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Experimental Study on Partial Replacement of Cement with Nano Silica in the Concrete

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ABSTRACT

The main objective of this work is to study the mechanical strength and durability of the concrete when the particular cement dosage in concrete in replaced with Nano silica powder. However it is expected that the use of Nano-silica in concrete improve the strength properties of concrete. Also it is an attempt made to develop the concrete using Nano sized particles as a partial replacement of cement, which satisfies the various structural properties of concrete like compressive strength and tensile strength. It is expected that the final outcome of the project will have an overall beneficial effect on the utility of Nano-silica concrete in the field of civil engineering construction work.

Keywords: Nano-Silica , compressive strength , tensile strength , durability

INTRODUCTION

Concrete is one of the building materials widely used in civil engineering construction and their design consumes almost the total cement production in the world. When concrete structures are exposed to severe environment, its performance becomes inferior, there by leading to damage. It has become a recent topic of study in civil engineering to improve the mechanical and durability properties of concrete.

Better understanding and precise engineering of an extremely complex structure of cement-based materials at the Nano-level will apparently result in a new generation of concrete that is stronger and more durable. Novel properties of materials manufactured on the Nano-scale can be utilized for the benefit of construction infrastructure. Application of Nano materials in concrete technology can potentially change the service life and life-cycle cost of construction infrastructure.

1.1. Materials:

CEMENT : Ordinary Portland cement (OPC) of 53 grade is used in which the composition and properties is in compliance with the Indian standard organization . Calcium , Silica , Alumina , Iron are the major components. Calcium is usually derived from limestone, marl or chalk while silica, alumina and iron come from the sands, clays & iron ores. Other raw materials may include shale, shells and industrial by products.

FIG:01*(cement)*

FINE AGGREGATES

The aggregates which pass through 4.75 mm IS sieve and retain on 75 micron IS sieve are known as fine aggregates.

FIG:02(*fine aggregate)*

COARSE AGGREGATES

The aggregates which pass through 75mm IS sieve and retain on 4.75mm IS sieve are known as coarse aggregates.

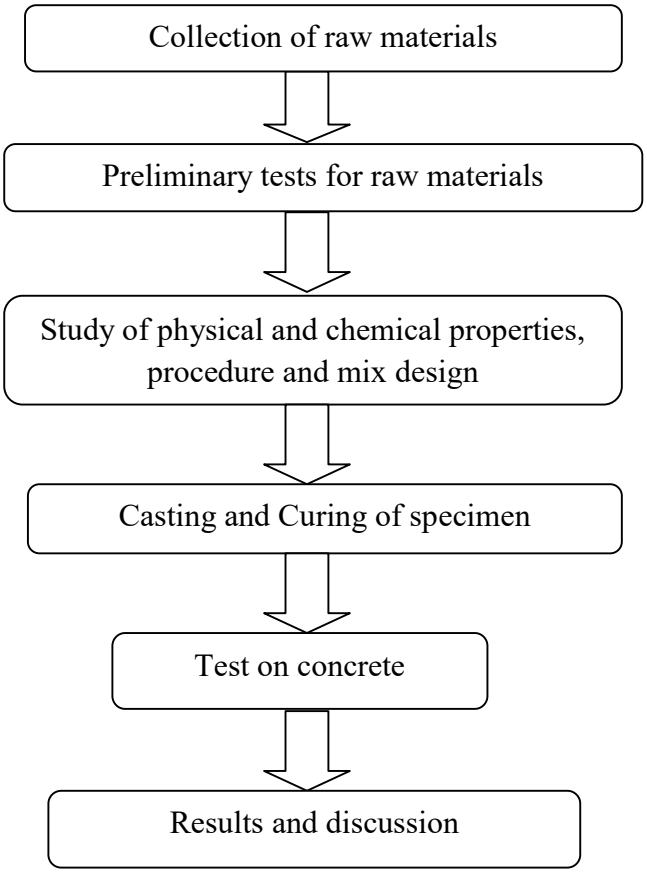
FIG:03*(Coarse aggregate)*

NANO-SILICA:

Lowered levels of environmental contamination Nano silica is typically a highly effective pozzolanic material. It normally consists of very fine vitreous particles approximately 1000 times smaller than the average cement particles. It has proven to be an excellent admixture for cement to improve strength and durability and decrease permeability Nano Silica reduces the setting time and increases the strength (compressive, tensile) of resulting cement in relation with other silica components that were tested Nano-silica is obtained by direct synthesis of silica sol or by crystallization of Nano-sized crystals of quartz.

FIG:05 *(Nano silica powder)*

1.2.1 METHODOLOGY



2. LITERATURE REVIEW

(1) Nanotechnology is one of the most active research areas that encompass a number of disciplines including civil engineering and construction materials. Interest in nanotechnology concept for Portland cement composites is steadily growing. 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 alumina and silica particles. If cement with nano-size particles can be manufactured and processed, it will open up a large number of opportunities in the fields of ceramics, high strength composites and electronic applications.

-Perumalsamy Balaguru and Ken Chong, 2006, National Science Foundation, USA, NANOTECHNOLOGY AND CONCRETE: RESEARCH OPPORTUNITIES.

(2) Conventional concrete improved by applying nanotechnology aims at developing a novel, smart, eco- and environment- friendly construction material towards the green structure. In today's life, though utilization of cement based materials plays a vital role

in the infrastructure development, it is polluting the environment by emitting CO2. Based on this view, researchers have been pursuing to evolve new or alternate material towards a green and sustainable solution. It also discusses the application of nanotechnology in the area of cement based materials, their composites. . It has been observed that the inclusion of nano particles would improve the toughness, shear, tensile and compressive & flexural strength, durability of cement based materials, better understanding and engineering of complex structure of cement- based material at nano-level.

-B.BHUVANESHWARI, SASMAL, NAGESH R.IYER , Nanoscience to Nanotechnology for Civil Engineering – Proof of Concepts, Recent Researches in Geography, Geology, Energy, Environment and Biomedicine

(3) Nanotechnology is the science of engineering that deals with particle which are less than 100 nm in size. It is the study of manipulating matter on molecular and atomic scale. In civil engineering and construction, the nanotechnology is applied in (I) concrete for reducing segregation in self compacted concrete, (ii) the use of copper nano-particles in low carbon HPS is remarkable, (iii) the use of nano sensors in construction phase to know the early age properties of concrete is very useful. Amit Srivastava, Kirti Singh, 2011, NANOTECHNOLOGY IN CIVIL ENGINEERING AND CONSTRUCTION: a REVIEW ON STATE OF THE ART AND FUTURE PROSPECTS, Indian Geotechnical society, 1077-1080.

(4) Nanotechnology is one of the most active research areas that encompass a number of disciplines, including civil engineering and construction materials. The potential for application of many of the developments in the nanotechnology field in the area of construction engineering has been growing. It also discusses the application of instruments to reach material properties of nano-scale. Furthermore, it has been observed that better understanding and engineering of complex structures made by cement, steel or composite materials at nano-level will definitely result in a new generation of construction materials with higher performance in strength, durability, and other properties. Ali Akbar Firoozi, Mohd Raihan Taha, Ali Asghar Firoozi,2014, Nanotechnology in Civil Engineering, EJEG, volume - 19 ,4673-4682.

3. PRELIMINARY TESTS

CEMENT COMPOSITION

S.NO	CHEMICAL COMPOSITION	LIMITS (%)
1	i. CaO	60-67
2	ii. SiO2	17-25
3	iii. Al2O	3 3-8
4	iv. Fe2O	3 0.5-6.0
5	v. MgO	0.5-4.0
6	vi. Alkalis	0.3-1.2
7	vii. SO	3 2.0-3.5

TABLE NO: 01

Aggregate Specific Gravity Test:

S.no	Descripition	Fine Aggregate(gm)	Corse Aggregate(gm)
1	A	1820	1000
2	B	1510	2154
3	C	500	1555
4	D	496	1000

TABLE NO: 02

Where,
A-weight of pycnometer + sample + Water
B-Weight of pycnometer+water

C- Weight of sample taken

D-The sample will be heated

Sieve Analysis test for fine aggregate:

Sieve size in mm	Weight of soil retained (gm)	% weight Retained	Cumulative % retained	% finer
10	0	0	0	0
4.75	16.5	3.3	3.3	96.7
2.36	28.5	5.7	9	91
1.18	69	13.8	22.8	77.2
600	151	30.2	53	47
300	212	42.4	95.4	4.6
150	20	4	99.4	0.6
75	1	0.2	99.6	0.4
PAN	1.5	0.3	99.9	0.1

TABLE NO: 03

Fineness modulus = Total sum of cumulative % retained/100 = 317.6/100 =3.17
Specific gravity for fine aggregate=D/C-(A-B) =496/500-(1820-1510) = 2.61

Sieve Analysis test for coarse aggregate:

Sieve size in mm	Weight of Aggregates Retained (gm)	% Weight Retained	Cumulative % Retained	% Finer
80	0	0	0	0
63	0	0	0	0
40	0	0	0	0
20	43	4.3	4.3	95.7
16	424	42.4	46.7	53.3
12.5	449.5	44.9	91.3	8.7
10	57.5	5.7	97.0	3
PAN	21	2.1	99	1

TABLE NO : 04

Specific gravity of coarse aggregate=2.41

Physical Properties of nano silica:

s.no	Particulars	Particulars
1	Colour	White
2	Sieve residue	0.02%
3	Bulk density	<0.10gm/cm^3
4	True density	2.4 g/cm^3
5	Specific gravity	1.03
6	Particle size	17 nano

TABLE N0: 05

4. CONCRETE MIX

Mix ratio = M_{20} (1:1.5:3)

Replace minute % of cement with the nana silica powder. i.e (0.75 % and 1.5%).

The mass of 0.75% and 1.5% nano silica is minute but the volume is high

PREPARATION OF CUBE AND PRISM SPECIMENS:

Cubes of 15 cm*15cm*15cm size we need to apply oil or grease for the cube and tighten the screws of cube as shown

FIG NO : 05

Required prisms are also oiled and tighten the screws and kept ready.

Wet mixing procedure:

Cement, fine and coarse aggregate were mixed together. Then 50% of mixing water was added to the mix. The rest 50% of mixing water was added to the nano particles and admixture**(0.8%)** and mixed together to insure dispersion of nano particles then it was added to the mix in the automatic mixer for 5 min. The perfect mixture is now quickly tested for slump and poured into the moulds which are readily placed on electric vibrator in three layers. After few seconds of vibration the surface is properly levelled before it is hardened. Let the moulds dry for 24 hours. Then remove the moulds and place it's in curing. The slump for all the mixes is carried out in a standard slump apparatus.

Fresh concrete tests:

Slump cone apparatus

FIG NO : 06

Slump cone test values

For the concrete of 0.75% nano silica: 30-4=26cm

For the concrete of 1.5% nano silica:30-3.7=26.3cm

Compaction factor test

FIG NO:07

compaction factor test values

For the concrete of 0.75% nano silica: 0.98

5. CASTING

Testing of specimen is done on 7^{th} ,14^{th} ,28^{th} day after casting.

So required number of prisims and cubes casted

s. no	Type of specimen	% of nano-silica	No.of specimen required on day			Total no of specimen
			7	14	28	
1.	Cube Prism	0.75	3 3	3 3	3 3	9 9
2.	Cube Prism	1.5	3 3	3 3	3 3	9 9
						36

TABLE NO: O7

6. CURING,TESTING

The test specimens are stored in moist air for 24hours and after this period the specimens are marked and removed from the moulds and kept submerged in clear fresh water until taken out prior to test.

FIG: 08 *(24hrs old specimen)*

FIG NO : 09

(Specimen submerged in water)

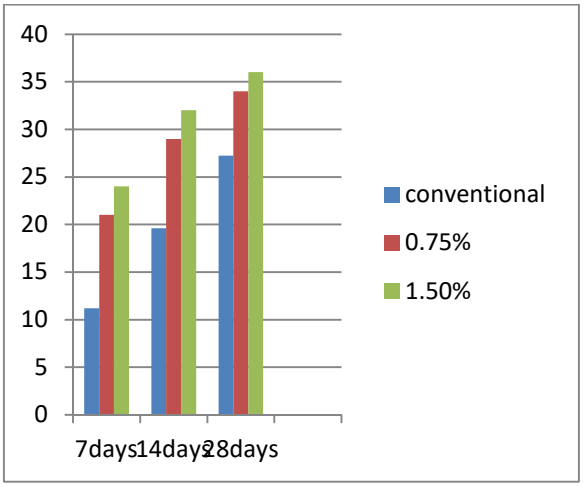
Compaction factor test:

FIG NO:10(UTM)

RESULT:

NO.OF DAYS	0.75% NANO SILICA	1.5% NANO SILICA
7DAYS	21 (N/mm²)	24(N/mm²)
14DAYS	29(N/mm²)	32(N/mm²)
28DAYS	34(N/mm²)	36(N/mm²)

TABLE NO : 08



GRAPH NO: 01

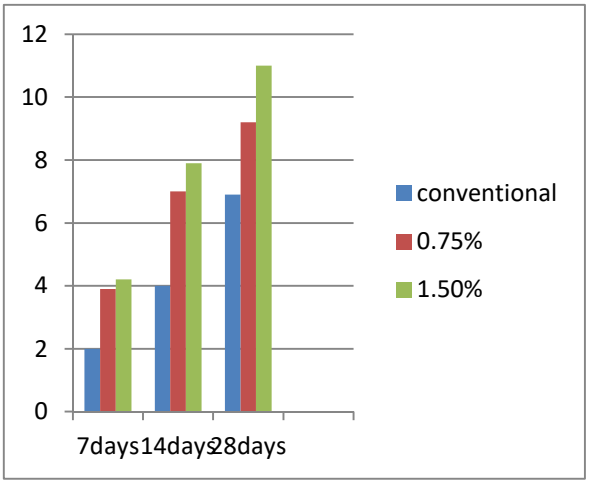
Tensile strength test:

FIG NO:11

RESULT:

NO.OF DAYS	0.75% NANO SILICA	1.5%NANO SILICA
7DAYS	3.9	4.2
14DAYS	7	7.9
28DAYS	9.2	11

TABLE NO : 11



GRAPH NO : 02

8. CONCLUSION

The study concludes that the addition of nano 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 study, the following were concluded

1. With the addition of nano silica in concrete, several unexplored potential in the field of concrete technology can be achieved. However, the technology in the conventional concrete has remained rather empirical and there are yet various aspects of concrete behavior that are beyond our comprehension.

2. Several new techniques are being incorporated in the field of nano science for the effective integration of nanotechnology in construction.

3. Mix design of nano silica concrete should take into account the specific field requirements of workability retention – this is by far the most important parameter for the design.

4. When the percentage by weight of nano silica exceeds 1.5% of the total weight of cement, it results in agglomeration.

5. Another important parameter to be included in the design mix is the determination of specific gravities of the aggregates, as they may affect the yield of the concrete, particularly in a project which involves huge quantity of concrete.

6. Skilled labour and adequate construction technique should be available on site to handle the proper proportioning of nanosilica in the concrete mix.

7. It is also concluded that concrete containing nano silica offers better workability, compared to the conventional concrete.

8. The nano silica concrete is also a green concrete as the addition of nano silica instigates C-S-H reaction which results in the reduction of carbon-dioxide emission thus making it eco-friendly.

9. The results obtained from 7th day ,14day & 28th day compressive and tensile strength tests prove that the nano silica concrete attains high initial and final strength compared to the conventional concrete. The percentage increase in strength of nano silica concrete after 28 days was found out to be increased.

10. The high initial and final strength values indicate that the nano silica concrete has a faster initial and final setting time.

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