A Thesis on

AN EXPERIMENTAL STUDY ON STRENGTH OF CONCRETE WITH THE USE OF NANO SILICA

Submitted in Partial Fulfillment for the Award of DEGREE OF

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Submitted by

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DECLARATION

We declare that the Project entitled **"An Experimental Study on Strength of Concrete With the Use of Nano Silica",** is the bonafide work carried out by me, under the guidance of Mr. Mohd Bilal Khan, Assistant Professor, Department of Civil Engineering, Integral University, Lucknow. Further we declare that this has not previously formed the basis of award of any degree, diploma, associate-ship or other similar degrees or diplomas, and has not been submitted anywhere else.

Date: Mohd Kashif

Place: Lucknow En. No. 1400102428

CERTIFICATE

This is to certify that the entitled "**An Experimental Study on Strength of Concrete with Use of Nano Silica**", is being submitted by Mohd Kashif (Roll no. 1801431009), in partial fulfillment of the requirement for the award of the Master of Technology in Structure Engineering of Integral University, Lucknow is a record of candidate's own work carried out by him under our supervision and guidance.

The results presented in this thesis have not been submitted to any other university or institute for the award of any degree or diploma.

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ABSTRACT

Concrete is the most usable material in the construction industry. Much infrastructure advancement is taking place due to rapid industrialization and urbanization in the region. In such conditions, the use of normal concrete will also lead to insufficient compaction, affecting the efficiency and long term durability of structures. Nanotechnology offers the possibility of great advances of concrete in construction and as added a new dimension to the efforts to improve its properties. In this research, the nano silica powders were used with average particle size of 6 to 20nm in the concrete to investigate the mechanical properties of concrete. Nano silica is very effective in the design and development of high strength concrete. This project represents the results of an experimental investigation carried out to find the suitability of silica in high strength concrete of M40 grade of concrete. In the mix, the low workability as taken and water/cement ratio were taken as 0.36, super plasticizers were used 1% of cement. Application of silica powder used in concrete at an increment of 2% each time .i.e. 0%, 2%, 4%, and 6%. Tests were performed after the 7 days and 28 days of curing. Compressive strength and split tensile strength of the specimens were determined as per coded guidelines. The tests conducted on it shows a considerable increase in early-age compressive strength, split tensile strength and a small increase in the overall strength of concrete.

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We would like to express my gratitude to all the people behind the screen who helped us to transform an idea into a real application.

We owe a dept of gratitude to ***Mr. Mohd Bilal Khan*** *for his excellent guidance, valuable supervision, timely suggestion, stimulating discussions, constructive criticism has enable me to complete this project.*

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Worlds may fail us, when we think of all, that our parents have done for us.

Throughout life, they have always been a constant source of inspiration and whose administration helps us in our academic pursuits. Their sacrifices, prays and good wishes made us to reach at this stage.

Mohd Kashif
M. Tech (Structure Engg)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1 GENERAL

Concrete is the building industry's most usable material. Increased construction of large and complex structures with heavy reinforcement and complicated shapes is demonstrated by the current global scenario. The wide spread use of it in structures, from buildings to factories, from bridges to airports, makes it one of the 21st century's most studied materials. Many infrastructure advancements are taking place due to rapid industrialization and urbanization in the region. In such conditions, the use of normal concrete will also lead to insufficient compaction, affecting the efficiency and long term durability of structures. Improving the strength and longevity of concrete is an important need. More recently, the use of concrete from decade to decade has led to comprehensive and successful research on the improvement of concrete properties, including a wide variety of additional cementing materials, such as pozzolans and nano particles. To concrete enhance its properties, various materials known as supplementary cement materials or SCMS are added. Fly ash, blast furnace slag, rice husk, silica fumes and even bacteria are some of these. Nano-technology appears to be a promising solution to enhancing the properties of concrete from the different technologies in use. Due to the new possible applications of particles on the nanometer scale, nanotechnology has gained widespread scientific interest. This may be due to the fact that particles of nano scale size are capable of substantially improving properties compared to materials of grain size of the same chemical composition.

Nano materials are very small sized materials with particle size in nano meters. These materials are very effective in changing the properties of concrete at the ultrafine level by the virtue of their very small size. The small size of the particles also means a greater surface area. Since the rate of a pozzolanic reaction is proportional to the surface area available, a faster reaction can be achieved. Only a small percentage of cement can be replaced to achieve the desired results. These nano materials improve the strength and permeability of concrete by filling up the minute voids and pores in the micro structure. The use of nano silica in concrete mix has shown results of increase in the compressive, tensile and flexural strength of concrete. It sets early and hence generally requires admixtures during mix design. Nano-silica mixed cement can generate nano-crystals of C-S-H gel after hydration. These nano-crystals accommodate in the micro pores of the cement concrete, hence improving the permeability and strength of concrete.

1.2 MOTIVATION OF THE STUDY

The increased use of cement is essential in attaining a higher compressive strength. But, cement is a major source of pollution. The use of nano materials by replacement of a proportion of cement can lead to a rise in the compressive strength and split tensile strength of the concrete as well as a check to pollution. Since the use of a very small proportion of Nano SiO^2 can affect the properties of concrete largely, a proper study of its mechanical properties is essential in understanding the reactions and the effect of the nano particles. The existing papers show the use of admixtures in concrete mix. This study is an attempt to explain the impact of a nano-silica on the compressive strength of concrete.

1.3 OBJECTIVE OF THE STUDY

The main objectives of the present study are as mentioned below:

- To find the appropriate percentage replacement of cement with nano silica.
- To study the effect of nano-silica on the compressive strength of concrete.
- To study the effect of nano-silica on the split tensile strength of concrete.
- To provide the economical construction material.

1.4 MATERIALS

- Cement
- Fine Aggregate
- Coarse Aggregate
- Water
- Nano silica
- Super plasticizers

Cement

Cement is a finely powered material made up of argillaceous and calcareous compounds. It is made from a mixture of elements that are found in natural materials such as limestone, clay, sand and shale. When cement is mixed with water, it can bind sand and gravel into a hard, solid mass called concrete. Cement is manufacture through a closely controlled chemical combination of calcium, silicon, aluminum, iron and other ingredients. Ordinary Portland Cement: Material made by heating a mixture of limestone and clay in a kiln at about 1450 °C, then grinding to a fine power with a small addition of gypsum. Portland cement, the main subject of these sites, is the most common type of cement -basic cement, if you like. In particular, ordinary Portland cement includes White Portland Cement and Sulfate Resisting Portland Cement (SRPC). Cement can be defined as the material having cohesive & adhesive properties which makes it capable to unite the different construction materials and for the compacted assembly. Ordinary/Normal Portland cement is one of the most widely used types of Portland cement. The name Portland cement was given by Joseph Aspdin in 1842 due to its similarity in colour and its quality when it hardens likes Portland stone is white grey limestone in island of Portland Dorset.

Table 1.1: Basic Composite of Cement

Contents	%
CaO	60-70
SiO2	17-25
Al2O3	3-8
Fe2O3	0.5-0.06
MgO	0.5-0.4
Alkalis	0.3-0.2
SO3	2.0-3.5

C-S-H gel refers to calcium silicate hydrates, making up about 60 % of the volume of solids in a completely hydrated cement paste. It has a structure of short fibers which vary from crystalline to amorphous form. Owing to its gelatinous structure it can bound various inert materials by virtue of Van der Waals forces. It is the primary strength giving phase in cement concrete.

Fig 1.1: Portland Pozzolana Cement

Aggregate

Aggregates are important constituents in concrete. They give body to concrete, reduce shrinkage and effect economy. Sand, natural gravel and crushed stone are mainly used for this purpose. Recycled aggregates (from construction, demolition and excavation waste) and over burnt brick chips are increasingly used as partial replacement of natural coarse aggregates , while a number of alternatives including stone dust , copper slug ground rubber and quarry dust are also available as replacement of natural fine aggregates .

Decorative stones such as quartzite, small river stones or crushed glass are sometimes added to the surface of concrete for a decorative exposed aggregate finish popular among landscape designers.

Aggregates are inert granular materials such as sand, gravel or crushed stone that, along with water and Portland cement are essential ingredient of concrete. Aggregates strongly influence concrete's fresh and hardened properties, mix proportions and economy. Consequently, selection of aggregates is an important process. Although some variation in aggregate properties is expected, characteristics that are considered include:

- Grading
- Durability
- Particle shape and surface texture
- Abrasion and skid resistance
- Unit weight and voids
- Absorption and surface moisture
- Specific gravity

Fine aggregates

Aggregates are those chemically inert materials which when bounded by cement paste from concrete. Aggregate constitute the bulk of the total volume of concrete and hence they influence the strength of concrete to great extent. Aggregate passing through 4.75 mm sieve are defined as fine. They may be natural sand - deposited by rivers, crushed stone sand obtained by crushing stone and crushed gravel sand. Sand is essentially quartz the smallest size of fine aggregate (sand) is 0.06 mm. Depending upon the particle size, fine aggregate are described as fine, medium and coarse sands. On the basis of particle size distribution , the fine aggregate are classed into four zone i.e. zone I to zone IV ; the grading zones being progressively finer from grading zone I to zone IV (IS 383).

Fig 1.2: Fine Aggregate

Fig 1.3 : Coarse Aggregate

Coarse aggregates

Aggregate retained on 4.75 mm sieve are identified as coarse. They obtained by natural disintegration or by artificial crushing of rocks. The maximum size of aggregate can be 80 mm. The size is governed by the thickness of section, spacing of reinforcement, clear cover, mixing, handling and placing methods. For economy the maximum size should be as large as possible but not more than one fourth of the minimum thickness of the member. For reinforced section the maximum size should be at least 5 mm less than the clear spacing between the reinforcement and also at least 5 mm less than the clear cover. Aggregate more than 20 mm sizes are seldom used for reinforced cement concrete structure member.

Water

Potable fresh water, which is free from concentration of acid and organic substances, is used for mixing of concrete. Combining water with a cementations material form a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it and allows it to flow more freely. Less water in the cement paste will yield in the stronger more durable concrete, more water will give free flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure. Hydration involves many different reactions, often occurring at the same time. As the reaction proceed, the products of the cement hydration process gradually bond together the individual sand and gravel particles, and other component of concrete, to from a solid mass.

Nano Silica

Nano silica is also known as silicon dioxide. Silica is most commonly found in nature of quartz, as well as various living organisms. In many parts of the world, silica is the major constituent of sand. Silica is one of the most complex and most abundant families of materials, existing both as several minerals and being produced synthetically. Silica is highly pozzolanic admixture, which is generally used to improve the concrete strength and durability properties. Silica reacts with calcium hydroxide formed hydration of cement which results in the increase I strength and the silica fills voids between cement particle leads to increase in the durability and mechanical properties of concrete.

Table 1.2: Property of Nano Silica

Property	Value
Colour	White
Particle size	6 – 20 nm
Apparent density	0.369g/cm^2
Silica content (Dry basis)	99.8 %

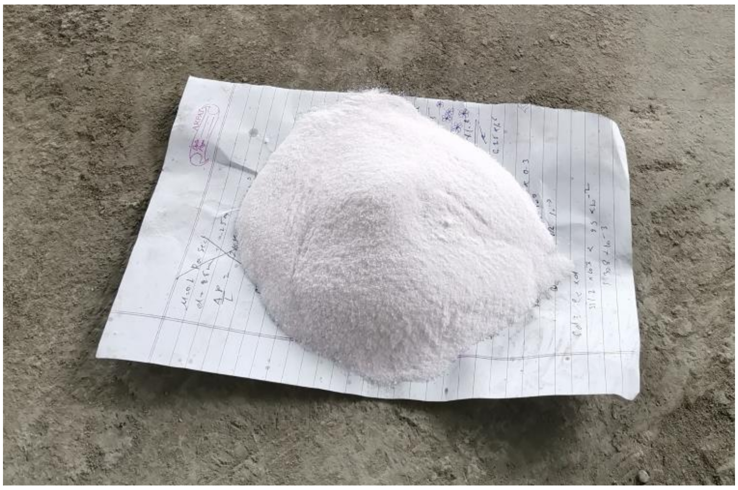


Fig 1.4: Super plasticizers **Fig 1.5: Nano Silica**

Super plasticizers

Conplast SP430G8 is based on Sulphonated Naphthalene Polymers and is supplied as a brown liquid instantly dispersible in water. Conplast SP430G8 has been specially formulated to give high water reductions up to 25% without loss of workability or to produce high quality concrete of reduced permeability.

- Improved workability - Easier, quicker placing and compaction.
- Increased strength - Provides high early strength if water reduction is taken advantage of.
- Increased quality - Denser, close textured concrete with reduced porosity and hence enhanced durability.
- Higher cohesion - Risk of segregation and bleeding minimized, thus aids pumping of concrete

CHAPTER 2: LITERATURE REVIEW

2.1 GENERAL OVERVIEW

In this chapter the works of various authors on the use of nano materials in concrete has been discussed in brief. A great number of researches have been performed to understand the nature of nano materials and their effect on the properties of concrete. A number of Research & Development work dealing with the use of nano materials like Nano silica, colloidal Nano Silica (CNS), Al_2O_3, TiO_2, ZrO_2,Fe_2O_3, carbon nano tubes (CNT) in cement based materials are discussed in the literature. The pozzolanic activity of the material is essential in forming the C-S-H gel and hence the CH crystals are prevented from growing and their number reduces. Thus the early age strength of hardened cement paste is increased. A comparative analysis of this work has been presented in the summary of this chapter which will highlight the significance of each work. Out of the numerous works done in the field only a few relevant works have been highlighted in the next section.

2.2 LITERATURE REVIEW

H. Li et. al. (2004) experimentally investigated the mechanical properties of nano-Fe_2O_3 and nano-SiO_2 cement mortars and found that the 7 and 28 day strength was much higher than for plain concrete. The microstructure analysis shows that the nano particles filled up the pores and the reduced amount of $Ca(OH)_2$ due to the pozzolanic reaction.

Tao Ji et.al (2005) experimentally studied the effect of Nano SiO_2 on the water permeability and microstructure of concrete. The findings show that incorporation of Nano SiO_2 can improve the resistance to water of concrete and the microstructure becomes more uniform and compact compared to normal concrete.

H. Li et.al. (2006) studied the abrasion resistance of concrete blended with nano particles of TiO_2 and SiO_2 nano particles along with polypropylene (PP) fibers. It was observed that abrasion resistance can be improved considerably by addition of nano particles and PP fibers. Also the combined effect of PP fiber + Nano particles shows much higher abrasion resistance than with nano particles only. It was found that abrasion resistance of nano TiO_2 particles is better than nano SiO_2 particles. Also relationship between abrasion resistance and compressive strength is found to be linear.

B.W Jo et. al. (2007) studied the characteristics of cement mortar with Nano SiO_2 particles experimentally and observed higher strength of these blended mortars for 7 and 28 days. The microstructure analysis showed that SiO_2 not only behaves as a filler to improve microstructure, but also as an activator to the pozzolanic reaction.

M.Nill et.al. (2009) studied the combined effect of micro silica and colloidal nano silica on properties of concrete and found that concrete will attain maximum compressive strength when it contains 6% micro silica and 1.5% nano silica. The highest electrical resistivity of concrete was observed at 7.5% micro and nano silica. The capillary absorption rate is lowest for the combination of 3% micro silica and 1.5% nano silica.

Ali Nazari et.al (2010) studied the split tensile and flexural strength together with the setting time of concrete by partial replacement of cement with nano-phase ZrO_2 particles has been studied. ZrO_2 nano particles with the average diameter of 15 nm were used with four different contents of 0.5%, 0.1%, 1.5% and 2.0% by weight. The results showed that the use of nano-ZrO_2 particles up to maximum replacement level of 2.0% produces concrete with improved split tensile strength. However, the ultimate strength of concrete was gained at 1.0% of cement replacement. The flexural strength of fresh concrete was increased by increasing the content of ZrO_2 nano particles. The setting time of fresh concrete was decreased by increasing the content of ZrO_2 nano particles. It is concluded that partial replacement of cement with nano phase ZrO_2 particles improves the split tensile and flexural strength of concrete but decreases its setting time.

Ali Nazari et.al (2010) studied the split tensile and flexural strength together with the setting time of concrete by partial replacement of cement with nano-phase TiO_2 particles has been studied. TiO_2 nano particles with the average diameter of 15 nm were used with four different contents of 0.5%, 0.1%, 1.5% and 2.0% by weight. The results showed that the use of nano-TiO_2 particles up to maximum replacement level of 2.0% produces concrete with improved split tensile strength. However, the ultimate strength of concrete was gained at 1.0% of cement replacement. The flexural strength of fresh concrete was increased by increasing the content of TiO_2 nano particles. The setting time of fresh concrete was decreased by increasing the content of TiO_2 nano particles. It is concluded that partial replacement of cement with nano phase TiO_2 particles improves the split tensile and flexural strength of concrete but decreases its setting time.

Alirza Naji Givi et.al. (2010) studied the size effect of nano silica particles. They replaced cement with nano silica of size 15nm and 80nm with 0-5, 1, 1.5 & 2% b.w.c. An increase in the compressive strength was observed with 1.5% b.w.c showing maximum compressive strength. A comparison between particle sizes showed that for 80nm particles the maximum strength was more than for 15nm particles, also a considerable improvement in flexural and split tensile strength of Nano SiO_2 blended concrete was observed.

A. Sadrmomtazi et.al. (2010) in another paper, have studied the effect of PP fiber along with nano SiO_2 particles. The nano silica was replaced up to 7% which improved the compressive strength of cement mortar by 6.49%. A PP fiber amount beyond 0.3% reduces the compressive strength but beyond 0.3% dose of PP fiber increases the flexural strength, showing the effectiveness of nano SiO_2 particles. Also up to 0.5% PP fibers in mortar water absorption decreases which indicates pore refinement.

Ali Nazari et.al. (2010) studied the combined effect of Nano SiO_2 particles and GGBFS on properties of concrete. They used nano silica with 3% b.w.c. replacement and 45% b.w.c. GGBFS, which shows improved split tensile strength. An improvement in the pore structure of SCC with silica particles was observed. Apart from this hey have studied the effect of ZnO_2 nano particles on SCC concrete with constant w/c ratio of 0.4. The results showed that by increasing the content of super plasticizer flexural strength decreases. Up to 4% b.w.c. of ZnO_2 content an increase in the flexural strength of SCC was recorded. In another experiment the same author studied effect of Al_2O_3 nano particles on the properties of concrete. The results showed that cement could be replaced up to 2% for improving mechanical properties of concrete, but Al_2O_3 nano particles decreased percentage water absorption of concrete. XRD analysis of the sample showed that there is more rapid formation of hydrated product.

M. Collepardi et.al. (2010) studied the effect of combination of silica fume, fly ash and ultrafine amorphous colloidal silica (UFACS) on concrete. The result shows that steam cured concrete containing SF and FA alone are much stronger than 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&UFACS for the manufacturing of precast unit.

M.S. Morsy et. al. (2010) studied the effect of nano-clay on the mechanical properties and microstructure of Portland cement mortar and observed that the tensile and compressive strength increased by 49% and 7% respectively at 8% nano-metakaolin (NMK).

Suraya Abdul Rashid et.al. (2011) worked on the effect of Nano SiO_2 particle on both mechanical properties (compressive, split tensile and flexural strength) and physical properties (water permeability, workability and setting time) of concrete which shows that binary blended concrete with nano SiO_2 particles up to 2% has significantly higher compressive, split tensile and flexural strength compared to normal concrete. Another inference drawn was that partial replacement of nano SiO_2 particles decreases the workability and setting time of fresh concrete for samples cured in lime solution.

Ali Nazari et.al. (2011) studied strength and percentage water absorption of SCC containing different amount of GGBFS and TiO_2 nano particles. The findings of the experimentation are that replacement of Portland cement with up to 45% weight of GGBSF and up to 4% weight of TiO_2 nano particles gives a considerable increase to the compressive, split tensile and flexural strength of the blended concrete. This increase is due to more the formation of hydrated products in presence of TiO_2; also the water permeability resistance of hardened concrete was improved. The author also studied effect of CuO nano particles on SCC and observed that increased percentage of polycarboxylate admixture content results in decreased compression strength. The CuO nano particles of average particle size 15nm content with up to 4% weight increased the compressive strength of SCC. CuO nano particles up to 4% could accelerate the first peak in conduction calorimetric testing which is related to the acceleration of formation of hydrated cement products.

Sekari and Razzaghi (2011) studied the effect of constant content of Nano ZrO_2, Fe_2O_3, TiO_2, and Al_2O_3 on the properties of concrete. The results showed that all the nano particles have noticeable influence on improvement on durability properties of concrete but the contribution of nano Al_2O_3 on improvement of mechanical properties of HPC is more than the other nano particles.

Navneet Chahal et.al (2010) studied *the effect of the ureolytic bacteria (*Sporosarcina pasteurii*) on the* compressive strength, water absorption and rapid chloride permeability of concrete made with silica fume. Cement was replaced with 5% and 10% of silica fume by weight. Test results indicated that inclusion of S. pasteurii in concrete enhanced the compressive strength, reduced the porosity and permeability of the concrete. Maximum increase of 38.2 MPa and 44 MPa in compressive strength at 28 and 91 days was observed. Scanning electron microscopy revealed the direct involvement of S. pasteurii in calcium carbonate precipitation which was further confirmed by XRD. Due to calcite deposition in concrete it was observed that reduction in chloride permeability of concrete occurred.

A.M. Said et.al. (2012) studied the effect of colloidal Nano silica on concrete by blending it with class F fly ash and observed that performance of concrete with or without fly ash was significantly improved with addition of variable amounts of nano silica. The mixture containing 30% FA and 6% CNS provides considerable increase in strength. Porosity and threshold pore diameter was significantly lower for mixture containing Nano silica. The RCPT test shows that passing charges and physical penetration depth significantly improved.

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

Heidari and Tavakoli (2012) investigated the combined effect of replacement of cement by ground ceramic powder from 10% to 40% b.w.c. and nano SiO2 from 0.5 to 1%. A substantial decrease in water absorption capacity and increase in compressive strength was observed when 20% replacement is done with ground ceramic powder with 0.5 to 1% as the optimum dose of Nano SiO2 particles.

J.Comiletti et.al. (2012) investigated the effect of micro and nano CaCO3 on the early age properties of ultra-high performance concrete (UHPC) cured in cold and normal field conditions. The micro CaCO3 was added from 0 to 15% b.w.c. and nano CaCO3 was added at the rate of 0, 2.5 and 5% b.w.c. Results show that by incorporating nano and micro CaCO3 the flow ability of UHPC is higher than the control mix which increases the cement replacement level. The mixture containing 5% nano CaCO3 and 15% micro CaCO3 gives shortest setting time at 10 °C and at 20°C the highest 24 hrs compressive strength is achieved by replacing cement with 2.5% nano and 5% micro CaCO3 and highest compressive strength at 26 days was achieved at 0% nano and 2.5% micro CaCO3.

Min. Hong Zhang et.al. (2012) studied the effect of NS & high volume slag mortar on setting time and early strength and observed that rate of hydration increases with addition of NS, compressive strength of slag mortar increases with increase in NS dosages from 0.5 to 2% by weight of cement. 2% NS reduces initial and final setting time and compressive strength increases by 22% and 18% at 3 days and 7 days with addition of 50% slag. NS with particle size 7 & 12 nm are more effective in increasing cement hydration and reaction compared with silica fume.

Rafat Siddique et.al (2013) studied the concrete mix, cement was replaced with fly ash, and silica fume. The percentage replacement of fly ash and silica fume was by weight of cement. The percentage use of fly ash was 0%, 10%, 20% and 30%, and that silica fume were 0%, 5% and 10%. The experiments were carried out to evaluate the effect of S. pasteurii on the compressive strength, water absorption, water porosity and rapid chloride permeability of concrete made with fly ash and silica fume up to the age 91 days. The test results indicated that inclusion of S. pasteurii enhanced the compressive strength, reduced the porosity and permeability of the concrete with fly ash and silica fume. The improvement in compressive strength was due to deposition on the bacteria cell surfaces within the pores which was scanned by electron microscopy and confirmed by XRD which revealed calcium carbonate precipitation.

G. Dhinakaranet. al. (2014) analyses the microstructure and strength properties of concrete with Nano SiO2. The silica was ground in the planetary ball mill till nano size reached and it was blended in concrete with 5%, 10% and 15% b.w.c.. The experimental results showed gain in compressive strength with maximum strength for 10% replacement.

Mukharjee and Barai (2014) the compressive strength and characteristics of Interfacial Transition Zone (ITZ) of concrete containing recycled aggregates and nano-silica. An improvement in the compressive strength and microstructure of concrete was observed with the incorporation of nano-silica.

Salim Barbhuiya et.al (2014) studied the effects of nano-Al2O3 addition on the early-age micro structural properties of cement paste is reported in this paper. The study was limited to evaluation of properties of cement paste hydrated up to an age of 7 days. Ordinary Portland cement was replaced by nano-Al2O3 powder at 2% and 4% by weight. The water–binder ratio was fixed at 0.4. No changes were noticed in the early-age compressive strength with nano-Al2O3 addition. XRD analysis confirmed that no new phase developed due to the addition of nano-Al2O3 powder. However, FTIR analysis shows a shift in water associated band to lower frequency mostly with 4% nano-Al2O3 addition. Scanning electron microscopy reveals the formation of much dense microstructure with larger crystals of portlandite within the cement matrix.

2.3 INFERENCES

The review of a number of literatures shows the importance of this field of research. The findings shows that a number of nano materials like SiO2, TiO2, Al2O3, colloidal nano silica, metakaolin and others can be incorporated to improve the properties of concrete. The results show the improved characteristics of the blended concrete in terms of compressive, tensile and flexural strength. It can also improve the physical properties of concrete in terms of water permeability, workability and setting time. To filled up minute voids and pores in concrete to make the microstructure more compact and uniform. Apart from that the permeability of the specimen can also be increased by adding a small percentage of the nano material. The microstructure analysis showed that SiO2 not only behaves as a filler to improve microstructure, but also as an activator to the pozzolanic reaction. The SEM, XRD and other analysis shows an improved microstructure with reduced number of pores.

CHAPTER 3: EXPERIMENTAL STUDY

3.1 MATERIAL PROPERTIES

The materials used to design the mix for M40 grade of concrete are cement, sand, coarse aggregate, water and Nano SiO^2. The properties of these materials are presented below.

Properties of constituents of concrete

The determination of the properties of the constituents of concrete is necessary to ensure that they do not contain any deleterious element which may affect the behavior of the composite or they may not conform to the specified requirement necessary to achieve a standard of performance. The sub-section under this head gives the detail of the tests carried out and the specification as mentioned in IS codes.

3.1.1 CEMENT

Portland Pozzolana Cement conforming to IS 1489 (part 1) manufactured by Ambuja Cement having specific gravity 3.15 was used throughout the experimental investigation. The following tests were carried out:

Consistency Test of Cement

The standard consistency of a cement paste is defined as that consistency which will permit the vicat plunger having 10mm diameter and 50mm length to penetrate to a point 5 to 7mm from the bottom of the vicat mould apparatus. Vicat Apparatus Conforming to IS: 5513-1976. This apparatus is used to find out the percentage of water required to produce a cement paste of standard consistency. IS 4031 (part IV): 1988 was conducted for the test.

Procedure

1. Unless otherwise specified this test shall be conducted at a temperature 27 + 20 C and the relative humidity of laboratory should be 65 + 5%.

2. Prepare a paste of weighed quantity of cement (300gms) with weighed quantity of potable or distilled water, taking care that the time of gauging is not less than 3 minutes nor more than 5 minutes and the gauging is completed before any sign of setting occurs.

3. The gauging is counted from the time of adding water to the dry cement until commencing to fill the mould.

4. Fill the vicat mould with this paste resting upon a non-porous plate.

5. Smoothen the surface of the paste, making it level with the top of the mould. Slightly shake the mould to expel the air.

6. In filling the mould operator's hands and the blade of the gauging trowel shall only be used.

7. Immediately place the test block with the non-porous resting plate, under the rod bearing the plunger. Lower the plunger gently to touch the surface of the test block and quickly release.

8. Allowing it sink into the paste. Record the depth of penetration.

9. 9 Prepare trial pastes with varying percentages of water and test as described above until the plunger is 5mm to 7mm from the bottom the vicat mould.

Fig 3.1: Consistency Test

Fig 3.2: Initial Setting Time

Initial and Final Setting Time of Cement

Initial setting time is that time period between the time water is added to cement and time at which 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5 mm to 7 mm from the bottom of the mould. Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression.

Procedure for test block preparation

1. Prepare a cement paste by gauging the cement with 0.85 times the water required to give a paste of standard consistency.

2. Start a stop-watch, the moment water is added to the cement.

3. Fill the Vicat mould completely with the cement paste gauged as above, the mould resting on a non-porous plate and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared in the mould is the test block.

Initial Time Test Procedure (conforming to IS 4031:1988 P5)

1. Take 300 gm of cement and mix it with water percentage as mentioned in consistency test of cement.

2. Now the prepared cement paste is filled in the vicat mould.

3. The square needle of cross-section 1 mm^2 is attached to the movable rod of the Vicat apparatus.

4. Then the needle is allowed to quickly release and allowed to penetrate in the cement paste. In initial stage, the needle penetrates completely. It is then taken out and dropped at a fresh place. The test procedure is repeated at regular intervals till the needle does not penetrate completely. The needle should penetrate up to about 5 mm measured from bottom.

5. The initial setting time is found out by taking the interval between the addition of water to cement and the stage when needle stops to penetrate completely. The time should be about 30 minutes for ordinary cement.

Final Setting Time of Cement Test Procedure:

1. The initial test procedure is same that of initial setting time test.

2. Instead of square needle, annular collar is used. The annular collar is attached to the movable rod of vicat apparatus.

3. The annular rod is gently released. The time at which annular rod makes an impression on test block and the collar fails to do so is noted.

4. The final setting time is found out by taking the difference between the time at which water is added to cement and time as recorded in.

5. The final setting time for ordinary cement should be 10 hours.

Table 3.1 : Properties of Cement

Characteristics	Values
Specific gravity	3.15
Grade of Cement	43
Initial and Final setting time	35 min and 600 min
Normal consistency	35%

AGGREGATE

Sand as fine aggregates are collected from locally available river and the sieve analysis of the samples are done. It is found that the sand collected is conforming to IS: 383-1970. For coarse aggregate, the parent concrete is crushed through mini jaw crusher. During crushing it is tried to maintain to produce the maximum size of aggregate in between 20mm to 4.75mm. The physical properties of both fine aggregate and recycled coarse aggregate are evaluated as per IS: 2386 (Part III)-1963.

Fine Aggregate

Aggregates are divided into two categories from the consideration of size. An aggregate whose size is 4.75 mm and less is considered as fine aggregates. Locally available river sand passed through 4.75 mm sieve was used throughout the experimental investigation. IS 383:1970 was used to determine the various properties of fine aggregates.

Sieve analysis of fine aggregate

The sieve analysis, commonly known as the gradation test, is a basic essential test for all aggregate technicians. The sieve analysis determine the gradation (the distribution of aggregate particles, by size, within a given sample) in order to determine compliance with design, production control requirements, and verification specifications. The gradation data may be used to calculate relationships between various aggregate or aggregate blends, to check compliance with such blends, and to predict trends during production by plotting gradation curves graphically, to name just a few uses. Used in conjunction with other tests, e sieve analysis is a very good quality control and quality acceptance tool.

Table 3.2: Sieve Analysis Table

IS Sieve Size	Wt. Retained	Percent Retained	Cumulative Percent Retained	Cumulative % passing
10mm	2	0.2	0.2	99.8
4.75mm	17	1.7	1.9	98.1
2.36mm	35	3.5	5.4	94.6
1.18mm	327	32.7	38.1	61.8
600µ	213	21.3	59.4	40.6
300µ	281	28.1	87.5	12.5
150µ	113	11.3	98.8	1.2
Pan	12	1.2	100	0

Fig 3.3: Sieve Analysis of Fine Aggregate

Table 3.3: Zone Grading

	Percentage Passing by Weight				
IS Sieve	**Grading Zone 1**	**Grading Zone 2**	**Grading Zone 3**	**Grading Zone 4**	**Observed readings in our Study**
10mm	100	100	100	100	99.8
4.75mm	90 – 100	90 – 100	90 – 100	95 – 100	98.1
2.36mm	60 – 95	75 – 100	85 – 100	95 – 100	94.6
1.18mm	30 – 70	55 – 90	75 – 100	90 – 100	61.8
600µ	15 – 34	35 – 49	60 – 79	80 – 100	40.6
300µ	5 – 20	8 – 30	12 – 40	15 – 50	12.5
150µ	0 – 10	0 – 10	0 – 10	0 – 15	1.2
Pan	0	0	0	0	0

From the table it is evident that our fine aggregate lies in Grading zone 2

Fineness Modulus of Sand

Fineness modulus is a ready index of coarseness or fineness of the material Fineness modulus is an empirical factor obtained by adding the cumulative percentages of aggregate retained on each of the standard sieves ranging from 80 mm to 150 micron and dividing this sum by an arbitrary number 100. The larger the figure, the coarser is the material.

Fineness modulus of fine aggregate = summation of percent retain on sieve /100

= (1.9+5.4+38.1+59.4+87.5+98.8) /100

= 2.91

From IS Code 383:1970

The range of fineness modulus of fine aggregate is = 2-4

Fig 3.4: Specific Gravity of Fine Aggregate

Specific Gravity of Fine Aggregate

Specific gravity is defined as the ratio of the weight of a given volume of solid to the weight of an equivalent volume of water at 4° C.

Pycnometer method is most accurate to find specific gravity of fine aggregate.

In concrete technology, specific gravity of aggregates is made use of in design calculations of concrete mixes. With the specific gravity of each constituent known, its weight can be converted into solid volume and hence a theoretical yield of concrete per unit volume can be calculated.

Weight of saturated and surface dry aggregate, (C) = 500g
Weight of Pycnometer + water, (B) = 1530g
Weight of Pycnometer + sample + water, (A) = 1835g
Weight of oven dry sample, (D) v = 496g

Specific Gravity of fine aggregate $= \frac{D}{C-(A-B)}$

$$= \frac{496}{500-(1835-1530)}$$

= 2.54

Water Absorption $= \frac{C-D}{D} \times 100$

$$= \frac{500-496}{496} \times 100$$

= 0.80 %

Table 3.4: Properties of Fine Aggregate

Properties	Test Value
Grade Zone	II
Fineness Modulus	2.9
Specific Gravity	2.54
Water Absorption	0.80 %

Coarse Aggregate

Aggregate fraction whose size is greater than 4.75 mm are considered as coarse aggregate. The locally available crushed stone aggregate, mainly quartzite in mineralogical composition of maximum nominal size of 16mm was used as coarse aggregate. To keep the aggregate free from silt, it was washed before being put to use in concrete as well as testing. The sieve analysis was carried out conforming to IS-383 1970.

Table 3.5: Sieve Analysis Table

IS SIEVE	Wt. Retained	Cumulative Wt. Retained	Cumulative Wt. % Retained	Cumulative % passing
40	0	0	0	100
20	415	415	8.3	91.7
10	3275	3690	73.8	26.2
4.75	1310	5000	100	0
Pan	0	5000	100	0

Total weight taken for sieve analysis = 5000g

Fineness Modulus of Coarse Aggregate

Fineness Modulus of Coarse Aggregate = summation of percent retain on sieve size / 100
= [8.3 + 73.8 + (6 × 100) / 100
= 6.82

From IS Code 383: 1970

The range of fineness modulus of fine aggregate = 6.5 – 8

Fig 3.5: Specific Gravity of Coarse Aggregate

Specific gravity and Water Absorption of Coarse Aggregate

Sample taken = 1000g

Weight of Vessel + sample + water, (A) = 1589g

Weight of vessel + water, (B) = 960g

Weight of Weight of saturated surface dry sample, © = 1001g

Weight of oven dry sample, (D) = 996g

Specific Gravity of coarse aggregate $= \frac{D}{C-(A-B)}$

$$= \frac{996}{1001-(1589-960)}$$

= 2.68

Water Absorption of coarse aggregate $= \frac{C-D}{D} \times 100$

$$= \frac{1001-996}{996} \times 100$$

= 0.50 %

Table 3.6: Properties of Coarse Aggregate

Properties	Test Value
Fineness Modulus	6.82
Specific Gravity	2.68
Water Absorption	0.50 %

3.1.2 Properties of Water

Tap water was used in this experiment. The properties are assumed to be same as that of normal water. Specific gravity is taken as 1.00.

METHODS

3.2.1 Mix Design

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. The purpose of designing as can be seen from the above definitions is two – fold. The first object is to achieve the stipulated minimum strength and durability. The second object is to make the concrete in the most economical manner.

To design a concrete mix for a desired strength , first we need to decide the constituents of concrete mix such as cement , fine aggregate , coarse aggregate and admixture etc. Their optimum quantity that will result in achievement of the requisite performance. In general, the acceptance criteria of a concrete mix are its workability in fresh state and compressive strength at the age of 28 days.

For the Mix design procedure IS 10262: 2009 and IS 456: 2000 is used throughout. Detailed procedure for mix design adopted in the present study is given below:

The mix design for M40 grade of concrete is described below in accordance with Indian Standard Code IS: 10262-2009

TARGET STRENGTH FOR MIX PROPORTIONING:

Characteristic compressive strength at 28 days (f_{ck}) = 40N/mm^2

Assumed standard deviation (Table 2 of IS 10262:2009), S = 5N/mm^2

Target average compressive strength at 28 day = f_{ck}+ 1.65S

= 40 + 1.65 × 5
= 48.25 N/mm^2

I. SELECTION OF WATER-CEMENT RATIO:

From Table 5 of IS: 456-2000, maximum water-cement ratio = 0.45
To start with let us assume a water-cement ratio of 0.36
0.36 < 0.45, hence O.K

II. SELECTION OF WATER CONTENT

From Table 4, water content = 186 kg (for 50 mm slump) for 20 mm aggregate.
Estimated water content for 75 mm slump

$$= 186 + \frac{3 \times 186}{100} = 191.58 \text{ kg}$$

As super plasticizer is used, the water content may be reduced. Based on trial data, the water content reduction of 23 percent is considered while using super plasticizer the rate 1.0 percent by weight of cement.

Hence the water content

= 191.58 × 0.77

= 147.52 kg ≈ 148 kg

III. CALCULATION OF CEMENT CONTENT

Water-cement ratio = 0.36

Cement content $= \frac{148}{0.36} = 411.11\ kg/m^3 \approx 412\ kg/m^3$

From Table 5 of IS 456, minimum cement content for 'severe' exposure condition

= 320 kg/m3

$412\ kg/m^3 > 320\ kg/m^3$, hence O.K.

IV. PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGETE CONTENT

From Table 5, the proportionate volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone III) for water-cement ratio of 0.50 = 0.62.

As the water-cement ratio is lowered by 0.05, the proportion of volume of coarse aggregate is increased by 0.01

Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.36 = 0.62 + 0.028 = 0.648.

Volume of fine aggregate content = 1 – 0.648 = 0.352

V. MIX CALCULATIONS

a) Volume of concrete = 1 m^3

b) Volume of cement $= \frac{Mass\ of\ cement}{specific\ gravity\ of\ cement} \times \frac{1}{1000}$

$$= \frac{412}{3.15} \times \frac{1}{1000} = 0.130$$

c) Volume of water $= \frac{Mass\ of\ water}{specific\ gravity\ of\ water} \times \frac{1}{1000}$

$$= \frac{148}{1} \times \frac{1}{1000} = 0.148$$

d) Volume of chemical admixture (super plasticizer) (@ 1.0 percent by mass of cementitious material)

$$= \frac{Mass\ of\ chemical\ admixture}{specific\ gravity\ of\ admixture} \times \frac{1}{1000}$$

$$= \frac{4.12}{1.145} \times \frac{1}{1000} = 0.0036\ m^3$$

e) Volume of all in aggregate = [(a – (b + c + d)]
= [(1 – (0.130 + 0.148 + 0.0036)]
= 0.7184 m^3

f) Mass of coarse aggregate = g × Volume of coarse aggregate × Specific gravity of coarse aggregate × 1 000
= 0. 7184 × 0.648 × 2.68 × 1 000
= 1247.6 kg ≈ 1247 kg

g) Mass of fine aggregate = g × Volume of fine aggregate × Specific gravity of coarse aggregate × 1 000

= 0. 7184 × 0.352 × 2.54 × 1 000
= 642.3 kg ≈ 642 kg

VI. MIX PROPORTIONS

Cement = 412 kg/m^3

Water = 148 kg/m^3

Fine aggregate = 642 kg/m3

Coarse aggregate = 1247 kg/m^3

Chemical admixture = 4.12 kg/m^3

Free water-cement ratio = 0.36

3.2.2 Mix proportion for Cube

For batch of 6 cubes of 150 mm side, the volume of concrete

$= (150)^3 \times 6 \times 1.1 = 0.022m^2$ (taking 10 % for losses)

Cement required = 0.022 x 412 = 9.064 kg
Fine aggregate required = 0.022 x 642 = 14.124 kg
Coarse aggregate required = 0.022 x 1247 = 27.434 kg
Water required = 0.022 x 148 = 3.256 kg

Table 3.7: Mix proportion of concrete Cube

Materials	% of Proportion	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Silica (kg)	Water(kg)	Super plasticizers(kg)
Nano Silica	0 %	9.07	14.124	27.434	0	3.256	0.0907
	2 %	8.88	14.124	27.434	.1814	3.256	0.0907
	4 %	8.70	14.124	27.434	0.3628	3.256	0.0907
	6 %	8.53	14.124	27.434	0.5442	3.256	0.0907

3.2.3 Mix proportion for Cylinder

For batch of 6 cylinders of 150 mm dia. × 300 mm height, the volume of concrete

$= [(\pi \times 0.150^2 \times 0.300) / 4] \times 6 \times 1.1 = 0.0349m^2$ (taking 10 % for losses)

Cement required = 0.0349 x 412 = 14.378 kg
Fine aggregate required = 0.0349 x 642 = 22.405 kg
Coarse aggregate required = 0.0349 x 1247 = 43.52 kg
Water required = 0.0349 x 148 = 5.165 kg

Table 3.8: Mix proportion of concrete Cylinder

Materials	% of Proportions	Cement(kg)	Fine Aggregate(kg)	Coarse aggregate(kg)	Silica(kg)	Water (kg)	Super plasticizers (kg)
Nano Silica	0 %	14.38	22.405	43.52	0	5.165	0.1438
	2 %	14.09	22.405	43.52	0.2876	5.165	0.1438
	4 %	13.80	22.405	43.52	0.5752	5.165	0.1438
	6 %	13.52	22.405	43.52	0.8628	5.165	0.1438

3.2.4 Procedure of Mixing and Casting of concrete cube and cylinder

- First of all the interior of mixing drum was wetted with water in order to minimize the absorption of water added as a part of the Concrete mixture.
- Firstly the coarse aggregate, fine aggregate and cement paste content was added and silica powder was added after it and mixed properly. Plasticizers was mixed with water and then added to the cement paste in three steps. All mixed for about 5 minutes.
- Clean the standard moulds 6 no's thoroughly and tight all nuts – bolts properly.
- Apply oil to all contract surface of mould.
- Take the sample from the mixing spot while concreting.
- Fill the concrete in moulds in 3 layers.
- Compact each layer with 35 no's of stroke by tampering rod.
- Finish the top surface by trowel after completion of last layer.
- Place mould on vibrator table for 10 sec vibration for properly compaction of concrete.
- The specimens were left in the laboratory at room temperature for 24 hours.
- After the 24 hours remove the specimen out of mould.
- While removing take care to avoid breaking of edges.
- Submerge the specimen in fresh water till the time of testing.
- Test 3 specimens for 7 days and test 3 specimens for 28 days.
- Average strength of 3 specimens represents the strength of concrete.

Different stages of cube casting

Fig 3.6: Mixing

Fig 3.7: Casting

Fig 3.8: Moulded cube **Fig 3.9: Curing**

Different Stages of cylinder casting

Fig 3.10 : Materials Added in Mixer **Fig 3.11 : Casting of Cylinder**

Fig 3.12: Casted Cylinder **Fig 3.13: Curing of Cylinder**

3.3CONCRETE TEST

3.3.1 Compressive Strength Test

Compressive strength is the capacity of a material or structure to withstand axially directed pushing forces. The specimens are determined after 7 and 28 days of curing with surface dried condition as per Indian Standard IS: 516-1959. When the limit of compressive strength is reached, brittle materials are crushed and hardness of cubical and cylindrical specimens is determined. The cube specimen is of the size 15 x 15 x 15 cm. If the largest nominal size of the aggregate does not exceed 20 mm, 10 cm size cubes may also be used as an alternative. Compressive strength was determined by using compression testing machine (CTM) of 3000 KN capacity.

$$F = P/A$$

Where,

F = Compressive strength
P = Maximum load applied to the specimen
A = Area of the cube

Fig 3.14 : Compressive Testing Machine

Split Tensile Test

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The cylinders are placed in the compression testing machine and load is applied as similar to the cube. The cylinder is placed horizontally and the test is performed. The load is increased until the specimen fails and the maximum load applied to test specimen during the test is recorded. In these 6 concrete cylinders moulds are filled with concrete at every casting or with different percentage. Cylindrical test specimens have a length equal to twice the diameter. They are 15 cm in diameter and 30 cm long.

$$T = 2P / \pi LD$$

Where,

T = Split Tensile Strength
P = maximum Applied Load
L = Length of cylinder
D = Diameter of cylinder

CHAPTER 4: EXPERIMENTAL RESULTS AND DISCUSSION

4.1 GENERAL

The study is conducted to analyze the compressive and split tensile strength of concrete when the cement is partially replaced by nano silica, and 0 %, 2 %, 4%, 6% of cement content is replaced with silica powder. There were a total of 24 specimens of cube (150 mm X 150 mm X 150 mm) and 24 specimens of cylinder (150 mm X 300 mm). All the specimens were tested for compressive and split tensile strength after a curing period of 7 days and 28 days. The result of the test specimen is given below:

4.2 EXPERIMENTAL RESULTS

4.2.1 Compressive test results

Table 4.1: Compressive Strength of cube on normal specimen

Sample no.	Nano silica (%)	Load on 7th day (Kn)	Load on 28th day (Kn)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
1	0 %	692.2	--	30.7	30.5
2		700.3	--	31.1	
3		669.9	--	29.7	
4		--	1122.0	49.8	49.3
5		--	1093.4	48.5	
6		--	1117.8	49.6	

Fig 4.1: Testing of Cube

Fig 4.2: Tested Cubes

Table 4.2: Compressive Strength of cube with nano-silica 2%

Sample no.	Nano silica (%)	Load on 7^{th} day (Kn)	Load on 28^{th} day (Kn)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
1	2 %	752.7	--	33.4	32.5
2		726.9	--	32.3	
3		717.4	--	31.8	
4		--	1165.4	51.7	51.66
5		--	1142.3	50.7	
6		--	1185.4	52.6	

Table 4.3: Compressive Strength of cube with nano-silica 4%

Sample no.	Nano silica (%)	Load on 7^{th} day (Kn)	Load on 28^{th} day (Kn)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
1	4 %	804.8	--	35.7	35.1
2		807.7	--	35.9	
3		758.2	--	33.7	
4		--	1246.5	55.4	54.9
5		--	1259.5	55.9	
6		--	1202.8	53.4	

Table 4.4: Compressive Strength of cube with nano-silica 6%

Sample no.	Nano silica (%)	Load on 7^{th} day (Kn)	Load on 28^{th} day (Kn)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
1	6 %	784.8	--	34.8	35.7
2		817.4	--	36.3	
3		810.2	--	36.0	
4		--	1266.2	56.2	56.33
5		--	1282.6	56.9	
6		--	1259.7	55.9	

4.2.2 Split tensile test

Table 4.5: Split Tensile Strength of cylinder on control specimen

Sample no.	Nano silica (%)	Load on 7th day (Kn)	Load on 28th day (Kn)	Split tensile strength (N/mm²)	Average compressive strength (N/mm²)
1	0 %	130.8	--	1.85	1.87
2		136.6	--	1.93	
3		129.3	--	1.83	
4		--	214.9	3.04	2.98
5		--	206.4	2.92	
6		--	211.7	2.99	

Table 4.6 :Split Tensile Strength of cylinder with nano-silica 2%

Sample no.	Nano silica (%)	Load on 7th day (Kn)	Load on 28th day (Kn)	Split tensile strength (N/mm²)	Average compressive strength (N/mm²)
1	2 %	154.1	--	2.18	2.21
2		162.6	--	2.30	
3		151.9	--	2.15	
4		--	242.1	3.42	3.41
5		--	249.3	3.52	
6		--	233.4	3.30	

Fig 4.3: Testing of Cylinder

Fig 4.4: Tested Cylinder

Table 4.7: Split Tensile e Strength of cylinder with nano-silica 4%

Sample no.	Nano silica (%)	Load on 7^{th} day (Kn)	Load on 28^{th} day (Kn)	Split tensile strength (N/mm^2)	Average compressive strength (N/mm^2)
1	4 %	174.5	--	2.46	2.50
2		180.3	--	2.54	
3		171.1	--	2.42	
4		--	267.0	3.77	3.86
5		--	280.4	3.96	
6		--	272.7	3.85	

Table 4.8: Split Tensile Strength of cylinder with nano-silica 6%

Sample no.	Nano silica (%)	Load on 7^{th} day (Kn)	Load on 28^{th} day (Kn)	Split tensile strength (N/mm^2)	Average compressive strength (N/mm^2)
1	6 %	2.67	--	2.64	2.59
2		181.2	--	2.56	
3		183.6	--	2.61	
4		--	286.13	4.05	4.07
5		--	289.66	4.10	
6		--	286.83	4.06	

4.3 COMPARISON OF RESULTS

4.3.1 Comparison of Compressive Strength Results

Table 4.9 Comparison of compressive strength of cube for 7 day

NANO SILICA (%)	STRENGTH (N/mm^2)	INCREASE IN STRENGTH (%)
0 %	30.5	-
2 %	32.5	6.55
4 %	35.1	15.08
6 %	35.7	17.04

Table 4.10 Comparison of compressive strength of cube for 28 day

NANO SILICA	STRENGTH	INCREASE IN STRENGTH (%)
0 %	49.3	-
2 %	51.6	4.66
4 %	54.9	11.35
6 %	56.3	14.19

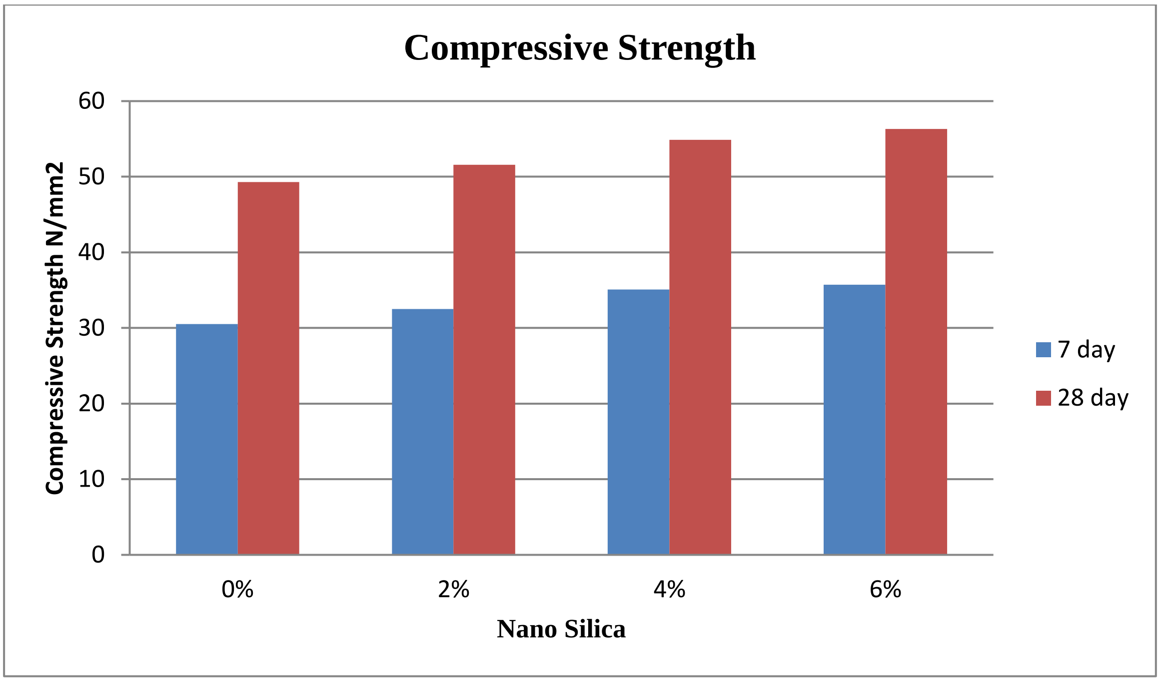
4.3.2 Comparison of Split Tensile Results

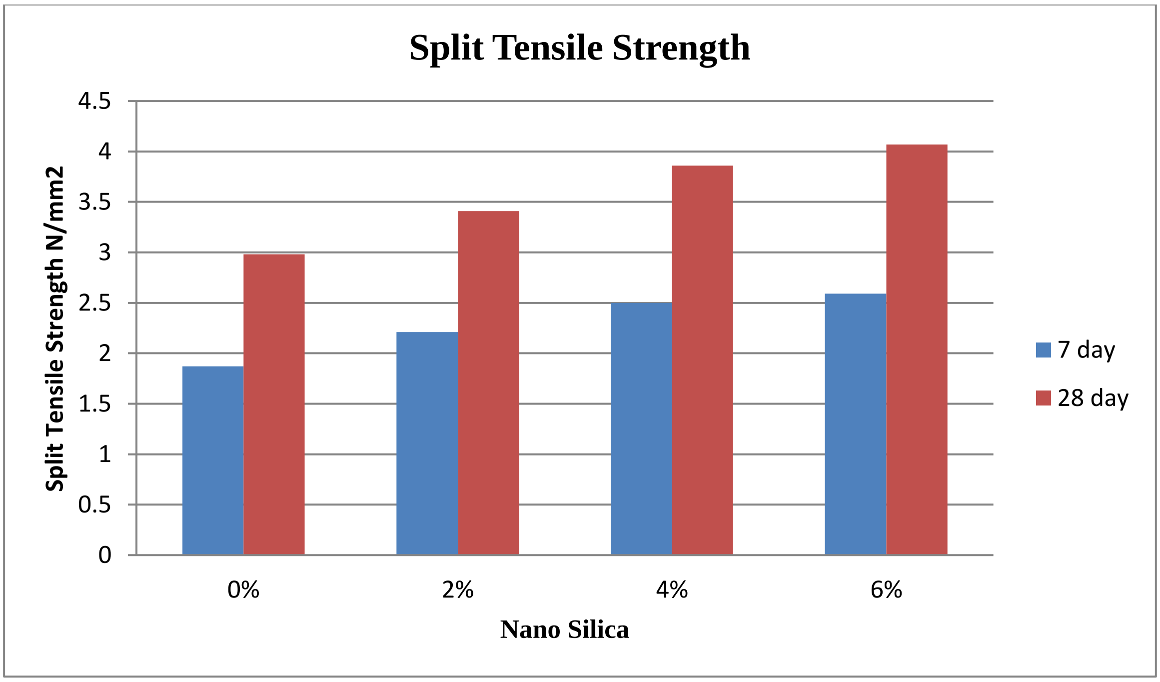
Table 4.11 Comparison of Split Tensile strength of Cylinder for 7 day

NANO SILICA	STRENGTH	INCREASE IN STRENGTH (%)
0 %	1.87	-
2 %	2.21	13.36
4 %	2.50	33.68
6 %	2.59	38.50

Table 4.12 Comparison of Split Tensile strength of Cylinder for 28 day

NANO SILICA	STRENGTH	INCREASE IN STRENGTH (%)
0 %	2.98	-
2 %	3.41	14.4
4 %	3.86	29.53
6 %	4.07	36.57


Compressive Strength
Compressive Strength N/mm2
60
50
40
30
20
10
0
0%
2%
4%
6%
Nano Silica
7 day
28 day


Split Tensile Strength
Split Tensile Strength N/mm2
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0%
2%
4%
6%
Nano Silica
7 day
28 day

4.4 STANDARD DEVIATION

Table 4.13 Calculation of Standard Deviation

S.no.	Reading (x)	Mean (μ)	Difference From Mean	Square of Difference from Mean
1.	49.8	53.05	-3.25	10.5625
2.	48.5		-4.55	20.7025
3.	49.6		-3.45	11.9025
4.	51.7		-1.35	1.8225
5.	50.7		-2.35	5.5225
6.	52.6		-0.45	0.2025
7.	55.4		2.35	5.5225
8.	55.9		2.85	8.1225
9.	53.4		0.35	0.1225
10.	56.2		3.15	9.9225
11.	56.9		3.85	14.8225
12.	55.9		2.85	8.1225
			Total	97.35

Mean (μ) = [49.8 + 48.5+ 49.6 + 51.7 + 50.7 + 52.6 + 55.4+ 55.9 + 53.4 + 56.2 +56.9 + 55.9] / 12

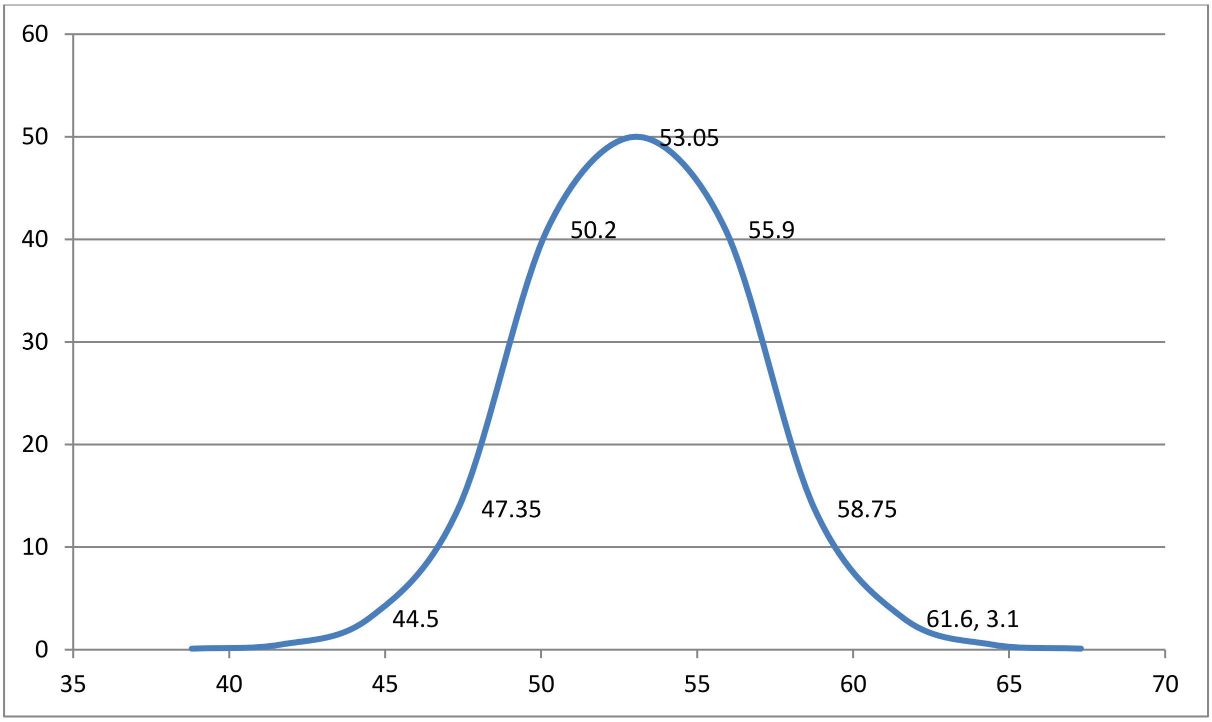
μ = 53.05

Variance = 97.35 / 12
Variance = 8.113

Standard deviation = $\sqrt{Variance}$

$= \sqrt{8.113}$

Standard deviation = 2.8483



Standard Deviation Curve

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From the experiments carried out and based on the results obtained on the "**An Experimental Study on Strength of Concrete with the Use of Nano Silica**", some conclusions can be drawn:

1. The nano silica particle mixes with concrete shows the higher compressive and split tensile strength at the ages of 7 and 28 days of curing in comparison to convectional concrete.

2. It has been found that the cement could be advantageously replaced by SiO2 nano-particle up to maximum limit of 6.0% with average particle sizes of 6 and 20 nm.

3. The experimental work, it is observed that increase in the content of nano silica will increase in the compressive strength. The maximum strength gained by silica powder in compressive strength for 7 days is 17.04 % and for 28 days is 14.19 %.

4. Split tensile strength of concrete with application of silica increase with an increase in the percentage of silica content. The maximum strength gained by silica powder in split tensile strength for 7 days is 38.50 % and for 28 days is 36.57 %.

5. By enhancing the strengthen of concrete, its cause low cost construction materials and make the structure economical.

5.2 RECOMMENDATIONS

From this work and its findings, some recommendations can be suggested for an eventual future study to ascertain the use of nano silica into concrete in the construction industry

a. To extend compressive strength test after 90 days and 1 year to follow the strength development with time regardless of compressive, splitting tensile and flexural tests.

b. The scanning electron microscopy (SEM) and transmission electron microscopy (TEM) should be investigated to show the microstructure and chemistry of a range of materials.

c. In future, the size effects of nano silica can be studied in detail.

d. A detailed study of the microstructure at specific intervals throughout a year can give a very good idea about the reactions taking place in the concrete.

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6.2 IMPACT FACTOR

ISO International Organization for Standardization 7021-2008

EXPERIMENTAL STUDY OF CONCRETE THROUGH THE APPLICATION OF NANO SILICA

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ABSTRACT - Many infrastructure advancement are taking place due to rapid industrialization and urbanization in the region. Due to the ongoing and continuous technical requirement to satisfy the various demanding requirements, comprehensive and wide ranging research work is carried out in the concrete technology field. The application of nano-technology in concrete has added a new dimension to the efforts to improve its properties. Nano silica, by virtue of their very small particle size can affect the concrete properties by altering the microstructure. In the present experimental investigation, High Strength Concrete Mixes of M40 are studied for their mechanical properties. The present investigation deals with application of silica powder in concrete at an increment of 2% each time .i.e. 0%, 2%, 4%, 6%. The tests conducted on it show a considerable increase in early-age compressive strength and split tensile strength.

Keywords - *Nano materials, nano-silica, workability, compressive strength, Split Tensile strength*

1. INTRODUCTION

Concrete is the building industry's most usable material. Increased construction of large and complex structures with heavy reinforcement and complicated shapes is demonstrated by the current global scenario. The wide spread use of it in structures, from buildings to factories, from bridges to airports, makes it one of the 21st century's most studied materials. Many infrastructure advancements are taking place due to rapid industrialization and urbanization in the region. In such conditions, the use of normal concrete will also lead to insufficient compaction, affecting the efficiency and long term durability of structures. Improving the strength and longevity of concrete is an important need. More recently, the use of concrete from decade to decade has led to comprehensive and successful research on the improvement of concrete properties, including a wide variety of additional cementing materials, such as pozzolana and nano particles. To enhance the properties of concrete, various materials known as supplementary cement materials or SCMS are added. Fly ash, blast furnace slag, rice husk, silica fumes and even bacteria are some of these. Nano-technology appears to be a promising solution to enhancing the properties of concrete from the different technologies in use. Due to the new possible applications of particles on the nanometer scale, nanotechnology has gained widespread scientific interest. This may be due to the fact that particles of nano scale size are capable of substantially improving properties compared to materials of grain size of the same chemical composition.

NANOMATERIALS- Use in Concrete

Nanomaterials are materials of very small size with particle size in nanometres. By virtue of their very small scale, these materials are very successful in altering the properties of concrete at the ultrafine level. A greater surface area is also indicated by the small size of the particles (Alireza Naji Givi, 2010). Since the rate of a pozzolanic reaction is proportional to the available surface area, it is possible to achieve a quicker reaction. To produce the desired effects, only a small percentage of cement can be substituted. By filling up the minute voids and pores in the microstructure, these nanomaterials enhance the strength and permeability of concrete.
The use of nano-silica in concrete mixtures has shown that the compressive, tensile and flexural strength of concrete has improved. It sets early and thus requires admixtures during mix design in general, Nano-silica mixed cement can generate nano-crystals of C-S-H gel after hydration. These nano-crystals accommodate in the micro pores of the cement concrete, hence improving the permeability and strength of concrete.

2. OBJECTIVE

- To find the appropriate percentage replacement of cement with nano silica.
- To study the effect of nano-silica on the compressive strength of concrete.
- To study the effect of nano-silica on the split tensile strength of concrete.
- To provide the economical construction material.

3. EXPERIMENTAL PROGRAM

In this research work, four different mixes of concrete were casted with varied percentage of silica powder (partial replacement with cement) for M40 grade of concrete. There are total 24 cube and 24 cylinder were casted in which 6 cubes and 6 cylinder were casted for each mix 0%, 2%, 4%, 6%.
Water-cement ratio were taken as 0.36, due to low w/c ratio the value of slump test were decreases. Test were performed after the 7 days and 28 days of curing. Compressive strength and split tensile strength of the specimens were determined as per coded guidelines.

3.1 Materials

Pozzolona Cement (PPC) conforming to IS 1489 (Part 1) manufactured by Ultratech Cement having specific gravity 3.15 was used for the concrete mixes in this study. Fine aggregate (natural sand) of specific gravity 2.68 and coarse aggregate (crushed stone) having nominal size of 20 mm and specific gravity 2.54 was used in this experimental work. Physical and mechanical properties of cement, fine aggregate and coarse aggregate has been shown in table

Properties of cement, fine aggregate and coarse aggregate

Properties	Observed value
Initial setting of cement	33 min
Final setting of cement	610 min
Grade zone of fine aggregate	II
Specific Gravity if fine aggregate	2.54
Water Absorption of fine aggregate	0.502
Specific Gravity if fine aggregate	2.68
Water Absorption of fine aggregate	0.80

3.2 MIX PROPORTION

Mix proportion of concrete

Mix Design	M40
Cement	412 kg/m^3
Fine Aggregate	642 kg/m^3
Coarse Aggregate	1247 kg/m^3
Water	148 kg/m^3
Chemical Admixture	4.12 kg/m^3
Water – Cement Ratio	0.36

Mix proportion of concrete for 6 Cube

Materials	% of Proportion	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Silica (kg)	Water(kg)	Super plasticizers (kg)
Nano Silica	0 %	9.07	14.124	27.434	0	3.256	0.0907
	2 %	8.88	14.124	27.434	.1814	3.256	0.0907
	4 %	8.70	14.124	27.434	0.3628	3.256	0.0907
	6 %	8.53	14.124	27.434	0.5442	3.256	0.0907

Mix proportion of concrete for 6 Cylinder

Materials	% of Proportions	Cement(kg)	Fine Aggregate (kg)	Coarse aggregate(kg)	Silica(kg)	Water (kg)	Super plasticizers (kg)
Nano Silica	0 %	14.38	22.405	43.52	0	5.165	0.1438
	2 %	14.09	22.405	43.52	0.2876	5.165	0.1438
	4 %	13.80	22.405	43.52	0.5752	5.165	0.1438
	6 %	13.52	22.405	43.52	0.8628	5.165	0.1438

3.3 MIXING AND CASTING

First of all the interior of mixing drum was wetted with water in order to minimize the absorption of water added as a part of the Concrete mixture. Firstly the coarse aggregate, fine aggregate and cement paste content was added and silica powder was added after it and mixed properly. Plasticizers was mixed with water and then added to the cement paste in three steps. All mixed for about 5 minutes.
A total of 24 cube of 150mm size and 24 cylinder of 150 mm × 300mm size were casted. All the specimens were taken to the vibrating table after casting in order to achieve proper and consistent compaction. The specimens were left in the laboratory at room temperature for 24 hours.
After 24 hours of placing concrete in moulds, the sample were de-moulded and were kept in water for curing. After the curing for 7 days and 28 days, the specimens were tested.

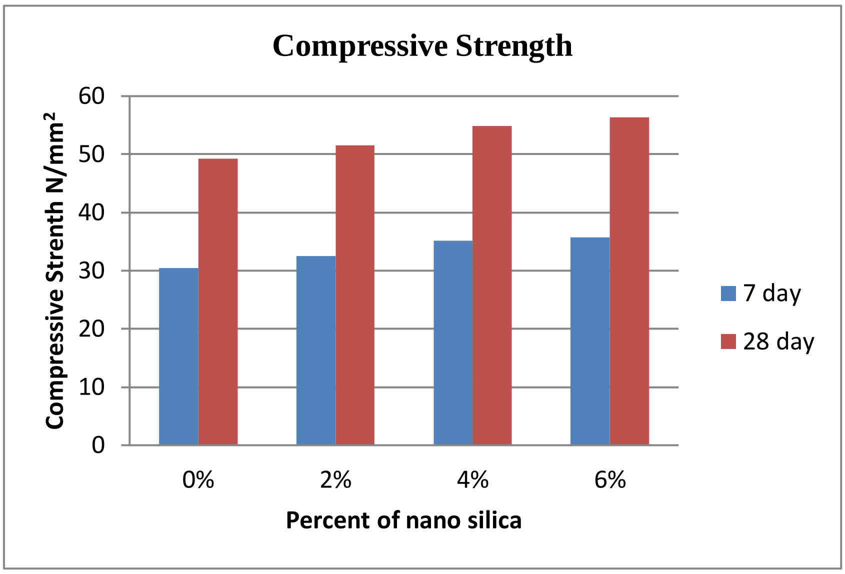
4. EXPERIMENTAL RESULTS

The compressive strength of specimens were determined according to the Indian Standard IS 516:1959 on cube specimens if sizes 150 mm × 150 mm × 150 mm. the split tensile strength test of specimens were carried out according to Indian Standard IS 5816:1999 on cylinder specimen of height 300 mm and diameter 150 mm.

4.1 Compressive Strength Test

The compressive strength test is the most common test conducted on concrete because it is the desirable characteristic property of concrete are quantitatively related to its compressive strength. Compressive strength was determined by using compression testing machine (CTM) of 3000 KN capacity.

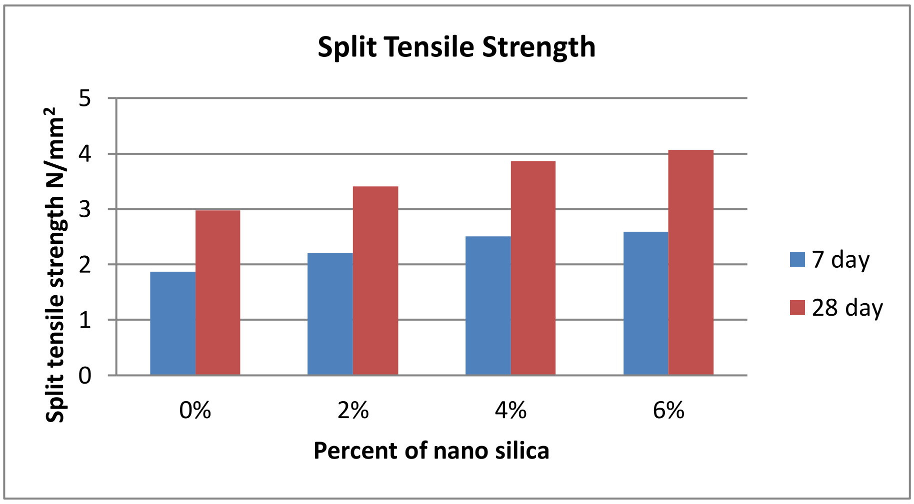
NANO SILICA (%)	Compressive Strength	
	7th day (N/mm²)	28th day
0 %	30.5	49.3
2 %	32.5	51.6
4 %	35.1	54.9
6 %	35.7	56.3



4.2 Split Tensile Strength Test

The tensile strength of concrete is one of the basic and important properties . Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete . The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension . The cylinders are placed in the compression testing machine and load is applied as similar to the cube . The cylinder is placed horizontally and the test is performed . The load is increased until the specimen fails and the maximum load applied to test specimen during the test is recorded . In these 6 concrete cylinders moulds are filled with concrete at every casting or with different percentage.

NANO SILICA (%)	Split Tensile Strength	
	7th day (N/mm^2)	28th day
0 %	1.87	2.98
2 %	2.21	3.41
4 %	2.50	3.86
6 %	2.59	4.07



5 CONCLUSION

- Nano silica is a desirable material for partial replacement of cement in concrete.
- It has been found that the cement could be advantageously replaced by SiO2 nano-particle up to maximum limit of 6.0% with average particle sizes of 6 and 20 nm.
- The experimental work, it is observed that increase in the content of nano silica will increase in the compressive strength.
- Split tensile strength of concrete with application of silica increase with an increase in the percentage of silica content.
- By enhancing the strengthen of concrete, its make structure economical.

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