Replacement Of Cement With Nano Silica To Build An Nano Concrete.

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Abstract : Nano science and technology is a new field of emergence in materials science and engineering, which forms the basis for evolution of novel technological materials. The basic concept behind using nano material which are having large surface area is to improve compressive and flexural strength at early ages when compared with conventional cementitious material. The purpose of this study is to compare the properties of conventional concrete and nano concrete. Strength and durability tests will be carried out. Thus, there is a scope for development nano materials can also pave the path to reduce the cement content in concrete than the conventional mixes while maintaining same strength characteristics, which will lead into the production of 'greener' concrete.

IndexTerms **- Nanosilica; Concrete durability; Compressive strength; Nanotechnology, Flexure Strength.**

I. INTRODUCTION

Nano technology is the study of the control of matter on an atomic and molecular scale. It deals with the size 100 nanometres or smaller, and involves developing materials or devices within that size. Nano concrete is one of the most active research areas that encompass a number of disciplines including civil engineering and construction materials, currently, the most active research areas dealing with cement and concrete are: understanding of the hydration of cement particles and the use of nano-size ingredients such as titanium oxide, silica, carbon nano-tubes, and nano-sensors. Concrete is probably unique in construction, it is the only material exclusive too the business and therefore is the beneficiary of a fair proportion of the research and development money from industry.

Concrete is the most widely used construction material in the world. It is the mixture of cement, coarse aggregate, fine aggregate and water. Fresh concrete is freshly mixed material which can be moulded into any shape. It is one of the most widely used construction material and has a long history of use. Cement is the main ingredient in concrete. In manufacturing process of Portland cement, clinker in incinerated at about 1300ºC to 1500ºC resulting in emission of huge amount of CO2 into the atmosphere. Huge amount of CO2 emission causes very bad effects on the environment.

Use of nano material in concrete also possess very important properties like high ductility, self crack controlling ability, low electrical resistivity, self-sensing capabilities, self healing. Nano silica possess more pozzolanic nature, it has the capability to react with the free lime during the cement hydration and forms additional C-S-H gel which gives strength, impermeability and durability to concreteAt the same time, this new concrete should be sustainable as well as cost-and energy effective, exhibiting qualities that modern society demands. These developments will revolutionalise the construction industry. One of the newest technologies to break into the concrete design arena is the use of nS in the concrete matrix. By using nS, the development of the strength bearing crystals of cement paste can be increased or controlled.

Nano-concrete also results in a lower rate of corrosion of the steel reinforcements due to the pore filling nature of the nano silica particles in the concrete. If Portland cement can be manufactured using the nano sized particles, it will open up a large number of opportunities for further research and development of concrete used in construction industry. The nano particles also make the cement more environmentally friendly and reduce the impact of the construction industry on the environment, hence leading to a more sustainable future. The cement manufactured using this method will not only be more economical than ordinary cement polymers, but will also have a fire resistance. Hence the structure built using nano particles will be stronger and more durable than conventional concrete, which in turn increases the service life of the building

II. AIMS AND OBJECTIVE

The main objective of the work is are as follows

- To study the effect of Nano-silica on compressive and tensile strength.
- To study the workability and durability of concrete
- Properties of cement such as Normal consistency, initial and final setting time can be improved

III. LITERATURE REVIEW:-

1. Li et.al(2004) incorporated Nano silica into ordinary traditional concrete and reported 3days compressive strength increase and also at later stages same trend was observed with 4% nano-Silica in high volume fly ash concrete. Same results were obtained for Split tensile and flexural strength test. An increase of about 23-38 % and 7-14% at 7days and 28days respectively. Investigations on Nano-silica in concrete resulted in reduction in water absorption, coefficient of water absorption and permeability than Normal concrete.

2. Wijdan D et.al (2017) made a conclusion that Nano concete is not only important as an enhanced construction material but also in the context of energy and effort conservation effort. Thus enabling the construction of more creative forms which was impossible to construct the use of ordinary concrete mix. Self-compacting concrete (S.C.C) which is produced through the addition small amount of Nano silica results in concrete with high strength and Durability. Hence, it could be used to construct complex shapes and improved concretes mechanical strength. Self-cleaning concrete could be made by adding nano titanium dioxide (Nano TiO2). This results in self cleaning concrete with special photo catalytic property to convert air pollutents into harmless substance with sunlight help. It also caused cement for rapidly Hydrate

3. Sayed Abdel-Baky et al (2013), investigated workability, compressive and flexure strengths. Nano silica particles with size of 19 nm have been used as a cement addition by 1,3,5,7 and 10% by weight of cement content. The study showed that 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 decreases due to the decreasing of calcium hydroxide that exhausted in the activation process by 7% nano-silca.

IV. MATERIAL USED AND THEIR PROPERTIES

4.1 CEMENT

The Ordinary Portland Cement (OPC) of 53 Grade Ambuja cement is used. It has specific gravity of 3.11. The test conducted on cement was as per IS :12269-1987.

Table-1: Properties of cement

Sr No	Characteristics	Values obtained
1	Normal Consistency	33 %
2	Initial Setting Tim	52 min
3	Final Setting Time	285 min
4	Fineness	4.8

4.2 FINE AGGREGATE

Fine aggregate is used for this study was local river sand confirming to zone-II of IS: 383-1970

Table-2: Properties of Fine Aggregate

Sr No	Characteristics	Values obtained
1	Type	Uncrushed
2	Specific Gravity	2.65
3	Total Water	0.65%
4	Grading Zone	II

4.3 COARSE AGGREGATE

Locally available coarse aggregate having the maximum size of 20 mm was used in our work. The aggregates were tested as per Indian Standard Specifications IS: 383-1970

Table-3: Properties of Coarse Aggregate

Sr No	Characteristics	Values obtained
1	Type	Crushed
2	Specific Gravity	2.76
3	Water Absorption	0.995%
4	Maximum size	20mm

4.4 NANO SILICA

Nano silica obtained from "Bee-Chem" Chemicals Ltd, BHIWANDI , MAHARASTRA.

Table-4: Properties of Nano silica

Sr No	Characteristics	Values obtained
1	Parameter	Cem Syn XTX
2	Active Nano content	30 – 32%
3	pH(20 ° C)	9 – 10
4	Specific Gravity	1.20 – 1.22
5	Particle Size	5 – 40 nm

4.5 WATER

Tap water was used in this experiment. The properties are assumed to be same as that of normal water. Specific gravity is taken as 1.00. Potable water confirming to IS: 456-2000 is used for casting and curing

V. RESEARCH METHODOLOGY

To prepare Nano Silica conrete ,initially water reducing agent of suitable proportion is mixed in water thoroughly. Then the required quantity of Nano Silica is added to the mix and stirred for two minuites. Cement ,sand & coarse aggregate are mixed in pan mixer for five minuites. The mixture of water,water reducing agent & Nano Silica is poured into the pan mixer and rotated for ten minuites to achieve homogeneity. Fresh concrete is tested for workability, then concrete is poured into the cube mould and vibrated, The specimens are kept for 24 hours at room temperature. After demoulding, specimens are immersed in the water tank for curing.

Table 5.1 Parameters for mix design (M30 grade of Nano concrete).

Grade	M30
Condition of exposure	Moderate
Type of cement	OPC- 53grade
Brand of cement	Ambuja cement
Mineral admixture	
Fine aggregate Zone	Zone II
Maximum size of aggregate	20mm
Degree Of Supervision	Good

Steps of Mix design

Determination Of Target Mean Strength

Fm = fck + (t) (s) = 30+ (1.65)(5) = 38.9 ≈ 40 MPa (refer table no.3.12, 3.13)

Where,

'fck' is the specified minimum or characteristic strength of concrete

s' is the standard deviation determined from table no. 3.4 for the above value of fck and degree of quality control expected

't' is the constant depending on the probability of certain number of results likely to fall below fck.

Note: The above values correspond to the site control having proper storage of cement, weigh batching of all materials; controlled addition of water, regular checking of all materials, aggregates grading and moisture content; and periodical checking of workability and strength**. (Where there is deviation from the above the values given in the above table shall be increased by)**

Table no 5.2 Value of 't' (IS 10262 – 1982)

Accepted proportion of Low results	T
1 in 5	0.84
1 in 10	1.28
1 in 15	1.50
1 in 15	**1.65**
1 in 40	1.96
1 in 100	2.33

Determination Of Water To Cement Ratio

Table 5 Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size

(Clauses 6.1.2, 8.2.4.1 *and* 9.1.2*)*

Sl No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content kg/m³	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete
1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Mild	220	0.60	–	300	0.55	M 20
iii)	Moderate	240	0.60	M 15	300	0.50	M 25
iii)	Severe	250	0.50	M 20	320	0.45	M 30
iv)	Very severe	260	0.45	M 20	340	0.45	M 35
v)	Extreme	280	0.40	M 25	360	0.40	M 40

NOTES

1 Cement content prescribed in this table is irrespective of the grades of cement and it is inclusive of additions mentioned in 5.2. The additions such as fly ash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement content and water-cement ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit of pozzolona and slag specified in IS 1489 (Part 1) and IS 455 respectively.

2 Minimum grade for plain concrete under mild exposure condition is not specified.

As per the table is 456 table no 5

Maximum water content is 0.45

Adopted water content is **0.45**

Selection Of Water Content:

From The table, For aggregate = 20mm and Slump = 50mm

Maximum Water Content (50mm Slump) = 186 L

186L of water is required to get 50mm slump but we need water content for **100mm slump.**
Clause 4.2 suggests increasing of 3% of water content for every extra 25mm slump from 50mm slump

Therefore as per clause 4.2 For aggregate = 20mm, Slump = 100mm

Water-Content For 100mm Slump

= 186+ (0.06*186)
= 197.58 L
Adopted Water Content**= 198 L**

Calculation Of Cement Content:-

Adopted Water Cement Ratio = 0.45

Cement required = Water Content / W-C Ratio

= 198/0.45
= 495 kg/ m3
Adopted Cement Content = **495 kg/ m3**
Minimum Cement Content =320kg/ m3 AS PER THE IS STANDARDS

Determination of aggregate proportions

There are usually 4 zones of sand according to its grading

Table no 5.3 Various zones of sand

Zone 1	Preferred (not available)
Zone 2	Preferred
Zone 3	Not good
Zone 4	Worst

In this mix design we have used sand which belongs to Zone 2

Since our maximum size of aggregate is 20mm, according to IS:10262 : 2009

For water cement ratio of 0.5, coarse aggregate is 0.62% - (Table 3)

Table no 5.4 Volume of coarse aggregate per unit volume of total aggregate for different zones of fine aggregate

NOMINAL MAX SIZE OF AGGREGATE	ZONE IV	ZONE III	ZONE II	ZONE I
10	0.50	0.48	0.46	0.44
20	0.66	0.64	0.62	0.60
40	0.75	0.73	0.71	0.69

Hence, final volume of coarse aggregate = 0.62%

Therefore fine aggregate = 1- 0.62 = 0.38%.

1. Volume of concrete 1m3

2. Volume of cement = (495/ 3.15) x 0.001 = 0.157 m3

3. Volume of water = (198/ 1) x 0.001 = 0.198 m3

4. Volume of all in aggregate = 1- (0.157+0.198) = 0.645m3

5. Mass of aggregate = Volume of all in aggregate x Volume of coarse aggregate x specific gravity of coarse aggregate x 100

= 0.645 x 0.62x2.74 x 1000
= 1095 kg.

6. Mass of aggregate = Volume of all in aggregate x Volume of fine aggregate x specific gravity of coarse aggregate x 100

= 0.645 x 0.38 x 2.44 x1000
= 598 kg.

Since Specific gravity of coarse aggregate = 2.74

Specific gravity of fine aggregate = 2.44

Among coarse aggregate we assume 55% of 20 mm aggregate, and 45% of 10mm aggregate
Therefore, 20mm aggregate = 0.55 x 1095 = 602.4 kg ~ 603 kg
10mm aggregate = 1095 – 603 = 492 kg

Determination of nano silica proportions

Nano Silica - 2.5% = 51gms /CUBE

Nano Silica - 3% = 61gms/CUBE

Nano Silica - 3.5% = 71gms/CUBE

Mix Proportion:

For a batch of 36 cubes of 150mm side

The volume of concrete required = $(0.15)^3 \times 36 \times 1.2 = 0.1485$ m3
(Taking into account 20 % extra for losses)

Cement required = 0.1485x495 **= 72.21 kg**

Fine aggregate required =0.1485 x 598 = **88.18 kg**

Coarse aggregate required = 0.1485x1095= **162.60 kg**

Water required = 0.1485 x 198 = **29.403kg**

Nano Silica Required =

Table No.5.5 Nano Silica Calulation

NS%	Cement replaced IN GRAMS	7 DAYS	14 DAYS	21 DAYS
NORMAL	0	3CUBE	3 CUBE	3 CUBE
2.5	459	3 CUBE	3 CUBE	3 CUBE
3	549	3 CUBE	3 CUBE	3 CUBE
3.5	639	3 CUBE	3 CUBE	3 CUBE
TOTAL	**1.647 KG Of Nano Silica Is Replaced**			

THEREFORE ACTUAL QTY OF CEMENT REQUIRES IS = 72.21 - 1.647

= 70.553 KG

Casting Of TEST Specimen:-

In present study the specimen of standard cubes of size 150 X 150 X 150mm, Beam of size 100x100x500 mm length are casted. Cube specimens were tested after 7,14, 28 days of curing. And beam specimens were tested after 28 days of curing.
For conducting compressive strength test on concrete cubes of size 150X150X150mm are casted. A rotary mixture is used for thorough mixing and a vibrator is used for good compaction. After successful casting, the concrete specimens are de-moulded after 24 hours and immersed in water for 14 days maintaining 270C.

1) Mixing
Measured quantities of coarse aggregate and fine aggregate were spread over an impervious concrete floor. The dry OPC were spread out on the aggregate and mixed thoroughly in dry state turning the mixture over and over until the uniformity of color was achieved. Water was measured exactly and it was thoroughly mixed to obtain homogenous concrete. The mixing shall be done for 10 to 15 minutes.
2) Placing and Compacting The cube and beam moulds are cleaned and all care is taken to avoid irregular dimensions. The mix was placed in 3 layers and the layer was contacted using table vibrator to obtain dense concrete.

Compaction By Vibration

Concrete Block

3) Curing

The test specimens were stored in a place free from vibration in moist air at 90% relative humidity and at temperature of 27+/ for 24 ½ hours from the time of addition of water to dry ingredients. After 24 hours the specimens are demoulded and immediately immersed in clean, fresh water tank for period of 3, 7, 28 days.

Curing

Block

VI. TEST AND RESULT

COMPRESSIVE STRENGTH TEST

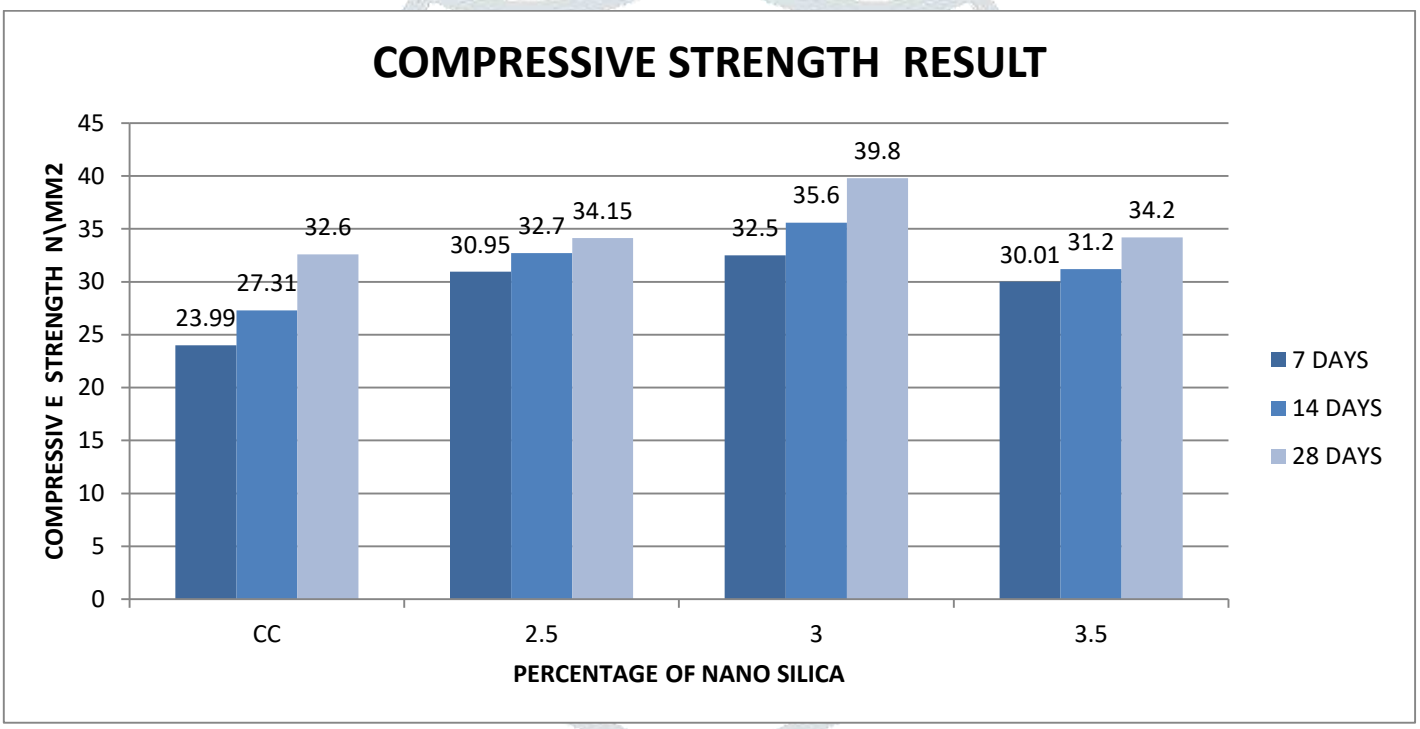
The concrete cubes of 150mm size were cast for finding the compressive strength. The prepared cubes were cured in water for 28 days. The cured specimens were taken out and dried. After drying, the specimen is loaded using compression testing machine. The compressive strength of concrete cube specimens was investigated by measuring the load and it was calculated by using the equation.

Compressive Strength of concrete = Maximum compressive load / Cross Sectional Area

Table no: 6.1 Results of Compressive Strength Test

Nano Silica%	Compressive Strength N/Mm^2		
	7 Days	14ays	28 Days
Conventional Concrete	23.99	27.31	32.60
2.5	30.95	32.7	34.15
3	32.5	35.6	39.80
3.5	30.01	31.2	34.20

CHART 6.1 Results of Compressive Strength Test



- **Discussion**

The compressive strength of concrete initially increased up to 3% of 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.A considerable increase split tensile strength of Nano- Silica concrete was observed compared to controlled concrete.

FLEXURAL STRENGTH TEST

The concrete beam of 100x100x500mm size were cast for finding the compressive strength. The prepared beam were cured in water for 28 days. The cured specimens were taken out and dried. After drying, the specimen is loaded using universal testing machine. The flexural strength of concrete beam specimens was investigated by measuring the load and it was calculated by using the equation

$$f_{cr} = PL / bd^2$$

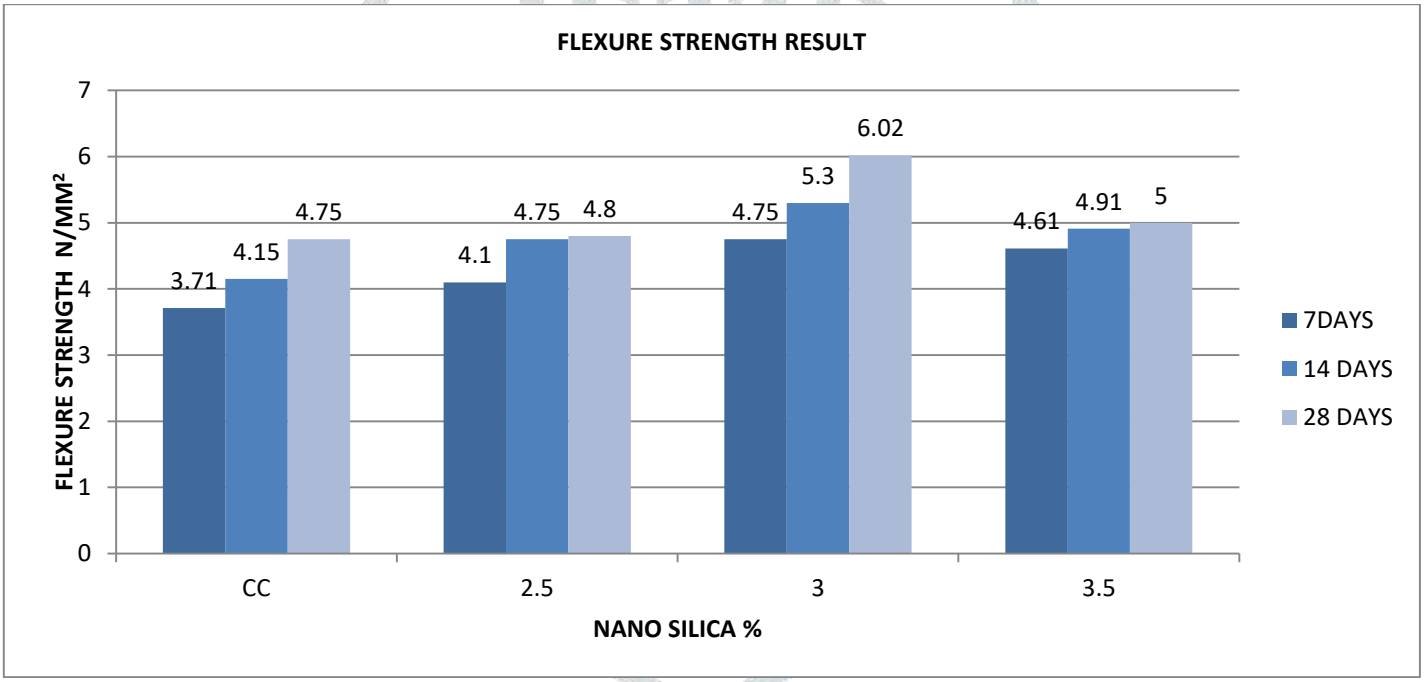
Where, fcr - flexural strength; P – Load; b - Measured width; d - Measured depth

M30 grade concrete beams cast with and without Nano-silica cured in water subjected to flexure strength test using compression testing machine with a suitable arrangement.

Table-6.2: Flexure Strength Test Results of M30 Grade Concrete Beams

Nano Silica%	Flexure Strength N/Mm^2		
	7 Days	14ays	28 Days
Conventional Concrete	3.71	4.15	4.75
2.5	4.10	4.57	4.80
3	4.75	5.30	6.02
3.5	4.61	4.91	5.17

CHART 6.2 Results of FLEXURE Strength Test



- **Discussion**

  It is obvious that, the addition of Nano-silica to the concrete mix, increases its flexural strength regardless of the testing age.

  The flexural strength of the CC beams at 14 days cured in water is found to be 4.15 N/mm2, whereas the NS 3% had 5.30 N/mm2 value. This is a 27.82% increase.

VII. CONCLUSION

- The project concludes that the addition of nS in the concrete mixture behaves not only as a filler to improve the microstructure, but also as an activator to promote pozzolanic reaction thereby resulting in the enhancement of the durability and mechanical properties of the mix. It is very cost effective when considering the expenditure for the repair and renovation of conventional concrete structures. From the project, the following were concluded

- Based on the experimental results, use of Nano-Silica as partial replacement of cement in small quantities is advantageous on the performance of concrete.

- Nano-Silica added in small quantities can improve the strength and permeability resistance. It can also be concluded that the permeability of concrete decreases with the increase in the percentage of Nano-Silica up to 3% due to the effect of Nano-Silica filling the voids in concrete.

- The initial and final setting times of cement mortar containing Nano-silica was found to decrease with increase in the replacement percentage. Use of Nano – silica in the concrete reduces the co2 emission

- The inference from the test results is increased the flexural strength of 27.37% for M30 grade NS in comparison with same grade CC cured in water.
- Therefore, the addition of Nano-silica to the concrete mix has been shown to lead to an increase incompressive strength, flexural strength, and durability with respect to conventional concrete.
- Nano Products used in this study, are costlier than other additives, so use of nano product increases the overall cost of the project.
- It is a self compacting concrete and a green concrete.

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REFERENCES

1. A.M. Neville and J.JBrooks, "Concrete Technology" Published by Pearson Education System, Pg 77-88.

2. Comparative Studies on High Strength Concrete Mixes Using Micro Silica and Nanosilica, Siva Sai, International Journal of Engineering and Technical Research (IJETR) ISSN: 2321-0869, Volume-1, Issue-7, September 2013.

3. Experimental investigation on behaviour of nano concrete, International Journal of Advanced Research in Civil, Structural, Environmental and Infrastructure Engineering and Developing, Volume: 2 Issue: 2 Apr,2016,ISSN_NO: 2320-723X

4. Experimental Investigation on Nanomaterial Concrete, Saloma, Lecturer, Faculty of Civil Engineering, Sriwijaya University, International Journal of Civil & Environmental Engineering (IJENS 137403-5858 Vol: 13, No: 03, pp.15-20, June 2013

5. M.S.Shetty, "Concrete Technology Theory and Practice" Published by S. Chand company Ltd, Pg. 14-21, 420-457

6. Indian Standard Codes
   - IS 10262-2009 Recommended guidelines for concrete mix design
   - IS: 456-2000, Indian Standard "Plain and Reinforced Concrete", Code of Practice 2000. Bureau of Indian Standards, New Delhi 110002.
   - IS: 516-1959, Indian Standard "Methods of testing for strength of concrete", Code of Practice. Bureau of Indian Standards, New Delhi 110002.