A Study on Mechanical Properties of Concrete with Addition of Nano-Silica

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Abstract- *Concrete is the most common used material for construction and their design consumes almost the totals cement production in the world. The use of large quantities of cement produces increasing CO_2 emissions, and as a consequence the greenhouse effect. A method to reduce the cement content in concrete mixes is the use of silica fines. One of the silica fines with high potential as cement replacement and as concrete additive is Nano-silica (NS). This would save not only the natural resources and energy but also protect the environment with the reduction of waste material.*

The present work deals with addition of Nano-silica to concrete as partial replacement to cement in dosages of 1%, 1.5% and 2% by weight of cement. Based on early research M_20 grade concrete has been chosen for this work. Addition of Nano-silica to normal cement concrete show increase in compressive strength and decrease in splitting tensile strength.

Keywords- Nano-silica, Compressive strength, Split tensile strength

I. INTRODUCTION

General:

Concrete is a composite material made up of cement, fine aggregate & coarse aggregate sand, water and sometimes admixtures. Cement is the most active component of concrete binding usually has the greatest unit cost, its selection and proper use are important in obtaining economical concrete and also concrete of desired properties. The use of large quantities of cement results in increasing CO_2 emissions and as a consequence of the greenhouse effect. One of the methods to reduce the cement content in concrete mixes is the use of Nano materials. The properties of concrete in hardened state such as strength and durability are affected by the mix proportions and grading which results in particle packing.

Nanotechnology in Concrete:

Nanotechnology is rapidly becoming the Industrial Revolution of 21st century. It will affect almost every aspect of one's life. In comparison to other technologies, nanotechnology is much less well defined and well-structured. It is known that 'Nano' is a Greek word and means 'dwarf' it does not mean dealing with dwarfs but it became a common word for everything which is smaller than I Micron or I million of a millimeter. I Micron is 1000 Nanometer. The Nano science and Nano-engineering (Nano modification) of concrete are terms that have come into common usage and describe two main approaches or applications of nanotechnology in concrete (Scrivener and Kirkpatrick, 2008: Scrivener, 2009). Until today, concrete has primarily been seen as a structural material. Nanotechnology is helping to make it a multipurpose "smart" functional material. Concrete can be Nano-engineered by the incorporation of Nano-sized building blocks or objects e.g., nano particles, Nano admixtures and nano tubes) to control material behavior and add trailblazing properties, or by the grafting of molecules into the cement particles, cement phases, aggregates, and additives (including Nano-sized additives) to provide the surface functionality adjusted to promote the specific interfacial interactions of the Molecules. Recently, nanotechnology is being used in many applications and it has received increasing attention also in building materials, with potential advantages and drawbacks being underlined.

Objective:

The objective of the present work is to fine the influence of the application Nano-silica on various strength properties of M_20 grade of concrete. 1%, 1.5% and 2% of Nano-silica are adopted as cement replacement by weight Cube and cylinder moulds are casted for the purpose of testing. Specific objectives are:

- To fine the workability aspects of M_20 grade concrete using Nano-silica.
- To know the influence of Nano-silica on the strength characters of concrete.

II. LITERATURE RIEVIEW

Concrete:

C.K. Sridhar et.al (2014)[1] From their study it can be concluded that the optimum replacement of Nano Silica is 2%

and 1.5% respectively for M_{20} concrete. Addition of Nano particle makes concrete more sticky hence, suitable Super plasticizer can be used to achieve required workability. Due to the addition of Nano Silica. The percentage increase in M_{20} concrete is 15.31, 16.3 respectively for 7 days & 28 days, where as in M_{40} concrete is 11.0, 11.20 respectively for 7 days & 28 days.

Dr. D.V. Prasada Rao et.al (2014)[2] On the basis of experimental investigation, it can be concluded that compressive e strength of concrete initially increased up to 3% on Nano-Silica and with further increase in the Nano-Silica content the compressive strength of concrete decreases. Concrete containing lower percentages (3%) of Nano-Silica possess higher values of compressive strength than that of controlled concrete Sayed EI-Bakyet.al (2013)[4] workability of cement mortar which decreased by increasing the amount of interactive Nano-silica as long as the inserted Nano-silica can be interactive with calcium hydroxide resulting from hydration process of cement with water.

Compressive and flexural strength of the cement mortar increases proportionally with increasing the amount of Nano-silica, especially at early ages. Until achieving the optimum percentage, NS at 7% then decrease due to the decreasing of calcium hydroxide that exhausted in the activation process by 7% Nano-silica. As any amount more than that have no activation and take place of cement by inert powder, so it's naturally to decrease the strengths

Concrete with Nano-silica:

G. Quercia et.al (2013)[5] A new Nano-silica (NS) can be produced in high quantities and for low prices that allows for amass application in concrete. It may replace cement in the mix, which is the most costly and environmentally unfriendly component in concrete. The use of NS makes concrete financially more attractive and reduces the CO_2 footprint of the produced concrete products. The NS will also increase the product properties of the concrete: the workability and the properties in hardened state, enabling the development of high performance concretes for extreme constructions. That means that a concrete with better performance, lower costs and an improved ecological footprint can be designed..

III. METHODOLOGY

General:

The present method deals with evolution of Mechanical properties of Concrete Compressive Strength and Split-Tensile Strength. Cement is partially replaced with Nano-Silica Gel of dosages (1%, 1.5%, and 2%) in Standard Grade of M20 which designed in accordance with IS 10262-2009. The program involves Casting and Testing of specimens where the standard size of the cube (150mm x 150mm x 150mm) and standard size of cylinder (150mm x 300mm).

Laboratory Setup:

The concrete lab available at the college is used for the project. The Compressive Testing Machine is used for Compressive Strength and Split-Tensile tests. All the specimens are stored in a storage tank which is used for Curing

Procurement of Materials:

The Materials used for the study are:

- Cement
- Fine Aggregate
- Coarse Aggregate
- Nano-Silica

Cement:

In the present investigation Birla Shakti, Pozzolana Portland cement (PPC) of 53 Grade confirming to IS: 12269:1999 was used. The Physical properties of cement as per IS: 12269:1999 when tested at the concrete lab at the college are shown in Table.

Table: Properties of Cement

S No	Property	Value
1.	Specific Gravity	3.15
2.	Normal Consistency	27%
3.	Setting Time Initial Setting Time Final Setting Time	 36 min 390 min

Fine Aggregate:

Locally available river sand conforming to IS: 383:1970 was used as the fine aggregate in the concrete preparation. The properties of fine aggregate are shown in Tables below.

Weight of Sand = 1000 gms
Weight of Pan = 814 gms
Weight of Pan+Sand = 1814 gms

Table: Sieve Analysis Results

S No	Sieve Size(mm)	Percent retained	Cumulative % retained	Percentage Passing
1.	4.75	5.20	5.20	94.80
2.	2.36	3.00	8.20	91.80
3.	1.18	8.60	16.80	83.20
4.	600 microns	25.80	42.60	57.40
5.	300 microns	32.80	75.40	24.60
6.	150 microns	20.70	96.10	3.90

Table: Properties of Fine Aggregate

S No	Property	Result
1.	Specific Gravity	2.6
2.	Fineness Modulus	2.8
3.	Bulk Density (Loose)	15.75 kN/m^3
4.	Grading of Sand	Zone-II

Coarse Aggregate:

Coarse Aggregate of nominal size 20 mm & 10 mm, obtained from the local quarry confirming to IS: 383:1970 was used. The properties of coarse aggregate are shown in Table The coarse aggregate used for the preparation of concrete is a mixture of 20 mm & 10 mm size aggregates in ratio 1.5 : 1.0.

Table: Properties of Coarse Aggregate

S No	Property	Result
1.	Specific Gravity	2.60
2.	Bulk Density (Loose)	14.15 kN/m^3
3.	Water Absorption	0.5%
4.	Fineness Modulus	7.2

Nano-Silica Gel:

Nano-Silica is a new pozzolanic material commercially available in the form of water emulsion of colloidal silica. It is potentially better than the other pozzolanic materials because of high contest of amorphous silica (> 99%) and the reduced size of its spherical particles of order 5-10 mm. In this experimental investigation cement is replaced by weight. The properties of Nano-Silica are shown in the Table.

Table: Properties of Nano-Silica Gel

S No	Property	Actual Analysis
1.	Active Nano-Silica Content	35-40%
2.	PH	9.3-9.6
3.	Specific Gravity	1.08-1.11
4.	Texture	Milky White Liquid
5.	Dispersion	Water

Water:

Water used for casting and curing of concrete test specimens is free from impurities which when present can adversely influence the strength of concrete conforming to IS: 3025:1964 (part 22 & part 23) and IS: 456:2000.

Concrete:

Mixing concrete is simply defined as the “complete blending of the materials which are required for the production of a homogeneous concrete. “Batching is the “process of weighing or volumetrically measuring and introducing into the mixer the ingredients for a batch of concrete.” Initially we have weighed coarse aggregate, fine aggregate and cement according to the mix design and water according to the w/c ratio. Then we weighed the desired quantities of admixtures. First we added coarse aggregate in the concrete mixer followed by fine aggregate, cement and admixtures. Then start the mixer and allowed dry mixing until the materials are properly mixed and started adding water simultaneously. Mixed for about one and a half minute so that we get a homogeneous mixture.

Casting:

The Cube mould plates should be removed properly cleaned assembled and all the bolts should be fully tight. A thin layer of oil then shall be applied on all the faces of the mould. It is important that cube side faces must be parallel. After taking concrete samples and mixing them. The cubes shall be cast as soon as possible. The concrete sample shall be filled into the cube moulds in layer approximately 5 cm deep. In placing each scoopful of concrete, the scoop shall be moved around the top edge of the mould as the concrete slides from it, in order to ensure a symmetrical distribution of the concrete

with in the mould. Each layer shall be compacted either by hand or by the vibration as described below.

Table: No. of specimens casted

SI No	Mix Designation	No of Cubes		No of Cylinders
		7 days	28 days	
1.	CC	3	3	3
2.	CS 1%	3	3	3
3.	CS 1.5%	3	3	3
4.	CS 2%	3	3	3
Total		**12**	**12**	**12**

Compaction:

Each layer of the concrete filled in the mould shall be compacted by not less than 35 strokes by tamping bar. The strokes shall penetrate into the underlying layer and the bottom layer shall be roded through its depth. Where voids are left by the tamping bar the sides of the mould shall be tapped to close the voids.

When compacting by vibration each layer shall be vibrated by means of an electric or pneumatic hammer or vibrator or by means of a suitable vibrating table until the specified condition is attained. The casted cubes shall be stored under shed at a place free from the vibration at a temperature of 27-2^{0}C for 24 hours covered with wet straw or gunny sacking.

Curing:

The cube shall be removed from the moulds at the end of 24 hours and immersed in clean water till the 7 or 28 days age of testing. The cubes shall be tested in the saturated and surface dry condition. For the true representation of actual strength of concrete in the structure, extra cubes shall be cast, stored and curded as per the identical conditions of that structure, and tested at required age.

Slump Test:

Slump Test is used to determine the consistency of concrete mix of given proportions. Scope and significance unsupported fresh concrete flows to the sides and a sinking in height takes place. This vertical settlement is known as slump. In this test fresh concrete is filled into a mould of specified shape and dimensions. And the settlement or slump is measured when supporting mould is removed. Slump increases as water-content is increased. For different works different slump values have been recommended. The slump is a measure indicating the consistency or workability of cement concrete. It gives an idea of water content needed for concrete to be used for different works. A Concrete is said to be workable if it can be mixed, placed, compacted and finished.

A Workable concrete should not shown any segregation or bleeding. Segregation is said to occur when coarse aggregate tries to separate out from the finer material and a concentration of coarse aggregate at one place occurs. This results in large voids, less durability and strength. Bleeding of concrete is said to occur when excess water comes up at the surface of concrete. This causes small pores through the mass of concrete and is undesirable. By this test we can determine the water content to give specified slump value. In this test water content is varied and in each case slump value is measured till we arrive at water content giving the required slump value. This test is not a true guide to workability. For example, a harsh mix cannot be said to have same workability as one with a large proportion of sand even though they may have the same slump.

Compressive Test:

The dimensions of the specimens to the nearest 0.2 mm and their weight shall be noted before testing. The bearing surfaces of the testing machine shall be wiped clean and any loose sand or other materials removed from the surface of the specimen which is to be in contact with the compression platens. The cube shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast that is not to the top and bottom. The axis of the specimen shall be carefully aligned with the center of the thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine. As the spherically seated block is brought to bear on the specimen, the movable portion shall be rotated gently by hand so that uniform seating may be obtained.

The load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.

Split- Cylinder Test:

It is the standard test, to determine the tensile strength of concrete in an indirect way. This test could be

performed in accordance with IS: 5816-1970. A standard test cylinder of concrete specimen (300mm X 150mm diameter) is placed horizontally between the loading surfaces of Compression Testing Machine. The compression load is applied diametrically uniformly along the vertical diameter. Concrete cylinders split into two halves along this vertical plane due to indirect tensile stress generated by poission's effect.

IV. RESULTS AND DISCUSSION

Workability:

The influence of different combinations of Nano-silica 1.5%, and 2% by weight with 1%m normal concrete at a constant w/c ratio of 0.5 has shown a trend of decrease in workability (slump). The observed values are tabulated below.

Table: Slump cone results

S No	Description	Slump Value
1.	Control Concrete	85mm
2.	CS 1%	80mm
3.	CS 1.5%	75mm
4.	Cs2%	70mm

Although workability has decreased marginally with addition of Nano-silica it has not been a concern for regular works. For specific works where workability is of due importance use of super-plasticizers can be encouraged. Though the combined effect of Nano-silica and super-plasticizers has not been studied in this project, from the earlier papers referred there are no adverse effects with usage of plasticizers.

Compressive Strength:

The compressive strengths of the casted of the casted specimens were determined by the compressive test machine and are tabulated as follows.

Table : Compressive test results

S No	Mix Designation	Characteristic Compressive Strength (N/mm^2)	
		7 Days	28 Days
1	CC	17.51	34.32
2	CS 1%	19.30	35.03
3	CS 1.5%	20.69	38.94
4	CS 2%	21.65	40.78

Graphs are plotted for the obtained results and increase in the characteristic compressive strengths can be clearly read out. It was observed that the percentage increase in compressive strength was greater for 7 days compared to 28 days. Hence from the experimental investigation results it can be inferred that Nano-silica improves early strength also.

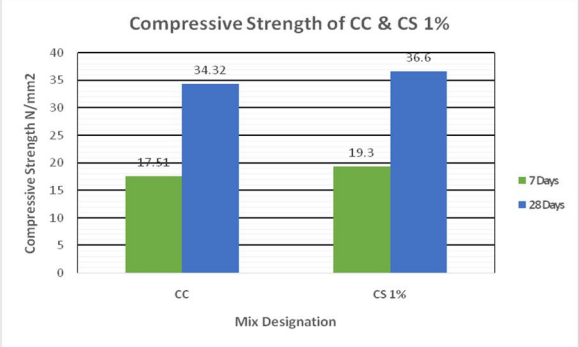

Fig: Compressive Strength of CC & CS 1%

By analyzing the results, it can be understood that the strength variation in the specimens added with Nano silica indicated increase in both 7 and 28 day compressive strengths compared to that of controlled concrete. But percentage increase in strength varies differently for different dosages of Nano silica. Following are the percentage increases in the compressive strengths of cube compressive strengths.

Table: Percentage increase in compressive strength with NS dosage

S No	Dosage of Nano-Silica	Percentage increase in Characteristic Compressivestrength (N/mm^2)	
		7 days	28 days
1	1%	10.22	6.64
2	1.5%	18.16	13.46
3	2%	23.64	18.82

Nano silica reacts with calcium hydroxide ($Ca(OH)_2$ to develop more of the strength carrying structure of cement: calcium silica hydrate (C-S-H). Hence there is an increase in the compressive strength in specimens in which cement is replaced by Nano- silica.

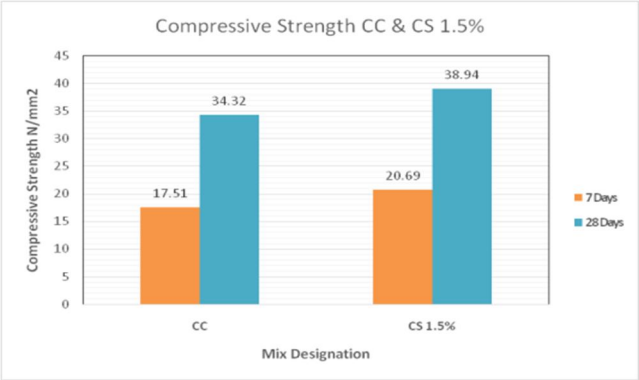

Fig: Compressive Strength of CC & CS 1.5%

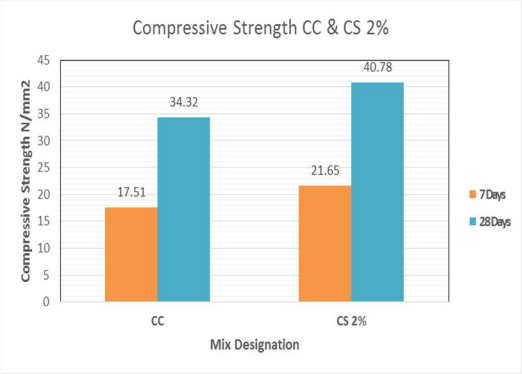

Fig: Compressive Strength of CC & CS 2%

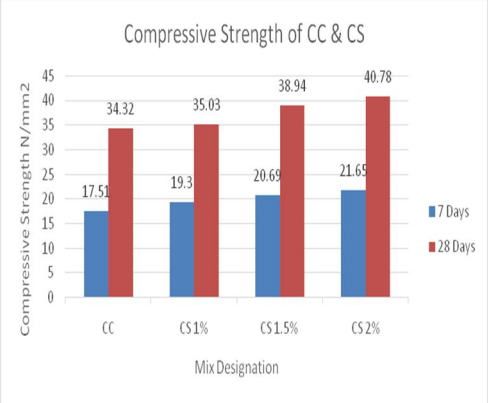

Fig: Compressive Strength of CC & CS

Tensile Strength:

It can be observed that as the percentage of Nano-silica is increased, split tensile strength of concrete is also decreased. The split tensile strength of M_{20} grade controlled concrete is 3.306N/mm^2

Table: Tensile strength of concrete with Nano-silica

S No	Mix Designation	Tensile Strength(N/mm^2)
1	CC	3.306
2	CS-1%	3.154
3	CS-1.5%	2.987
4	CS-2%	2.872

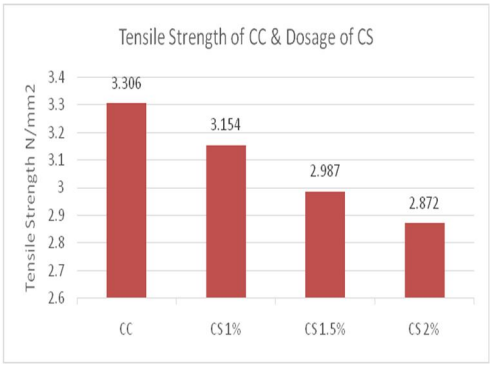

Fig: Tensile Strength of CC & CS

V. CONCLUSIONS

From the above experimental study it can be concluded that the optimum replacement of Nano Silica is 2% for M_{20} concrete. The compressive strength of cement concrete can be increased considerably by the addition of Nano-silica gel. Based on the experimental results, use of Nano-Silica as partial replacement of cement in small quantities is advantageous on the performance of concrete.

Compressive strength with NS dosage of 1% has increased by 10.22% and 6.64% for 7 and 28 days respectively compared to normal concrete.

The percentage increase in compressive strength with NS dosage of 1.5% is 18.16% for 7 days and 13.46% for 28 days over normal concrete.

Similarly, NS dosage of 2 % has increase of 23.64% 7 days and 18.82% for 28 days has been observed when compared to that of normal concrete.

Tensile strength of specimens added with Nano-silica was observed to be decreased when compared to normal concrete.

The workability of the concrete along with Nano-silica has decreased

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