EFFECT OF NANO-SILICA ON SELF COMPACTING CONCRETE AS PARTIAL REPLACEMENT OF CEMENT

Submitted in partial fulfillment of the requirements

Of the degree of

MASTER OF TECHNOLOGY

In

CIVIL ENGINEERING

By

ASIF BASHIR MIR

(11210830)

Supervisor

MS. GEETA MEHTA

Transforming Education Transforming India

School of Civil Engineering

LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA

2017

DECLARATION

I, Asif Bashir Mir bearing registration number 11210830, hereby declare that this project report entitled **"Effect of Nano-silica on self-compacting concrete"** submitted in the partial fulfilment of the requirements for the award of degree of Master of Civil Engineering, in the School of Civil Engineering, Lovely Professional University, Phagwara, is my own work. The matter embodied in this report has not been submitted in part or full to any other university/ institute for the award of any degree.

Date: **Asif bashir**

Place:

CERTIFICATE

Certified that this project report entitled, "**Effect of Nano-silica on self-compacting concrete"** submitted by, "**ASIF BASHIR**", registration number, "**11210830**" student of Civil Engineering Department, Lovely Professional University, Phagwara Punjab carried out Project work under my supervision.

To the best of my knowledge, the matter embodied in the project report has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Ms. Geeta Mehta
Assistant professor
Supervisor

Ms. Geeta Mehta
Research Coordinator
School of Civil Engineering

ACKNOWLEDGEMENT

It is pleasure and moment of satisfaction for me to express my gratitude and sincere thanks to my project guide **Assistant Prof. Ms. Geeta Mehta**, school of civil engineering, lovely professional university, Phagwara Punjab, who always inspired me and have been a constant source of encouragement and guidance.

I also express my gratitude to **Head of civil department Ms. Mandeep Kaur**, lovely professional university, Phagwara Punjab, for providing me facilities to carry out my project work.

I would love to thank **Assistant prof. Ms. Aanchana**, Lovely professional university, Phagwara Punjab, who guided and inspired me and how to start my project.

I express my special thanks to **Assistant prof. Mr. Anshul Garg**, lovely professional university, Phagwara Punjab, who supported me in finding the mix design and helped me whenever it was required.

I would love to thank **Mr. Iftikhar gul** and **Professor Dr. Tantray**, National institute of technology Srinagar, who guided me in a proper way, were my external mentors.

I am grateful to my associates and colleagues who helped me directly or indirectly.

Signature of Student

ASIF BASHIR

ABSTRACT

The most common material used for construction purpose is concrete and total production of cement is consumed in concrete for construction purpose. When we use cement in large quantities its production emits more and more carbon dioxide and hence results in greenhouse effect which leads to ozone layer depletion. So, consumption of cement in concrete in this research is reduced by replacing cement by Nano-silica. Self-compacting concrete flows and settles under its own weight and any kind of vibration for compaction is not required. Hence, reduces noise and onsite manpower (labor) to operate vibrator. Nano-silica is very fine material its size is in nano range and is pozzolanic in nature. In this research self-compacting concrete has been tested with and without Nano-silica as partial replacements of cement by 3%, 4%, and 5% by the weight of cement. Fresh properties by L-Box, slump test, V-funnel, of concrete has been tested and Compressive strength, tensile strength and flexural strength has been checked after 7 days, 14 days, 28 days and 56 days. It was found that Nano-silica enhances all the above mentioned properties as Nano-silica is very fine material and is pozzolanic in nature. The results further revealed that optimum dosage is 4%.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

%	Percentage
min	Minutes
mm	Millimeter
cm	Centimeter
m	Meter
L	Litre
sec	Second
w/b	Water/binder
Kg/m^3	Kilogram per meter cube
d	Days
MPa	Mega Pascal
^0C	Degree Celsius

CHAPTER 1

INTRODUCTION

1.1 General

Self-compacting concrete is a special and recent development of concrete in construction world, which flows and fills all the gaps of the formwork/moulds under the influence of its own weight, even in congested reinforcement bars. Self-compacting concrete does not require any mechanical vibrator for filling the gaps in the formwork and resisting segregation, hence, it reduces onsite manpower (labor) for all operations and reduces noise as well due to absence of vibrator at construction site as well as in the plants. Low water-cement ratio is preferred hence results in rapid strength development and durability. Workability is obtained by adding super plasticizers to the concrete.

Fresh self-compacting concrete must possess the following:-

1 Filling ability: this is the ability of self-compacting concrete to fill all the gaps present in the frame work, under the influence of its own weight only.

2 Passing ability: this is the ability of self-compacting concrete to pass or flow through the reinforcement bars having tight openings, under the influence of its own weight only.

3 Resistance to segregation: self-compacting concrete must possess first two conditions and the composition must remain homogeneous through the process of transport and placing, no segregation should take place. We can check that by doing slump flow test, L-box test, V-funnel test etc.

1.1.1 History behind Development of SCC

In last few decades, to enhance the performance of concrete in hardened state i.e. to increase the strength and durability of concrete, a lot of research were carried out throughout the world. Use of concrete in congested reinforcement bars and in special architectural structures , have made it requisite to produce a concrete that have proper passing ability, filling ability, good overall strength and adequate permeability. For enhancement of strength and durability properties of concrete researchers has under gone from macro level to micro level study, from 1980's onwards. By this study, development of self-compacting concrete was resulted. Self-compacting concrete was first developed by Okamura in 1988 in Japan to overcome the declension of concrete quality due to lack of skilled labour. Okamura's method is referred as Japanese method for design of self-compacting concrete. Okamura's method suggests that the coarse aggregate content in concrete mix should be 50% of its packed density and in mortar, sand content should be 50% of its packed density. After self-compacting concrete was developed, whole Europe started working on self-compacting concrete, which is noise free concrete i.e. why called as silent concrete. In Europe, 1991-2000 decade remain quite active for research field in self-compacting concrete. This is the reason why, Europe has given specifications and guidelines for self-compacting concrete EFNARC 2002, ahead of USA. Self-compacting concrete is found to be economical and environmental friendly as compared to conventional vibrated concrete.

Su *et.al.* And Su and Miao developed an alternate method for making self-compacting concrete, which is known as Chinese method henceforth.it first starts with packing of gravel and sand together and after that the voids present in aggregates are getting filled with cement paste. This method saves cement and filler constituents which are considered to be expensive hence results in less paste and is easier to carryout, and a concrete of normal strength is developed. The main disadvantage of using self-compacting concrete is that it needs more time as compared to conventional vibrated concrete to test before placing the concrete. Further research is going on self-compacting concrete, as it is not fully understood yet.

In 1988, first prototype of self-compacting concrete was completed, which performed satisfactorily to hardening shrinkage, heat of hydration, and other properties and hence was named as "High performance concrete". But, professor Aitcin defined high performance concrete as a concrete which shows high durability properties with low water-cement ratio. Hence Okamura defined this concrete as "self-compacting high performance concrete". In 1990's, Sweden in Europe, where research and development work into self-compacting concrete began and now in Europe almost every country is doing some research on self-compacting concrete. In 1996, London conference first research work at an international RILEM "international union of testing and research laboratories of materials and structures" was published from Europe. In January 1998, first bridge using self-compacting materials was casted and is considered to be the first bridge casted with this material outside of japan. In 2000, French recommendations were established for the use of self-compacting concrete and are referred as guidelines at construction sites. In France, two buildings were constructed, one was constructed with conventional vibrated concrete and other one was constructed with self-compacting concrete material, it was observed that construction with self-compacting concrete was completed 2.5 months before that of conventional concrete construction and saving cost of overall was 21.4%.

1.1.2 Motivation behind the development of SCC

It has been observed that in self-compacting concrete we can add upto 70%(by the weight of powder content) of supplementary cement materials such as fly ash, silica fume, granulated blast furnace, etc.so by using these more and more supplementary cement materials we can reduce the use of cement in concrete. During production of cement lot of carbon-dioxide is released which leads to greenhouse effect and further to Ozone layer depletion, so, by developing self-compacting concrete this problem can be reduced to some extent and we will get more durable concrete as compared to other conventional concrete. Self-compacting concrete is a recent development in construction world and further research is going on this material as it is not fully understood yet. As discussed above the construction rate is faster as compared to conventional concrete mix and it also reduces overall cost of construction. So, if I need to construct a structure in a limited period of time I can go for self-compacting concrete.

In India, not much work on self-compacting concrete has been reported, but due to lack of skilled labour and non-mechanization of construction industry, the future for SCC concrete is very bright. For few decades, main problem that engineers were facing is the durability of concrete. For durable concrete structures there is sufficient requirement of compaction which is done by using a mechanical vibrator in conventional concrete. But, if over compaction is done, segregation of concrete will occur, by developing self-compacting concrete there is no scarcity of segregation and enhancement in strength is obtained. As self-compacting concrete is segregation resistant, have flow and passing ability and compact under the influence of its own weight only and does not require any mechanical vibrator, hence reduce labour and equipment cost. For life long structures and for structures where construction period is limited and where we require more strength of the structures we can go for self-compacting concrete. In congested reinforcement structures where it is difficult to pour the concrete, self -compacting concrete has the property to flow and settle under its own weight, so using self-compacting concrete we can easily place the concrete. The main reason why Self-compacting came into existence is that during those days there were lack of skilled labour and researchers were worried about hardened properties of concrete. So, they made a concrete which can settle and compact under its own weight only.

1.2 Advantages and benefits of self –compacting concrete:

1. As self-compacting concrete consolidates and flows through reinforcement without segregation under the influence of its own weight only hence it will not require any mechanical vibrator.
2. Since self-compacting concrete does not require vibrator for consolidation and flow hence reduces noise and labour required.
3. Self –compacting concrete helps in faster (rapid) construction and ease of flow through congested reinforcement.
4. It is silent concrete, as it reduces noise at sites, pre-cast factory etc.
5. As vibrator and labours for handling that vibrator is not required hence it reduces the equipment cost as well as labour cost.
6. It is called a healthy concrete as it eliminates problems with blood circulation leading to "white fingers" caused by compacting equipment.
7. In situations where the casting is difficult due to congested reinforcement, self-compacting concrete yields homogenous concrete.
8. Normally, 1 cum requires 1.5 man-hours but using self-compacting concrete it is reduced to 0.35 man-hours.
9. It extends the service life of forms as it reduces wear and tear of forms.

1.3 Objectives of the study

1. To replace cement by nano-silica material.
2. To study the effect of nano-silica on self-compacting concrete.
3. To find the optimum dosage of nano-silica.
4. To find the effect of nano-silica on compressive strength of self-compacting concrete.
5. To study the effect of nano silica on split tensile strength of self-compacting concrete.
6. To study the effect of Nano-silica on flexural strength.

1.4 Supplementary cement materials:

Concrete is made of Portland cement, sand, coarse aggregate, and water. The main binder element in concrete is cement. Some supplementary materials are called pozzolans, which do not have cementitious properties but when reacts with cement they form cementitious products (during pozzolanic reaction). Supplementary cement materials are mineral admixtures, which enhances mechanical and durability properties of concrete due to hydraulic and pozzolanic activity. Supplementary cement materials can be used combined or individually in concrete. The supplementary cement materials I am using in this research is nano-silica.

1.4.1 Advantages of using supplementary cement material

1 Using supplementary cement materials the overall cost of construction is less as compared to using cement.
2 Supplementary cement materials can be used as partial replacement of cement, during production of which lot of carbon dioxide is released which leads to greenhouse effect and further to Ozone layer depletion, hence reduces the use of cement in concrete.
3 Supplementary cement materials enhances workability and other properties.
4 Supplementary cement materials in concrete enables us to use these byproducts which otherwise can be landfilled as wastes
5 Supplementary cement materials can retard setting time and some may accelerate setting time.
6 Supplementary cement materials reduces bleeding because of additional fines
7 Supplementary cement materials increases compressive strength.
8 Supplementary cement materials decrease permeability and hence reduces freeze and thaw and reduces chloride penetration.

1.4.2 Use of Nano silica

Nano-silica are also known as silicon dioxide nano particles or silica nano particles. Nano-silica is very fine material having particle size in the nano range. Cementitious material which is most referred and used is amorphous silica. According to their structures, nano silica has two types, one is P-type and second is **S**-type. The S-type Nano-silica particles have comparatively smaller surface area. It has been observed that nano-silica used in concrete enhances compressive strength of concrete and reduces overall permeability of concrete in hardened state of concrete due to pozzolanic properties of nano-silica, which results in densification of concrete matrix. As Nano-silica is very fine material, the voids which are there in coarse aggregates are filled by fine aggregates (sand) and the voids in fine aggregates are filled by cement material used in concrete and the voids present in cement material are filled by nano-silica additives used in concrete, hence results in overall densification of concrete matrix.

1.4.3 Reaction mechanism of Nano-silica (M.H.Beigi ***et al.*)**

Nano-filling property

During hydration process calcium hydroxide crystals is produced which causes voids in the concrete .nano particles ,having filling ability fills the voids in Calcium-Silicate-Hydrate gel and makes a denser adhesive cement paste.

Acting as a nucleus:

Nano particles can act like nucleus forming an extremely strong bond with Calcium-Silicate-Hydrate gel particles, in the structure of the Calcium-Silicate-Hydrate gel. Thus, increases stability of hydration products and hardened properties of concrete (mechanical and durability properties) are expected to improve.

Pozzolanic reaction:

When water-cement reaction takes place a large amount of calcium hydroxide crystals is produced. The calcium hydroxide Crystals of is a hexagonal crystal which exists between the transition area of cement paste matrix and aggregates and are harmful for strength and durability of concrete. Nano-silica, having high surface area, is very reactive, and Produces Calcium-Silicate-Hydrate condensed gel .Therefore, in the pozzolanic reaction, Calcium-Silicate-Hydrate gel increases and calcium hydroxide crystals decreases. Calcium-Silicate-Hydrate is a product of pozzolanic reaction, it Increases the density of transition region/ area by filling empty spaces which leads to increase in strength.

$2C_3S + H_2O \rightarrow C\text{-}S\text{-}H + 3((Ca\ (OH)_2)$

$2C_3S + 9H_2O \rightarrow C\text{-}S\text{-}H + Ca\ (OH)_2$

$2SiO_2 + 3Ca\ (OH)_2 \rightarrow 3CaO.\ 2SiO_2.\ H_2O$

To further explain the fast reactivity of nano-silica particles it can be said that for nano silica with unsaturated bonds, the reaction process between SiO_2 is as follows

$\equiv Si\text{-}O\text{-} + H – OH \rightarrow \equiv Si - OH$

$\equiv Si - + H – OH \rightarrow \equiv Si – OH$

$\equiv Si\text{-}\ OH + Ca\ (OH)_2 \rightarrow C\text{-}S\text{-}H$

CHAPTER 2

LITERATURE REVIEW

2.1 Physical properties of Nano-silica

Table 2.1: Physical properties of Nano-silica

Properties	M.H.Beigi	Ali Nazari	Karamoozain	Ehsan Mohseni
Diameter(nm)	15±5	15±5	15±3	15±3
Surface-volume ratio(m^2/g)	160±20	165±17	165±17	200
Density g/cm^3	<0.15	<0.15	<0.15	-
Purity	>99.9	>99.9	>99.9	>99.9

2.2 Properties of concrete

2.2.1 Fresh properties of concrete:

A concrete is said to be in fresh state when this concrete can be moulded in any shape and during this stage concrete is in plastic state. It includes workability, setting time, bleeding and segregation, air entrainment etc.

Workability of concrete depends on water-cement ratio, quantity and type of aggregates, quantity and type of cement, temperature, fine to coarse aggregate ratio etc. setting time is dependent on water to binder ratio, type of cement and admixture used, weather conditions, amount of cement and aggregates etc.

M.H.Beigi *et al*. (2013) they made concrete, by replacing cement with nano-silica and nano-silica + steel fibers. They used 0%, 2%, 4%, and 6% of nano-silica by the weight of cement as replacement of cement. From the experiments that they conducted on concrete to check workability they concluded that workability decreases when we add more and more silica. This is because, nano-silica is very fine material having size in the nano-range and have very high specific area. So, more area is in contact with water hence absorbs too much water, which results in decrease in workability. They conducted slump test, v-funnel, and L-box test to check the workability of concrete.

Erhan Guneyisi *et al*.(2015) According to him, he made self-compacting concrete, in which he replaced cement by various percentages of nano-silica and have taken constant water to binder ratio i.e. 0.33. He replaced cement by 0%, 2%, 4%, 6% of nano-silica, by the weight of cement. During his study he concluded that as we increase percentage of nano-silica in self-compacting concrete workability decreases this is due to, self-compacting concrete incorporated with nano-silica becomes more cohesive and high viscous, due to high specific area of nano-silica.

Chithra *et al*. (2016) he made high performance concrete in which he replaced fine aggregate by copper slag at constant of 40% and cement were replaced by colloidal nano-silica by the weightage of 0%, 0.5%, 1%, 1.5%, 2%, 2.5%, and 3%. Water to binder ratio for all mixs were 0.31 and binder quantity for all mixs were also kept constant i.e. 516 kg/m. By replacing sand with copper slag workability was increased due to glassy surface of copper slag. As we add nano-silica to concrete, workability gets decreased, the fact is nano silica absorbs the mixing water added to the concrete. According to him due to high specific area and high reactivity, nano-silica attracts readily water to itself which results in reduction of free water in concrete, required for fluidity. To increase fluidity of concrete, super plasticizers are required to solve this problem.

Sadarmontazi *et al*. (2010) made concrete by taking water to binder ratio constant 0.43 and total binder used was 450kg/m^3, sand and gravel quantity was also kept constant 850kg/m^3 and 770kg/m^3 respectively. In his research he used rice husk ash and nano-silica as partial replacement of cement. He made cubes of control SCC, SCC with 20% replacement of cement by rice husk ash, cubes with 20% of rice husk ash and 3% of nano-silica, cubes with 7% of nano-silica. The flow diameter of all mixtures 690±20 mm were also kept constant, and it was observed that we need more amount of super plasticizer in cubes containing 7% of nano-silica as compared to control SCC to maintain the same flow diameter. Self-compacting concrete with nano-silica becomes thicker and viscous.

Arya p. Nayar *et al*.(2014) he adopted M50 grade in which he used cement quantity as 350kg, coarse and fine aggregate quantity as 740kg and 950kg respectively, fly ash 200kg, superplasticizer1.8 by the weight of binder, water 180kg. he made one reference concrete of same proportions mentioned above and five other mixs in which he added 0.1%(by volume) of alkali resistant glass fibre (AR) and 0%, 0.5%, 1.5%, 2.5%, and 3.5% (total weight of cement) of nano-silica as partial replacement of cement. To attain the same workability of reference concrete super plasticizers were used and it was observed that as we add more and more nano-silica to concrete we need more amount of super plasticizers as compared to rest of the mixs, which means workability decreases with increase in percentage of nano-silica.

G. Quercia *et al*.(2013) He made self-compacting concrete in which he replaced cement by two forms of nano-silica i.e. powder and colloidal form of nano-silica. He concluded that mix containing colloidal nano-silica shows lower limit of flow diameter as per specifications and guidelines. He concluded that for every 1% nano-silica added to concrete 0.21% of additional super plasticizer is required. From his study he also concluded that there is more air content present in mixs which are incorporated with nano-silica, this is because of higher specific area of nano-silica, which in turn results in higher viscosity of paste.

S.Rao *et al*. (2015) they conducted tests on self-compacting mortars using nano-silica and nano-TiO_2. From his work he concluded that workability or flow ability of mortar decreases with addition of nano-silica. The reduction in workability was because of nano-silica has higher specific area as compared to cement material, hence more area will be in contact with water which results in more absorption of water, hence decreases the workability of mortar. From his work we can conclude that, same will happen with self-compacting concretes containing nano-silica.

2.2.2 Hardened properties of concrete:

Hardened properties of concrete is that stage when concrete starts gaining its strength. Hardened properties of concrete may include compressive strength, split tensile and flexural strength, modulous of elasticity, permeability of concrete. But we often focus on compressive strength of concrete, as concrete is used for compressive loads and all other properties are related to compressive strength.

2.2.2.1 Compressive strength, Tensile strength, Flexural strength.

(1) G. Quercia *et al*. (2013) they made concrete incorporated with two forms of nano-silica i.e. colloidal form and powder form. He replaced cement in both the cases with 3.8% nano-silica (by the weight of cement). He observed that compressive strength at 1 day of curing was higher of reference mix as compared to other two mixs incorporated with two forms of nano-silica. At 7 days, compressive strength of powder nano-silica was same as that of reference mix, but it increases after 91 days and was higher than that of reference mix. The reason behind this is, due to pozzolanic reaction calcium silicate hydrate gel is produced which fills the voids present in concrete and makes the concrete denser which results in improvement in strength. It was also observed that at 91 days compressive strength of colloidal nano-silica was higher than powder type mix and reference mix.

Tensile strength: After 28 days, tensile strength of reference mix was found to be 4.51 N/mm^2 while as those incorporated with two forms of nano-silica it was 4.92 N/mm^2 and 5.48 N/mm^2 for colloidal and powder form respectively. Reason behind development of tensile strength is that nano-silica produce more calcium silicate hydrate gel due to pozzolanic reaction which improves the quality of interfacial transition zone. At 91 days, there were improvement of 13% - 18% in compressive and split tensile strength of self- compacting concrete incorporated with 3.8% nano-silica.

(2) M.H.Beigi *et al*. (2013) they made concrete, by replacing cement with nano-silica. They used 0%, 2%, 4%, and 6% of nano-silica by the weight of cement as replacement of cement. He observed that upto 4% of nano-silica (by the weight of cement) compressive strength increases but if we add more than 4% compressive strength decreases, but still is more than reference mix. The increase in compressive strength is because, during hydration of cement $Ca(OH)_2$ is produced, as nano-silica is very reactive it utilizes that $Ca(OH)_2$ and produces calcium silicate hydrate gel, which fills the voids present in concrete hence makes the concrete more denser which results in increase in strength. The reduction in compressive strength is due to formation of unstable balls due to agglomeration of concrete.

Tensile strength: It was observed that tensile strength increased in specimen which were incorporated by nano-silica. At 28 days the split tensile strength at 0%, 2%, 4%, and 6% of nano-silica were 4, 4.3, 5.4, 5.4 Mpa respectively. Increase in tensile strength is due to, during hydration of cement $Ca(OH)_2$ is produced, as nano-silica is very reactive it utilizes that $Ca(OH)_2$ and produces calcium silicate hydrate gel, which fills the voids present in concrete hence makes the concrete more denser which results in increase in strength. But after 4% there is agglomeration of concrete takes place hence no effect on tensile strength.

Flexural strength: From his study he concluded that upto 4% flexural strength increases and at 6% there is no improvement in flexural strength this increase in flexural strength is due to nano-filler effect and due to pozzolanic effect of nano-silica.

(3) Arya p. Nayar *et al*. (2014) he adopted M50 grade in which he used cement quantity as 350kg, coarse and fine aggregate quantity as 740kg and 950kg respectively, fly ash 200kg, superplasticizer1.8 by the weight of binder, water 180kg. he made one reference concrete of same proportions mentioned above and five other mixs in which he added 0.1%(by volume) of alkali resistant glass fibre (AR) and 0%, 0.5%, 1.5%, 2.5%, and 3.5% (total weight of cement) of nano-silica as partial replacement of cement. It was observed that at 0.5% compressive strength at early ages was more but at later ages it decreases whereas at 1.5% and 2.5% early and later age strength were more than reference mix (more at 2.5%). At 3.5% it was found that early and later age strength was less as compared to other mixs incorporated with nano-silica. The increase in compressive strength was because the filling ability of nano-silica and pozzolanic reaction of nano-silica. Decrease in compressive strength was observed because due to high specific area of nano-silica there is formation of unstable balls in concrete which results in reduction in strength.

Tensile strength: Tensile strength at 2.5% was maximum and at 3.5 it was minimum even less than reference mix and mix with addition of 0.1% of AR. Increase in tensile strength is due to pozzolanic action of nano-silica which improves the quality of interfacial transition region of aggregates and paste hence increases the bond strength. Decrease in tensile strength is due to high specific area of nano-silica there is formation of unstable balls in concrete which results in reduction in strength.

Flexural strength: From his study he concluded that optimum dosage is 2.5% of nano-silica. Flexural strength increases upto 2.5% and then it decreases. Improvement in flexural strength is due to filling ability and pozzolanic reaction of nano-silica, and deduction in strength is due to formation of unstable balls due to agglomeration of concrete.

(4) Erhan Guneyisi *et al*. (2015) According to him, he made self-compacting concrete, in which he replaced cement by various percentages of nano-silica and have taken constant water to binder ratio i.e. 0.33. He replaced cement by 0%, 2%, 4%, 6% of nano-silica, by the weight of cement. It was observed that compressive strength of concrete was increased using nano-silica upto 4% and decreases at 6% of nano-silica this may be due to pozzolanic reaction of nano-silica, which consumes calcium hydrate produced during hydration of cement, hence fills empty spaces present in concrete which in turn results in densification of concrete matrix hence gain in strength. The decrease at 6% nano-silica is due to ball formation or agglomeration of concrete due to high specific area of nano-silica.

(5) Aref Sadeghi nik *et al*. (2013) they made concrete, by replacing cement with nano-silica and nano-silica + steel fibers. They used 0%, 2%, 4%, and 6% of nano-silica by the weight of cement as replacement of cement. The diameter of nano-silica used was 15±5nm and surface-volume ratio of 160±20 m^2/g. He observed that upto 4% of nano-silica (by the weight of cement) compressive strength increases but if we add more than 4% compressive strength decreases, but still is more than reference mix. The increase in compressive strength is because, during hydration of cement calcium hydrate $Ca(OH)_2$ is produced, as nano-silica is very reactive it utilizes that $Ca(OH)_2$ and produces calcium silicate hydrate gel, which fills the voids present in concrete hence makes the concrete more denser which results in increase in strength. The reduction in compressive strength is due to formation of unstable balls due to agglomeration of concrete.

(6) Ali Nazari *et al*. (2010) they made self-compacting concrete cubes and cubes in which there was partial replacement of cement by nano-silica with average size of 15nm and surface volume ratio of 165±7 m^2/g. nano-silica was incorporated in self-compacting concrete with 0%, 1%, 2%, 3%, 4%, and 5% as partial replacement of cement by the weight of cement. The binder content in all mixs was 450kg/m^3 and water to binder ratio of 0.4 were kept constant in all mixs. From the experiments he observed that compressive strength increases as we replace cement by nano-silica upto 4% and after that addition compressive strength decreases at 5% replacement but is still more than reference mix and mix incorporated with nano-silica upto 3%. The fact for increase in compressive strength is that nano-silica is very reactive and it consumes calcium hydrate produced during hydration process of cement, into calcium silicate hydrate gel by which almost all voids in concrete gets filled and hence increase overall compressive strength of concrete. The fact behind decrease in compressive strength at 5% replacement of cement by nano-silica, may be due to presence of more SiO_2 nanoparticles than required and thus leading to leaching of silica out and by replacing cement which is the main binder in concrete and hence does not contribute to strength gain.

Tensile strength: From his study split tensile strength of reference mix, and mixs with 0%, 1%, 2%, 3%, 4%, and 5% of nano-silica as partial replacement of cement were 1.6, 1.9, 2.4, 3.1, 3.5, 3.2 Mpa respectively at 28 days. From the data we can clearly see there is reduction in tensile strength after 4% of nano-silica. The fact for increase in tensile strength is that nano-silica is very reactive and it consumes calcium hydrate produced during hydration process of cement, into calcium silicate hydrate gel by which almost all voids in concrete gets filled and hence increase overall tensile strength of concrete. The fact behind decrease in tensile strength at 5% replacement of cement by nano-silica, may be due to presence of more SiO_2 nanoparticles than required and thus leading to leaching of silica out and by replacing cement which is the main binder in concrete and hence does not contribute to strength gain.

Flexural strength: He concluded that flexural strength increases upto 4% and then it decreases. The fact for increase in flexural strength is that nano-silica is very reactive and it consumes calcium hydroxide produced during hydration process of cement, into calcium silicate hydrate gel by which almost all voids in concrete gets filled and hence increase overall flexural strength of concrete. The fact behind decrease in flexural strength at 5% replacement of cement by nano-silica, may be due to presence of more SiO_2 nanoparticles than required and thus leading to leaching of silica out and by replacing cement which is the main binder in concrete and hence does not contribute to strength gain.

(7) A.A.Maghsoudi *et al* (2010) he made self –compacting concrete with water to binder ratio of 0.525 for cement type V and binder quantity 360kg/m^3 was kept constant with and without nano-silica cubes, also lime stone was used as filler and 40 kg/m^3 of micro silica was also used. He added colloidal nano-silica 2.4 liters (wt. % 5%) to self-compacting concrete. It was observed that compressive strength is more of cubes incorporated with colloidal nano-silica as compared to cubes without nano-silica. Due to pozzolanic reaction of nano-silica it fills the voids present in concrete hence helps in gain in strength of concrete.

(8) Hongjian Du *et al*. (2014) he made concrete cubes with and without nano-silica. Cubes in which nano-silica were added, it was added as 0.3% and 0.9% by the weight of cement, of nano-silica. After 28 days, at 0.3% and at 0.9% the improvement in compressive strength were recorded and it was found at 0.3% improvement was 9% and at 0.9% improvement was 12%. The reason behind this improvement is that nano-silica due to its nano size fills the voids present in concrete and pozzolanic reaction of nano-silica consumes unwanted harmful product of cement hydration which results in formation of calcium silicate hydrate gel. There is strong bond between the aggregates and cement paste which hence results in increase in compressive strength of concrete.

(9) Sadarmontazi *et al*. (2010) made concrete by taking water to binder ratio constant 0.43 and total binder used was 450kg/m^3, sand and gravel quantity was also kept constant 850kg/m^3 and 770kg/m^3 respectively. In his research he used rice husk ash and nano-silica as partial replacement of cement. He made cubes of control SCC, SCC with 20% replacement of cement by rice husk ash, cubes with 20% of rice husk ash and 3% of nano-silica, cubes with 7% of nano-silica. It was observed that in all mixs, cubes incorporated with 7% nano-silica shows higher compressive strength and then cubes with 20% of rice husk ash plus 3% of nano-silica shows second highest. The strength attribution of nano-silica is due to pozzolanic reaction by which it utilizes unwanted harmful calcium hydrate and converts that into calcium silicate hydrate which fills the voids and makes the matrix denser hence results in gain in strength.

Flexural strength: From his study he concluded that flexural strength was maximum for specimen incorporated with 7% nano-silica .this is because nano-silica acts as nucleus and hence absorbs more calcium ions present by which rate of hydration increases, hence results in gain in strength.

(10) Chithra *et al*. (2016) He made high performance concrete in which he replaced fine aggregate by copper slag at constant of 40% and cement were replaced by colloidal nano-silica by the weightage of 0%, 0.5%, 1%, 1.5%, 2%, 2.5%, 3%. Water to binder ratio for all mixs were 0.31 and binder quantity for all mixs were also kept constant i.e. 516 kg/m^3. At day 1, improvement in compressive strength at 0.5% of nano-silica was 40.1%, at 1% improvement was 56.4%, at 1.5% improvement was 75.6%, at 2% it was 89%, at 2.5% it was 78.5%, at 3% it was71.5% in comparison with reference mix . Using above mentioned type of mixs it was observed that compressive strength increases upto 2% replacement of cement by nano-silica and it decreases after this dosage. The reason behind increase in compressive strength is that because of pozzolanic reaction of nano-silica, voids present in concrete gets filled by utilizing the calcium hydrate which is produced during hydration of cement hence results in increase in strength of concrete. But as we increase percentage of nano-silica beyond 2%, compressive strength decreases the fact behind decrease in compressive strength is pozzolanic reaction of nano-silica by which voids present in concrete gets filled, which results in short cutting the entry of water to unhydrated cement particles hence results in deduction of strength.

Tensile strength: it was observed that upto 2% of nano-silica tensile strength increases then after it decreases this is because upto 2% there is strong bond formation between aggregates and cement paste but when we add beyond 2% agglomeration of concrete takes place which results in unstable ball formation hence decrease the strength.

Flexural strength: he observed that upto 2% of nano-silica flexural strength increases then after it decreases, this is because upto 2% of nano-silica there is strong bond formation between aggregates and cement paste but when we add beyond 2% agglomeration of concrete takes place which results in unstable ball formation hence decrease the strength.

(11) Karamoozain *et al*. (2013)he made self –compacting concrete with water to binder ratio of 0.42 in cement type ii and 0.525 for type V and binder quantity 360kg/m^3 was kept constant with and without nano-silica cubes, also lime stone was used as filler and 40 kg/m^3 of micro silica was also used. He added colloidal nano-silica 2.4 liters (wt. % 5%) to self-compacting concrete and in his research he used two types of cement, cement ii type and cement v type.it was observed that compressive strength is more of cubes incorporated with colloidal nano-silica as compared to cubes without nano-silica. The nano-silica presence in concrete may produce more reactive products which will react with the filler and hence helps in gain in strength of concrete.

Flexural strength: it was observed that flexural strength is more of specimen incorporated with colloidal nano-silica as compared to specimen without nano-silica. The nano-silica presence in concrete may produce more reactive products which will react with the filler and hence helps in gain in strength of concrete.

(12) Prakasam Ganesh *et al*. (2015) they made high strength concrete in which he used cement quantity of 730 kg/m^3 and silica fume 183kg/m^3. He made other two mixs in which he replaced 1% cement by nano-silica and other he replaced cement by 2%. Nano-silica used in this study have diameter of 15±5 nm and specific surface area of 600 m^2/g.

Table 2.2. The tensile strength at 28 days

Mix ID	Tensile strength
Reference	6.47
1% Nano-silica	7.08
2% Nano-silica	7.92

At 28 day split tensile strength at 1% nano-silica and at 2% nano-silica was improved by 17% and 24% respectively in comparison to reference mix. Split tensile is increased with addition of nano-silica and this increase is because of nano filling effect of nano-silica and due to pozzolanic reaction of nano-silica and at 56 day tensile strength decreases due to lack of formation of C-S-H gel.

Flexural strength: it was found that flexural strength increases and is maximum for concrete incorporated with 2% nano-silica. Flexural strength is increased with addition of nano-silica and this increase is because of nano filling effect of nano-silica and due to pozzolanic reaction of nano-silica.

(13) Mostafa Jalal *et al*.(2012) they made self-compacting concrete in which they used various amount of binder (cement) i.e. 400kg/m^3, 450kg/m^3, 500kg/m^3 with constant water-binder ratio of 0.38. He made other specimen in which he replaced 2% binder by nano-silica with above mentioned amount of binders. It was observed that cubes incorporated with 2% Nano-silica shows more compressive strength as compared to mix without Nano-silica. The reason behind increase in compressive strength is utilization of crystalline calcium hydroxide which were formed during hydration of cement.

Tensile strength: As it can be seen that tensile strength increases in all mixs incorporated with nano-silica the fact behind this increase is formation of calcium silicate hydrate which is formed when nano-silica reacts with crystalline calcium hydroxide in pozzolanic reaction.

Table 2.3. Tensile strength at 90 days

Concrete	Tensile strength at 90 days in Mpa
SCC400	3.9
SCC450	4.6
SCC500	4.8
SCC400 NS2%	4.4
SCC450 NS2%	4.8
SCC500 NS2%	4.9

Flexural strength: It was found that flexural strength is maximum for specimen incorporated with nano-silica as compared to those without nano-silica. The fact behind this increase is formation of calcium silicate hydrate which is formed when nano-silica reacts with crystalline calcium hydroxide in pozzolanic reaction.

CHAPTER 3
EXPERIMENTAL PROGRAMMES

3.1 General

Self-Compacting Concrete is that concrete which flows under its own weight with low water-cement ratio. The flow ability of concrete is achieved by using superplasticizers. When there is congested reinforcement it is very difficult to pour concrete in it, hence we prefer Self-Compacting Concrete, for which I have limited coarse aggregate size. Self –Compacting Concrete shows more strength and is found to be economical as compared to conventional vibrated concrete, as it does not require any kind of vibration.

3.2 Material used

3.2.1 Cement and its tests.

Cement is fine binder, usually organic substance which hardens and adheres to other materials together. In concrete it is used to bind fine and coarse aggregate together. In this study ordinary Portland cement of grade 53 is used produced by Trumbo industries PVT LTD, which sets quickly as compared to 43 grade.

Tests on cement

1 Fineness test: fineness of cement was determined by sieve method. The importance of determining fineness of cement is that we will come to know about the strength. If our material is finer, rate of hydration will increase due to large surface area hence more will be the strength.

Table 3.1. Weight of residue of cement.

Sample	**Weight of residue in grams**
1	2.7
2	2.3
3	2.5

Average residue = (2.7+2.3+2.5)/3 = 2.5g

Fineness = 2.5*100/100 = 2.5

2 Specific gravity of cement. Specific gravity of cement was determined by Le-Chatelier's flask.

Observation

W_1 = 111g

W_2 = 161g

W_3 =386.6g

W_4 =352.5g

$$\text{Specific gravity} = \frac{(W_2 - W_1)}{(W_2-W_1) - (W_4-W_3)} = \frac{(161-111)}{(161-111)-(386.6 - 352.5)}$$

Specific gravity = 3.15

3 Consistency of cement

It is defined as water requirement for cement paste to bring the Vicat plunger needle upto 5 to 7mm from the bottom.

Observation

It was found that normal consistency for cement was 28%. Normal consistency is required so that we can say amount of water to be added for initial and final setting time test and for soundness test. Which we take 0.85 of consistency for setting time and 0.78 for soundness.

4 Initial and final setting time for cement

Initial setting time is time after which Vicat's needle will not penetrate in cement paste after 35±5mm from the top, final setting time is the time after which there will not be any mark on hardened cement paste. As per specification initial setting time is 30 minutes minimum and final setting time is 600 minutes maximum

Observation

It was observed that initial setting time was 65 minutes and final setting time was 225 minutes.

5 Soundness test of cement

Soundness of cement is measured in terms of expansion of cement. Cracks may develop if our cement is unsound and ultimately leads to failure. For SCC soundness is limited to 5mm.

Observation

It was found that distance after 24 hours was 1.5 cm and after 3 hours was 1.8 cm. therefore soundness is 1.8 – 1.5 =0.3 cm which is 3mm hence is in limit.

Table3.2 Physical properties of cement

Specific gravity	Setting time(min) Initial	final	Consistency	Fineness
3.15	65	225	28%	2.5

3.2.2 Filler: In this study stone powder is used as inert filler and it does not affect the strength neither positively nor negatively. It is just used to increase the paste content in the mixture. According to EFNARC by stone dust we may have durability problems but by Nano-silica we can compensate that problem as well.

3.2.3 Water: water participates in chemical reactions when it reacts with cement during hydration of cement, hence is an important ingredient. In this research normal drinking water has been used.

3.2.4 Fine aggregates and tests.

In this study natural sand is used as fine aggregate with specific gravity 2.67 and water absorption of 1%. Moisture content should be supervised closely as this affect the quality of SCC. The reason for finding specific gravity of fine aggregates is that while designing the mix it is requisite that you should know specific gravity of fine aggregate to find quantity of fine aggregate

Tests on fine aggregate

1 Specific gravity and water absorption. Specific gravity of fine aggregates was found by using pycnometer.

Observation

X = surface dry wt. = 500g

X_1 =Wt. of bottle + sample +water=1830g

X_2 =Wt. of bottle+ water = 1517g

X_3 = Oven dry wt. = 495g

$$\text{Specific gravity} = \frac{X_3}{X-(X_1 - X_2)} = \frac{495}{500 - (1830 - 1517)} = 2.67$$

$$\text{Water absorption} = \frac{X - X_3}{X_3} = \frac{500 - 495}{495} = 1\%$$

2. Sieve analysis of fine aggregate

Table 3.3 Sieve analysis for fine aggregate.

Sieve No	Sieve size(mm)	Wt. retained (g)	% retained	% passing	Cumulative % retained
1	4.75	17	1.7	98.3	1.7
2	2.36	210	21	77.3	22.7
3	1.18	310	31	46.3	53.7
4	0.6	70	7	39.3	60.7
5	0.3	240	24	15.3	84.7
6	0.15	120	12	3.3	96.7
7	PAN	33	3.3	0	
total		1000			320.2

Calculations

Fineness of sand = 320.2/100 = 3.2

3.2.5. Coarse aggregate and its tests

According to EFNARC guidelines and specifications the maximum size of aggregates are limited to 20mm. but in this study I have used 10mm size aggregate with specific gravity 2.65 and water absorption of 0.5%.

Tests on coarse aggregate

1 Specific gravity

Specific gravity is defined as density of substance compared to density of water at 4^0c. Density of coarse aggregate should be in between 2.6 to 2.7. The reason for finding specific gravity of aggregates is that while designing the mix it is requisite that you should know specific gravity of coarse aggregate to find quantity of coarse aggregate

Observation

Surface dry wt. X_2 = 1005g

X = Wt. of gravel + basket mesh= 1500g. X_1=Wt. of empty mesh =875g

X_3=dry wt. of sample = 998g

Calculation

$$\text{Specific gravity} = \frac{X_3}{X_2 - (X - X_1)} = \frac{998}{1005 - (1500 - 875)} = 2.65$$

$$\text{Water absorption} = \frac{X_2 - X_3}{X_3} \times 100 = \frac{1005 - 998}{998} \times 100 = 0.7\%.$$

2 Sieve analysis

This test is conducted because we will know the grading of material and fineness of material.

Table 3.4 Sieve analysis for coarse aggregate

Sieve No.	**Sieve size(mm)**	**Wt. retained (g)**	**% retained**	**% passing**	**Cumulative % retained**
1	12	30	1.5	98.5	1.5
2	10	646	32.3	66.2	33.8
3	4.75	1292	64.6	1.6	98.4
4	2.36	32	1.6	0	100
total		2000			233.7

Fineness modulous = 233.7 / 100 =2.34

3.2.6 Superplasticizer: SCC is made with low water-binder ratio, to compensate water requirement and to decrease viscosity or to increase flow ability of concrete superplasticizer is used. In this study SNF was used as superplasticizer. It was already available in the laboratory.

3.2.7 Nano-silica: Nano-silica was used as partial replacement of cement obtained from ASTTRA CHEMICALS PVT LTD. It was observed that Nano-silica enhances both the fresh and hardened properties of concrete due to its nano filling effect and pozzolanic nature.

3.3 Mix proportion

In this research few trial mixes have been prepared to obtain desired 40Mpa strength, finally I got one having ratio cement**:** sand**:** gravel as 1**:** 1.4**:** 1.9. All samples were prepared with constant water- binder ratio 0.4, binder here is cement + Nano-silica. Binder, fine aggregate and coarse aggregate were also kept constant. Only cement quantity were varied with Nano-silica, but total binder quantity were kept constant. Samples incorporated with Nano-silica by 0%, 3%, 4%, and 5%, as partial replacement of cement, by the weight of cement were prepared. The abbreviation used SCC stands for self-compacting concrete SNS3% stands for self-compacting concrete incorporated with 3% Nano-silica, SNS4% stands for self-compacting concrete incorporated with 4% Nano-silica, SNS5% stands for self-compacting concrete incorporated with 5% Nano-silica. Mix design used in this study are provided in table below. All EFNARC guidelines and specifications were followed.

Table 3.5 Mix proportion used in this study

Mix ID	cement	River Sand	Stone dust	Water-binder ratio	Water	superplasticizer	gravel	Nano-silica
SCC	520	572	156	0.4	208	5.2(1%)	988	0
SNS 3	504.4	572	156	0.4	208	7.8(1.5%)	988	15.6
SNS 4	499.2	572	156	0.4	208	8.84(1.7%)	988	20.8
SNS 5	494	572	156	0.4	208	10.4(2%)	988	26

All the values are in kg/m^3 Binder = cement + Nano-silica

3.4 Mixing Procedure and curing.

First, cement sand and aggregates were mixed thoroughly in dry form in drum mixer for 3 to 5 minutes and then Nano-silica dispersion was added which was already prepared in laboratory using sonicator (figure). During sonication required amount of Nano-silica and 30% of water required were added, to form dispersion of Nano-silica. Dispersion of Nano-silica took 15 minutes. This dispersed Nano-silica were mixed to the already dry mixed aggregates for 3 minutes and rest 70% of water were added to the mixture and were mixed for 3 more minutes. Finally

Fig 3.1 pouring of concrete

Superplasticizer were added to attain flow ability and were mixed for a minute or two. This freshly mixed concrete has been tested for workability by slump flow test, V-funnel test, L-box and slump T50. After satisfying these tests this freshly mixed concrete was poured in cubes, cylinders and rectangles as per requirement, which were oiled before pouring this concrete and no vibration were given to these specimen as Self-Compacting Concrete settles under its own weight. After 24h these specimen were demoulded and were kept in sump tank for curing purpose at room temperature.

Fig 3.2 sonication of Nano-silica

3.5 Tests Performed

3.5.1 Tests in fresh state of concrete.

A concrete is said to be in fresh state when this concrete can be moulded in any shape and during this stage concrete is in plastic state. It includes workability, setting time, bleeding and segregation, air entrainment etc. Workability of concrete depends on water-cement ratio, quantity and type of aggregates, quantity and type of cement, temperature, fine to coarse aggregate ratio etc. setting time is dependent on water to binder ratio, type of cement and admixture used, weather conditions, amount of cement and aggregates etc.

Workability of concrete was checked by slump flow diameter, T_{50} slump flow time, L-box and V-funnel test.

3.5.1.1 Slump flow and T_{50} Slump: In Slump flow, when concrete flows on slump table, flowing factor is the mean diameter of two measured perpendicular diameters as shown in figure.It should lie between 650mm and 800mm [efnarc 2002]. When concrete flows over slump table to a diameter of 500mm, the time taken by this concrete gives T_{50} slump value which should lie between 2sec- 5sec for housing applications and 3sec to 7sec for civil engineering applications [efnarc 2002]. Slump flow and T_{50} slump shows filling ability of concrete.

Fig 3.3 slump test

Procedure

1. Take slump table of rectangular shape and mark 500mm diameter at the center of the table.
2. Place the Abrams cone on the table from the smaller diameter, oil it before placing.
3. Fill the cone with concrete by trowel without tamping
4. Strike off and Remove the surplus concrete at the top and bottom of cone respectively.
5. Let the concrete flow freely by raising the cone vertically
6. Simultaneously start stop watch and note down time taken by concrete to reach 500mm diameter, gives you T_{50} slump.

7. Measure two perpendicular diameters and take the average of two, gives you slump flow diameter.

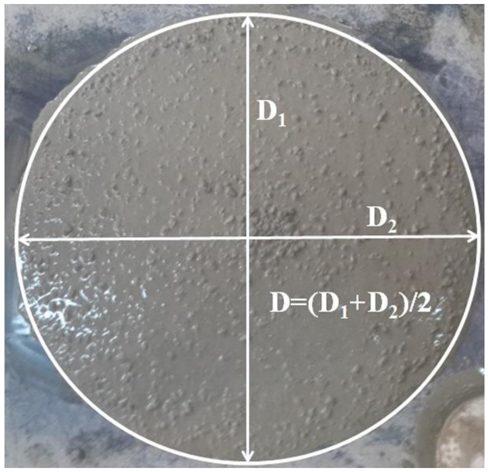

Fig 3.4 slump flow measure

3.5.1.2 L-Box test: In L-Box test concrete passes through vertical reinforced bars and the height attained by SCC passing through these bars are measured. The ratio of h_2/h_1 as shown in figure below is limited to 0.8 to 1. L-Box test of concrete shows passing ability of concrete.

Procedure:

1. Place the L-box on ground and level it if required.
2. Oil inside walls of the box and close the sliding gate after ensuring that it can be opened freely.
3. Pour concrete in vertical section and wait for one minute
4. Allow the concrete to flow through reinforced bars into horizontal section by lifting sliding gate.
5. Measure two heights as shown in figure after concrete stops flowing, gives you passing ability of concrete.

3.5.1.3 V-Funnel test: V-funnel test gives filling ability of concrete. It is time taken by concrete, when light is seen from above through the funnel. According to EFNARC 2002 recommended range for V-funnel is from 6sec to 12 sec.

Procedure

1. Place V-funnel on ground and level it if required.
2. Oil it well and remove any surplus water
3. Keep the trap door close and place a bucket under it.
4. Fill the funnel with concrete without tamping and wait for 10sec.

5. Open trap door and simultaneously start stop watch.
6. Note down time when light is seen from above through the funnel.

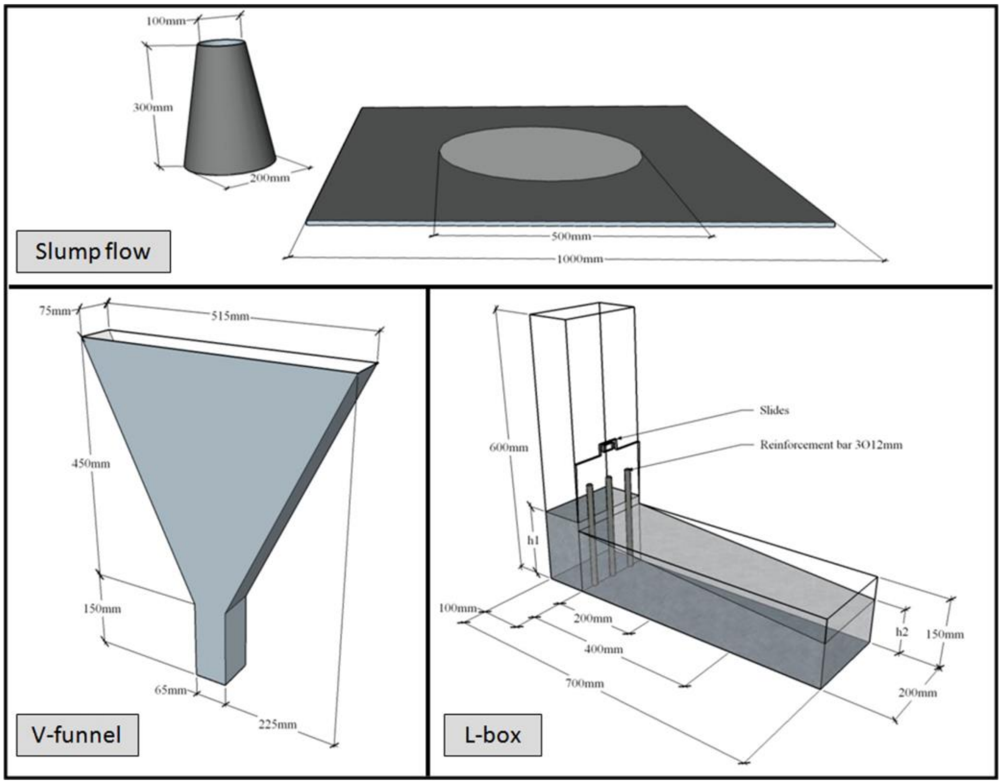

Fig 3.5 apparatus for workability check

3.5.2 Tests in hardened state of concrete.

Hardened properties of concrete is that stage when concrete starts gaining its strength. Hardened properties of concrete may include compressive strength, split tensile and flexural strength, modulous of elasticity, permeability of concrete. But we often focus on compressive strength of concrete, as concrete is used for compressive loads and all other properties are related to compressive strength. Compressive strength, split tensile strength, flexural strength of specimen were checked after 7, 14, 28 and 56days.

3.5.2.1 Compressive strength:

The most useful and important properties of concrete is its compressive strength. It is Compressive stresses which are resisted by concrete in most structural applications. In structures, where primary importance of strength is in tension or shear these are measured in terms of compressive strength. Compressive strength is inversely proportional to area of specimen and directly proportional to load applied on the specimen. Hence if the size of specimen is decreased its compressive strength will increase. Compressive strength of concrete depends on water-cement ratio, if water quantity is increased than required compressive strength will decrease but workability will increase. Compressive strength is also dependent on aggregate size, shape, type of cement, quantity of aggregate etc. Cubes of 150mm side each were casted and were checked for compressive strength after 7 days, 14days, 28 days and 56 days of curing. Tests were conducted as per IS 516:1959. Results are presented in table. It was found that compressive strength increases with increase in percentage of Nano-silica as replacement of cement. Average of two cubes were taken as compressive strength. CTM of 300 ton capacity were used to determine the failure load. Cubes were tested after removed from water with surface a bit dry. Cubes were put into the CTM in such a way that the surface which were expose to air was neither on the top side or bottom side of the load. Alignment of cubes was done by steel plates.

Fig 3.6 Compression test.

Load was applied slowly at the rate of 140 kg/sq. cm/min. it was a digital machine which were showing the peak load as well compressive strength due to that load by itself. It was concluded that compressive strength increases upto 4% and then it decreases, but still have more compressive strength as compared to mix incorporated with 3% Nano-silica. Increase in compressive strength can be attributed by the reaction mechanism of Nano-silica.

Pozzolanic reaction:

When water-cement reaction takes place a huge amount of calcium-hydroxide crystals are produced. These Crystals are hexagonal crystals which exists between the transition area of cement paste matrix and aggregates and are harmful for concrete as these create voids in the concrete. Nano-silica, having high surface area, is very reactive, and Produces Calcium-Silicate-Hydrate condensed gel. Therefore, in the pozzolanic reaction, Calcium-Silicate-Hydrate gel increases and calcium-hydroxide crystals decreases. Calcium-Silicate-Hydrate fills empty spaces present in concrete which leads to increase in strength.

Water + cement → calcium-hydroxide + C-S-H (calcium-silicate-hydrate).

Calcium-hydroxide + Nano-silica → calcium-silicate-hydrate.

Nano-filling property

During hydration process calcium-hydroxide crystals is produced which causes voids in the concrete. Nano particles fills the voids in Calcium-Silicate-Hydrate gel and hence results a denser Cement paste.

Formula used.

Compressive strength = load / area

Generally we measure compressive strength in terms of mega Pascal (Mpa)

1 Mpa = N/mm^2.

Load = X * 1000 = X 1000 N.

Where X is load in KN.

Area of cube is 150 * 150 = 22500 mm^2.

3.5.2.2 Tensile strength.

We know that concrete is weak in tension and is strong in compression. Tensile stresses may develop due to drying shrinkage, steel rusting, temperature gradient and so on. That is why, we should know about tensile strength of concrete. Split tensile strength of concrete incorporated with Nano-silica depends on reaction mechanism of Nano-silica. Tests were conducted as per IS 516:1999 after 7 days, 14 days, 28 days and 56 days of curing. For tensile strength cylinders of 150mm diameter and 300mm height were used. Before placing the specimen in the machine, the surface of specimen were cleaned properly. Two plates were also placed, one below the specimen and other above the specimen to balance the specimen. Loads were applied at the rate of 140kg/sq.cm/min. load at which failure occurred was noted down.

Formulas used to calculate tensile strength.

T.S = 2 * P / Π D L

Where P is compressive load

D is diameter of cylinder

L is length of specimen

Fig 3.7 tensile test

3.5.2.3 Flexural strength.

Direct method to find tensile strength is not yet there. So, we find indirect tensile strength. In beams it is find in terms of flexural strength. Flexural strength of concrete incorporated with Nano-silica depends on reaction mechanism of Nano-silica. Tests were conducted as per IS 516:1959 for flexural strength after 7 days, 14 days, 28 days and 56days of curing. For flexural strength beams of 100mm X 100mm X 500mm were used. Before placing the sample into U.T.M it was completely cleaned so that there was no sand or any kind of dust on the specimen.

Fig 3.8 flexural test

Two point loading was applied on the specimen at the rate of 180kg/min. beam was placed in the machine in such a way that the surface exposed to air during casting is directly placed under the load. Two rollers are placed at L/3 from their nearest supports so as to distribute the load uniformly. The failure load of the specimen is recorded.

Formula used

$F.S = P*L/BD^2$

Where P is failure load

L is span length of the specimen.

B is width of the beam.

D is depth of the beam.

CHAPTER 4
EXPERIMENTAL RESULTS AND DISCUSSION

4.1 General:

The basic reason of using Nano-silica was to find its effect on fresh and hardened properties of concrete. It is revealed from the results that Nano-silica significantly increases compressive, tensile and flexural strength of Self-Compacting Concrete. It was also revealed that Nano-silica increases water demand as we go on adding this material. Even though the cost of Nano-silica is very high but for life long buildings were main motive is its strength properties we can go for Nano-silica. From previous studies it was revealed that Self-Compacting Concrete is economical as compared to conventional vibrated concrete, so cost of Nano-silica can be compensated by using such material. One important thing which I observed during experiments was that the surface of specimen was very smooth and there was no requirement of any kind of finishing.

4.2 Use of Nano-silica

Nano-silica are also known as silicon dioxide nano particles or silica nano particles. Nano-silica is very fine material having particle size in the nano range. Cementitious material which is most referred and used is amorphous silica. According to their structures, nano silica has two types, one is P-type and second is **S**-type. The S-type Nano-silica particles have comparatively smaller surface area. It has been observed that nano-silica used in concrete enhances compressive strength of concrete and reduces overall permeability of concrete in hardened state of concrete due to pozzolanic properties of nano-silica, which results in densification of concrete matrix. As Nano-silica is very fine material, the voids which are there in coarse aggregates are filled by fine aggregates (sand) and the voids in fine aggregates are filled by cement material used in concrete and the voids present in cement material are filled by nano-silica additives used in concrete, hence results in overall densification of concrete matrix.

4.3 Fresh properties of concrete

During experimentation it was observed that as we keep on adding Nano-silica, there is increase in water demand. Various tests were performed like L-box, V-funnel, slump flow diameter, T50 slump. First I add 1% superplasticizer to reference mix and all the above mentioned tests were performed and it was revealed from the results that all the values were in range as mentioned in EFNARC. Then I replaced cement by 3% Nano-silica and same quantity of superplasticizer was used, but there was no flow ability in Self-Compacting Concrete. So I keep on adding superplasticizer till I got the results in the range mentioned in EFNARC. Same procedure was repeated for 4% and 5%. Finally I conclude that as we keep on incrementing Nano-silica more and more requirement of Nano-silica was there by the weight of cement, as presented in table and figure. The reason behind increase in water demand was because Nano-silica is very fine material which means it is having a very high specific area, hence more area will be in contact with water, by which it absorbs more water even the water present in voids hence results in water demand. So, final conclusion is that as we keep on increasing percentage of Nano-silica there is more and more requirement of water which results in decrease in workability of concrete.

Table 4.1superplasticizer requirement

Mix id	Requirement of superplasticizer
SCC	1%
NSN3%	1.5%
NSN4%	1.7%
NSN5%	2%

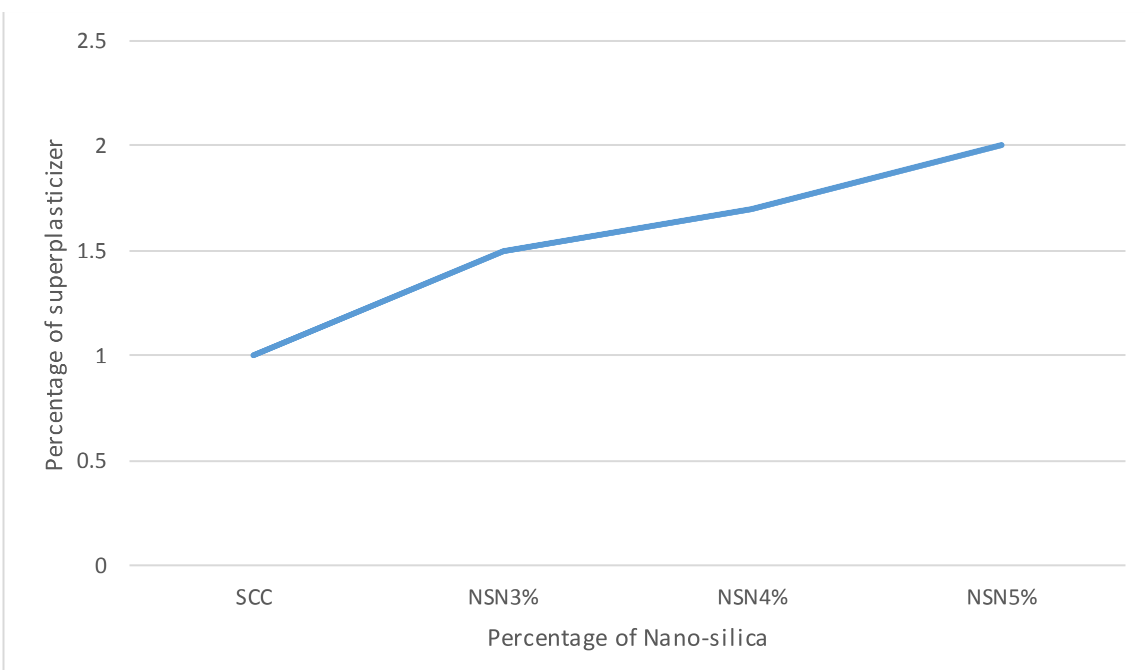

Figure 4.1 percentage of superplasticizer

Various tests as mentioned above were conducted and the results of those tests are presented in table 4.2 below.

Table 4.2 fresh property results

Mix id	Slump flow mm	T50 slump sec	L-Box h_2/h_1	V-funnel sec
SCC	713	4	0.92	9
NSN3%	710	4	0.89	10
NSN4%	705	5	0.85	10
NSN5%	712	4	0.9	9

4.3 Hardened properties of concrete

4.3.1 Compressive Strength

Cubes were tested for compressive strength and the results obtained are presented in table below.

Table 4.3 Average Compressive strength

Mix ID	7 days Mpa	14 days Mpa	28 days Mpa	56 days Mpa
SCC	27	36	45	47
SNS3%	29	40	48	51
SNS4%	32	43	52	54
SNS5%	30	41.5	50	52

It can be seen from the above table and figure 4.1 that with increase in percentage of Nano-silica as partial replacement of cement, compressive strength increases upto 4% and then it decreases at 5% but still have more than Self-Compacting Concrete incorporated with 3% Nano-silica and reference mix i.e. SCC. It can be seen from the above table that with increase in number of curing day's compressive strength increases. Which means during this study maximum compressive strength is at 4% Nano-silica after 56 days of curing and minimum is at 0% Nano-silica after 7 days of curing. We can further study on 4.5% of Nano-silica, as 0.5% is a big difference.

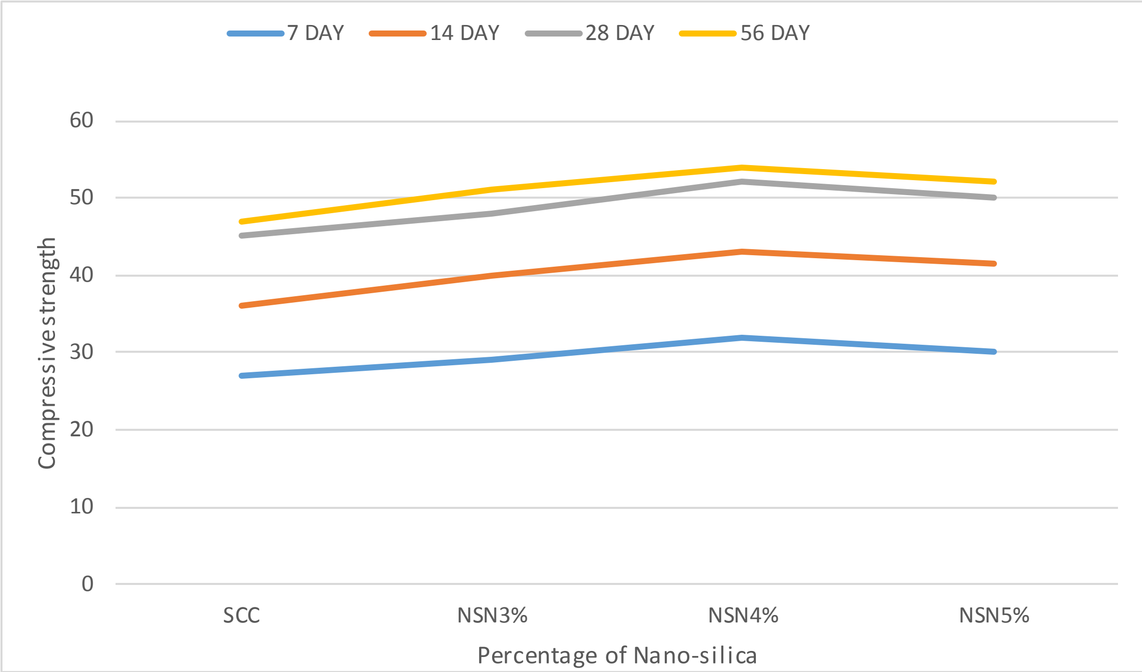

Figure 4.2 average compressive strength

The reason behind increase in compressive strength is reaction mechanism of Nano-silica. Which is pozzolanic nature and nano filling effect of Nano-silica. During hydration of cement that is when cement is reacted with water, Calcium-Hydroxide and Calcium-Silicate hydrate is produced. This produced Calcium Hydroxide is harmful to concrete as this create voids in the concrete so we need to utilize this. So, when we add Nano-silica to concrete as replacement of cement this Nano-silica reacts with this calcium hydroxide and converts this into Calcium-Silicate Hydrate which is cementitious material hence there is significant increase in compressive strength. This is pozzolanic nature of Nano-silica. Second reason behind increase in compressive strength is nano filling effect of Nano-silica. When cement, sand and aggregates are mixed together there are some empty spaces present in that mix, as Nano-silica is very fine material finer than cement it fills those voids. First the voids which are present in coarse aggregate are filled by fine aggregate and the voids which are there in fine aggregate are filled by cement and the voids which are there in cement can be filled only by that material which is finer than cement, as Nano-silica being finer than cement fills those voids hence helps in increase in compressive strength.

It can be also seen that with increase in number of days compressive strength increases the reason behind this is, as we increase number of curing days more and more Calcium-Silicate Hydrate is produced and more Calcium Hydroxide gets utilized. But if we compare 28days of curing and 56 days of curing there is not a significant increase in compressive strength as compared to 14 days of curing and 7 days of curing. Reason is that, reaction was almost complete after 28 days of curing. It can be shown in terms of graph also using 4% of Nano-silica results that, with increase in number of curing days compressive strength increases. I choose 4% Nano-silica results because it was revealed at 4% compressive strength was maximum.

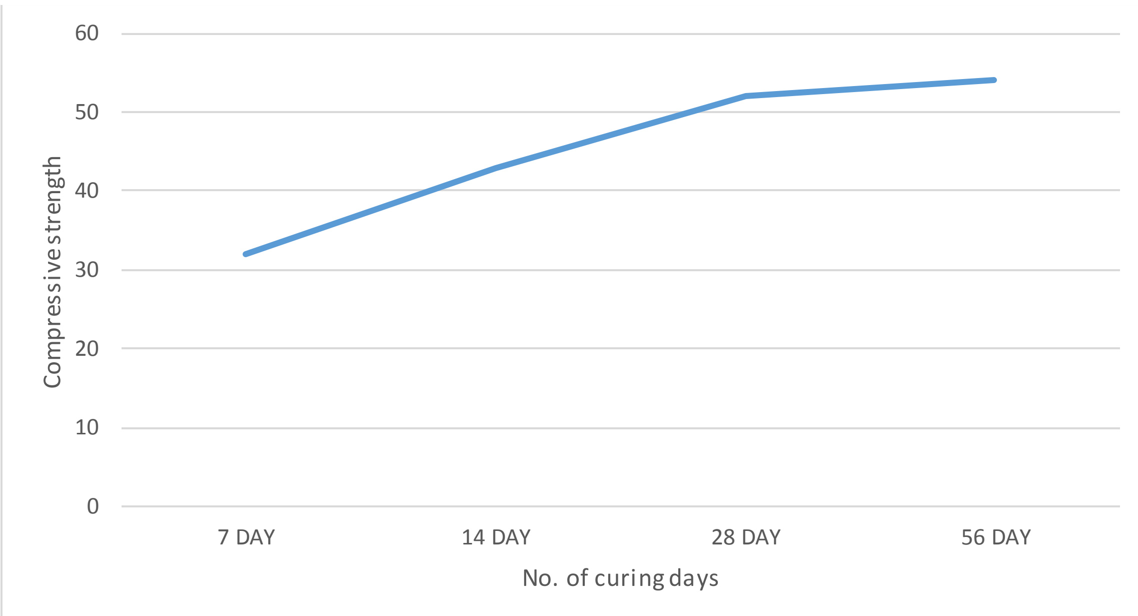

Figure 4.3 compressive strength at various ages

4.3.2 Split tensile strength:

Split tensile strength results are presented in table below and in figures below.

Table 4.4 average split tensile strength

MIX ID	7 day Mpa	14 days Mpa	28 days Mpa	56 days Mpa
SCC	3.7	3.9	4.1	4.3
SNS3%	3.8	4.2	4.5	4.7
SNS4%	4.1	4.4	4.8	4.95
SNS5%	3.95	4.31	4.7	4.75

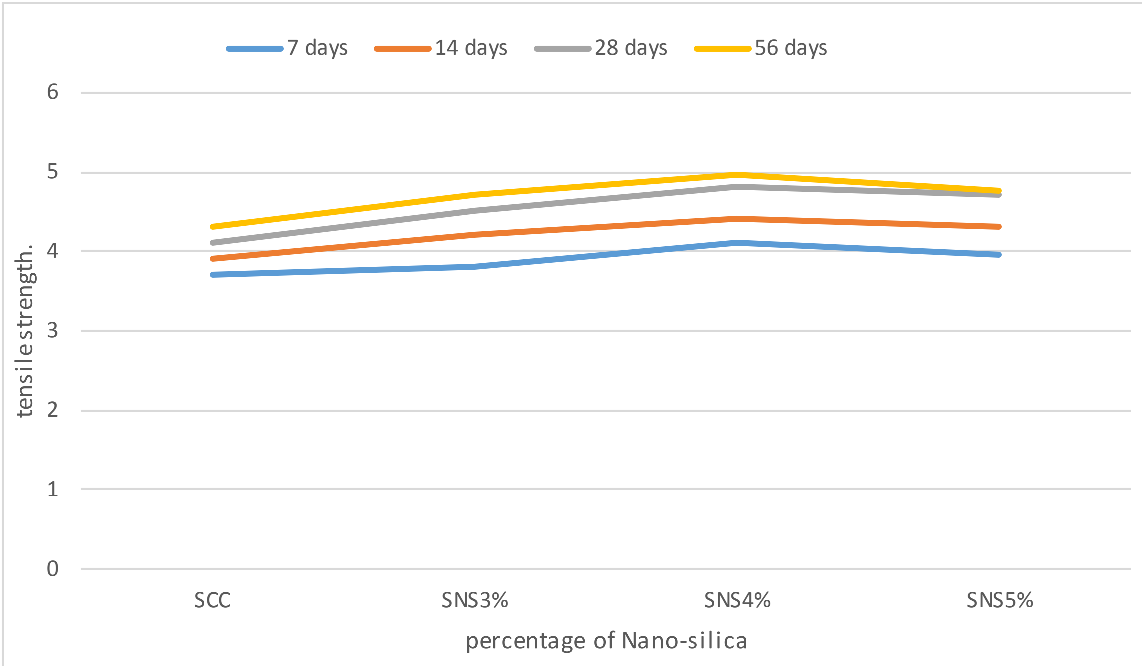

Figure 4.4 tensile strength

It can be seen from the table and graph above that tensile strength increases as we increase percentage of Nano-silica upto 4% and then it decreases at 5% but still have more tensile strength than 3% of Nano-silica and reference mix.

The main reason behind increase in tensile strength is that there is strong bond formation between aggregates and cement paste but as we keep on increasing percentage of Nano-silica there is agglomeration of concrete which decreases strength of concrete. Another reason may be pozzolanic nature and nano filling effect of Nano-silica. By which more hydrated products are produced. During pozzolanic reaction Calcium-Silicate Hydrate is produced, when Calcium-Hydroxide reacts with Nano-silica, which was produced when cement and water reacts (hydration process). By utilizing this Calcium-Hydroxide and producing Calcium-Silicate Hydrate helps in gain in strength.

There is another graph (figure) from which we can conclude effect of Nano-silica on tensile strength with respect to increase in number of curing days for that I have chosen tensile strength of 4% Nano-silica results this is because at 4% there is maximum tensile strength.

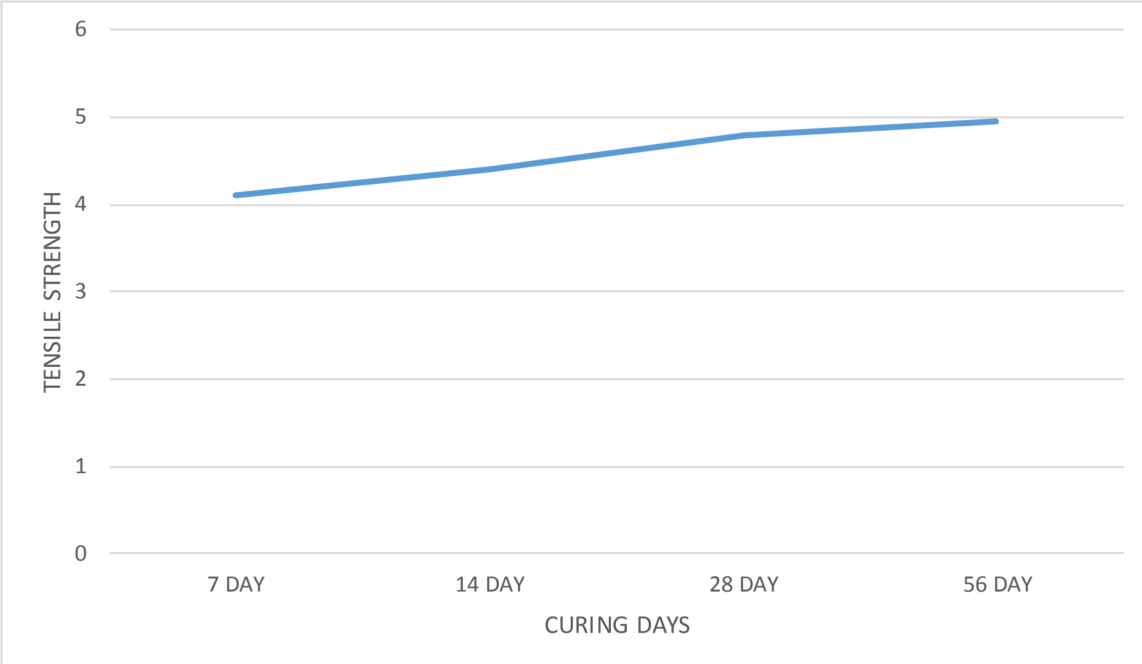

Figure 4.5 tensile strength at various ages

From the results we conclude that there is increase in tensile strength as we increase number of curing days this is because, as we increase number of curing days more and more Calcium-Silicate Hydrate is produced and more Calcium Hydroxide gets utilized. But if we compare 28days of curing and 56 days of curing there is not a significant increase in tensile strength as compared to 14 days of curing and 7 days of curing. Reason is that, reaction was almost complete after 28 days of curing. It can be shown in terms of graph also using 4% of Nano-silica results that, with increase in number of curing days tensile strength increases.

4.3.3 Flexural strength:

Table 4.5 average flexural strength

Mix id	7 days Mpa	14 days Mpa	28 days Mpa	56 days Mpa
SCC	6.1	6.4	7.1	7.3
NSN3%	6.3	6.65	7.5	7.7
NSN4%	6.7	6.97	7.8	7.98
NSN5%	6.45	6.85	7.75	7.84

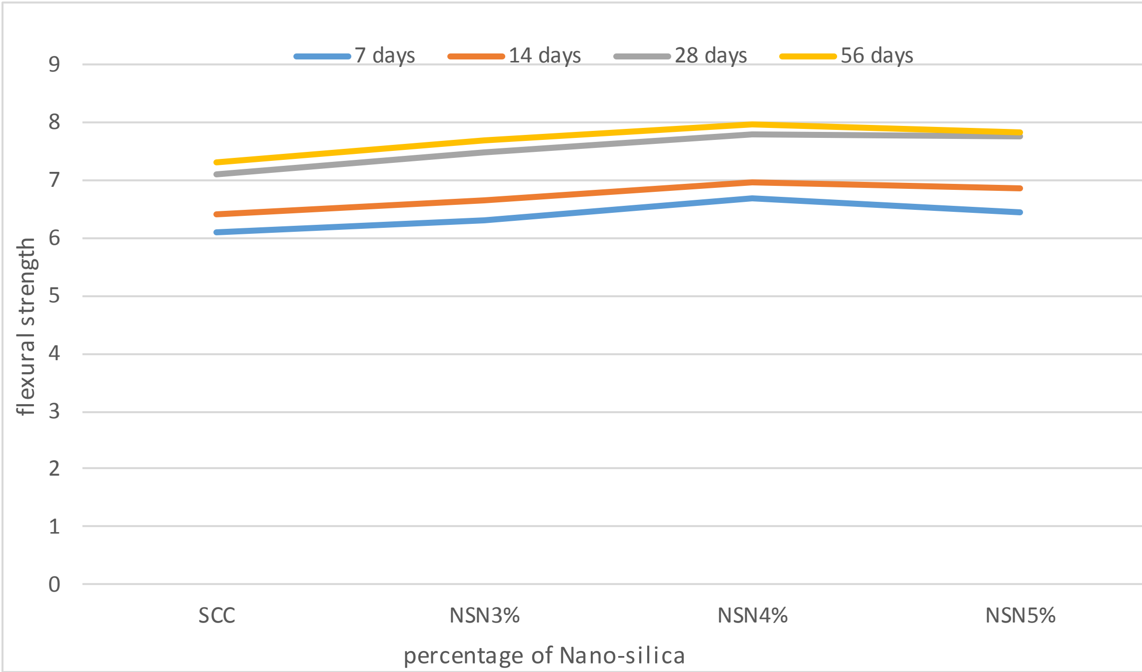

Figure 4.6 flexural strength

It can be seen from the above graph and table that with increase in percentage of Nano-silica there is increase in flexural strength of concrete. It is revealed from the results that maximum flexural strength is at 4% and at 5% there is slight decrease in tensile strength but still have more strength as compared to reference mix and mix incorporated with 3% Nano-silica. Reason behind increase in flexural strength is same as that of compressive strength and tensile strength, which is due to pozzolanic nature and nano filling effect of Nano-silica. During hydration of cement that is when cement is reacted with water, Calcium-Hydroxide and Calcium-Silicate hydrate is produced. This produced Calcium Hydroxide is harmful to concrete as this create voids in the concrete so we need to utilize this. So, when we add Nano-silica to concrete as replacement of cement this Nano-silica reacts with this calcium hydroxide and converts this into Calcium-Silicate Hydrate which is cementitious material hence there is significant increase in strength. This is pozzolanic nature of Nano-silica. Second reason behind increase in strength is nano filling effect of Nano-silica. When cement, sand and aggregates are mixed together there are some empty spaces present in that mix, as Nano-silica is very fine material finer than cement it fills those voids. First the voids which are present in coarse aggregate are filled by fine aggregate and the voids which are there in fine aggregate are filled by cement and the voids which are there in cement can be filled only by that material which is finer than cement, as Nano-silica being finer than cement fills those voids hence helps in gain in strength.

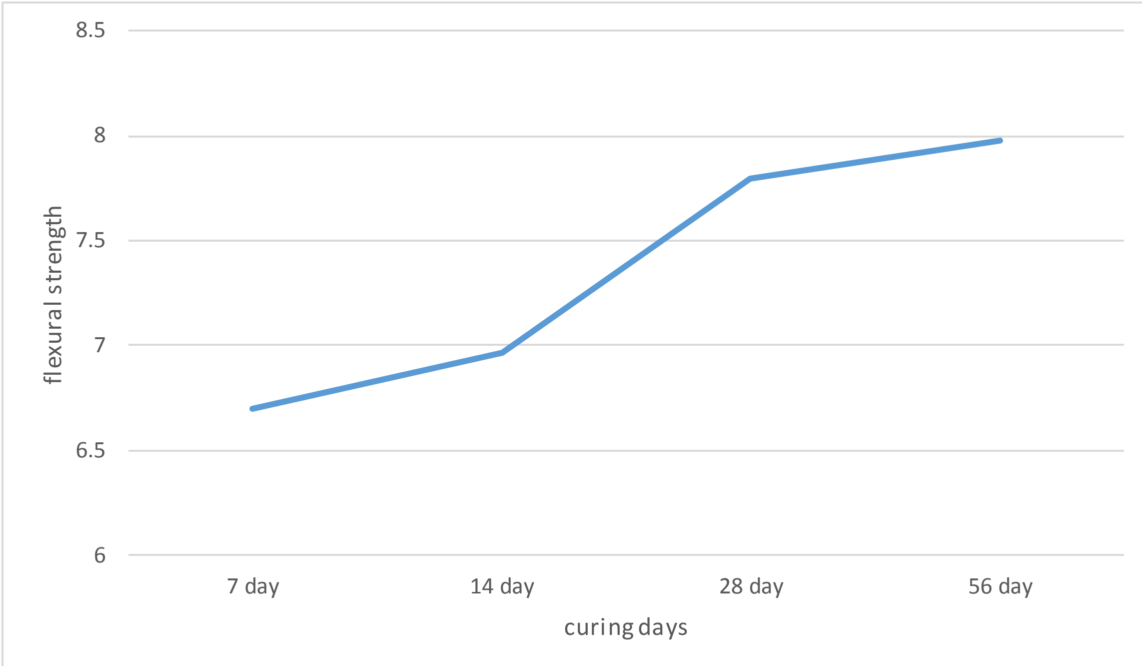

Figure 4.7 flexural strength at various ages

The above graph is obtained from the result of 4% Nano-silica. From the results we conclude that there is increase in flexural strength as we increase number of curing days this is because, as we increase number of curing days more and more Calcium-Silicate Hydrate is produced and more Calcium Hydroxide gets utilized. But if we compare 28days of curing and 56 days of curing there is not a significant increase in flexural strength as compared to 14 days of curing and 7 days of curing. Reason is that, reaction was almost complete after 28 days of curing.

CHAPTER 5

Conclusion

1. Self-compacting concrete shows more strength properties and is found to be economical as compared to conventional vibrated concrete
2. It is revealed that nano-silica incorporated in concrete enhance strength properties and workability as well.
3. It is observed that compressive strength increases in mixs incorporated with Nano-silica upto 4% and then it decreases at 5% but is still more than reference mix and mix incorporated with 3% Nano-silica.
4. It is revealed that split tensile and flexural strength increases in concrete incorporate with nano-silica upto 4% and then it decreases at 5% but is still more than reference mix and mix incorporated with 3% Nano-silica.
5. The reason behind increase in strength is its nano-filling nature and pozzolanic reaction of Nano-silica, by which calcium-silicate-hydrate gel is produced which fills the voids. The fact behind decrease in strength is that, at 5% there is agglomeration form of concrete by which unstable balls are formed which results in decrease in strength.

REFERENCES AND BIBLOGRAPHY

[1] G. Quercia, P. Spiesz, G. Husken, H.J.H. Brouwers SCC modification by use of amorphous nano-silica, Cement & Concrete Composites,2014.

[2] Arya P Nair, Mohammed asim, department of Civil Engineering TKM College of Engineering Kollam, India, Effect of nano silica on the strength and durability properties of glass fiber reinforced self-compacting concrete, 2014.

[3] Morteza H. Beigi, Javad Berenjian , Omid Lotfi Omran , Aref Sadeghi Nik, Iman M. Nikbin, An experimental survey on combined effects of fibers and nano-silica on the mechanical, rheological, and durability properties of self-compacting concrete, 2013.

[4] George Quercia, Przemek Spiesz, Gotz Husken, Jos Brouwers, Effects of amorphous nano-silica additions on mechanical and durability performance of SCC mixtures, 2012.

[5] A.A. Maghsoudi, Assistant professor, department of civil engineering, Shahid Bonahur university, Kerman, Iran and F. Arabpour Dahooei, M.Sc. student of coastal and offshore structures Engineering , department of civil engineering, Hormozgan university, Bandarabbas, Iran, Effect of nano scale materials in engineering properties of performance self-compacting concrete, 2010.

[6] Mostafa Jalal, Ali Reza Pouladkhan, Ali Akbar Ramezanianpour, Hassan. Norouzi, Effects of silica nano-powder and silica fume on rheology and strength of high strength self –compacting concrete, 2012.

[7] Sanga Kranthi Kumar, Influence of Nano-Silica on the Strength and Durability of Self Compacting Concrete, July 2015.

[8] A.Lazaro and H. J. H. Brouwers, Nano-silica production by a sustainable process; Application in building materials, June 2010.

[9] Javier Puentes, Gonzalo Barluenga, Irene Palomar, Effects of nanocomponents on early age cracking of self-compacting Concretes, 2014.

[10] Javier Puentes, Gonzalo Barluenga, Irene Palomar, Effect of silica-based nano and micro additions on SCC at early age and on hardened porosity and permeability, 2015.

[11] Erhan Guneyisi, Mehmet Gesoglu, Asraa Al-Goody, Suleyman _Ipek, Fresh and rheological behavior of nano-silica and fly ash blended self-compacting concrete, 2015.

[12] Hongjian Du, Suhuan Du, Xuemei Liu, Durability performances of concrete with nano-silica, 2014.

[13] Mahmoud Khashaa Mohammed, Andrew Robert Dawson, Nicholas Howard Thom, Macro/micro-pore structure characteristics and the chloride penetration of self-compacting concrete incorporating different types of filler and mineral admixture, 2014.

[14] Ehsan Mohseni, Bahareh Mehdizadeh Miyandehi, Jian Yang, Mohammad Ali Yazdi, Single and combined effects of nano-SiO2, nano-Al2O3 and nanoTiO2 on the mechanical, rheological and durability properties of self-compacting mortar containing fly ash, 2015.

[15] Ali Nazari, Shadi Riahi, The effects of SiO2 nanoparticles on physical and mechanical properties of high strength compacting concrete, 2011.

[16] S. Rao, P. Silva, J. de Brito, Experimental study of the mechanical properties and durability of self-compacting mortars with nano materials (SiO2 and TiO2), 2015.

[17] A.Sadarmomtazi, A. Barzegar, Assessment of the effect of Nano-SiO_2 on physical and mechanical properties of self-compacting concrete containing rice husk ash, June 2010.

[18] EFNARC, Specification and Guidelines for Self-Compacting Concrete, 2005,

[19] Paratibha AGGARWAL, Rafat SIDDIQUE, Yogesh AGGARWAL, Surinder M GUPTA, Self-Compacting Concrete - Procedure for Mix Design, 2008.

[20] Chris I. Goodier Senior Consultant, Centre for Concrete Construction, Building Research Establishment, development of self-compacting concrete, 2003.

[21] H.J.H. Brouwers, H.J. Radix, Self-Compacting Concrete: Theoretical and experimental study, 2005.

[22] Masahiro Ouchi**,** Kochi University of Technology, JAPAN, Makoto Hibino, Nagaoka University of Technology, Japan, Development, Applications And Investigations Of Self-Compacting Concrete.

[23] Ouchi, Nakamura, Osterson, Hallberg, Lwin, applications of self-compacting concrete in japan, Europe and the united states, 2003.

[24] J. Guru Jawahar, C. Sashidhar, I.V. Ramana Reddy and J. Annie Peter, A Simple Tool for Self Compacting Concrete Mix Design, may 2012.

[25] Krishna Murthy.N, Narasimha Rao A.V, Ramana Reddy I .V and Vijaya Sekhar Reddy.M, Mix Design Procedure for Self Compacting Concrete, 2012.

[26] P.L. Domone, A review of the hardened mechanical properties of self-compacting concrete, 2006.

[27] IS 516: 1959, methods of test for strength of concrete, Bureau of Indian standard, New Delhi.

[28] IS 516:1999, Split tensile strength of concrete, method of test, Bureau of Indian standard, New Delhi.

[29] IS 383:1970, specifications for fine and coarse aggregate from natural sources for Bureau of Indian standard, New Delhi.

[30] IS 12269:1987, specifications for 53 grade ordinary Portland cement, Bureau of Indian standard, New Delhi.

[31] SHETTY. M. S. Concrete Technology, by S. CHAND Publisher.

[32] S.K.Duggal, Building material.