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Experimental Study on the Effect of Different Nanomaterials in Concrete

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Abstract: **The infused nanoparticles within a concrete known as Nanoconcrete, has been an unindustrialized area of research that is yet to be commercialized. These exorbitant materials are still in progress of having their prices reduced through different sustainable production to get their way into the concrete industry as sustainable, durable and economical material. The importance of the incorporation of nanomaterials in concrete has emerged as a promising research interest due to the outstanding functionalized properties of the materials at that size level. This study aims to investigate the change in compressive strength as well as flexural strength of the concrete after the addition of hybrid nanomaterials. This paper deals with only three kinds of nano materials: Nano- silica, Multiwalled Carbon Nanotubes and Nano Graphene oxide. Concrete with water-cement ratio of 0.35 is used with 20% paste content and the proportions are fixed using packing density method containing different percentages of nanomaterials. A number of test has been carried out on 100mm^3 concrete cubes and 645mm^2 briquette mould is used for flexural tests. Investigation shows that the addition of nanomaterials has a significant effect on the physical and mechanical properties of concrete. The compressive strength is elevated about 10% to 30% and the flexural strength is also increased from 12% to 25%. the strength of the concrete depends on the percentages of nanomaterials, increment causes decrease in strength. Increase in the ages of concrete, increase the strength of concrete. As compared with ordinary concrete, nanoconcrete exhibit greater performance. This research paper is a trial given some highlight for the introduction of nanomaterials in various types of concrete.**

Keywords: **Nanoconcrete, Nano- silica, Multiwalled carbon nanotubes, Nano graphene oxide.**

I. INTRODUCTION

Nanotechnology is the science and engineering at the scale of atoms and molecules. It is the manipulation and use of materials and devices so tiny that nothing can be built any smaller. Nanomaterials are typically between 0.1 and 100 nanometres (nm) in size – with 1 nm being equivalent to one billionth of a metre (10 -9 m). this is the scale at which the basic functions of the biological world operate – and materials of this size display unusual physical and chemical properties. These profound different properties are due to an increase in surface area compared to volume as particles get smaller. The incorporation of ultra-fine particles into a Portland-cement paste within a concrete mixture in accordance with top-down approach of nanotechnology alters the concrete's material properties and performance by reducing the void space between the cement and aggregate in the cured concrete. This improves strength, durability, shrinkage and bonding to steel reinforcing bars. To ensure the mixing is thorough enough to create nanoconcrete, the mixer must apply a total mixing power to the mixture of 30-600 watts per kilogram of the mix. This mixing must continue long enough to yield a net specific energy expended upon the mix of atleast 5000 joules per kilogram of the mix, and may be increased to 30-80 KJ per kilogram. A superplasticizer is then added to the activated mixture which can later be mixed with aggregates in a conventional concrete mixer. In the HEM process, the intense mixing of cement and water with or without sand in conditions of queasy laminar flow, Reynolds number 20-800 provides dissipation and absorption of energy by the mixture and increases shear stresses on the surface of cement particles. As a result, the temperature of the mixture increases by 20-25

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and more degree Celsius. This intense mixing serves to deepen hydration process inside the cement particles. The nano-sized colloid Calcium Silicate Hydrate (C-S-H) formation increased several times compared with conventional mixing. Thus, the ordinary concrete transforms to nanoconcrete. The initial process of cement hydration with formation of colloidal globules about 5nm in diameter spreads into the entire volume cement-water matrix as the energy expended upon the mix. The liquid activated mixture can be used by itself for casting small architectural details and decorative items, or

expanded with gas-forming admixture for making aerated HEM Nanoconcrete hardens in low and subzero temperature conditions because the liquid phase inside the nano-pores of C-S-H gel doesn't freeze at temperature from -8 to -42 degree Celsius. The increased volume of gel reduces capillarity in solid and porous materials.

II. MATERIALS

Concrete is a composite material consisting of a binder, which is typically cement, rough and fine aggregates, which are usually stone and sand, and water. These comprise the constituent materials of concrete. A cement is a binder, a chemical substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and aggregate together. Cement starts to set when mixed with water, which causes a series of hydration chemical reactions. The constituents slowly hydrate and the mineral hydrates solidify and harden. The interlocking of the hydrates gives cement its strength.

A. Cement : Portland Pozzolana Cement: Grade 53 is used in this experimental study. PPC is a type of blended cement or interground with pozzolanic materials such as flyash, calcined clay, rice husk ash, etc. It consists of 15-35% pozzolanic material, 4% gypsum and the rest is clinker. PPC is environmental friendly, it contains flyash. It is economic. Better quality and high strength with less effort is gained by PPC. The heat of hydration of PPC is lower, thus can be used during mass concreting. PPC has higher fineness; low permeability thus higher durability. PPC prolongs the setting time of concrete, hence help in better finishing of concrete. PPC has ingredients which react with calcium hydroxide to form C-S-H gel, to provide additional strength, which actually makes the concrete grow in strength over the years. The concrete produced by using Portland Pozzolana cement has high ultimate strength, is more durable, resists wet cracking, thermal cracking and ha a high degree of cohesion and workability in concrete and mortar.

B. Fine Aggregate (Sand): Fine aggregate (sand) fills voids between aggregates. It forms the bulk and makes mortar or concrete economical. It provides resistance against shrinking and cracking. It is naturally available. As per IS 383: 2016 the aggregates should pass 4.75mm sieve and retained on 0.15mm sieve.

C. Coarse Aggregate: Coarse aggregate is stone which are broken into small sizes and irregular in shape. It occupy large volumes in concrete mix. As per IS: 383-2016, it should retained on 4.75mm IS sieve. In this experiment, fine gravel ranges from 6mm- 8mm is used.

D. Multi- walled Carbon Nanotube: A carbon nanotube (CNT) is a tube made of carbon with diameters typically measured in nanometers. MWCNTs consist of multiple carbon nanotubes nested within one another. The number of nanotubes that are within a MWCNT can vary – from as little as 3 to 20. At the same time the diameter of both the internal nanotube and the external nanotube can vary from 2nm for the innermost tube to over 50nm for the outer wall.

E. Nano Graphene Oxide: Graphene oxide (GO) is a biocompatible nano-material possessing good antibacterial activity. Graphene is an allotrope of carbon consisting of a single layer of atoms arranged in a two-dimensional honeycomb lattice nanostructure. Graphene has become a valuable and useful nanomaterial due to its exceptionally high tensile strength, electrical conductivity, transparency, and being the thinnest two-dimensional material in the world. Graphene is the strongest material ever tested,with an intrinsic tensile strength of 130 GPa (19,000,000 psi) (with representative engineering tensile strength ~50-60 GPa for stretching large-area freestanding graphene) and a Young's modulus (stiffness) close to 1 TPa (150,000,000 psi).

F. Nano Silica: Silica nanoparticles (SiNPs) or silicon dioxide are amorphous substances that have a spherical form. They can be produced in a variety of shapes and sizes, and the properties of their surfaces can be easily changed to suit several purposes. Silica nanoparticles are abrasive and absorbent in their nonporous form, but mesoporous silica nanoparticles with hexagonal pore structures have great potential in nanomedicine and drug applications. Nanosilica, also called quartz dust or silica dust, is a material that, like SF, is characterized by its high $SiO2$ percentage, over 99%. The use of nanosilica (crystalline $SiO2$) reduces the volume of cement and completes the grading curve of the aggregate mix in the zone of the smallest sizes.

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III. METHODOLOGY

The mix proportioning of the concrete is performed using the packing density method. This approach is carried out in two step. The determination of the fine and coarse aggregate fraction is accomplished in the first step by evaluating the maximum bulk density of the aggregate and the minimum void content. The percentage content of the fine and coarse aggregate at which the maximum packing density achieved is confirmed from the graphical representation. In the second step, the mix proportionating of the binder material, fine and coarse aggregate and water are calculated using packing density approach.

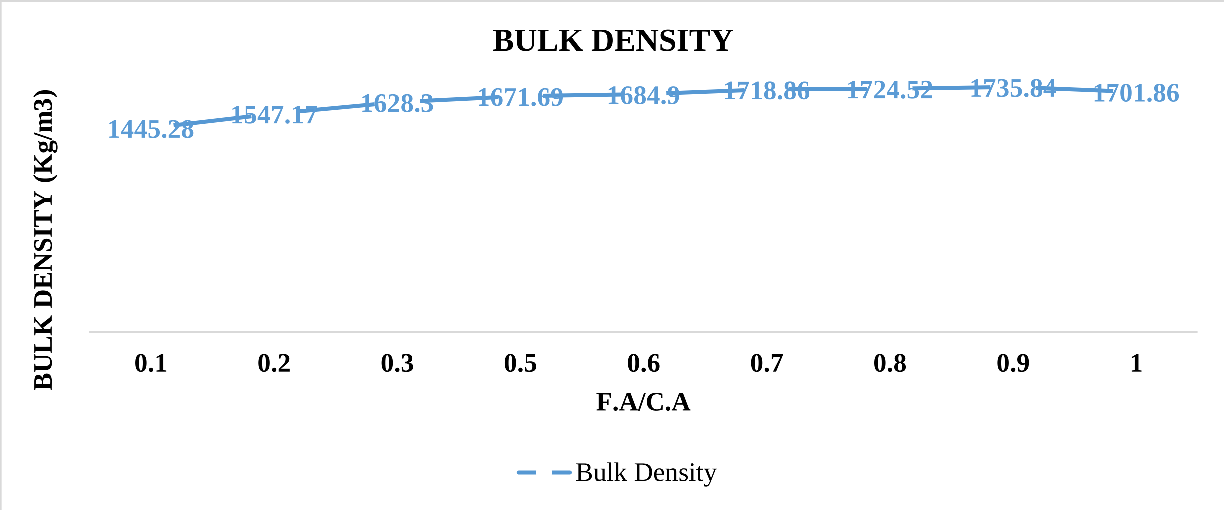

Fig. 1. Relationship between Bulk Density and ratio of F.A/C.A

.All the experiment are carried out by the following guideline mentioned in the Indian Standard 516: 1959. The detailed test procedure to produce the concrete test specimen are illustrated as follows:

- The concrete is prepared by volume batching of the Portland Pozzolona cement, river sand, 10 mm nominal sized graded coarse aggregate and portable water. Nanomaterials are mixed with water and then added to the dry mix.
- The concrete specimen are prepared using moulds of specific dimension 70.6 mm X 70.6 mm X 70.6mm. The moulds are of metal.
- The concrete are placed into the mould immediately after preparing the mix and compacted using a tamping rod. Each cube mould are filled with fresh concrete in three layers and each layer of concrete is tamped carefully so that there is no honeycomb present in the specimen.
- After demoulding of the concrete specimen they are taken for the curing process. The curing chamber are filled with water and the concrete specimen is drowned into the water. The open surface of the specimen are covered with wet jute bags.
- After 28 days the concrete samples are taken out of the water and placed over a plastic sheet for air curing.

IV. RESULTS

A. Compressive Strength of Conventional Concrete

TABLE 1. COMPRESSIVE STRENGTH OF CONVENTIONAL CONCRETE

Sl. No.	Materials	Compressive Strength (N/mm2)			Average Compressive Strength
		7 days	14 days	28 days	
1.	Conventional concrete(CC1)	15.9	21.9	30.8	7 days - 20.4N/mm2
2.	Conventional concrete(CC2)	20.3	27.8	28.6	14 days - 25.2N/mm2
3.	Conventional concrete(CC3)	25.0	25.9	31.0	28 days - 32.8N/mm2

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B. Compressive Strength of Multi- walled Carbon Nanotube

TABLE 2. COMPRESSIVE STRENGTH OF DIFFERENT PERCENTAGES OF MWCNT

Sl. No.	Materials	Percentage of Materials	Compressive Strength (N/mm2)			
			7 days	14 days	28 days	56 days
1.	CNT (C-1)					-
	Sample 1	0.01%	8.8	22.6	23.0	
	Sample 2	0.01%	10.0	27.4	27.8	
	Sample 3	0.01%	9.5	20.8	23.0	
	Average	0.01%	9.4	23.6	24.6	
2.	CNT (C-2)					-
	Sample 1	0.02%	18.5	29.8	37.2	
	Sample 2	0.02%	21.3	35.6	45.6	
	Sample 3	0.02%	19.6	33.6	40.8	
	Average	0.02%	19.8	33.0	41.2	
3.	CNT (C-3)					-
	Sample 1	0.03%	29.8	33.8	39.8	
	Sample 2	0.03%	35.2	39.6	45.6	
	Sample 3	0.03%	26.2	28.0	36.2	
	Average	0.03%	30.4	33.8	43.2	
4.	CNT (C-4)					
	Sample 1	0.04%	30.3	32.9	34.6	40.8
	Sample 2	0.04%	28.6	30.5	37.8	43.2
	Sample 3	0.04%	36.5	34.7	42.2	48.0
	Average	0.04%	31.8	32.7	32.2	44.0
5.	CNT (C-5)					
	Sample 1	0.05%	19.8	20.4	24.4	29.7
	Sample 2	0.05%	22.6	25.6	33.1	37.9
	Sample 3	0.05%	22.4	25.4	28.9	35.0
	Average	0.05%	21.6	23.8	28.8	34.2

C. Compressive Strength of Nano Graphene Oxide

TABLE 3. COMPRESSIVE STRENGTH OF DIFFERENT PERCENTAGES OF NANO GRAPHENE OXIDE

Sl. No.	Materials	Percentage of Materials	Compressive Strength (N/mm2)			
			7 days	14 days	28 days	56 days
1.	Nano Graphene Oxide (G-1)					-
	Sample 1		19.8	25.1	33.7	
	Sample 2	0.01%	23.7	33.0	40.7	
	Sample 3		20.1	28.0	34.8	
	Average		21.2	28.7	36.4	
2.	Nano Graphene Oxide (G-2)					
	Sample 1	0.02%	25.9	29.6	36.8	44.5
	Sample 2		40.8	44.8	52.3	65.8
	Sample 3		35.0	35.1	37.5	57.7
	Average		33.9	33.9	42.2	56

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D. Compressive Strength of Nano Silica

TABLE 4. COMPRESSIVE STRENGTH OF DIFFERENT PERCENTAGES OF NANO SILICA

Sl. No.	Materials	Percentage of Materials	Compressive Strength (N/mm2)		
			7 days	14 days	28 days
1.	Nano Silica (N-1)				
	Sample 1		12.8	22.8	28.9
	Sample 2		16.9	32.0	36.7
	Sample 3		16.8	30.7	28.6
	Average	0.01%	15.6	28.5	31.4
2.	Nano Silica (N-2)				
	Sample 1		22.8	34.8	44.9
	Sample 2	0.02%	28.9	39.9	51.2
	Sample 3		31.1	47.4	52.7
	Average		27.6	40.7	49.6

V. DISCUSSIONS

- In concrete, addition of CNT in different percentages shows different variation of compressive strength and flexural strength. Addition of 0.01% CNT gives low compressive strength as compared to conventional concrete. Addition of 0.02% and 0.03% CNT gives 30% more compressive strength in 28 days compared to conventional concrete. But 0.03% CNT gives more initial strength than 0.02% CNT. Addition of 0.04% and 0.05% CNT gives less compressive strength on 28 days comparable to 0.02% and 0.03% CNT, but on 56 days they achieved compressive strength same as other percentages of CNT. But addition of 0.05% CNT reduces compressive strength randomly.

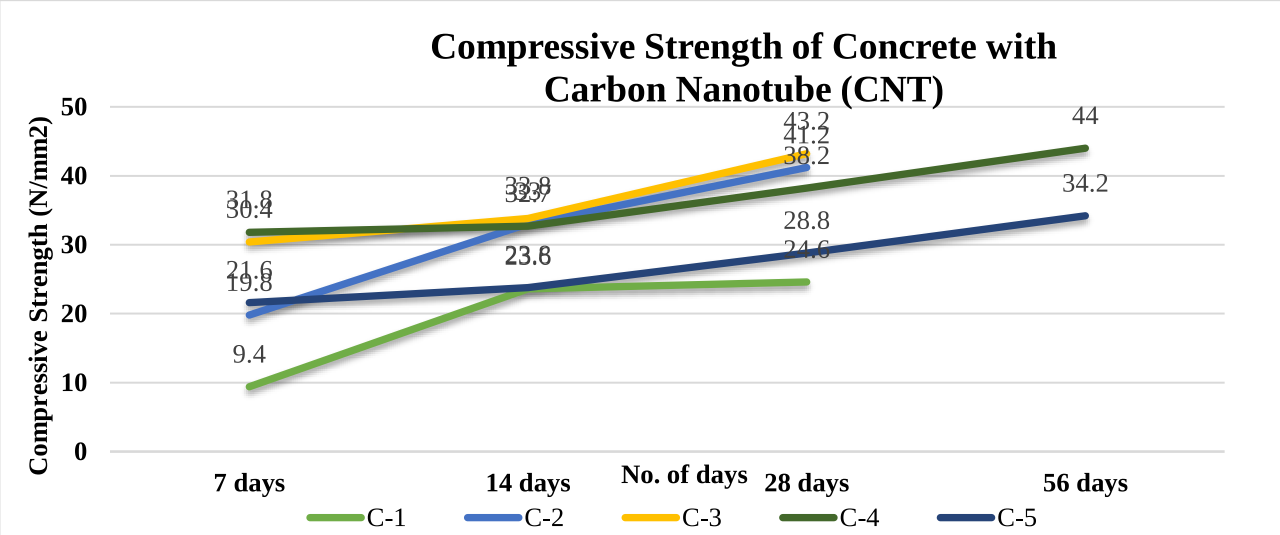

FIG.2. COMPRESSIVE STRENGTH OF DIFFERENT PERCENTAGES OF CNT

- In concrete, addition of nano graphene oxide in different percentages shows different variation of compressive strength. Addition of 0.01% nano graphene oxide does not show any highlighted changes in compressive strength compared to conventional concrete, but there no decrease in compressive strength is also seen. Change is observed in 0.02% of nano graphene oxide, the compressive strength is increased by 30% in 28 days and goes on increasing upto 56N/mm2 in 56 days.

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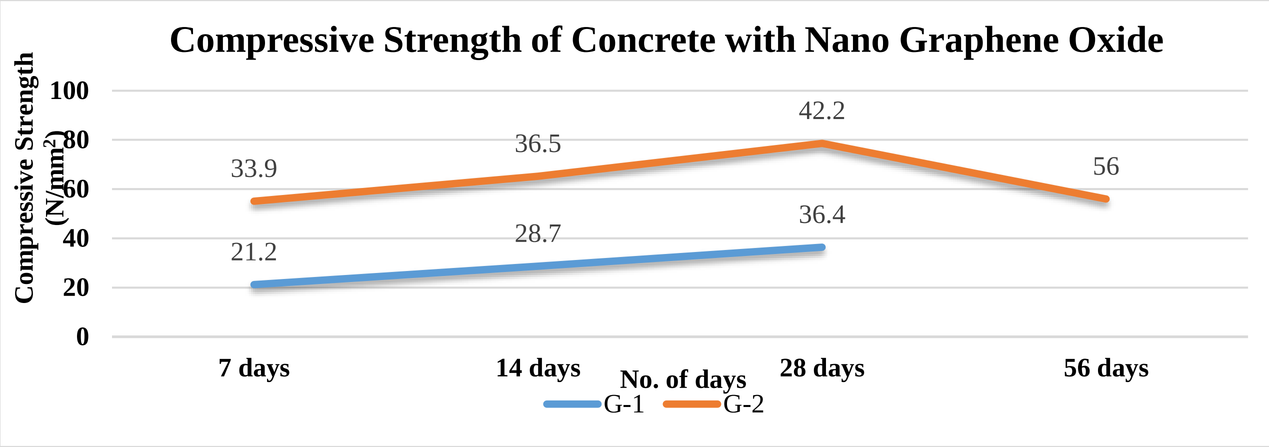

FIG.3. COMPRESSIVE STRENGTH OF DIFFERENT PERCENTAGES OF NANO GRAPHENE OXIDE

- In concrete, addition of nano silica in different percentages shows different variation of compressive strength. Addition of 0.01% nano silica shows less compressive strength compared to conventional concrete. But 0.02% of nano silica shows 52% increase in compressive strength compared with conventional concrete.

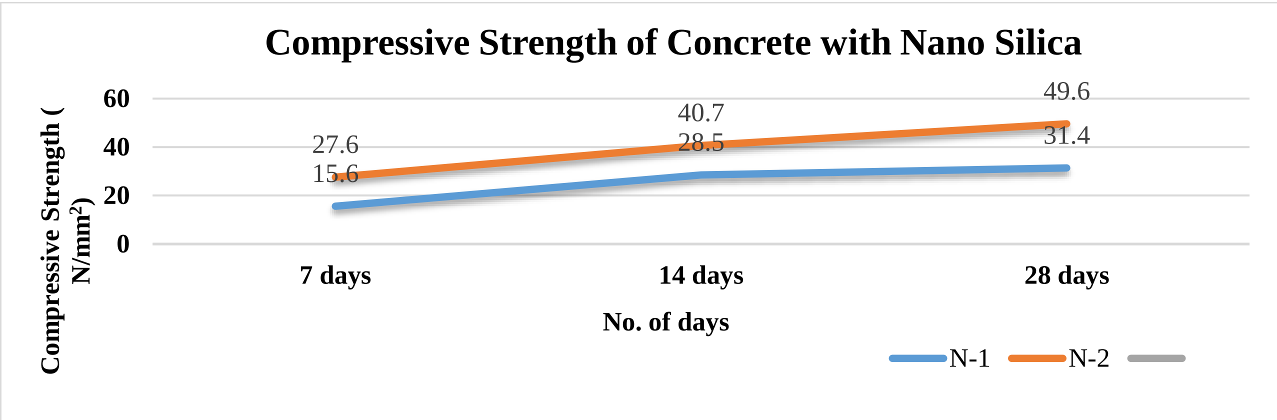

FIG.4. COMPRESSIVE STRENGTH OF DIFFERENT PERCENTAGES OF NANO SILICA

VI. CONCLUSIONS

The effect of the different nanomaterials on the mechanical strength of hardened properties of nanoconcrete can be concluded as follows :

- The concrete with nanomaterials exihibits superior mechanical properties compared to the ordinary cement concrete.
- The compressive strength of concrete with nanomaterials has a significant increment over the plain cement concrete.
- Proper visual inspection is recommended during the preparation of nanoconcrete as the higher content of nanomaterials has a effect of formation of agglomerates during the mixing that disturbs the uniform distribution of nanomaterials throughout the concrete mass.
- With the use of 0.02% nanosilica, the 28 days compressive strength of concrete can be increased upto 52% when it is compared to the plain cement concrete.
- With the use of 0.03% multi walled carbon nabotube and 0.02% nano graphene oxide, the 28 days compressive strength of concrete can be increased upto 30% when it is compared to the plain cement concrete.
- Incorporation of 0.03% CNT gives high initial compressive strength than plain cement concrete.
- With the use of 0.02% CNT and 0.02% nano graphene oxide, the performance of nano graphene oxide in compressive strength is much better than CNT.

- Although 0.04% CNT gives less 28 days compressive strength but later on the compressive strength increases upto 15% during 56 days.
- On 56 days compressive strength 0.02% nano graphene oxide shows increment upto 33% on comparing with 28 days compressive strength.
- Although 0.05% CNT gives less 28 days compressive strength but later on the compressive strength increases upto 20% during 56 days.

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