ENHANCING PROPERTIES OF CONCRETE BY USING NANO-SILICA AS A PARTIAL REPLACEMENT OF CEMENT

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ABSTRACT

Concrete is most commonly used construction material and it consumes huge amount of cement. Manufacturing of cement produces increasing CO_2 emission which is harmful to the environment. Method used to reduce cement content in concrete is use of nano-silica and Flyash as a partial replacement of cement in concrete. Nanotechnology is one of the most promising areas of science. The use of nano materials in concrete is new revolution. Nano silica is presently used in concrete to modify its strength properties. In this study strength properties such as Compressive strength, Split tensile strength, Pullout strength of M40 grade of concrete with the use of nano silica 1.5%, 3%, 4.5%, 6%, 7.5% and 10% of constant rate of flyash as partial replacement of cement were studied. It was observed from the experimental study that concrete composites with superior properties can be produced using combination of nano silica and flyash.

Keyword : - *Nano silica, Compressive strength, Split tensile strength, Pullout strength.*

1. INTRODUCTION

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 CO_2 into the atmosphere. Huge amount of CO_2 emission causes very bad effects on the environment. So, nowadays a key issue for the construction industry is the need for sustainable concrete. Since last few decades concrete technology has experienced substantial advances, resulting in innovative use of supplementary additives and cementatious materials has developed new generations of concrete with improved properties. So in present work cement is replaced by nano-silica Flyash to reduce cement content in concrete.

Nanotechnology has changed our vision, expectations and abilities to control the material world. The developments in nano-science can also have a great impact on the field of construction materials and other fields in science. Also, Nanotechnology is one of the most active research areas with both novel science and useful applications that has gradually established in the last two decades. Nanotechnology concerns with the use of materials of diamension approximately 1 to 100 nanometers. Encompassing nanoscale science, technology and engineering involves imaging, measuring, manipulating and modelling matter at this length scale. Nanotechnology is the study of the controlling of matter on an atomic and molecular scale. Nano-concrete is produced by incorporating nanomaterial into cement during mixing has established itself as a promising method, which encompasses the structure at the nanometer scale to develop multi-functional cementatious composites with superior durability and mechanical performance. Use of nanomaterial 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 concrete

2. MATERIAL USED AND THEIR PROPERTIES

2.1 Cement

The Ordinary Portland Cement (OPC) of 53 Grade Birla Shakti 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 Time	52 min
3	Final Setting Time	285 min
4	Specific Gravity	3.11
5	Fineness	4.8

2.2 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	Value obtained
1	Type	Uncrushed
2	Specific Gravity	2.65
3	Total Water	0.65%
4	Fineness Modulus	2.5
5	Grading Zone	II

2.3 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	Value obtained
1	Type	Crushed
2	Maximum size	20 mm
3	Specific Gravity	2.76
4	Water Absorption	0.995%

2.4 Nano Silica

Colloidal nano silica obtained from "Bee-Chem" Chemicals Ltd, Kanpur.

Table-4: Properties of Colloidal Nano silica

Sr. No.	Characteristics	Value obtained
1	Parameter	CemSynXTX
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

2.5 Fly ash

Fly ash of grade P-60 is used as partial replacement to the cement. Flyash is obtained from "DIRK India Pvt. Ltd.", Nashik, Maharashtra. Fly ash is guaranted to meet the physical and chemical requirements of IS 3812 PART 1.

2.6 Water

Potable water confirming to IS: 456-2000 is used for casting and curing.

3. EXPERIMENTAL PROGRAMME

3.1 Mix Design

To investigate the effect of nano-silica on the properties of conventional concrete the mix design is done according to IS 10262:2009. Strength properties of M40 grade concrete were studied.

3.2 Casting of test specimen

In present study the specimen of standard cubes of size 150 X 150 X 150mm, cylinders of size 150mm diameter and 300mm length are casted . Cube specimens were tested after 3, 7, 28 days of curing. And cylinder specimens were tested after 28 days of curing.

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, beam and cylinder 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.

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.

4. TESTS AND RESULTS

4.1 Compressive Strength Test

In Compression testing Machine, the top surface of machine is fixed and load is applied on the bottom surface of specimen. The rate of loading is gradual and failure (crushing) load is noted and compressive strength is calculated.

Table-5: Results of Compressive Strength Test

Sr. No.	Replacement of cement (%)		Compressive Strength (N/mm^2)		
	Nano silica	Fly ash	3 Days	7 Days	28 Days
1	0	10	18.87	29.49	46.71
2	1.5	10	19.55	33.89	47.89
3	3	10	20.05	35.21	54.12
4	4.5	10	19.65	34.11	52.89
5	6	10	19.42	33.61	49.67
6	7.5	10	19.27	28.33	48.12

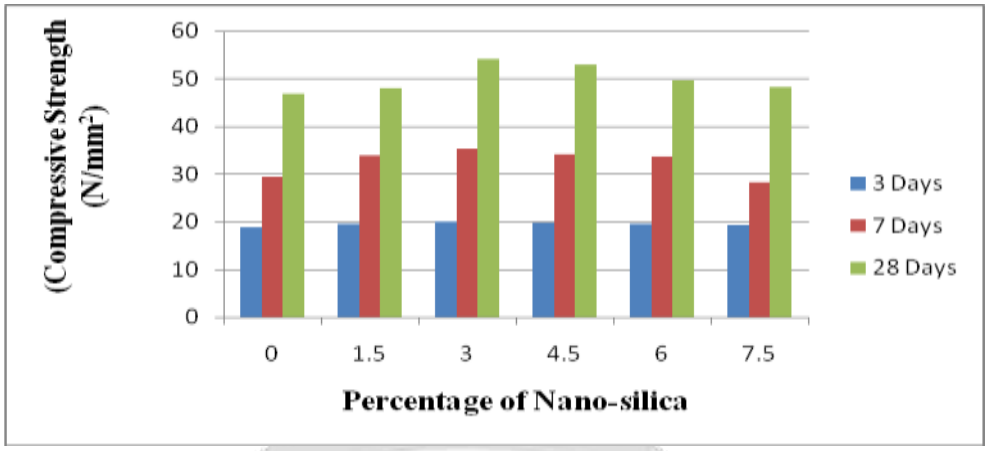

Chart -1: Compressive Strength of concrete for replacement of cement by Nano-silica and Flyash for different curing periods

4.2 Split Tensile Strength Test

For determining split tensile strength, cylinder specimens of size 150mm in diameter & 300mm in length are placed between the two plates of Compression Testing Machine. The load is applied at a uniform rate till the specimen failed by a fracture along vertical diameter. The failure load is noted and split tensile strength is calculated.

Table-6: Results of Split tensile Strength Test

Sr. No.	Replacement of cement (%)		Split Tensile Strength (N/mm^2)
	Nano silica	Flyash	28 Days
1	0	10	3.82
2	1.5	10	3.91
3	3	10	4.95
4	4.5	10	4.43
5	6	10	3.96
6	7.5	10	3.21

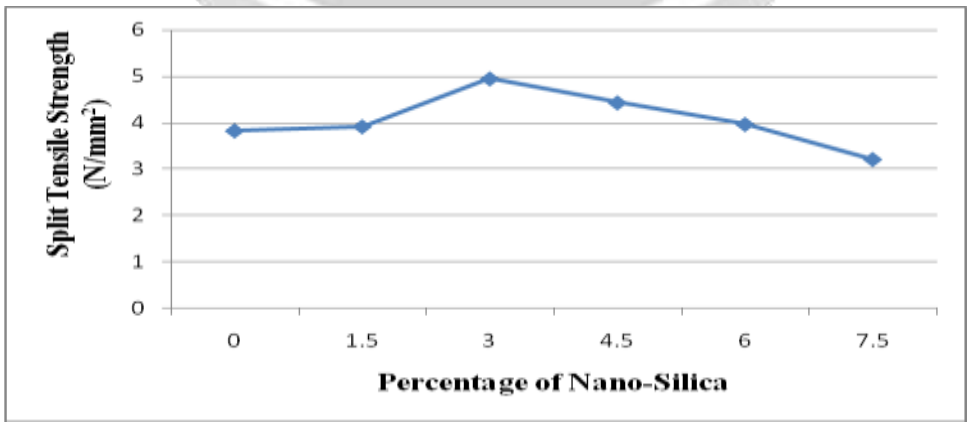

Chart-2: Split tensile strength of concrete for replacement of cement by Nano-silica and Fly ash after 28 Days

4.3 Pullout Strength Test

The test specimen was mounted in UTM in such a manner that the bar is pulled axially from the cube. The end of the bar at which pull is applied which projects from the top face of the cube. In assembling the testing apparatus on the specimen the distance between the face of the concrete and the point on the loaded end of the reinforcing bar at which the device for measuring slip is attached, shall be carefully measured so that the elongation of the bar over this distance may be calculated and deducted from the measured slip. For pullout test cube specimens of 150 mm size were casted. And 12 mm diameter bar were inserted in specimens. The purpose of this test is to know bond stress between concrete and steel. Bond stress can be calculated by the following formula,

$$\text{Bond stress} = \frac{\text{Applied load at slip}}{\text{Surface area of embedded length of bar}}$$

$$\text{Bond stress} = P / \pi LD$$

Where,

P = Applied load in N
L = Embedded length of bar in mm
D = Diameter of bar in mm

Table-7: Results of Pullout Strength Test

Sr. No.	Replacement of cement (%)		Pullout Strength (N/mm^2) 28 Days
	Nano silica	Fly ash	
1	0	10	9.30
2	1.5	10	9.69
3	3	10	10.53
4	4.5	10	10.91
5	6	10	11.35
6	7.5	10	9.35

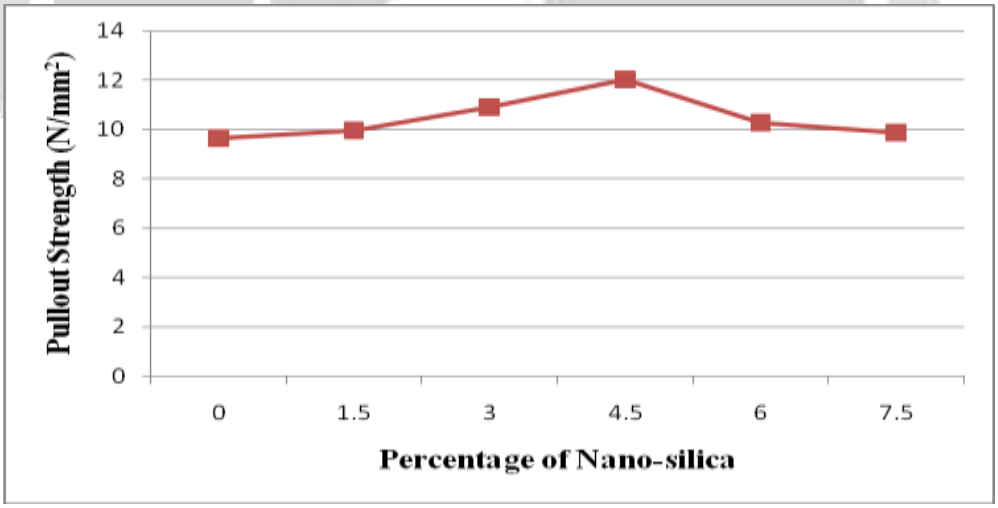

Chart-3: Pullout strength of concrete for replacement of cement by Nano-silica and Fly ash after 28 Days

4. CONCLUSIONS

- The compressive strength was found 3.6%, 6.25%, 4.13%, 2.91%, 2.12% higher than that of conventional concrete when the cement is replaced by 1.5%, 3%, 4.5%, 6%, 7.5% by Nano-silica respectively and 10% Fly ash at constant rate for the age of concrete 3 days.
- The compressive strength was found 14.92%, 19.39%, 15.66%, 13.97% higher than that of conventional concrete when the cement is replaced by 1.5%, 3%, 4.5%, 6% by nano-silica respectively and 10% Fly ash for the age of concrete 7 days.

- The compressive strength was found 4.09% lower than that of conventional concrete when the cement is replaced by 7.5% nano-silica and 10% Fly ash for the age of concrete 7 days.
- The compressive strength was found 2.53%, 15.86%, 13.23%, 6.33%, 3.01% higher than that of conventional concrete when the cement is replaced by 1.5%, 3%, 4.5%, 6%, 7.5% by Nano-silica respectively and 10% Fly ash for the age of concrete 28 days.
- Split Tensile strength of nano-silica and Fly ash based concrete was higher by 2.35%, 29.58%, 15.96%, 3.66% than that of conventional concrete for the replacement of 1.5%, 3%, 4.5%, 6% at the age of concrete 28 days. For further increased in the percentage of replacement at 7.5% Split Tensile strength was decreased by 16.23% than that of conventional concrete.
- The pullout strength was found 4.19%, 13.22%, 17.31%, 22.04%, 0.005% higher than that of conventional concrete when the cement is replaced by 1.5%, 3%, 4.5%, 6%, 7.5% by Nano-silica respectively and 10% Fly ash for the age of concrete 28 days.
- Nano-silica based concrete gives more strength than conventional concrete.

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