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STUDY AND DEVELOPMENT OF THE PROPERTIES OF NANO-CONCRETE

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ABSTRACT
Nano technology in civil field has proved to make the construction faster, cheaper, safer and more varied. Automation of Nano technology construction can allow for the creation of structures from advanced home to skyscrapers much more quickly and efficiently. Amorphous nano-silica (nS) particles were incorporated in cement concrete, and their effect on the fresh state behavior was analyzed. Nano concrete is defined as a concrete made by filling the pores in traditional concrete using nano particles of size <500nano meters. Nano particles of silica turn into nano particles of cement (nano cement) in the chemical reactions that take place in the concoction of the concrete.When concrete is reduced to Nano level its properties are strongly influenced so that it increases their strength & durability. Addition of nano silica to the concrete leads to improve the material passing which results in the densifying of micro & Nano structures. In this project, Nano-silica has been replaced in various proportions such as 5%, 10%, 15% and 20% to the weight of cement. Then the mechanical properties of concrete such as compressive strength, tensile strength and flexural strength of the respective specimens were tested after 7 days and 28 days curing. Results have been obtained and compared with conventional concrete mix. Nano concrete was concluded to have a higher strength than the ordinary concrete.

INTRODUCTION
Nano technology has the proven to make the construction faster, cheaper, safer and more varied. Automation of Nano technology construction can allow for the creation of structures from advanced home to skyscrapers much more quickly and efficiently. When concrete is reduced to Nano level its properties are strongly influenced so that it increases their strength & durability. Addition of nano silica to the concrete improves the properties of materials, which results in the densification of micro & Nano structures. Nano particles of silica turn into nano particles of cement (nano cement) in the chemical reactions that take place in the concoction of the concrete. Thus the nano particle acts as the filler of pores in the concrete which in turn influences the results.

ROLE OF NANO PARTICLES
When ultra-fine particles are incorporated into Portland-cement paste, mortar or concrete, materials with different characteristics apart from conventional materials were obtained. The performance of these cementitious based materials is strongly dependent on nano-sized solid particles, such as particles of calcium–silicate–hydrates (C–S–H), or nano-sized porosity at the interfacial transition zone between cement and aggregate particles. Typical properties affected by nano-sized particles or voids are strength, durability, shrinkage and steel-bond. Nano-particles of SiO_2 (nS) can fill the spaces between particles of gel of C–S–H, acting as a nano-filler. Furthermore, by the pozzolanic reaction with calcium hydroxide, the amount of C–S–H increases, resulting a higher densification of the matrix, which improves the strength and durability of the material. Besides, the compressive strength of mortar or concrete with silica fume was improved when compared with formulations without addition.

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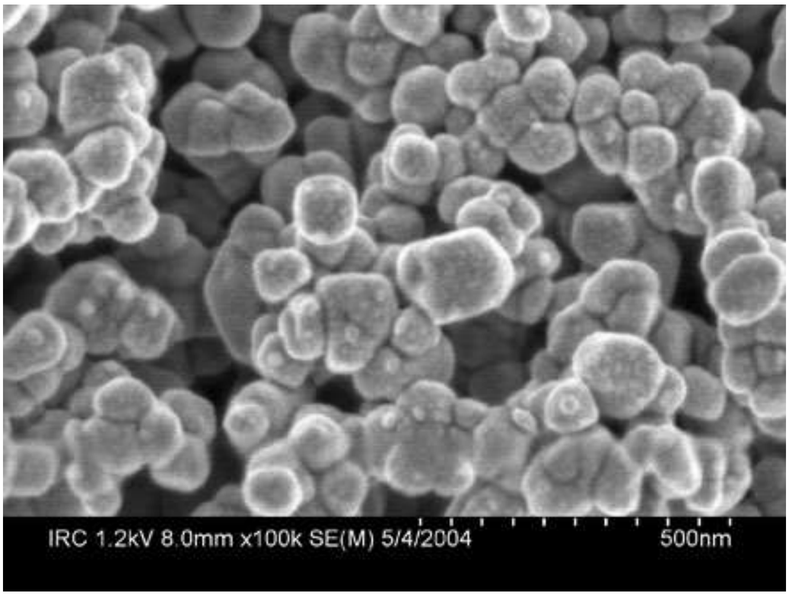

Fig: 1.1 Scanning electron microscope image of nano-sized particle

Thus Nano-silica has been utilized in the manufacturing of Nano-Concrete by partial replacement of cement in various proportions such as 5%, 10%, 15% and 20% and to study the mechanical characteristics of it. It is then compared with the normal conventional concrete.

TESTS ON INGREDIENTS

INGREDIENTS	SPECIFIC GRAVITY
Cement	**3.316**
Fine Aggregate	**2.90**
Coarse Aggregate	**2.98**

Sieve Analysis test for Fine Aggregate

IS-sieve size (mm)	Weight Retained (kg)	Cumulative Weight Retained (kg)	Cumulative Percentage Retained	Cumulative Percentage Passing
4.75	0.000	0.000	0.000	100.00
2.36	0.020	0.020	2.000	98.00
1.18	0.085	0.105	10.500	89.50
0.60	0.265	0.370	37.000	63.00
0.30	0.390	0.760	76.000	24.00
0.15	0.200	0.960	96.000	4.00
Pan	0.040	1.000	100.000	-

Result:
From the given table,
The sand taken in this investigation belongs to **ZONE – III**.
Sieve Analysis test for Coarse Aggregate

IS –Sieve Size (mm)	Weight Retained (kg)	Cumulative Weight Retained (kg)	Cumulative % retained	Cumulative % passing
40	0	0	0	100.00
20	.335	.335	16.75	83.25
10	1.425	1.761	88.05	11.95
4.75	0.228	1.989	99.45	0.55
Pan	0.011	-	100	-

Result:
From the table,
The given aggregate is **Single sized aggregate**

Test on Nano-Silica:
The test on Nano-Silica has been conducted in the laboratory with necessary equipments and the results obtained are given in the table 3.4

Test results of Nano-silica

S.NO	TEST CONDUCTED	RESULTS	REQUIREMENTS AS PER IS: 15388-2003
PHYSICAL TEST RESULTS			
1	Specific Gravity	2.62	Not Specified
2	Compressive strength at 7 days	117	Min. 85
3	Oversize percent retained on 45 micron IS sieve	0	Max. 10
CHEMICAL TEST RESULTS			
4	Silicon dioxide (SiO_2), (% by mass)	97.02	Min. 85
5	Loss on Ignition, (% by mass)	0.45	Max 4
6	Moisture Content, (% by mass)	0.12	Max 3
7	Alkalies, (Na_2O equivalent), (% by mass)	0.28	Max 1.5

PROPERTIES OF MATERIALS

Cement:
Cement is a substance which acts as a binding agent or material. The raw material used in the manufacture of cement consists of lime, silica, alumina and iron oxide. This oxide, when subjected to high clinkering temperature combine with each other to form a complex compounds called Bogue's compounds (C_3A, C_3S, and C_2S). Among this C_3S and C_2S are the most important compounds responsible for strength. The properties of cement used are given in the table 4.1

Table: 3.5 Physical properties of cement

PROPERTIES	VALUES
Compressive strength	43MPa
Fineness	5%
Initial setting time	30 minutes
Final setting time	10 hours
Standard Consistency	29%
Specific Gravity	3.15

Coarse Aggregates in Concrete:
The coarse aggregate used for the experimental study was obtained from the nearby quarry. The properties of the coarse aggregate are given in the table 4.2

Physical properties of coarse aggregate

Coarse Aggregate	Values
Size	20 mm
Fineness Modulus	7.3
Specific Gravity	2.6
Water Absorption	0.50%

Fine Aggregates in Concrete:
Naturally occurring river sand was used as fine aggregate. Fine aggregate with a rounded particle shape and smooth texture was preferred, as it requires lesser amount of water during mixing in concrete. The properties of fine aggregate are given in the table 4.3

Physical properties of Fine Aggregate

Fine Aggregate	Values
Size	Passing through 4.75 mm sieve
Fineness Modulus	3.5
Specific Gravity	2.6
Water Absorption	1.0%

Properties of Nano-silica

Physical properties	
Specific Gravity	2.62
Size	less than 500 nm
Chemical properties: (% by mass)	
SiO2	97.02
Loss on ignition	0.45
Moisture content	0.12
Alkalis	0.28

RESULTS AND DISCUSSION

Determination of compressive strength of the concrete
The compressive strength tests were carried out on 150mm x 150mm x 150 mm cubes as specified by IS 516-1959 (1989). This test was carried out by using the AIMIL compression testing machine of 2000 kN capacity at a uniform stress of 149 kg/cm^2/minute after the specimen had been centered in the testing machine. The ultimate load (*P*) was noted

Compressive strength of cubes

SPECIMEN	COMPRESSIVE STRENGTH (N/mm^2)	
	After 7 days	After 28 days
5%	31.12	37.78
10%	34.97	40.97
15%	33.57	39.22
20%	33.72	39.22
Conventional	18.95	27.36
Silica Fume (15%)	19.36	26.67

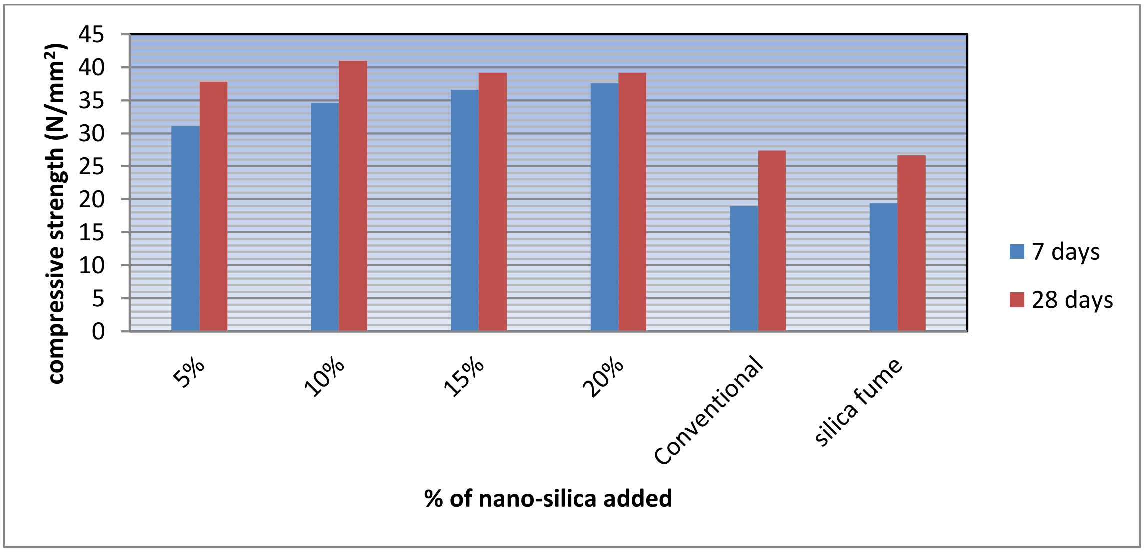

Fig: Compressive strength of Cubes

From the fig it is evident that the addition of 10% of nano-silica with the concrete cubes, the compressive strength after 7 days (34.97 N/mm^2) and 28 days (40.97 N/mm^2) is more when compared to the other mix percentages.

Determination of tensile strength of the concrete

The tensile strength tests were carried out on the concrete specimen of size 150 mm in diameter and 300 mm in length conforming to the specifications IS 5816-1970 (1985). This test was carried out by using the AIMIL compression testing machine of 2000 kN capacity by placing the cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load was applied until the failure of the cylinder, along the vertical diameter.

Split Tensile Strength of Cylinders

SPECIMEN	SPLIT TENSILE STRENGTH (N/mm^2)	
	After 7 days	After 28 days
5%	3.39	4.95
10%	3.5	5.16
15%	2.8	4.46
20%	2.76	4.42
Conventional	1.62	2.93
Silica Fume (15%)	2.83	3.53

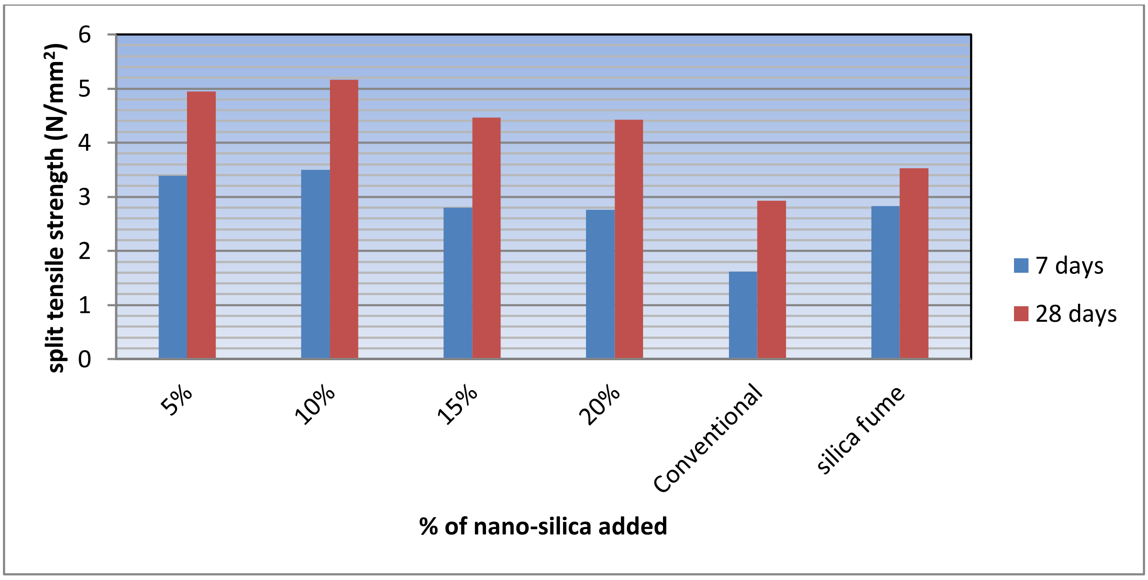

Fig: Split Tensile Strength of Cylinders

From the fig it is evident that the addition of 10% of nano-silica with the concrete cylinders, the split tensile strength after 7 days (3.5 N/mm^2) and 28 days (5.16 N/mm^2) is more when compared to the other mix percentages.

Determination of flexural strength of plain cement concrete beams

The size of the concrete specimen used for carrying out these tests was of size 700mm x 150mm x 100mm beam. This test was carried out using 5000 kN capacity flexural strength testing machine subjected to two point loading to determine the flexural strength of concrete as per IS 516-1959 (1989).

Flexural Strength of Beams

Specimen	**FLEXURAL STRENGTH (N/mm²)**	
	After 7 days	After 28 days
5%	10.25	15.75
10%	13.92	23.8
15%	12.82	20.88
20%	13.92	21.97
Conventional	2.54	4.68
Silica Fume (15%)	5.32	9.41

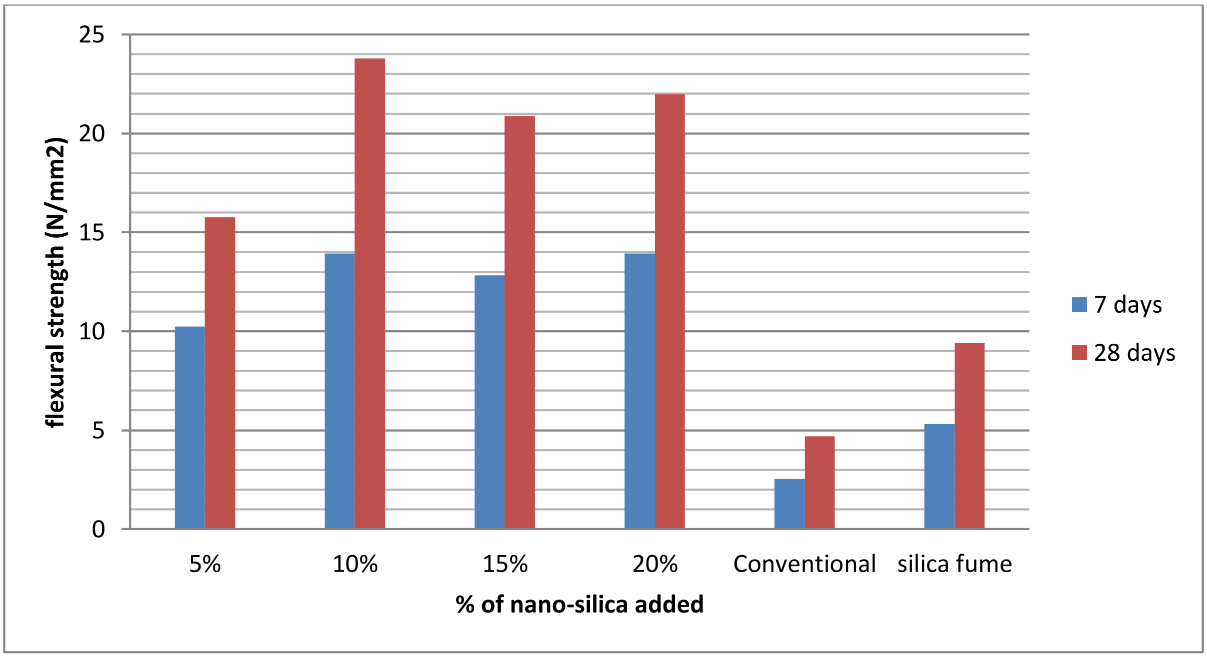

Fig: Flexural Strength of Beams

From the fig it is evident that the addition of 10% of nano-silica with the concrete beams, the flexural strength after 7 days (13.92 N/mm^2) and 28 days (23.80 N/mm^2) is more when compared to the other mix percentages.

DISCUSSION

The test results indicate that the addition of Nano-silica by 10% partial replacement of cement gives maximum strength than the other mix percentages. Therefore the optimum content of nano-silica to be used can be quoted as 10%. This reduces the porosity and gives good bonding strength. The hydration process is faster hence the concrete achieves the maximum strength within a shorter period. It also provides good workability at low water-cement ratio, it also adds to the cause for increase in strength.The result from the table and graph shows that the nano-silica is statistically significant than the conventional concrete and the concrete with silica fumes.

Properties of Fly-Ash

Physical properties	
Specific Gravity	2.1
Fineness	233 m^2/kg
Chemical properties: (% by mass)	
SiO2	40-80
Al_2O_3	10-20
Fe_2O_3	2-5
MgO	1-3
CaO	2-8
Na_2O	1-3

In addition to this 10% cement was replaced by Nano-silica in the Fly-ash concrete. It influences the strength and durability properties to a greater extent. It also increases the binding property with the reduction of cement.

Properties of GGBS

Physical properties

Specific Gravity	2.9
Size	300µ
Chemical properties: (% by mass)	
SiO2	29-38
Al_2O_3	14-22
FeO	0.1-1.9
MgO	7-11
CaO	31-40
MnO	0.01-1.2

In addition to this 10% cement was replaced by Nano-silica in the GGBS concrete. It influences the strength and durability properties to a greater extent. The effect of Nano-silica in GGBS concrete was determined.

RESULTS

The results obtained for the Green Concrete with and without the replacement of Nano-silica were given in the following table 5.3

Compressive strength of Green Concrete

SPECIMEN	**COMPRESSIVE STRENGTH (N/mm²)**	
	Without nS	With nS
Fly Ash	35.96	42.3
GGBS	28.32	35.93
C & D debris	32.54	39.33

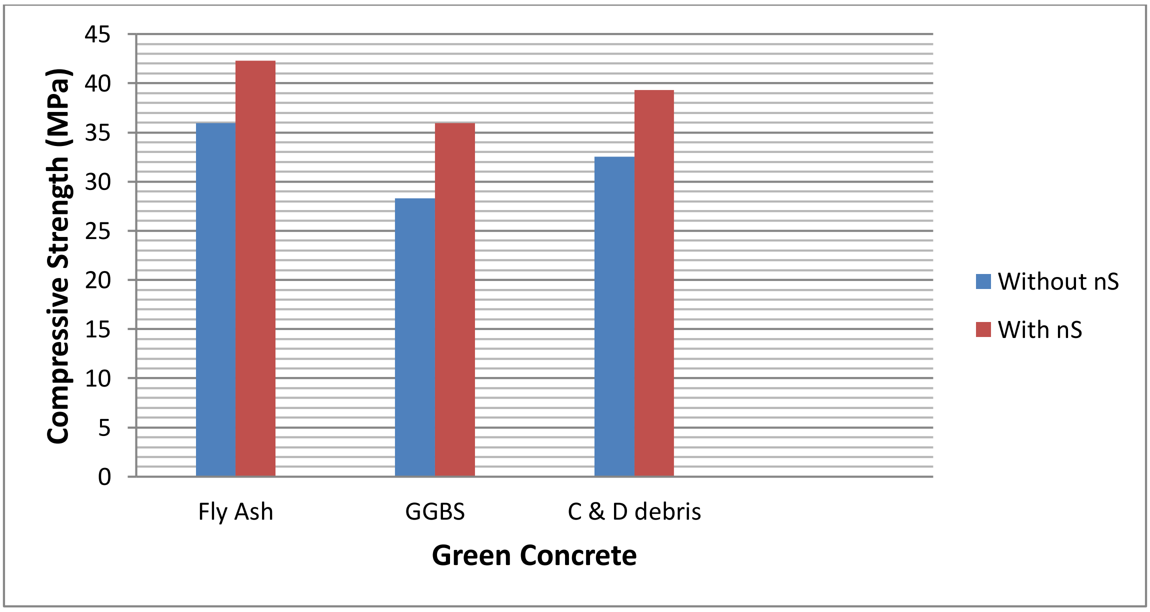

Fig Compressive strength of Green Concrete

DISCUSSION

The test results indicate that the addition of Nano-silica by 10% partial replacement of cement to the Green Concrete gives maximum strength. This reduces the porosity and gives good bonding strength. The hydration process is faster hence the concrete achieves the maximum strength within a shorter period. It also provides good workability at low water- cement ratio, it also adds to the cause for increase in strength. The result from the table and graph shows that the Green Concrete with nano-silica is statistically significant than the other. The effective utilization of waste materials can be achieved. This leads to reduction in the hazards caused by land filling, incineration, dumping of waste, etc,. Hence it paves the way for the development of sustainable concrete according to the norms of Environmental Protection Agency.

COST COMPARISON

The comparison has been given in the table 6.1.

Cost Comparison

MATERIALS	COST OF NORMAL BUILDING	COST OF BUILDING WITH nS
Cement	Rs. 75000 for 250 kg	Rs.69000 for 225 kg
Nano-silica	-	Rs. 2800 for 25 kg
Total cost per site	Rs. 1,35000 (app)	Rs. 1,31000
Saving	-	Rs. 4000

From the table it is evident that the material Nano-silica is economical to be used as a replacement material for cement.

CONCLUSION

STRENGTH TEST RESULTS

Well dispersed nano particles increase the viscosity of the liquid phase and improve the segregation resistance and workability of the system which accelerates the hydration process. Besides these it provides better bond between aggregates and cement paste which improves the toughness, shear, tensile strength and flexural strength of concrete. It is useful to make High Strength concrete with reduced water-cement ratio. The use of additives such as super plasticizers is unnecessary. Hence the optimum content of 10% gives maximum results in all tests that have been conducted. So we conclude that the maximum amount of Nano-silica that can be used to replace cement should be in the range of 5%-10%.

SUSTAINABILITY OF NANO-SILICA

Every 1 ton of cement produced leads to about 0.9 tons of CO_2 emissions and a typical cubic yard (0.7643 m3) of concrete contains about 10% by weight of cement. Therefore this has to be reduced and this project gives one of the solutions for preparing the sustainable concrete. As nano-silica is used to replace the cement partially, the production of cement can be reduced respectively. Thus Cement can be saved up to 35 – 45% by incorporating Nano-silica in the construction field.This paves the way for effective management of waste and the reduction of Global warming. This enables us to make green concretes which are eco-friendly and economical.

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