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EFFECT OF AMORPHOUS SIO2 (nS) AND CARBON NANO PARTICLES ON MECHANICAL PROPERTY OF CONCRETE

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Abstract:- In the investigation the strength of M60 concrete with the use of Nano silica and in combination with Carbon nano tube (CNT) was used to study the mechanical properties. It has been reported that nano silica (nS) addition increases the compressive strength and reduces the overall permeability of hardened concrete due to the pozzolanic properties and Carbon nano tube have been provided High conductivity (being more than copper), elastic deformability, strength (being stronger than steel), surface chemistry, high stability. In this investigation cement replaced by Nano silica with 10%, 12% and 14% and carbon nano tube used 0.3% of cement content. To compare the results of cement replaced mixture, specimen without cement replacement are also casted. Performance of the various mixes is tested by the compressive strength, split tensile strength and flexure strength. A cube specimen of size 150mm X 150mm X 150mm, cylindrical specimen of size 150 mm dia X 300 mm high and beam specimen of size 150mm × 150 mm × 700mm were cast and demoulded after 24 hours then they allowed for normal water curing for 7 days and 28 days. The results show improvement in compressive strength, split tensile strength and flexural strength in cement replaced mixes.

Keywords:- Nano Silica (nS), Carbon nano tube (CNT), Compressive strength, Split Tensile strength, Flexure strength, Durability.

INTRODUCTION

The theoretical basis for producing high-strength concrete was originally developed in the field of ceramic materials in the late 1950s and early 1960s. Based on single-phase polycrystalline ceramic materials, it was shown that reduced particle dimension increased the strength. The dependence of the particle size on the strength was explained on the basis of Griffith's theory for the rupture of brittle materials with internal cracks. However, it was not until the early 1970s that new and very effective agents for dispersing the fine cement particles in water became available, and then, a tremendous advance in the production of high-quality concrete was achieved. At the same time, large quantities of ultra-fine condensed silica fume particles also became available. Therefore, a commercial basis for production of concrete with very high density and strength was established, and a rapid development of high-strength concrete took place.

One of the most referred to and used new cementitious nano-materials is amorphous silica with a particle size in the nano-range, even though its application and effect in concrete has not been fully understood yet. It has been reported that nano-silica addition increases the compressive strength and reduces the overall permeability of hardened concrete due to the pozzolanic properties, which are resulting in finer hydrated phases (C-S-H gel) and densified microstructure (nano-filler and anti-Ca(OH)2-leaching effects).[1] The main characteristic of nano-silica, such as particle size distribution, specific density, specific surface area, pore structure, and reactivity (surface silanol groups), depends on the production method.[1] 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. NS reduces the setting time and increases the strength (compressive, tensile) of resulting cement in relation with other silica components that were tested (Roddy et al., 2008). Nano-silica is obtained by direct synthesis of silica sol or by crystallization of nano-sized crystals of quartz.[2]

Carbon nano-materials, especially Carbon Nano tubes (CNT), is one of the most prospective advanced material for application in cement based products for the construction industry, due to its excellent material property. In this study, their application in cement mortar was comparatively studied. Three mechanical properties, 7 and 28-day compressive strength, split tensile strength and flexural strength, of CNT cement composites were investigated herein. Carbon Nano tubes (CNT) have an average diameter ranging from <1 nm up to 50 nm and an average length from 1 micron to 1 cm (ASTM 2011a).[3] High conductivity (being more than copper), elastic deformability, strength (being stronger than steel), surface chemistry, high stability are some of the properties that CNT's provide due to their structure and topology.[4] Increasing the strength for a longer duration of time and prolonging life along with giving boost to the compressive strength and contributing to the tensile strength by improving the flexural strength is reported from earlier research work, when CNT's are mixed with asphalt and concrete.[4]

MATERIALS USED AND THEIR PROPERTIES

In this work material used were cement, fine aggregate, coarse aggregate, admixture, water, nano silica (nS), carbon nano tube (CNT). The specifications and properties of these materials are as under:

Cement:- Ordinary Portland cement of grade 53 make from a single lot is used for the study. The physical properties of cement as obtained from various tests are listed in Table 1. All the tests are carried out in accordance with procedure laid down in IS 1489 (Part 1):1991, valid for ordinary portland cements.

Table 1: Physical Properties of Ordinary Portland cement

Sr. No.	Characteristics	Test Value	Value specified by IS : 1489-1991 (Part 1)
1.	Standard Consistency (%)	32	---
2.	Soundness (mm)	0.86	Max 10 mm
3.	Fineness of cement as retained on 90 micron sieve (%)	8 %	---
4.	Setting time (mints) 1. Initial 2. Final	 120 210	 Min 30 (min) Max 600 (min)
5.	Specific gravity	3.15	

Fine Aggregate:- Locally available sand is used as fine aggregates in the preparation of the concrete mix. The physical properties of sand are shown in Table 2.

Table 2: Physical Properties of fine Aggregate

Sr. No.	Characteristics	Value
1.	Specific gravity (oven dry basis)	2.64
2.	Fineness modulus	3.35
3.	Water absorption	0.54 %
4.	Grading Zone (Based on percentage passing 600 µm sieve)	Zone III

Coarse Aggregate:- Local natural coarse aggregate from village chikhli Dist. Navsari was used in experimental work. Two sizes of coarse aggregates 10 mm down and 20 mm down were used. The physical property of coarse aggregates is given in Table 3.

Table 3: Physical Properties of Coarse aggregate

Sr. No.	Characteristics	Value	
		CA – I	CA – II
1.	Type	Crushed	Crushed
2.	Maximum nominal size (mm)	20 mm	10 mm
3.	Specific gravity	2.93	2.847
4.	Total water absorption	1 %	1.12 %
5.	Fineness modulus	7.67	5.97

Water:- Fresh and clean water is used for casting and curing the specimens. The water is relatively free from organic matter, silt, oil, sugar, chloride and acidic material as per requirements of Indian standard. The water, which is fit for drinking is used for making concrete.

Admixture:- MasterGlenium SKY 8784 is used as a admixture in concrete mix design. MasterGlenium SKY 8784 is a ready-to-use liquid which is dispensed into the concrete together with the mixing water.

Nano Silica (nS):- Nano silica is used in this study which have Particle size of 20-30 nm and density of 200 Kg/m3. Physical and Chemical characteristics of nano silica are shown in Table 4 and Table 5 respectively.

Table 4: Physical Properties of Nano silica

Sr. No.	Characteristics	Value
1.	Colour	White
2.	Particle size (nm)	20-30
3.	Density (Kg/m3)	200
4.	Purity (%)	99.8

Table 5: Chemical Properties of Nano silica

Sr. No.	Constituents	Content
1.	SiO_2 (wt%)	99.4
2.	Na_2O (wt%)	0.45
3.	Al_2O_3 (wt%)	0.075
4.	Sulphate (wt%)	<0.1
5.	Fe (ppm)	25
6.	Ca (ppm)	10
7.	Zn, Pb and Cu (ppm)	<0.1

Carbon nano tube (CNT):- MWCNT (multi walled carbon nanotubes) are used in this study with density of 2.60 gm/cm3. Property of CNT is shown in Table 6.

Table 6: Property of Carbon nano tube (CNT)

Sr. No.	Property	Value
1.	Average Diameter (nm)	9.5
2.	Average Length (μm)	1.5
3.	Carbon Purity, (%)	90
4.	Metal Oxide, (%)	10
5.	Surface Area, m2/g	250-300
6.	Density (g/cm3)	2.60
7.	Young's Modulus (TPa)	0.9

EXPERIMENTAL PROGRAMME

Mix Design (M-60):-

Concrete mix design for M-60 grade concrete is prepared as per IS 10262: 2009 with using Nano silica (10%, 12%, 14%) and carbon nano tube (0.3%) which is shown in Table 7.

Table 7:- Mix Design M60 for 1 m3

Sr. No.	Material	Quantity
1.	Cement	490 Kg
2.	F.A. (39%)	661 Kg
3.	C.A. – I (40%)	751 Kg
4.	C.A. – II (21%)	383 Kg
5.	Water	167.5 Lit
6.	Admixture (0.5%)	3.92 Kg
7.	W/C Ratio	0.34

Table 8: Percentage of Nano silica replace and Carbon nano tube adding

Sr. No.	Mix	Nano silica	Carbon nano tube
1.	Standard Mix (M)	0%	0%
2.	Mix 1 (M1)	10%	0%
3.	Mix 2 (M2)	12%	0%
4.	Mix 3 (M3)	14%	0%
5.	Mix 4 (M4)	10%	0.3%
6.	Mix 5 (M5)	12%	0.3%
7.	Mix 6 (M6)	14%	0.3%

Specimen preparation and curing:-

Casting and testing of specimen was carried out as per IS codes IS:516-1959 for compression strength, split tensile and flexural strength. Materials are weigh batched, mixed in a mixer, cast into steel moulds and specimens were stored in room temperature for 24 hours, then removed from the moulds, and cured in normal water until tested.

Testing:-

Cubes of size 150 mm × 150 mm × 150 mm were tested to compute compressive strength, cylinders of size 100 mm dia × 200 mm high were tested to compute split tensile strength and beam of size 150mm × 150 mm × 700mm were tested to compute flexural strength of concrete. Specimens were tested under the Compression testing machine of 3000 KN capacity. Average of 3cubes compressive strength, 3 cylinders split tensile strength and 3 beams flexural strength are tabulated.

RESULTS AND DISCUSSION

A. Mechanical properties:

The test results of compressive strength, split tensile strength and Flexural strength for confined and unconfined specimens are tabulated.

1) Compressive Strength:-

Compressive strength test results are shown in table 5. The compressive strength results shows that there is good positive effective of replacing Nano silica (nS) + Carbon nano tube (CNT) content up to 10 to 14 % + 0.3%% by weight of cement. The main reason for the increase in compressive strength is due to the physical effect of Nano silica (nS) + Carbon nano tube (CNT) powder grains that allows denser packing within the cement particle and Carbon nano tube also acts as pozzalanic materials and improves the micro structure which leads to increase in compressive strength.

Table : 9 Compressive Strength.

Sr. No.	Specimen description	Compressive strength (MPa)	
		7 Days	**28 Days**
1.	M	45.39	59.73
2.	M1	46.10	64.28
3.	M2	49.13	67.24
4.	M3	52.76	70.09
5.	M4	49.04	71.52
6.	M5	54.96	79.54
7.	M6	53.23	77.33

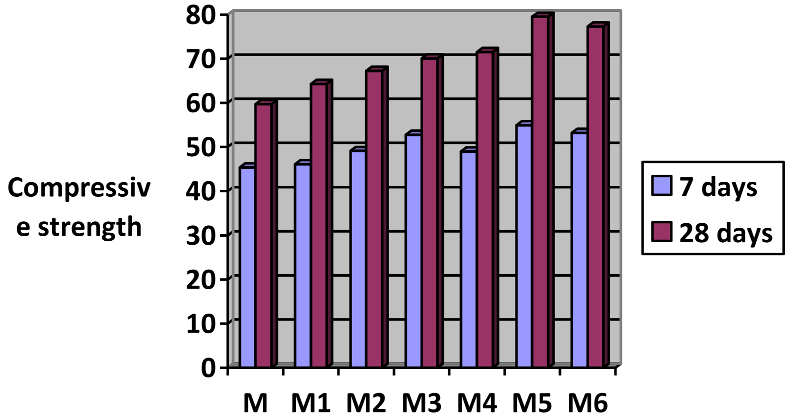

Figure 1:- Compressive strength after 7 days and 28 days of curing.

2) Split Tensile Strength:-

Confined and unconfined specimens of size 150 mm dia. and 300 mm height were tested for split tensile strength. Split tensile strength test results are shown in table 10. The split tensile strength result shows that there is an increase in tensile strength of Nano silica and CNT added specimen compare to the control specimen. The highest tensile strength of 5.70 MPa is obtained at 28 days for 12% nano silica and 0.3% CNT specimen.

Table : 10 Split tensile strength

Sr. No.	Specimen description	Split tensile strength	
		7 days	**28 days**
1.	M	2.47	2.96
2.	M1	2.59	3.26
3.	M2	2.75	3.92
4.	M3	3.14	4.40
5.	M4	2.96	4.45
6.	M5	3.89	5.70
7.	M6	3.55	5.22

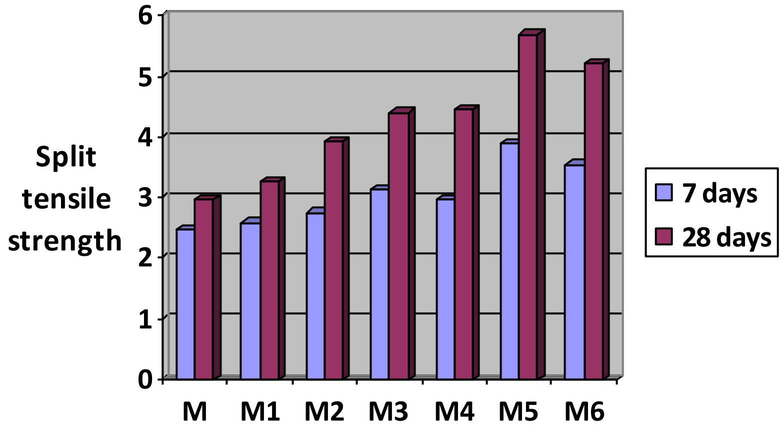

Figure 2:- Split tensile strength after 7 days and 28 days of curing.

3) **Flexural Strength:-** Flexural strength results are shown in table 9. It was recorded that maximum flexural strength is 14.56 N/mm² for Mix 5 (M5).

Table : 11 Flexural strength

Sr. No.	Specimen description	Flexural strength	
		7 days	28 days
1.	M	7.26	9.55
2.	M1	7.92	11.12
3.	M2	10.32	13.02
4.	M3	11.28	13.60
5.	M4	10.72	13.33
6.	M5	12.02	14.56
7.	M6	11.67	14.02

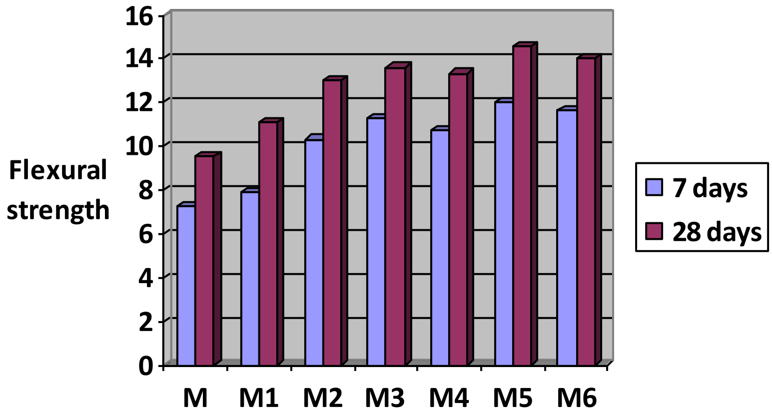

Figure 3:- Flexural strength after 7 days and 28 days of curing.

CONCLUSIONS

In this paper, the effect of replacing cement with Nano silica and adding Carbon nano tube on mechanical properties were experimentally studied. in this regard ,one hundred and ten specimens were tested experimentally under compressive test, split tensile and flexural test .and also performed acid attack test and SEM analysis. Then, based on relatively large experimental database was carried out. Following conclusions can be highlighted:

(1) The combined effect of Nano silica and Carbon nano tube improves the mechanical properties.
(2) Mix(M5) with 12% cement replacement with Nano silica and adding 0.3% Carbon nano tube gave highest 28 days compressive strength of 79.54 N/mm² as compared to Standard mix (M) having 28 days strength of 59.73 N/mm².
(3) Mix (M5) with 12% cement replacement with Nano silica and adding 0.3% Carbon nano tube gave highest 28 days split tensile strength of 5.70 N/mm² as compared to Standard mix (M) having 28 days strength of 2.96 N/mm².
(4) Mix (M5) with 12% cement replacement with Nano silica and adding 0.3% Carbon nano tube gave highest 28 days flexural strength of 14.56 N/mm² as compared to Standard mix (M) having 28 days strength of 9.55 N/mm².

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