EFFECTS OF SILICA FUMES (MICRO SILICA OR NANO SILICA) ON MECHANICAL PROPERTIES OF CONCRETE: A REVIEW

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ABSTRACT

In the present era very vast development occurred in the field of construction specially in concrete technology. Concrete is the most versatile material due to its continuous demand. Many researchers and scientists have been developed a no. of techniques to improve the parameters of concrete i.e. strength & durability. Engineers are continuously pushing the limits to improve the performance with the help of supplementary cementitious material like blast furnace slag, Flyash, steel slag, silica fume etc. The present research work focused on one of such product i.e. silica fume. Silica fume is an amorphous (non crystalline) polymorph of silicon oxide. It has its forms also i.e. micro silica (MS) and nano silica (NS). It is ultrafine powder with an average particle size of 0.1 to 0.5 μ. Silica fume is pozzolanic material and is available in different forms. The past investigations revealed that silica fume is an excellent pozzolanic material in producing high performance concrete (HPC). In this review paper we will study the effect of MS and NS in the concrete properties with their different different percentages in the different grades of concrete.

Nano technology is most promising area of science. It is revolution in construction industry. Different nano materials like nano silica, nano titanium oxide, carbon nano tube etc. are now a days used by the engineers in construction work. Nano silica and micro silica particles sizes are very very small so they can fill the pores or small spaces of concrete easily and effectively. Thus there is a scope for cracks free concrete towards the crack free sustainable construction. So here in the article we will discuss about the silica fume and its forms i.e. micro silica and nano silica and their effects on the properties of the concrete. It is found from the previous studies that the combine use of the pozzolan i.e. MS & NS can produce superior properties.

Key words: Concrete, Silica Fume (silicon oxide fume), Nano Silica (NS), Micro Silica (MS), compressive strength, Flexural Strength, Split Tensile Strength, Pozzolan & High Performance Concrete (HPC), TEM (Transmission Electron Microscopy Analysis).
1. INTRODUCTION
Concrete is highly heterogeneous material of the housing industry or construction industry. It is a combination of cement, sand, aggregate & water in specified proportion. Reaction of these materials with the help of water forms the hard mass called concrete. Because of its immense demand, it is most generally used for the construction in the world. Materials employed in forming the concrete are not renewable. They are available in the nature with in limited quantity. Over use of these material can cause the scarcity. In order to avoid the wasting of natural ores & reach additional strength it is important to seek out new supplementary building materials. So this can be rationale why in recent years researchers have targeted on development of concrete properties by adding alternative byproducts like silica fume (micro silica, nano silica), flyash, blast furnace slag with in construction. These materials are pozzolanic and have cementitious properties and conjointly a byproduct i.e. supplementary material. Here we are discussing only one supplementary material that is silica fume. Silica fume is byproduct of silicon and ferrosilicon. Chemically silica fume composed of SiO2, Al2O3, Fe2O3, MgO, Na2O, K2O, So3. Specifications of silica fume acc. to IS-15388 (2003) is given in table (1, 2, 3).

2.1. Indian standard Silica Fume – Specifications according to IS -15388 (2003)

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Silica fume helps to improve concrete by two effects i.e. pozzolan effect and micro filler effect. Now a days new technology has been introduced in concrete application. One in every of the foremost used nano material is nano silica (NS). This product has replaced the use of micro silica (MS). The advancement created by the study of concrete with nano silica at broad scale has proved that nano silica is far better than silica fume employed in standard concrete NS possess lot of pozzolanic nature, its capacity to react with the free lime throughout the hydration and forms C-S-H gel which supplies a strength, impermeability and sturdiness to concrete.
2. OBJECTIVE

My objective to study about silica fume is to know about the silica fume’s properties & its effects on concrete with its varying percentage. In my project I am using silica fume to treat chemically inert plastic surface (PET) fibers and then putting this treated plastic in concrete to improve concrete properties. So before using silica fume I am studying about it. Some researches have been done on it previously. But the coating of silica fume or other pozzolanic material like metakaolin, fly ash, slag etc. on fibers is not so vast yet . In this area we needed to work more to improve the concrete properties upto very high level.

3. LITERATURE REVIEW

To find the alternative supplementary material for construction with cementitious properties a lot of researches done by the researchers. Some of them are give below in the literature.

(Verma Ajay et al. 2012) in this analysis they studied the result of micro silica (MS) and the strength of concrete with normal Portland cement. They ascertained that silica fume will increase the strength of concrete and reduces the capillary pores. (Ji Tao, 2005) the study was additionally done on the water porosity resistant behavior and micro structure of concrete with Nano silica (NS) and ascertained that NS concrete includes a higher resistance permeability than normal concrete. (Sanchez F. and Sobolev K. 2010) recently nano technology is getting used or thought of to be used in several application and it’s received increasing attention in building material, with potential benefits and downsides being underlined. (Sololev K. 2009) the role of nano silica fume (SF) is to act as filler in void or empty areas. (Lin D.F. et al. 2008) they describe the advance in compressive strength on sludge / flyash mortar among the presence of nano silica (NS). (Li G. 2004) demonstrated the result of addition of nano silica in an exceedingly fly Ash concrete. The results obtained and compared reported that the pozzolanic activity of flyash primarily based concrete with nano silica (NS) were hyperbolic significantly and located that decrements in porosity of concrete, gain high strength in early and latter stage.

(Nazari A. and Riahia S. 2011) it was investigated that the split tensile strength , thermal behavior and small structure of concrete containing completely different quantity of ground granulated furnace slag & silicon nano particles were bind in their investigation. (Mohammad Reza Zamani Abyaneh, et al.2013) It was found that the concrete manufactured with micro silica (MS) & nano silica (NS)shows higher degree of quality in their compressive (pressure resistance) strength than the ordinary concrete that solely have micro silica in their mixture . Specimen with 2% Nano silica and 10% micro silica had less water absorption and a lot of electric resistance. (Sadrmohtazi A., Barzegar A. 2010) It was terminated that properties of self compacting concrete with and without RHA (Rice Husk Ash), an Argo-industrial waste shows the improvement within the physical and mechanical property of concrete with addition of Nano silica. (Jo Byung-Wan el al. 2007) Studied the behavior of mortar with Nano silica particles and reported the importance of addition of Nano silica (NS) on mechanical properties. (Ha-Won Song et al. 2010) micro filler effect of silica fume greatly reduces the porosity and improves paste to mixture bond in silica fume concrete compared to traditional concrete. (Abdullah A. Almusallam et al. 2004) silica fume (SF) reacts chop-chop providing high early strength & sturdiness. The potency of silica fume is 3-5 times that of OPC and may be improved drastically. (Mastafa Jalal et al. 2012) An alternative study was reported for mechanical, rheological, durability and Microstructure properties of high performance self compacting concrete(HPSCC) containing silica of micro & nano size with mixed NS & SF. (Min-Hong Zhang et al. 2012) it found that corporation of NS by concerning 2% weight of cement with 50% GGBS cement mixture not only altered the setting time however conjointly hyperbolic the compressive strength by concerning 22% and 18% for 3rd and 7th days respectively compared to the reference slag concrete. (Shreeti S. Mavinkurve et al. 2003) found that the addition of some supplemenrty mineral admixtures in cement has dramatically increased on the event of concrete business due to the thought of price saving ,energy saving and environmental protection .However environmental concern with each i.e. the damage caused by the extraction of raw material, emission throughout cement producing. This has brought pressure to scale back the use of cement and use alternative supplementary material. (Stefanidou M., Papayanni I.
2012) Studied the influence of Nano silica (NS) with totally different dosages and reported that the addition of NS tends to primarily increase the mechanical response and caused 20-25% strength improvement. At identical time with the addition of super plasticiser in 1% w/w of cement reduced the water demand and strength will increase varied from 30% to 35%. (Kontoleontos F. et al. 2012) studied the influence of (NS) nano silica on ultrafine cement participation in terms of physiochemicals and microstructure characterization. Here NS behaves not solely as a filler to enhance microstructure i.e. less porosity. however conjointly a promoter of pozzolanic reaction by transferring CH into C-S-H Gel. (Feldman R.F., Sereda P.J. 1968) Their study indicated that the cement paste flow will increase as a water is removed till a degree , at that the flow decreases. now is indication of a attainable collapse within the nanostructure of hydration product and C-S-H. (Rui zhong & kay wille, 2015) Dealt with the SF and immoderate fine silicon oxide powder to enhance the ultra high performance pervious concrete matrix. to attain the goal of an immoderate high performance cement with compressive strength in way over 150 Mpa. (Jing yang, guoliang jiang 2012) Investigated the results of smaller sized aggregates, silicon oxide fume and super plasticizers to extend the concrete strength greatly. based on results, they ended that with the utilization of smaller sized aggregates it helps to enhance the significance strength of pervious concrete. SF and SP conjointly increased the strength of pervious concrete. (V.T. Giner et al. 2011) Studied the influence of SF addition within the quantities starting from 0-15% of cement mass on the dynamic and and static mechanical properties of concrete. The results well-tried that silicon oxide fume addition or replacement scale back each the dynamic modulus of elasticity and damping magnitude relation of concrete.

Silicon dioxide nano particles are also known as nano silica. These particles are the base for biomedical research due to the particles stability, low toxicity and ability to work with a range of molecules & polymers. Nano silica particles are categorized in P & S structures. Fig. 1,2,3 shows the TEM images of Nano silica.

4. TEM IMAGES OF NANO SILICA
(Sololev K. 2009) acc. To him the role of nano silica particle is to act as micro filler within the voids of empty area. what is more they found that nano silicon oxide will improve the crack resistance properties. (Yazdi A.D. et al. 2009) investigated the impact of nano oxide fume (SF) on fly ash concrete (HFC) and reported that to the low pozzolanic reaction of flyash ,early strength of HPC reduced considerably, however the addition of nano silicon oxide promotes the pozzolanic activity reaction that modify the enhancement of strength of HPC. Particularly in early ages. (R.Siddique and M. Iqbal Khan 2011) The addition of silicon oxide fume to concrete improves the durability of concrete through the reduction in permeableness , refined pore structure , resulting in a discount within the diffusion of harmful ions, reduces
calcium hydrate contents which ends up in higher resistance to salt attack, improvement in sturdiness also will improve the power of silica fume concrete in protecting the embedded steel from corrosion. (Aitcin, P.C. et al. 1990) Acc. To them silicon oxide fume have three mechanisms specifically (i) Strength sweetening by pore size refinement and mortar concentration. (ii) Strength sweetening by reduction in content of CH and (iii) strength sweetening by cement paste-aggregate surface refinement are believed to be accountable for the strength development of concrete and mortar containing silicon oxide fume. (Bhanja, S. and Sengupta, B. 2002) Silica fume concrete is extremely susceptible to temperature variations throughout the hardening process. The optimum silica fume content to attain higher strength looks to vary b/t 15% & 20%. (Alsana Bashir et al. 2014) HPC with silicon oxide fume at a continuing water binder magnitude relation (w/b)of 0.34 and replacement share of 0-25 %, with variable dosages of HRWRA will increase the compressive strength, the optimum share was obtained at 15% replacement level. (Wiesner et al. 2007) Nano particles have high extent to volume magnitude relation. During this method nano particles with 4nm dia. Have over 50 % of its atoms at the surface and are therefore terribly reactive. (Senff et al. 2010) They find out once the upper surface area is to be wetted, it decreases the free dispersant water in binary compound system obtainable within the mixture. therefore the utilization of nano particles in mortar and concrete considerably modify their behavior not solely in contemporary, however conjointly in hardened condition, because the fresh, mechanical and micro structural development. (Hou et al. 2013; Mondal, P. et al. 2010) From the nano identification studies, it absolutely was observed that the nano silicon oxide addition considerably alters the proportion of low stiffness and high stiffness C-S-H. (Gaitero et al. 2008; Porro et al. 2005) The addition of nano silica changed the consistency of paste of cement and increased the typical chain length of silicate chain. (Senff et al. 2009; Ltifi et al. 2011; Qing et al. 2007) Reduction within the initial setting time (IST) & final setting time (FST) of paste was determined on addition of Nano silicon oxide. conjointly difference b/t the IST & FST decrease with the rise in nano silica content. (Lea 1998; Li et al. 2004; Neville 1996) In the recent years the employment of nano particles has received explicit attention in several fields of applications to fabricate material with new functionalities. once the immoderate fine particles are incorporated in to Portland cement paste, mortar or concrete, material with totally different characteristics from conventional material were obtained. (Björnström et al. 2004; Lea, O. I. 1998; Qing, Y. et al. 2007) These previous papers indicates that the inclusion of nano particles modifies contemporary and hardened state properties, even when put next with conventional mineral additions. Colloidal particles of amorphous silicon oxide seems to significantly impact the process of C3S hydration.

5. MECHANICAL PROPERTIES
Various researchers have done their study on various forms of silica i.e. micro silica and nano silica. Some researchers used to add the silica in the construction material i.e. concrete. And some of them replace the some other material with silica fume. The effect of adding and replacing the silica on the mechanical properties of concrete as studied by various scientists and researchers are discussed in this section.

6. MECHANICAL PROPERTIES WITH MICRO SILICA
6.1. Compressive Strength (CS)
CS (Compressive strength) is the very valuable property on which the grading of concrete depends. It is very important to know the compressive strength of concrete before use even when the any other material is used to replace the concrete ingredients.
Effect of Adding of MS (Micro Silica) and Replacement of Cement  
(Shitole et al. 2014) It gives the brief information about how clearly silica fume affect the strength and durability of concrete. The various samples of M20 grade of concrete taken with water cement (w/c) ratio 0.5 with the addition of silica fume i.e. 0%, 7.5% & 10% of cement replacement. (Amudhavalli et al. 2012) Effect of silica fume with the replacement of cement on M35 by replacing the cement by silica fume by 0%, 5%, 10%, 20%. (Hussain et al. 2013) study the impact of partial replacement of cement by silica fume (MS). Studies have been conducted on concrete mixes for M40 grade at 0%, 5%, 7.5%, 10% & 15% replacement level of silica. (See fig. 4)

6.2. Flexural strength
It is the ability of structural member to resist bending failure is called flexural strength. This strength of structure is checked by three Point loading or four point loading test.

Effect of Addition or Replacement of Micro Silica on Flexural Strength  
(Shitole et al. 2014) Addition of silica at 0, 7.5 & 10% level cause the increase in the flexural strength. At ratio 7.5 flexural strength was maximum. (Amudhavali et al. 2012) the replacement of cement binder with silica fume shows a incredible change in flexural strength. The highest increase in flexural strength is observed as 7.75 N/mm² & 9.38 N/mm² at 7 and 28 days with the replacement of 15%. (Hussain et al. 2014) replacement of binder with silica fume at 0, 5, 7.5, 10 & 15% for M40 & M50 grade of concrete shows the following results for flexural strength. The flexural strength with silica fume increases up to optimum level & then start decreasing. Maximum increase was at the replacement of 7.5%. (See Fig. 5).
6.3. Split Tensile strength

Split tensile strength is mostly calculated to determine to understand the behavior of concrete under tension. It is difficult to measure the tensile strength directly because it is impossible to apply a truly axial load in direct tension. That’s why it is done by indirect methods.

Effect of Addition or Replacement of Micro Silica on Split Tensile Strength

(Tanveer Hussain et al. (2014)) With the replacement of SF or MS for M40 or M50 grade of concrete by 0%, 5%, 7.5%, 10% & 15% shows incredible change in the behavior of tensile strength of concrete. The tensile strength of concrete with silica fume at 7.5% after 28 days was maximum after that percentage it starts decreasing. (Amudhavalliel et al. (2012)) replacement of silica fume with 0, 5, 10, 15 & 20 percent for M35 grade of concrete shows awesome change in the tensile behavior of concrete. The maximum increase in the split tensile strength was observed at 10%. (See Fig. 6)
7. MECHANICAL PROPERTIES WITH NANO SILICA

7.1. Compressive Strength

(S. Tanveer Hussain et al. 2014) he found the strength of concrete with the varying percentage ratio of nano silica at 0, 1, 1.5, 2 & 2.5 percent (%) with the partial replacement of cement. They check the compressive strength at 28 days with M40 & M50 grade of concrete. The compressive strength of concrete continuous to increase up to 2% and after that decreases. (Satya Jit Parida 2015) studied the compressive strength of concrete with silica fume at 7 days and 28 days. The addition of silica fume was 0, 0.3, 0.6 & 1% for M25 grade of concrete. The compressive strength was maximum at 1% addition of NS In both 7 & 28 days. For 7th day at 1% it was 34.59 MPa & at 28th day it was 39.82 MPa. (M. Iyappan et al. 2014) studied the properties of HSSCC (High strength self compact concrete) with addition of NS after 7 & 28 days. The addition of nano silica is 0, 5 & 10%. The max. increase in compressive strength with nano silica was at 10% both on 7th And 28th days. On 7th day at 10% the strength was 38.7 MPa and 28th day it was 58.5 MPa. (See Fig. 7)

7.2. Flexural Strength

(S. Tanveer Hussain et al. 2014) flexural strength of concrete for grade M40 & M50 with NS after 28 days was recorded with the varying ratios of NS at 0, 1, 1.5, 2 & 2.5 percent. The flexural strength of concrete continuous to increase up to 2%. Flexural strength of M40 grade with 2% nano silica was 4.45 N/mm2 and for M50 with 2% was 4.71 N/mm2. (M. Iyappan et al. 2014) flexural strength of concrete with the replacement of cement with nano silica in varying %age of 0, 5 & 10% respectively. The max. strength was obtained with 10% addition of NS. After 7 day at 10% the strength was 6.9 MPa & AT 28th day it was 8.3 MPa. (See Fig. 8)

7.3. Split Tensile Strength

(S. Tanveer Hussain et al. 2014) the split tensile strength for M40 & M50 grade of concrete was observed max. at 2% replacement. Strength for M40 with 2% replacement the tensile strength was 3.960 N/mm2 & for M50 with 2% was 4.320 N/mm2. G. Quercia (2010) The use of nano silica makes concrete financially more attractive and reduces the carbon dioxide. Nano silica will also increase the product properties of concrete i.e. workability and properties in hardened state. That means the concrete with better

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performance, low cost and improved ecological footprint can be designed. Similarly various researches have been carried out by various researchers on silica and its type i.e. micro silica fume and nano silica fume. The range of silica fume varies from 0 to 20 percent (%) for micro silica (MS) and 0 to 5 percent for nano silica. All these studies show so many changes concrete properties and all were significant. (N.K.Amudhavalli et al. (2012); Verma Ajay el al. (2012); S. Tanveer Husain et al. (2012); Hasan Birick et al. (2014).

Figure 7 Compressive Strength with Nano Silica

Figure 8 Flexural Strength with Nano Silica

8. CONCLUSION

In this review paper no comparison is done on the strength of different – different grades of concrete with different %age of SF & NS. Here we have only studied the behavior of SF &NS with the concrete. From the literature review it can be concluded that the addition or replacement of silica fume with the cement can improve the mechanical properties of concrete. But the addition of SF in excess quantity can cause the degradation in the strength of concrete. So the SF can be added or replaced with calculated percentage. (Ghutke et al. 2014) with the increase in w/c ratio strength of concrete decreases. Optimum value of concrete can be achieved in 10% replacement of silica fume. Workability of concrete decreases with the increase in the percentage of silica fume. (Bashir el al. 2014) permeability in terms of water intrusion is
least for 15% of silica fume. With the increase in the silica fume content permeability decreases. At this content of silica fume workability if concrete remarkably reduced. So it is necessary to use superplasticizers. \textbf{(Victor Ajileye 2012)} cement replacement up to 10 percent (%) with silica fume leads to increase in compressive strength with M30 grade of concrete. The increase in compressive strength observed was 16.15 % to 29.24%. \textbf{(Shitole et al. 2014)} It can be concluded that 7.5% replacement of cement by micro silica can cause higher strength properties to normal concrete. Thus micro silica can be used to achieve the higher strength & it also helps to reduce air pollution.

9. FUTURE RESEARCHES SHOULD ADDRESS THE ISSUES ARE

1. Physical state and dispersion of nano silica into concrete is a major issue requiring through study.
2. The optimum equality of nano silica for the concrete and cement paste needs to be determine. A relationship needs to be established b/t optimum quality and characterization of nano silica.
3. Most of the researches are limited to the cement paste and mortar. Only a few researchers have worked on extensively on mechanical properties and permeability of concrete with nano silica.
4. Optimizational, microstructural, fresh & durability properties of concrete with mathematical modeling requires extensive research.
5. Silica fume itself is a very high reactive pozzolan. Some waste materials are not reactive i.e. plastic. So by treating the plastic surface with reactive silica fume by providing silica fume coating we can increase the concrete strength and reduce the waste. Plastic is a harmful waste and its useful life is very less and its life as a waste is very long . So by utilizing this waste in construction industry can help to reduce the waste and can protect the environment.

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