Behaviour of Reinforced Concrete Beam Containing Micro Silica and Nano Silica

Arunbalaji G[1], Nanthakumar N[2] and Suganya R[3],
[1]M.E Student, Structural Engineering, Dhirajlal Gandhi College of Technology, Salem, India.
[2]M.E Student, Structural Engineering, Dhirajlal Gandhi College of Technology, Salem, India.
[3] Asst. Professor, Department of Civil Engineering, Dhirajlal Gandhi College of Technology, Salem, India.

Abstract *- Silica fume is the one of the most popular pozzolana, whose addition to concrete mixtures results in lower porosity, permeability and bleeding. The aim of this study is to examine the mechanical properties of cement concrete with and without silica fume and Nano silica particles.*

The work focused on concrete mixes having a fixed water/binder ratio of 0.53. The percentages of silica fume that replaced cement in this research were: 10% and nano silica added were 0%, 0.5%, 1.0% and 1.5%. Development of mechanical strength indicates that replacement of 10 % micro silica and addition of 0.5% of nano silica as optimal proportion.

Keywords *– concrete compressive strength, flextural strength, water cement ratio line diagram*

I. INTRODUCTION

In our country the construction industry and the engineers have not taken advantages of research and scientific developments in concrete construction to its fullest extent due to lack of education and training facilities in concrete technology. Due to lack of knowledge and skill our engineers, supervisors and construction contractors have wrong notion that greater the quantity of cement in concrete better will be the quality and strength of concrete. For desired quality, strength and economy in concrete construction, it is necessary to study various aspects of concrete on scientific basis. India is a developing country and it has launched five year plans for multipurpose developments in Agriculture. Industry, Mining, Transport and Power etc., All these five year plans involve large construction of roads, bridges, dams, industries, dock and harbors, power houses, nuclear power plants, aerodromes, irrigation schemes, public health engineering schemes, educational buildings and public structures, residential building schemes and other public structures. All these constructions/ schemes demand optimum and efficient use of construction resources. Most of modern heavy constructions require huge quantity of cement concrete. Thus for efficient and optimum use of construction resources, it is most important to study properties and behavior of cement concrete. Proper knowledge and skill of cement concrete shall lead to lot of economy and quality in construction.

Cement concrete can be produced for very high strength (as high as 60 N/mm2 with ordinary Portland cement); different kinds of cement replacement materials are usually added to them to achieve low porosity and permeability. Silica fume is the one of the most popular pozzolana, whose addition to concrete mixtures results in lower porosity, permeability and bleeding.

II. NANOTECHNOLOGY

A common misconstrued belief is that nanotechnology is science fiction and not a realistic application in the present time. This idea, however, could not be more false. In the last 15 years, over twelve Nobel prizes have been awarded in nanotechnology. Working with technology at such a miniscule scale allows scientists to significantly improve physical, chemical, and biological properties.

Activity at the nano-scale may not be as predictable as those of a larger one. Nanotechnology can provide an unparalleled understanding about the inner workings of objects, and can positively impact many fields. For example, switching devices and functional units at the nano-scale can exponentially increase computer storage. New biological sensors can detect cancer at a much early stage.

Nanotechnology is especially relevant in the field of civil engineering. With the power of nanotechnology, steel cables and joints can be strengthened. Coatings and paints can be given insulating properties. The main way this science is being utilized in civil engineering is through the improvement of materials such as glass, steel, and lastly, concrete. There are various ways to incorporate nanotechnology into concrete that will greatly improve its desirable properties, such as durability, strength, ductility, and cleanliness.

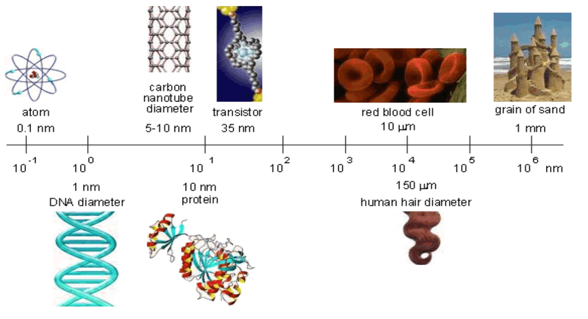


Fig.1 Size Comparison Nano Scale

III.MATERIALS USED

A. Cement

Cement is most important ingredient and acts as a binding material (having adhesive and cohesive properties). Cement is obtained by pulversing clinker formed by calcining raw materials primarily comprising of lime (CaO), silica (SiO2), Alumina (Al2O3), and ferric Oxide (Fe2O3) along with some minor oxides.

The Portland cements comprise of four principal compounds such as tricalcium silicate (3CaO, SiO2, dicalcium silicate 2CaO, SiO2), tricalcium aluminate (3CaO), and tetra calcium alumino ferrite (4CaO, Al2O3), and tetra calcium alumino ferrite (4CaO, Al2O3). The composition of these principal compounds is affected by the proportions of basic raw material oxides. The actual proportions of these principal compounds affect the behavior of cement and accordingly form the basis of classifying Portland cement into different types. These different types of Portland cements are suitable under different conditions and requirements of a structure.

B. Fine Aggregate

Sand is an inert occurring material of size less than 4.75 mm. It is used as a material of construction not only as filling and as a porous foundation blanket (as for roads) but also to a wide extent as a filtering medium and as constituent of mortars and concrete. In view of these important applications sand is described as naturally granular material of a certain grain size irrespective of the shape of the grains, thus, uniformity and their mineral composition. The formation of sand during the process of rock weathering and the way in which they are transported before reaching the final position affect all of these leading characteristics. The mineralogical nature of sand is important, especially in view of the popular belief that all sands are composed of quartz particles. Although quartz is frequently major constituent, pure silica sand is the exception rather than the rule. Depending on the nature of rock from which it was found and on the erosive action to which it has been subjected, many other minerals may be found as constituents, mica feldspars, shale are a few of them. Presence of feldspars an unstable mineral cause’s development of hair cracks in concrete. Similarly shale particles and soluble salts are injurious to concrete if present.

C. Coarse Aggregate

As explained fine aggregate used for concrete production is classified as fine aggregate and coarse aggregate depending on its particle size. Aggregate of size more than 4.75 mm, is called as coarse aggregate and is one of the most important ingredient of concrete. It gives strength to the concrete and constitutes about 70 to 75 percent volume of concrete. Crushed stone in general used as coarse aggregate which is black in colour, angular and in local name known as black metal.

Coarse aggregate are generally derived by crushing natural rocks available. There are three varieties of rocks available. These are Igneous rocks are fine grained, strong and dense, formed by the cooling of parts of the bodies of molten material which is called, in general Basalt are more common igneous rocks. Aggregate developed by crushing of these rocks are black in colour and very common: used much for concrete work, also known as black trap. Sedimentary rocks also called derivative rocks were deposited in some geological age mechanically through the agency of water, wind or ice action chemically or organically. .

D. Water

Although water is an important constituent of concrete, but it does not receive due attention in preparation and quality control of concrete. Strength and other properties of concrete are developed as a result of reaction of cement and water (hydration) and thus water plays a critical role. Quality of mixing and curing water sometimes leads to distress and disintegration of concrete reducing the useful life of the concrete structure. Water used for concrete mixture should not contain substances which can have harmful effect of strength (i.e., on hydration process of cement) or durability of the concrete in service. Certain substances if present, in mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, organic matter, sewage, and other substances which are deleterious to concrete or steel reinforcement..

Portland water is generally considered satisfactory for mixing and curing of concrete, in case of doubt, water should be tested for its suitability. The details of various tests (Physical and Chemical) for water used in concrete are given in IS: 3025 - 1964. Permissible limits of impurities in mixing water are specified in IS: 456 – 1978 and is given in table.

E. Micro Silica or Silica Fume

Silica fume (SF) is a by-product of the manufacture of silicon metal and Ferro-silicon alloy. The process involves the reduction of high purity quartz (SiO2) in electric arc furnaces at temperatures in excess of 2000°C. SF is a very fine powder consisting mainly of spherical particles or microspheres of mean diameter about 0.15 microns, with a very high specific surface area (15,000–25,000 m2/kg). Each microsphere is on average 100 times smaller than an average cement grain. At a typical dosage of 10% by mass of cement, there will be 50,000–100,000 SF particles per cement grain.

SF functions in a concrete as a highly efficient pozzolan, that is, it reacts chemically with the calcium hydroxide produced by the hydration of the Portland cement to form calcium silicate hydrates (C-S-H) which bind the concrete together. SF is highly reactive due to the high proportion of non-crystalline SiO2 and the large surface area. In bulk, SF is generally dark grey to black or off-white in colour and can be supplied as a densified powder or slurry depending on the application and the available handling facilities. SF is available globally.

Fig 2: Micro Silica

F. Nano Silica

Nano Silica has the ability to drastically improve the properties of concrete is nano sized silicon dioxide, known as nano-silica. When utilized correctly, this nano particle can block water penetration, help to make the concrete more dense, and also reduce the impact concrete has on the environment. To explain the usefulness of nano-silica, we need to go back to the basics of what composes concrete. A common misconception is that concrete and cement are two interchangeable words for the same exact material. However, this is not the case. Cement is a construction material made from limestone, calcium, silicon, and a few other ingredients. Concrete on the other hand is a material that uses cement to bind together crushed stone, rock, and sand. In fact, it is the cement content in concrete that causes the harmful carbon dioxide emissions. It is an engineer's duty to protect the environment, so this problem must be given some attention. One of the ways to reduce amount of cement in concrete is the use of nano-silica. This nano particle can be produced in multiple ways, such as through the vaporization of silica and a precipitation method. In a process known as the sol-gel process, Na2SiO4 is added in a solvent. The pH of the solution is changed until the precipitation of silica gel is reached. Lastly, the gel is dried and burned to produce a concentrated substance suitable for use in concrete. Once the nano-silica is added to the concrete mixture, it reacts with calcium hydroxide (CH) to form calcium silica hydrate (CSH), which is the strength carrying structure of the concrete. The nano-silica can also fill the voids in the concrete mixtures, which will in turn increase the final density of the material. Nano Silica filling in the holes of concrete is important because "cement pores are a route for salt and other chemicals to enter concrete and break it down." Not only can nano-silica strengthen the concrete and make it denser, but also positively affect its water permeability. In a recent test, nano-silica particles ranging from 10 to 20 nanometers were added to concrete mixes and evaluated. The results show that these particles can block water from penetration the surface by reacting with Ca(OH)2 crystals and reducing their size, making the surface of the material much denser.

Fig 3: Nano Silica

IV.SCOPE OF WORK

The following are the scope of work, Make a concrete with reduced cement content by replacing MS & added NS and with superior mechanical properties than normal concrete. Identify the best proportion to obtain high mechanical strength. Identify the SP content required to have a good workability when MS & NS are used. To compare the corrosion properties and its behaviour of Normal concrete and Nano Silica containing concrete. To study about flexural behaviour bond strength and of Normal and Nano Silica added concrete.

V. METHODOLOGY

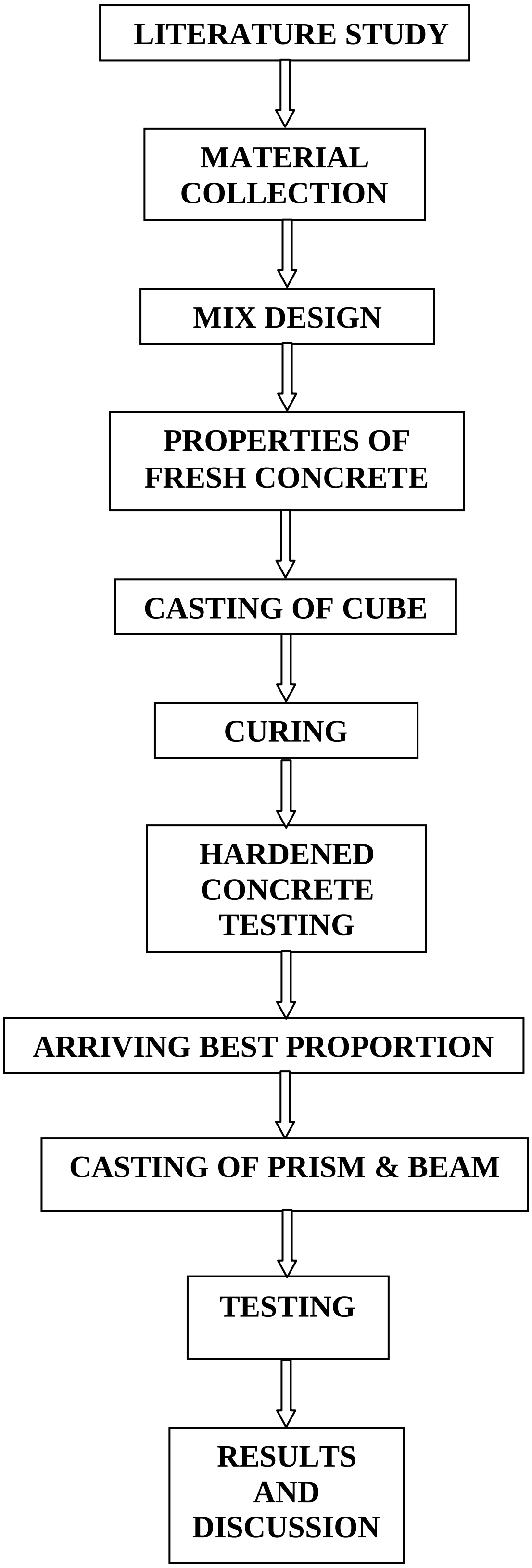


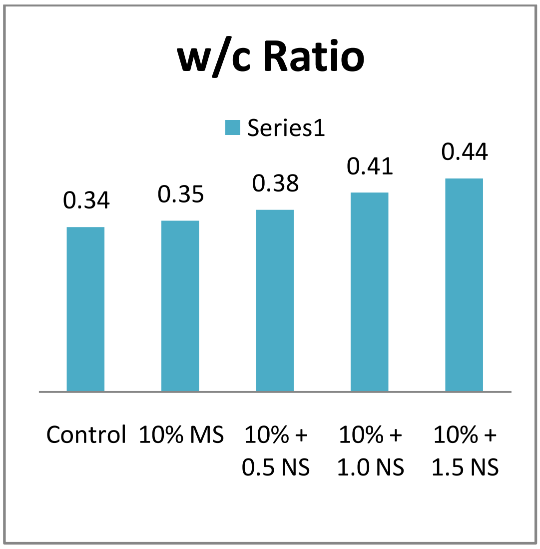
Fig 4: Flow Chart

VI. RESULTS AND CONCLUSION

CONSISTENCY

Mix	W/C ratio
Control (100 % OPC)	0.34
90 % OPC + 10% MS	0.35
90 % OPC + 10% MS + 0.5 % NS	0.38
90 % OPC + 10% MS + 1.0 % NS	0.41
90 % OPC + 10% MS + 1.5 % NS	0.44

Table 1: Consistency



Graph 1: Water Cement Ratio

The water demand increases with increase in Micro Silica and Nano Silica content. This happens because both are having higher specific surface area compared to cement, so that water demand increases. The standard consistency of pure cement paste was found out to be 0.34; while at 10% SF, it was 0.35. It is seen that from results, when Nano Silica content increased for 0.5 %, 1.0 % and 1.5 % NS, the consistency also increased as 0.38, 0.41, 0.44 respectively.

Concrete containing MS and NS leads to lower workability. Such effect can result in higher water demand to maintain a constant slump. Hence super plasticizers should be dosage by weight of cement in order to keep water demand and good workability. The physical properties of micro-silica and nano silica are known to reduce workability mainly due to small particle size that leads to higher water demand. The workability of concrete mix containing mineral admixture is considerably
improved by using chemical admixture. The above table shows SP requirement with various mix proportions. The SP quantity increased with increasing amount of Nano silica. Nano silica percentages as 0.5%, 1.0% and 1.5%, the SP quantity is 0.80%, 1.50% and 2.0% respectively by weight of cement.
The test was carried out conforming to IS 516 to obtain compressive strength of M20 grade of concrete. The specimens are prepared at a constant W/C ratio as 0.53 and required super plasticizer quantity. The compressive strength of concrete with Micro silica and Nano Silica concrete at the age of 7, 14 and 28 days are presented in above table. There is a significant improvement in the strength of concrete because of the high pozzolanic reaction of the mineral admixtures (Micro silica and Nano Silica). This was due to the reaction of Micro silica with calcium hydroxide formed during the hydration of cement that caused the formation of calcium silicate hydrate (C–S–H). It was also due to the filler role of very fine particles of silica fume. The compressive strength of the mix M20 at 7, 14 and 28 days in below chart.

replacement of cement by micro silica and addition of Nano Silica was increased gradually up to an optimum replacement level of 90% OPC + 10% MS + 0.5% NS and then decreased. The maximum 7, 14 and 28 days cube compressive strength of M20 grade with 90% OPC + 10% MS + 0.5% NS was 33.78, 37.04 and 43.85 respectively.

It is obvious that increase in the nano-SiO2content beyond 0.5% did not change the compressive strength significantly. It is found that large amounts of nano-SiO2 increase the compressive

Mix	Flexural Strength (N/mm2)
Control	6.1
10% MS	7.1
10% + 0.5 NS	8.4
10% + 1.0 NS	7.6
10% + 1.5 NS	5.4

Table 3: Average Flexural Strength at 28 days

Two fundamental mechanisms can be deduced for strength enhancement by nano silica:

strength of the composites instead of improving it. Because when the content of nano silica is large, nano particles are difficult to disperse uniformly. Therefore, they create a weak zone in the form of voids, consequently the homogeneous hydrated microstructure cannot be formed and a lower strength will be probable.

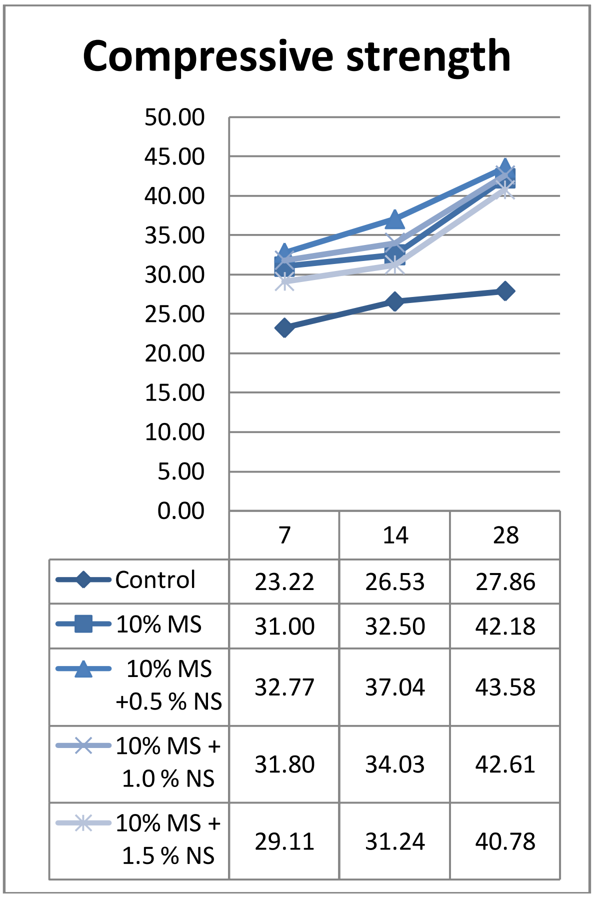


Table 2: Compressive Strength of Concrete

VII. FLEXURAL STRENGTH

The test was carried out conforming to IS 516 to obtain flexural strength of M20 grade of concrete. The specimens are prepared at a constant W/C ratio as 0.53 and required super plasticizer quantity. The flexural strength of concrete with Micro silica and Nano Silica.
1) Strength enhancement by matrix densification and paste-aggregate interfacial zone refinement
2) Strength enhancement by reduction in the content of Ca (OH)2.

The first strengthening mechanism is called the filler effect. The micro filling effect of micro silica and nano silica is one of the important factors for the development of dense concrete with very high strength, because small amount of air content significantly decreases the strength of the concrete. Nano Silica particles, due to their small size act as a filler to fill into the interstitial spaces inside the skeleton of hardened microstructure of cement paste to increase its density as well as the strength. The filling effect of nano silica is also valuable for generating strong transition zone. It has been reported that the microstructure of the transition zone between cement paste and aggregates strongly influences the strength and durability of concrete. Nano Silica particles reduce the wall effect in the transition zone between the paste and the aggregate and strengthen this weaker zone due to the higher bond between those two phases. It should be mentioned that the micro silica causes reduction in the volume of large pores and increases the concrete strength.

The second strengthening mechanism is the pozzolanic activity. Pozzolans are defined as siliceous or siliceous and aluminous materials that in themselves possess little or no cementing property but in finely dispersed form in the presence of moisture chemically react with calcium hydroxide at ordinary temperature to form compound possessing cementitious properties. Two major products of cement hydration are calcium silicate hydrate (CSH) and calcium hydroxide (CH) respectively. Calcium silicate hydrates which is produced by strength to concrete.

VIII. FLEXURAL BEHAVIOUR OF BEAM

For Control Beam

LOAD (KN)	DEFLECTION (mm)
0	0
2	0.001
6	0.003
12	0.185
18	0.510
24	1.180
30	1.515
36	2.725

Table 4: Control Beam Deflection

Collapse Load = 45.4 kN First Crack @ 12 kN

For 90% Cement + 10% MS

LOAD (KN)	DEFLECTION (mm)
0	0
2	0.005
6	0.005
12	0.13
18	0.52
24	1.09
30	1.525
36	2.085
42	3.25
46	4.65

Table 5: Deflection - 90% Cement + 10% MS

Collapse Load = 49.8 kN First Crack @ 13 kN

CONCLUSION

An experimental study was carried out to investigate the effect of micro silica and nano silica on the mechanical properties of concrete. Based on the experimental results, following conclusions can be drawn:

The increase in water demand for consistency of OPC with MS and NS is because of extreme fineness. Nano Silica and Micro Silica, both are having higher surface area so the water demand is also increased.

Nano-Silica concrete requires additional amount of water or super plasticizer to maintain the same workability level.

NS has a higher pozzolanic activity than SF. Therefore, incorporating NS can increase compressive strengths of hardened cement concrete. So, using a small amount of NS can enhance the durability and the mechanical properties of cement based materials.

The micro silica and nano silica particles are very good at infiltrating and plugging capillary pores in concrete making pores smaller and fewer and concrete more dense.

Compressive Strength of concrete increases upto 56.42 %. And Flexural strength increases upto 24.59 %.

Noticeable increase was observed in compressive and flexural strength of concrete upon adding nano silica, however high amounts of nano silica had a negative effect on mechanical properties in both compressive strength and flexural strength.

From the results it can be concluded that the optimum dosage is 90 % OPC + 10 % MS + 0.5 % NS for compressive strength and flexural strength.

Addition of NS fills the nano pores and make the structure densified one which lead to increase compressive strength and corrosive resistive.

Based on the conclusions arrived at, the following recommendations are made for future work:

It is recommended that testing of concrete produced with micro silica and nano silica concrete be extended to 56 or possibly 90 days to further determine the pozzolanic ability of the micro silica and nano silica.

Volume replacement methods are recommended to investigate the possibility of producing high strength concrete with micro silica.

Effect of addition and replacement of Nano silica alone can be studied.

To be done Corrosion studies and effects in concrete.

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