and application of the nano and micro silica particles with cementitious materials have been reviewed and discussed in detail. There is a limited knowledge about the mechanisms by which nano silica and micro silica affects the flow properties of cementitious mixes. In India, the research work on use of nano silica is still in elementary stage. Thus, a need arises to study extensively the various properties of paste, mortar, and concrete containing various percentages of nano silica, micro silica alone as partial replacement of cement and then studying their combined percentage effects. As the properties of nanosilica and micro-silica reported in literatures relate with those manufactured or exported from abroad, there is urgent need to study the effect of these materials (manufactured in India) on various properties of cement paste, mortar and concrete. Taking advantage of nanostructure and microstructure characterization tools and the optimal use of micro-silica and nanosilica can be determined to create a new concrete mixture that will result in long lasting concrete structures in the future. Considerable improvement in the properties of nanosilica based concrete such as strength properties, water and chloride permeability, pore filling effects, reduction of CH leaching, rheological behaviour of cement pastes, heat of hydration, micro structure analysis, the pozzolanic activity, workability were reported by researchers. As a whole, the entire review showed the ultimatum in using the nano technology in general and nano silica in particular.

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