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Experimental Study in Various Properties of High Strength Self-Compacting Concrete Incorporating NanoSilica

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Abstract: **Self-compacting concrete (SCC) is a well-defined flowable material, and non-segregating concrete that doesn't need mechanical vibration and has a capability to self-heal or compact itself by its own weight. Self-compacting concrete is categorized by a low yield stress, Designed Rheological workability (DRW), filling ability, passing ability, segregation resistance, high deformability and high durability as a High Performance Self-Compacting Concrete (HPSCC).In this paper mechanical properties of M30 grade concrete by partial replacement of cement with Nano-silica are studied. The results were obtained for compressive strength, split tensile strength and flexural strength at7days, 28days and 56days. It was observed that addition of Nano-silica increases the compressive strength at all replacements levels in comparison to control mix. Also, strength is much higher at the initial ages due to the reaction of unhydrated calcium hydroxide with Nano-silica.**

Keywords: **Self-Compacting Concrete, Designed Rheological Workability (DRW), High Strength Densified Micro Structure (HSDMS), Compressive Strength Test, Split Tensile Strength Test, Flexural Strength.**

I. INTRODUCTION

Concrete is the world's largest manmade material which is used worldwide, it is more special when it is design as a high performance self-compacting concrete (HPSCC). In this advance civilization, structural concrete research of self-compacting concrete is a revolutionary disk of civil infrastructure and its country growth. Self-compacting concrete (SCC) is well-defined as a flowable material, non-segregating concrete that doesn't need mechanical vibration and has capability to self-heal or compact under its own weight. Nano-SiO_2 is a cement based material which is used as Nano-filler in the cement matrix, the capillary pores were originate to be slighter and the total porosity is also reduced at Nano scale which make it multi-functional Nano-technological material [2 to 6]. In this study, colloidal Nano-SiO_2 (CNS) is a considered as a multi-functional Nano-technological material in cement-matrices performing as a designed self-compacting concrete [7].One of the concerns regarding the elastic performance of self-compacting concretes (SCC) is their inferior stiffness tendency compared to conventional concretes (CC) but it is a designed to give much better results as a high performance concrete [8]. Only a few researches carried out investigation on the fresh properties, hard properties and microstructural properties with NanoSilica. Many researchers reported dissimilar and inconsistent optimum quantities of NanoSilica along with some unusual effects which needs much concentration in the further research [9 to 11]. Nano-SiO_2 is the most broadly used material in the cement and concrete to increase the performance. In this modern world of advance infrastructure, it is essential to develop a high strength, durable, sustainable and environment friendly cementitious composites [12].

II. EXPERIMENTAL WORK METHODOLOGY

To obtain high performance results of SCC different research approaches are followed to perform its Designed Rheological Workability (DRW) and mechanical behaviour. The materials used to carry out the research work consist of cement, fine and coarse aggregate, superplasticizer, NanoSilica and water.

CEMENT

Ordinary Portland cement (OPC) Grade 43 Ultra Tech cement was used as a basic binder constituent of concrete for the casting cubes, cylinders and beams for all concrete mixes as per SCC design. The Ultra Tech cement fulfilled all requirements of BIS-8112/1989 specifications. Test results are given in Table 1 as below.

Table 1: Physical Properties of Ordinary Portland Cement

Characteristics	Experimental observations	Value Specified by IS:
Standard consistency%	28	………..
Specific gravity	3.15	………..
Fineness%	3.5	< 10%
Initial Setting Time(min)	96	30 minutes (min)
Final Setting Time(min)	185	600 minutes (min)
Soundness(mm)	1.5	10mm (max)
Compressive Strength		
3 days (MPa)	24.9	23.0(Min.)
7 days (MPa)	35.5	33.0(Min.)
28 days (MPa)	45.7	43.0(Min.)

FINE AGGREGATE

Fine aggregate obtained from river sand which was used as SCC basic constituent that is available in local market. Particles of size greater than 4.75mm as retained on sieving were removed. After that sand was washed and dried for the use in lab as per IS: 383-1970 Code specifications. Its physical properties and sieve analysis are given in Table 2.

Table 2: Physical Properties of Fine Aggregate

S.NO	Characteristics	Test Value obtained
1	Specific gravity	2.6
2	Water absorption %	0.602
3	Fineness Modules	2.56
4	Grading Zone	III
5	Loose bulk density (kg/m^3)	1670
6	Compacted bulk density (kg/m^3)	1960

COARSE AGGREGATES

Crushed Coarse aggregate with the size of 10mm were used. After the collection of coarse aggregate, it was washed and dry condition that ready for use in concrete as per IS:383-1970specifications. Physical properties and sieve analysis results are specified in Table 3.

Table 3: Physical Properties of Coarse Aggregate (10mm)

S.NO	Characteristics	Test Values obtained
1	Colour	Grey
2	Loose bulk density (kg/m^3)	1449
3	Compacted bulk density (kg/m^3)	1576
4	Specific gravity	2.70
5	Water absorption %	0.04
6	Fineness modulus	6.12

FLY ASH

Fly Ash is a fine cementious material obtained from the combustion of coal from “Rajpura Thermal Power Station” Punjab, India. The physical and chemical properties of fly ash are given in the Tables 4 and 5.

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Table 4: Physical Properties of Fly Ash

Physical Properties	Value
Color	Grey (blackish)
Specific Gravity	2.13

Table 5: Chemical Properties of Fly Ash

S.No.	Constituent determined	Percent by weight
1.	Loss in ignition	4.17
2.	Silica(SiO_2)	58.88
3.	Iron Oxide(Fe_2O_3)	3.44
4.	Alumina(Al_2O_3)	28.2
5.	Calcium oxide(CaO)	2.23
6.	Magnesium oxide (MgO)	0.32
7.	Total Sulphur(SO_3)	0.07
8.(a)	Sodium oxide(Na_2O)	0.58
8.(b)	Potassium oxide(K_2O)	1.26

WATER

Potable water was taken from lab water tank and used for the mixing of ingredient and for curing purpose also. It was observed to be free from organic materials and suspended solids, which may affect the properties of fresh as well as properties of durable concrete. Various properties to water conforming to Indian standard specifications IS 456- 2000

SUPER PLASTICIZER

Polycarboxylate polymers as a Master Glenium SKY 8952, a high performance super plasticizer was used as per SCC design. It is based on Polycarboxylate polymers with specific gravity as 1.1. The use of Superplasticizer considerably reduces the water demand in flowable concrete. Specifications of super plasticiser are given in Table 6.

Table 6: Specification of Superplasticizer

S.NO	Parameter	Specifications (As per IS: 9103	Results
1	Physical State	Reddish Brown liquid	Reddish Brown liquid
2	Chemical name of active Ingredient	Polycarboxylate Polymers	Polycarboxylate Polymers
3	Relative Density @25'c	1.11 ± 0.01	1.103
4	Ph	Min. 6	6.67
5	Chloride ion content(%)	Max. 0.2	0.0012
6	Dry Material content	35(±5%)	34.03

NanoSilica (NS)

Chemical composition of NanoSilica is CEMSYN- XTX (BEECHEMS Kanpur). This colloidal NANO SiO_2 is applied as per SCC design requirement. As cement paste is composed of small grains of hydrated calcium silicate gels, Nano sized individual pores, capillary pores and large crystals of hydrates products which leave a room for Nano phase materials to fills the pores of cement paste. Table 7 give the chemical compositions of NanoSilica.

Table7: Chemical composition of NanoSilica

S. No.	Parameters	CEMSYN- XTX
1.	Specific Gravity	1.213
2.	pH	10.3
3.	Viscosity(B4cap)	12 seconds
4.	SiO2 %	30.16
5.	Na2O %	0.45
6.	Dispersant	Water
7.	Nano particle size (nm)	20

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III. MIXDESIGN AND MIX PROPORTIONS OF SCC

The mix design of SCC was as per Japanese method with the target strength of 30 Mpa as per EFNARC Specifications and Guidelines for self-compacting concrete 2005 [40]

Table 8: Mix Design

S.No	Test Data For Contentious	Values
1	Specific Gravity of cement	3.15
2.	Specific Gravity of FA	2.6
3	Specific Gravity of CA	2.70
4	Specific Gravity of Fly Ash	2.13
5	Specific Gravity of Super Plasticizer	1.11
6	Specific Gravity of Water	1
7	Specific Gravity of Nano-SIO_2	1.213

MIX PROPORTIONS OF SCC.

Table 9: Quantity of Ingredients

Sr. No.	Ingredients	Qty/ M^3
1	Cement	440
2	Sand	948
3	Coarse Aggregate	665
4	Fly Ash	110
5	NanoSilica	As per research requirement %
6	Super plasticizer	2.2

IV. CASTING AND CURING

Procedure as specified in (EFNARC Specification and Guideline for self-compacting concrete 2005), was adopted for mixing of ingredients, casting and curing of specimens. The size and ages for Casting and Curing are specified in Table:10.

Table 10: Specifications for Casting and Curing

Sr. No.	Name of the test	Size Of Casting Specimens(mm)	Curing days
1	Cube Compressive strength	150x150x150	7, 28 and 56, days
2	Cylinder Split tensile strength	150x300	7, 28 and 56 days
3	Prism Flexural strength	100x100x 500	7, 28 and 56 days

V. TESTING PROCEDURE

The physical strength of a Self-Compacting Concrete is an important feature to stipulate its applicability and performance when subjected to a peripheral force during its use. The mechanical strength of SCC is generally categorized in terms of compressive strength, split tensile strength and flexural strength test.

Compressive Strength Test.

Compressive strength is the most significant parameter of concrete which helps to regulate the grade or superiority of concrete. It is a measure of concrete ability to resist loads which tends to compress it and crushing the concrete cube to its limits to identify its strength. The test was carried out according to IS 516-1959. Specimens of size 150x150x150 mm were casted to obtain the comparative strength, a total number of 15 cubes were casted for each mix after its harden state and curing period, were taken out from curing tank at various age interval of 7, 28 & 56 days and 3 cube of each mix were tested for compressive strength after surface drying condition. Specimens were tested on 200 tones capacity compressive testing machine. The load was applied gradually without any shock until failure of specimen took place, thus the compressive strength of specimen was found out using equation Fc = P/A.The compressive strength of NanoSilica concrete at the age of 7days, 28days and 56days is given in Table11 and Fig 1.

Table 11: Variation of Compressive Strength for different replacements of NanoSilica **(MPa)**

Sr. No.	**Mix Designation**	**Percentage Replacement by** NanoSilica	**Duration of Moist Curing (Days)**		
			7 days	**28 days**	**56 days**
			Compressive Strength (Mpa)		
1	CM	0%	26.32	36.64	39.37
2	CM1	0.25%	27.16	36.91	40.11
3	CM2	0.50%	31.19	37.48	40.24
4	CM3	0.75%	32.38	38.1	42.87
5	CM4	1.00%	34.59	39.22	44.46

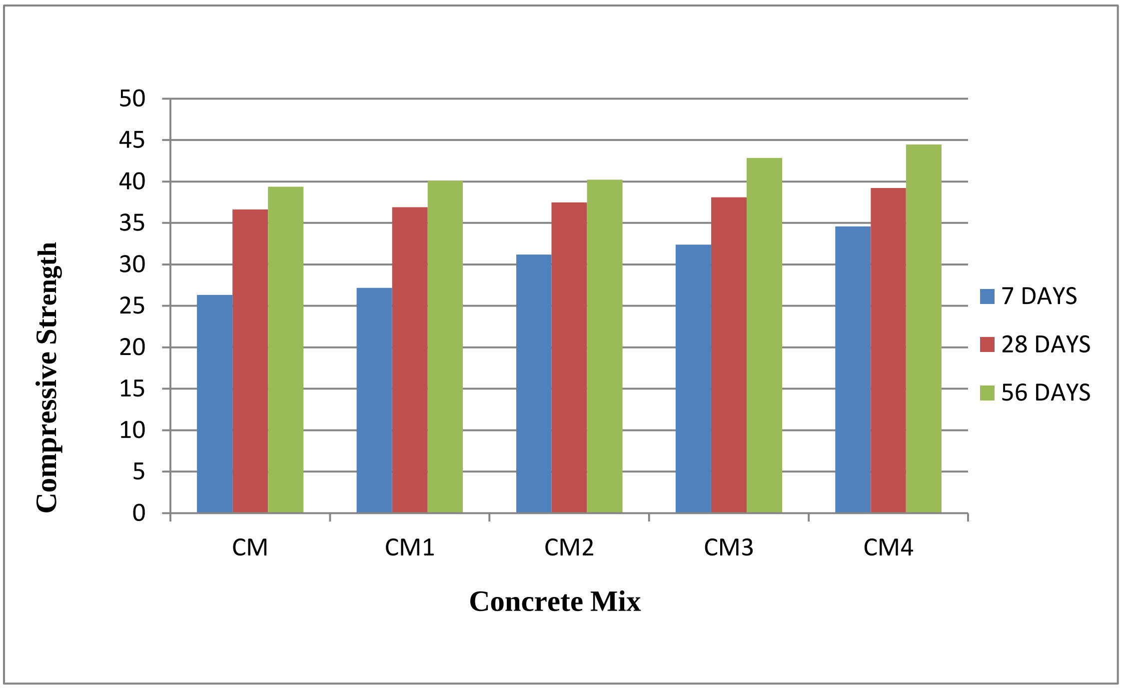

Figure 1: Comparison of concrete mixes with increasing curing ages

Split Tensile Strength Test.

The splitting tensile strength is well known indirect test used for determining the tensile strength of concrete, tensile strength is one of the most important fundamental properties of concrete. The test was conducted according to IS 5816-1999, cylindrical specimens of size 150mmx300 mm casted and placed for curing period at various age interval of 7,28 and 56days in curing tank and 3 cylinders of each mix were tested for Split Tensile Strength Test after surface dry condition. The test was performed on 100 tones capacity compressive test machine. The results of Nano-silica concrete at the curing age of 7,28 and 56days are given in Table 12 and Fig 2.

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Table 12: Variation of Split Tensile Strength for different replacements of NanoSilica **(MPa)**

Sr. No.	Mix Designation	Percentage Replacement by NanoSilica	Duration of Moist Curing (Days)		
			7 days	28 days	56 days
			Split Tensile Strength (Mpa)		
1	CM	0%	2.95	3.92	4.206
2	CM1	0.25%	3.51	3.95	4.3
3	CM2	0.50%	2.77	3.98	4.44
4	CM3	0.75%	3.19	4.15	4.62
5	CM4	1.00%	2.81	4.35	4.89

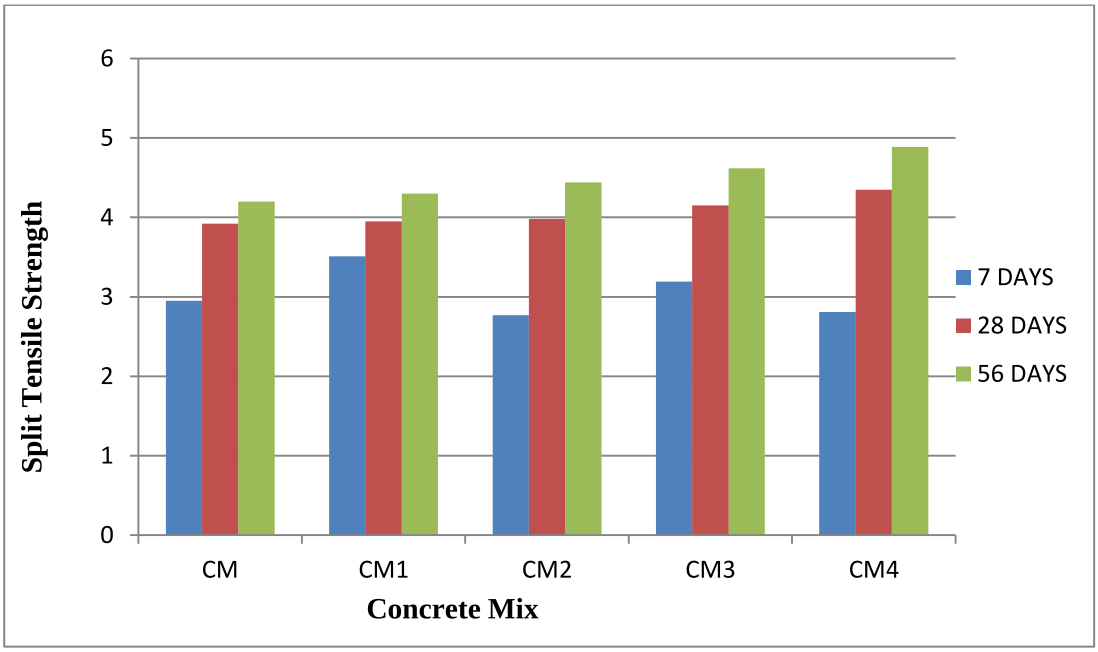

Figure 2: Comparison of concrete mixes with increasing curing ages

Flexural Strength Test.

Beam measuring 100 x 100 x 500 mm were casted and tested for each mix to determine the strength on 7, 28 and 56days. Flexural strength of all concrete mixes was found to increase with increase in varying percentage of NanoSilica.The results of NanoSilica concrete at the curing age of 7days, 28days and 56days are given in the Table 13 and Fig.3.

Table No 13: Variation of Flexural Strength for different replacement level of NanoSilica **(N/mm^2)**

Sr. No.	Mix Designation	Percentage Replacement by NanoSilica	Duration of Moist Curing (Days)		
			7 days	28 days	56 days
			Flexural Strength (Mpa)		
1	CM	0%	4.65	6.37	6.86
2	CM1	0.25%	4.905	6.53	7.35
3	CM2	0.50%	3.67	6.61	7.59
4	CM3	0.75%	4.905	6.86	8.08
5	CM4	1.00%	3.67	6.92	8.6

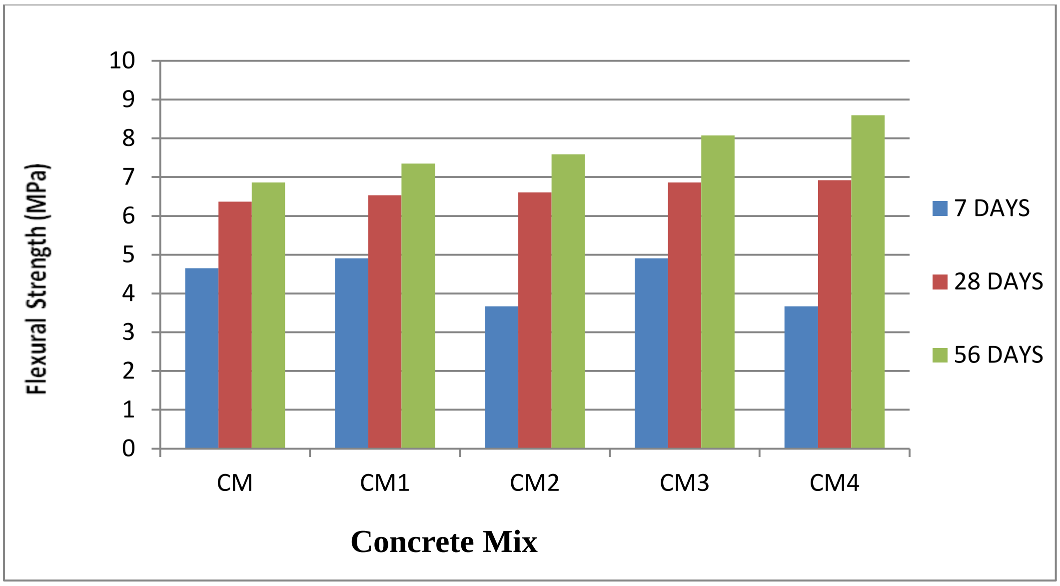

Figure 3: Comparison of concrete mixes with increasing curing ages

VI. CONCLUSION

The conclusions drawn from the research work carried out for Experimental Study in Various Properties of High Strength Self-Compacting Concrete Incorporating Nano-silicawith different percentages are as follows:

1) Compressive strength of concrete mixes increased with increase in replacement of cement with NanoSilica. However, compressive strength observed was suitable for structural use.

2) Concrete mixes obtained linear increase in 28 days splitting tensile strength for concrete mix with addition of NanoSilica with percentages of 0%, 0.25%, 0.50%, 0.75%,1.0% replacing cement.

3) Flexural strength of all concrete mixes was found to increase with increase in percentages of NanoSilica.

4) The compressive strength, split tensile strength& flexural strength of concrete increased with age but the rate of increase in compressive strength varied with the curing ages. The compressive strength, split tensile strength& flexural strength increased with addition of NanoSilica up to 1.0%

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